Atlantic Herring MSE

Part I - Data and Methods Overview
Part II – Preliminary results

Dr. Jonathan Deroba, NEFSC

NEFMC January 2017 Council Meeting

Portsmouth, NH

Part I: Data and Methods Overview

Multiple operating models represent uncertainty
Defined in Workshop #1

Sarah Gaichas

Herring N, B, Wt




Herring Fishery Yield

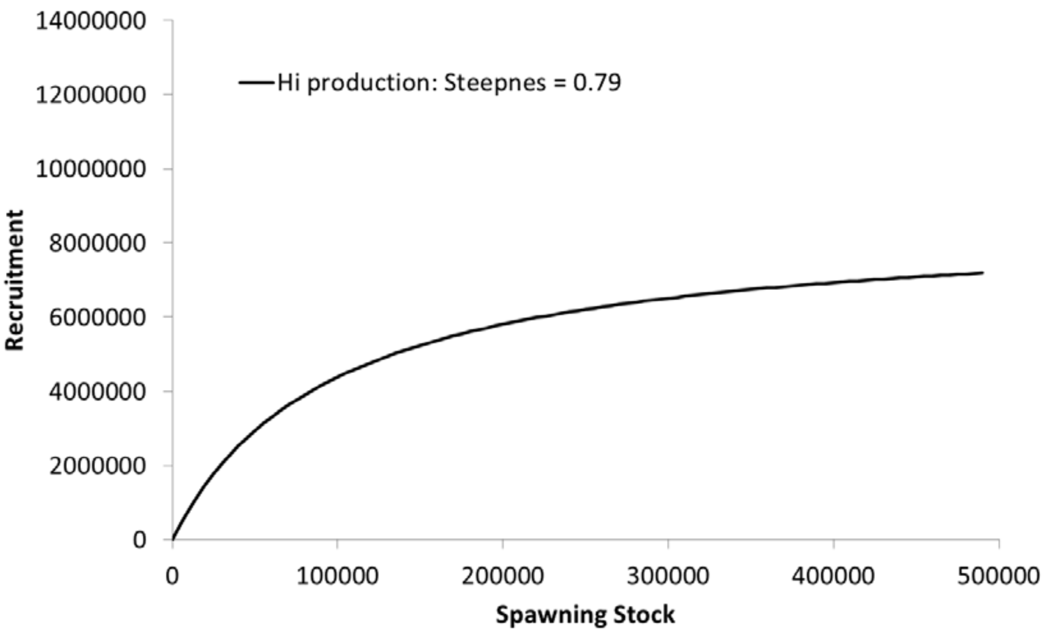
Min-Yang Lee

Herring recruitment (high or low?)
Herring natural mortality (high or low?)
Herring growth (good or poor?)
Herring assessment error/bias (yes or no?)

Evaluate ABC control rules for each OM

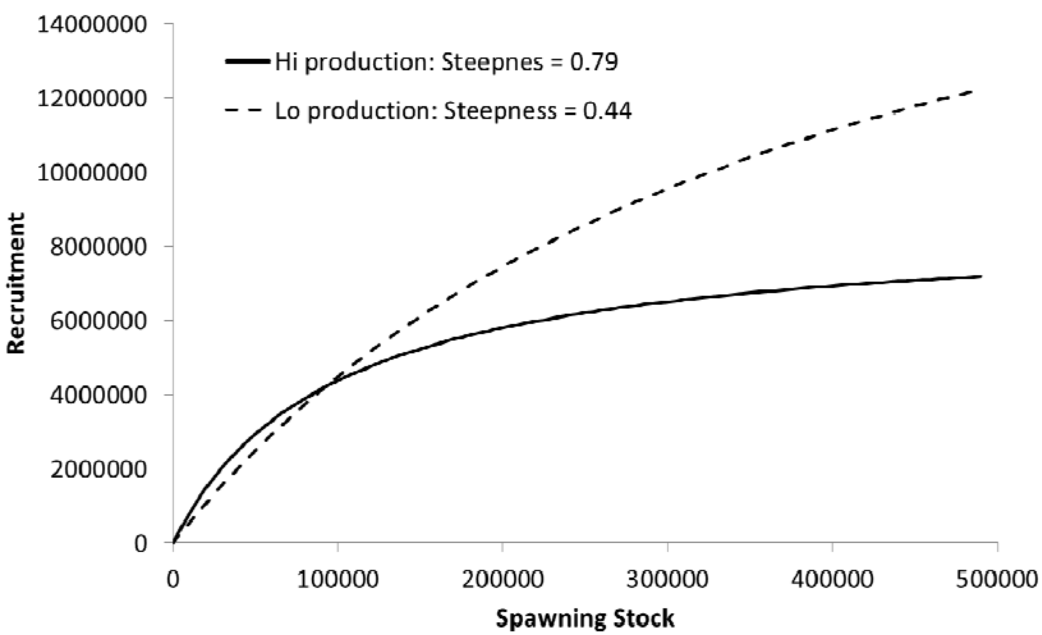
Recruitment and Natural Mortality

define Hi production and Lo production operating models



Recruitment and Natural Mortality

define Hi production and Lo production operating models



Based on longevity and size data, and stock assessment data and fits

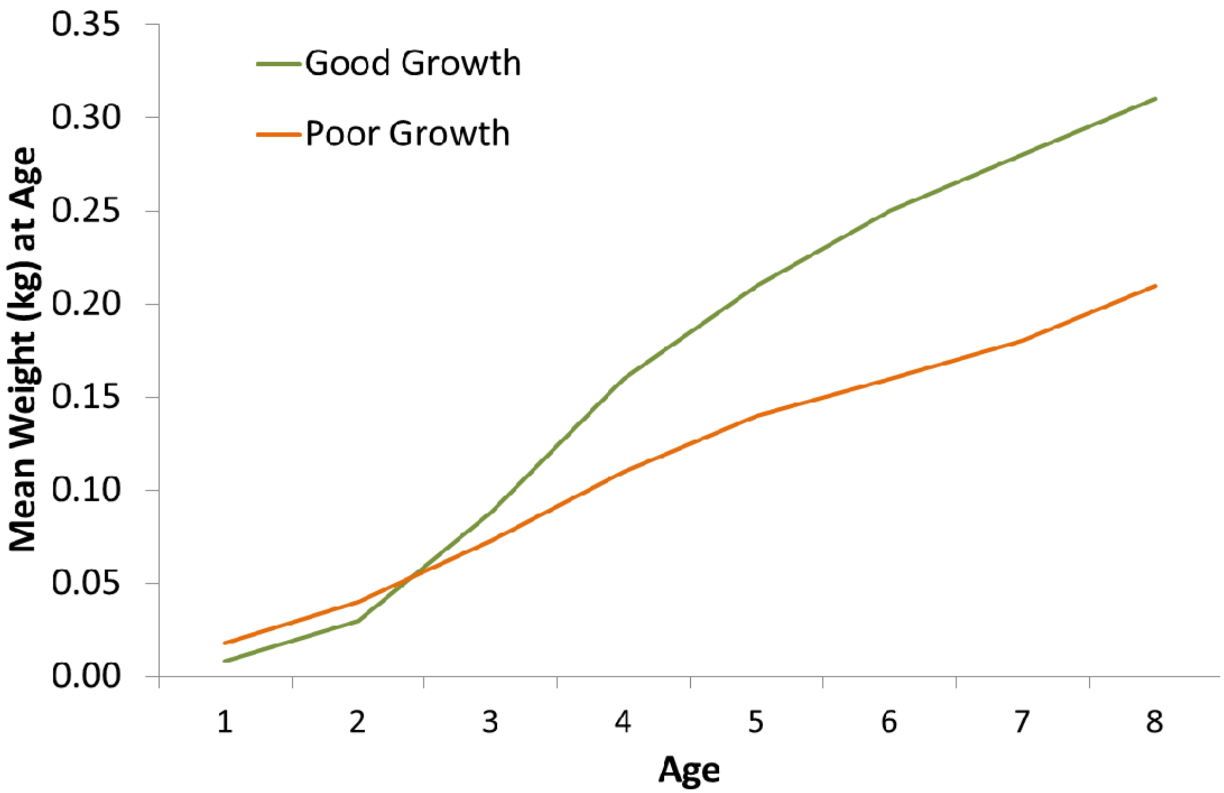
Uncertainties

At the May Workshop we identified uncertainties:

- Herring recruitment ☑
- Herring natural mortality ☑
- Herring growth
- Herring assessment error/bias

Growth

good and poor growth operating models



Based on survey weight at age data

Uncertainties

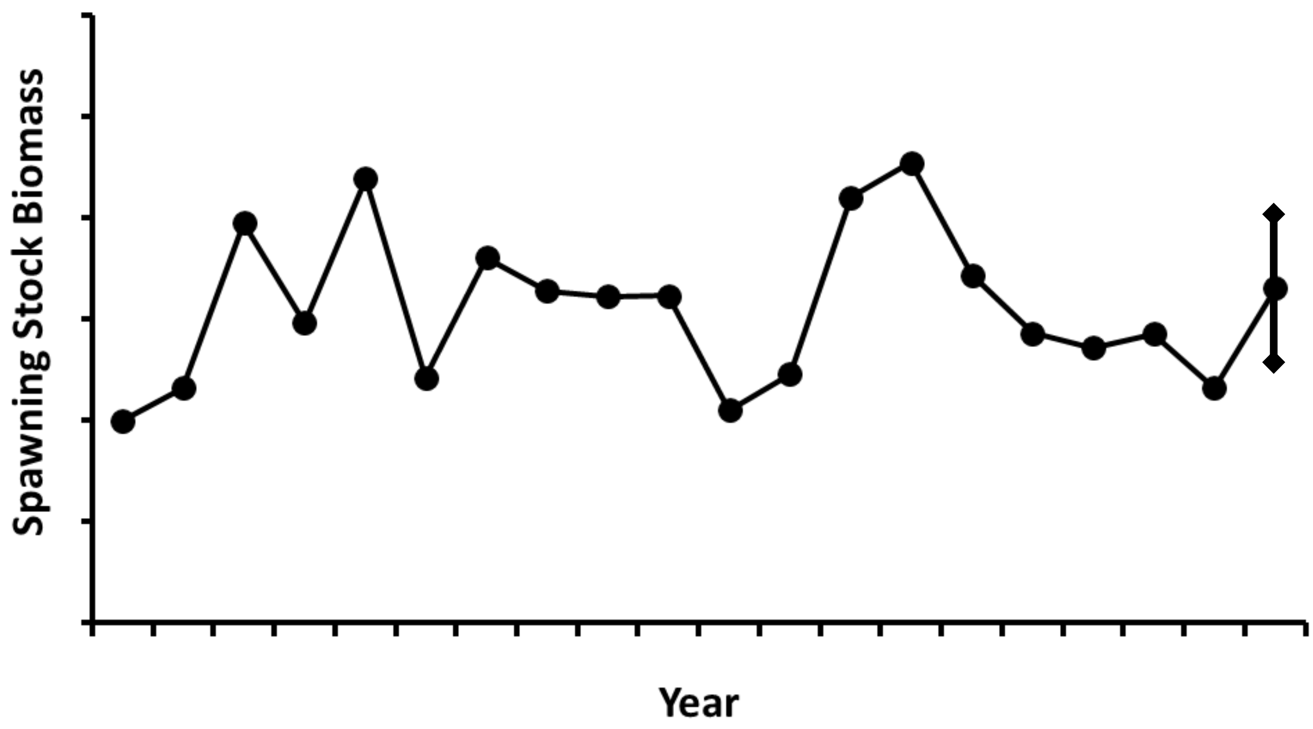
At the May Workshop we identified uncertainties:

- Herring recruitment ☑
- Herring natural mortality ☑
- Herring growth ☑
- Herring assessment error/bias

Production		Growth	
Hi	Lo	Good	Poor
x			x
	x		x
x		x	
	x	x	

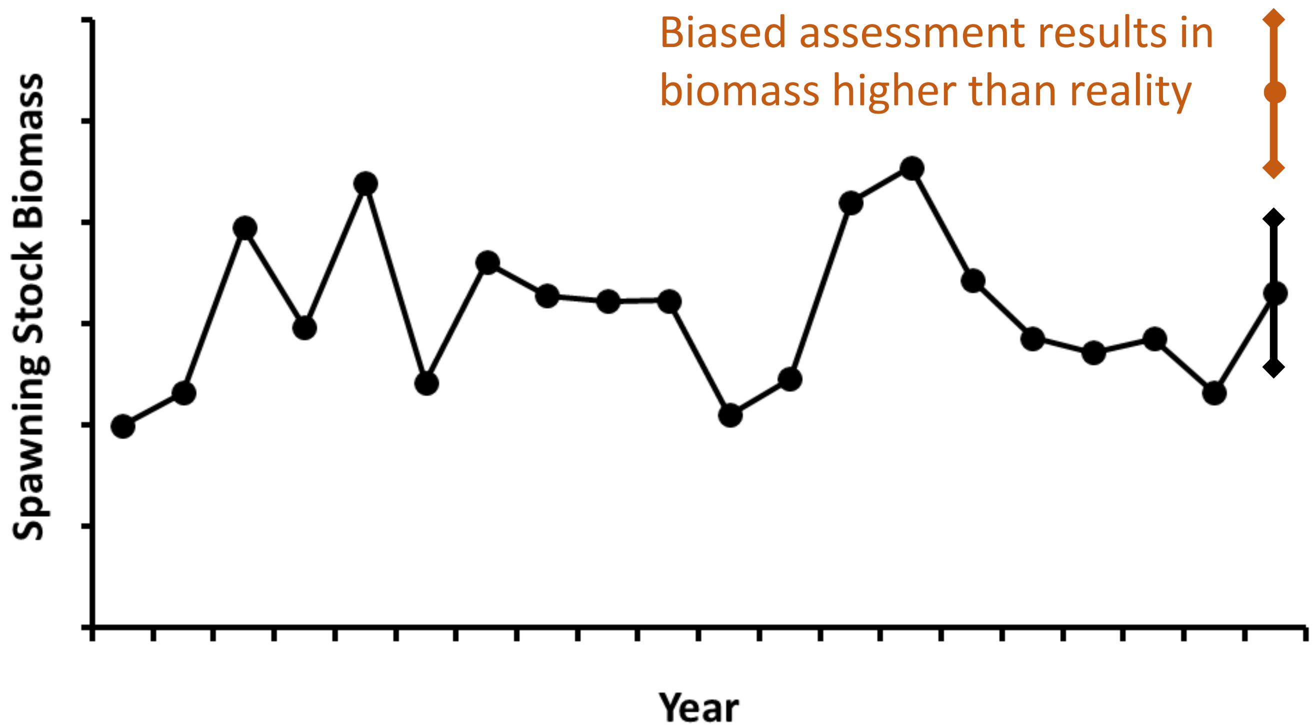
Assessment Error and Bias

unbiased and biased operating models



Assessment Error and Bias

unbiased and biased operating models



Based on the stock assessment retrospective pattern

Uncertainties

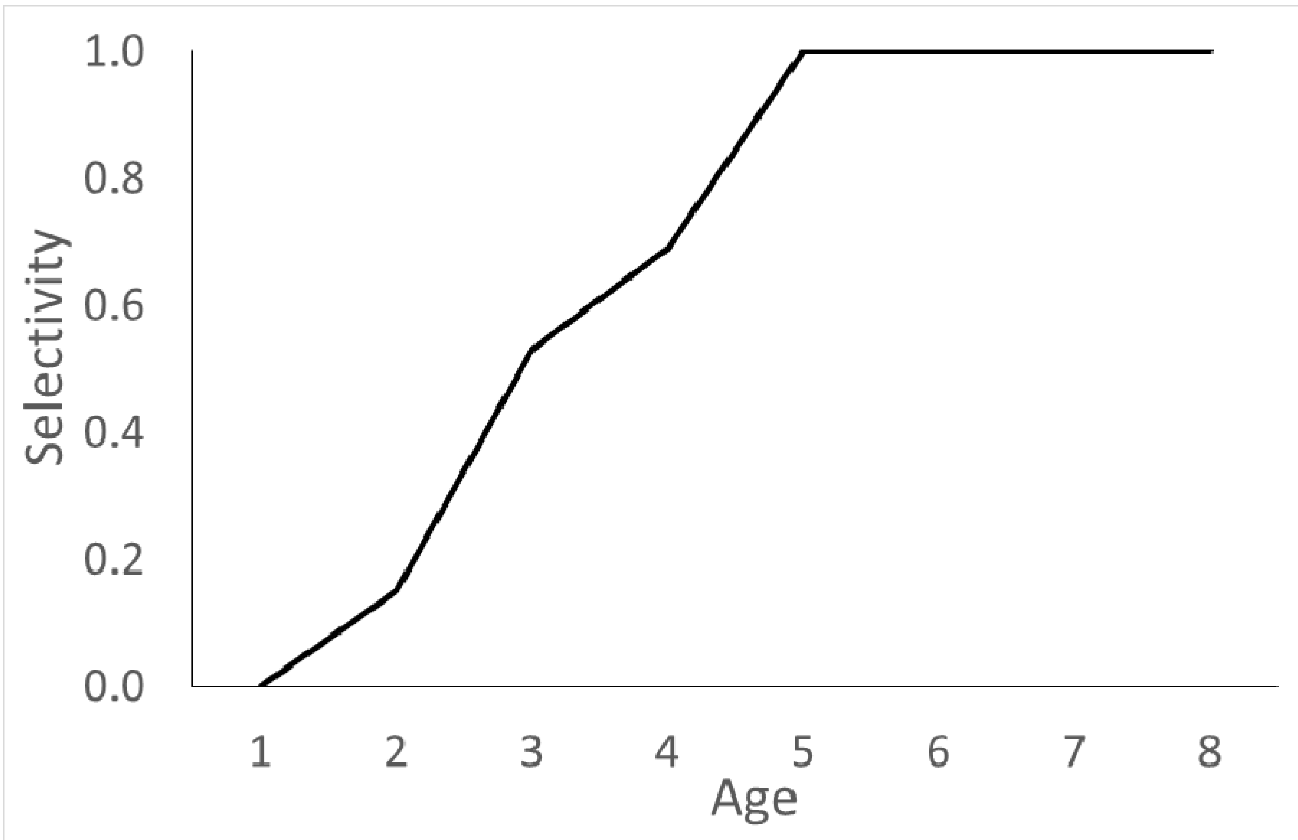
At the May Workshop we identified uncertainties:

- Herring recruitment ☑
- Herring natural mortality ☑
- Herring growth ☑
- Herring assessment error/bias ☑

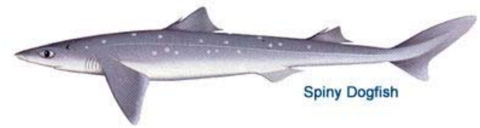
Production		Growth		Assessment bias	
Hi	Lo	Good	Poor	On	Off
x			x		x
	x		x		x
x		x			x
	x	x			x
x			x	x	
	x		x	x	
x		x		x	
	x	x		x	

Uncertainties combined into 8 different operating models

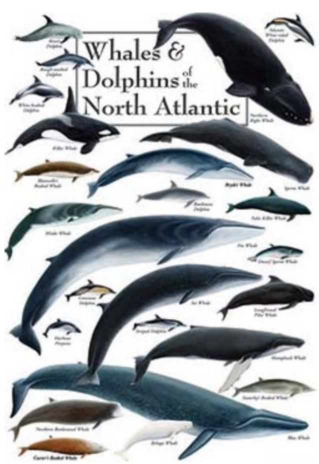
Fishery Selectivity



Based on purse seine and MWT age composition data



Predator models



Stolen or adapted from presentations

By Dr. Sarah Gaichas, NEFSC

Predator models

Are

- Focused on evaluating stock-wide herring ABC harvest control rules applied annually
- Developed balancing Council/ stakeholder specifications and time constraints of MSE
- Based on information from the Northeast US shelf and most recent stock assessments

Are <u>not</u>

- Spatial, do not address local scale or seasonal dynamics
- New or full stock assessments
- Accounting for any impacts on predators other than changes due to herring control rules
- Intended to predict actual predator population dynamics

Two components of predator modeling

Predator population model

- Delay-difference dynamics
- Information required:
  - Stock-recruitment relationship
  - Natural mortality rate
  - Fishing mortality rate
  - Initial population size
  - Weight at age
- Assessments or observations

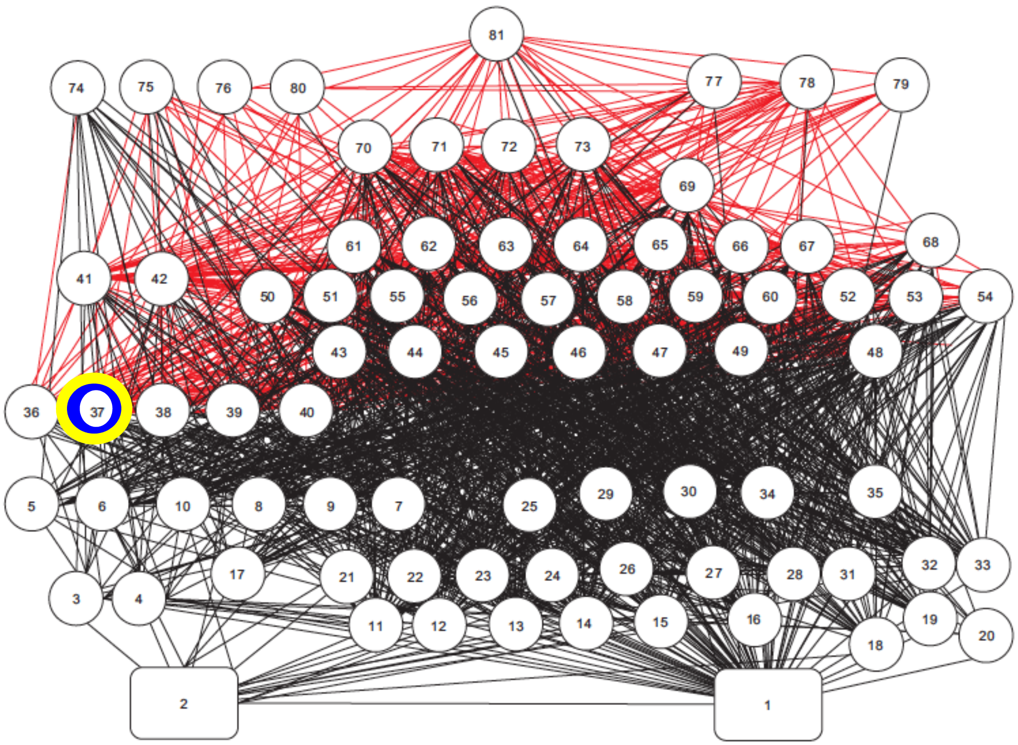
Herring→predator relationship

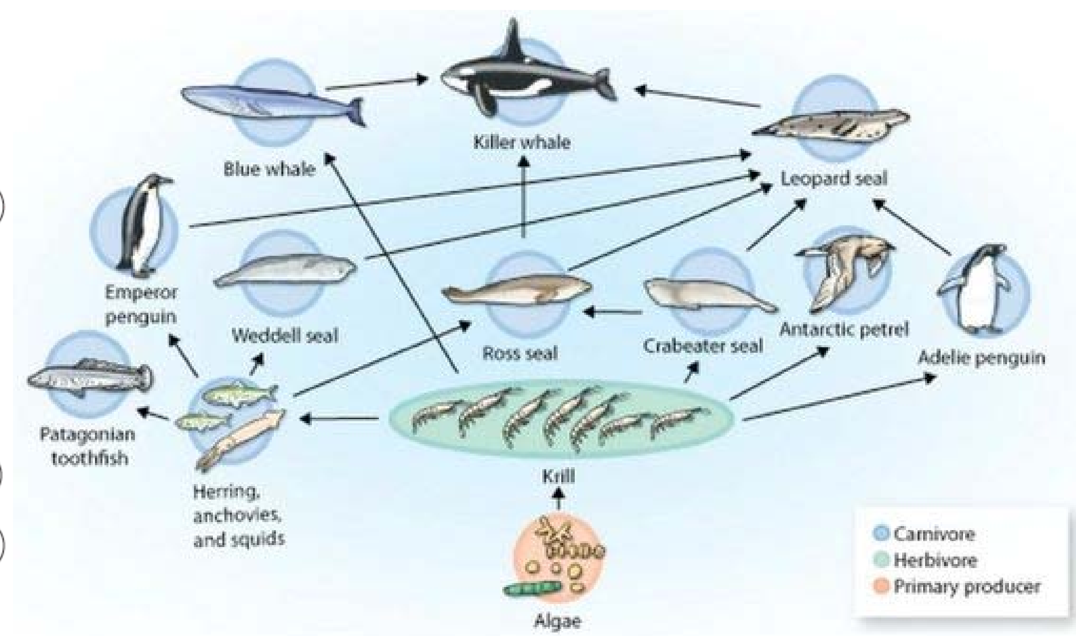
- What about herring…
  - Total abundance? Biomass?
  - Certain ages or sizes?
- Affects what about the predator
  - Predator growth
  - Predator reproduction
  - Predator survival
- And how? Base on observations

Predator population model summary

	Highly migratory	Seabird	Groundfish	Marine mammal
Stakeholder preferred species	Bluefin tuna	Common tern	Not specified	Not specified
Species modeled	Bluefin tuna (western Atlantic stock)	Common tern (Gulf of Maine colonies as defined by GOM Seabird Working Group)	Spiny dogfish (GOM and GB Atlantic cod stocks also examined)	None, data limited (Minke & humpback whales, harbor porpoise, harbor seal examined)
Stock-recruitment (or adults, recruits)	Porch and Lauretta 2016, ICCAT 2015	Derived from GOMSWG data	Rago and Sosebee 2010	No time series data for our region
Natural mortality	ICCAT 2015	Nisbet 2002	Rago and Sosebee 2013, 2015	Derivable from Waring et al. 2015?
Fishing mortality	ICCAT 2015	n/a	Rago 2016	Waring et al. 2015?
Initial population	ICCAT 2015	GOMSWG data	Rago 2016	Waring et al. 2015?
Weight at age	Restrepo et al. 2010	Nisbet 2002	Rago et al. 1998	General literature

Predator-prey relationships:
Northeast US Herring vs. Antarctic krill





Herring→Predator relationship issues/caveats

- Predator populations are affected by MANY factors, prey is one
- Northeast US predators have MANY prey options, herring is one
- Time limitation enforced model simplicity for these complex relationships
- Our approach is to use the **best-supported** relationship for each predator **based on observations from the Northeast US ecosystem**

- Isolating a clear herring→predator relationship from observations is difficult or impossible (e.g. cod)
- Even with good observations, the modeled herring→predator relationship may require strong assumptions and not be statistically significant (e.g. terns)
- Apparent positive herring→ predator relationships may not arise from the modeled mechanism (e.g. dogfish)

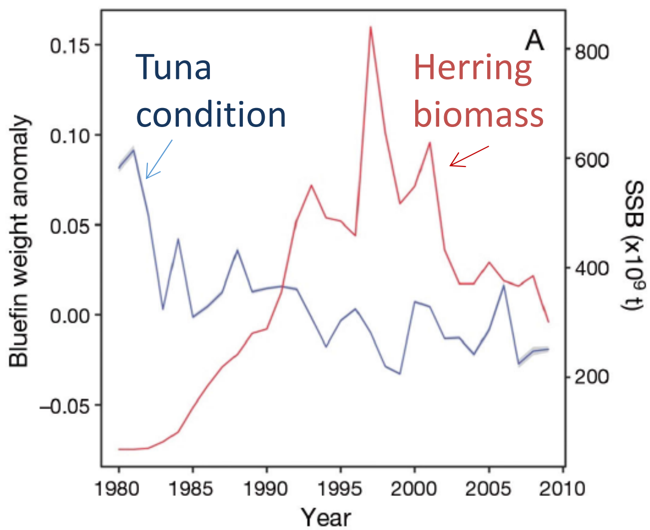
Predator relationships summary

Predator and overlap

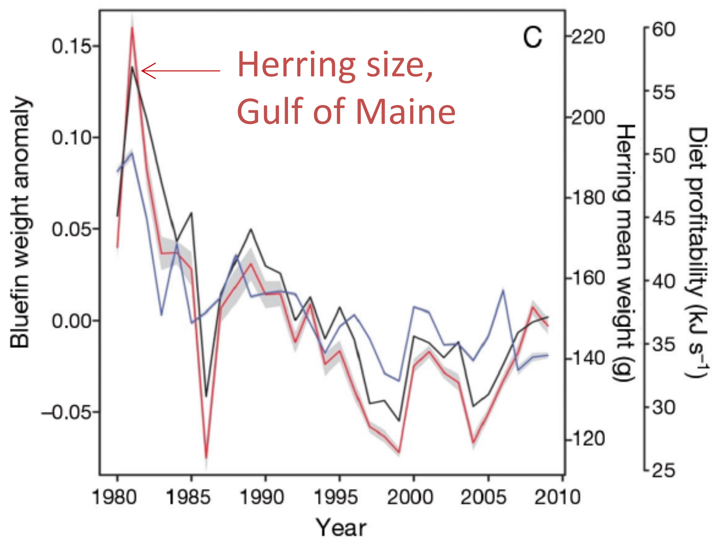
- Western Atlantic bluefin tuna
  Forage throughout North Atlantic, seasonally in GOM
- Common terns
  Forage seasonally near island breeding colonies in GOM
- Spiny dogfish
  Forage through same range as herring most of the year
- Marine mammals

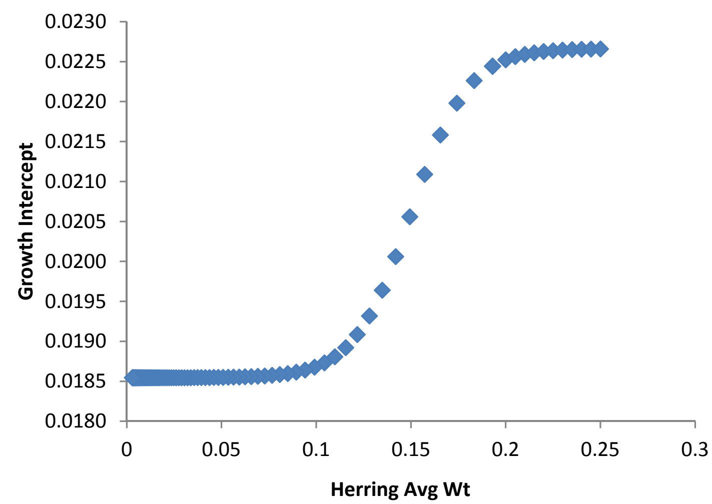
Modeled herring relationship

- Herring population average weight affects bluefin tuna **growth**
- Herring total biomass affects common tern **reproductive success (productivity)**
- Herring total abundance affects dogfish **survival**
- Food web model simulations



Golet et al.: Bluefin tuna foraging
Mar Ecol Prog Ser 527: 181–192, 2015

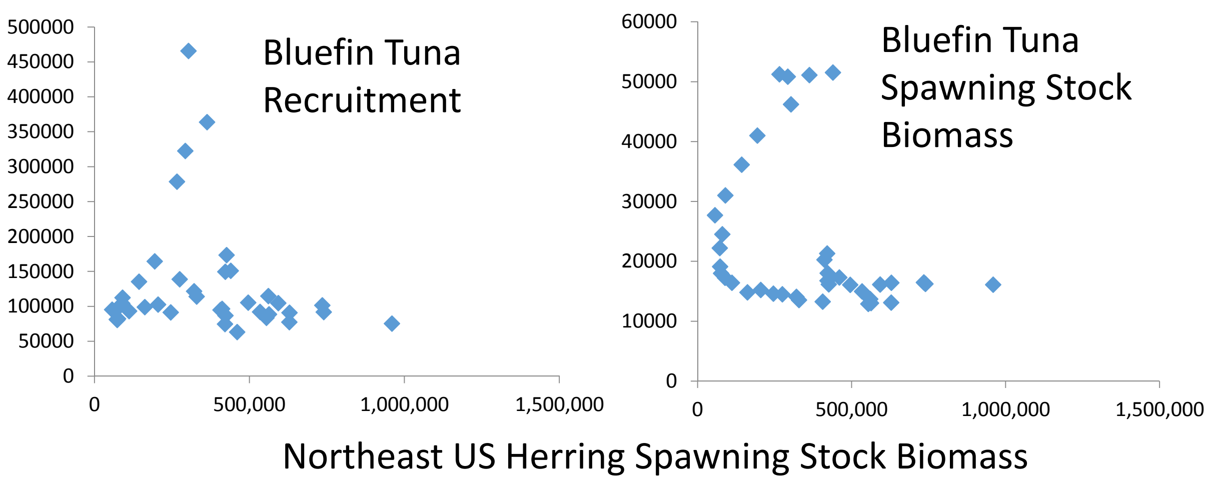


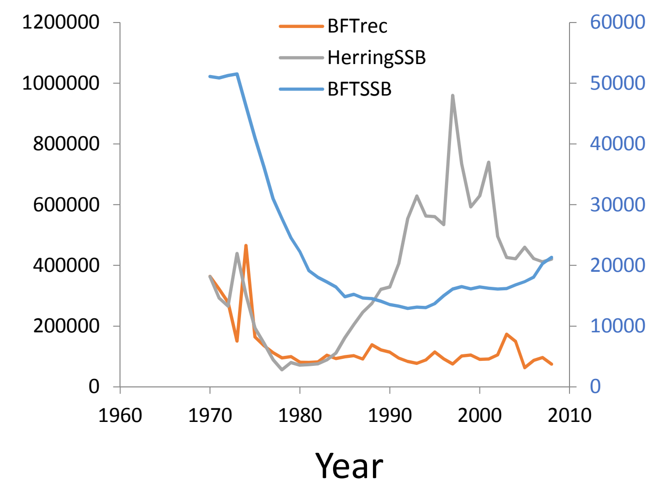


Modeled relationship: Tuna grow better with heavier herring overall, and/or with a higher proportion of large herring in the population

Tuna modeling notes

- Available data do not support a positive relationship between herring and tuna populations:





- Our models do not address herring/tuna interactions in a specific place or time. Tuna follow herring and likely aggregate around herring while feeding.
- We can draw no conclusions from our modeling about predator/prey co-occurrence at the local scale.
- Similarly, without additional observations, we cannot extrapolate local scale co-occurrence to population level relationships.

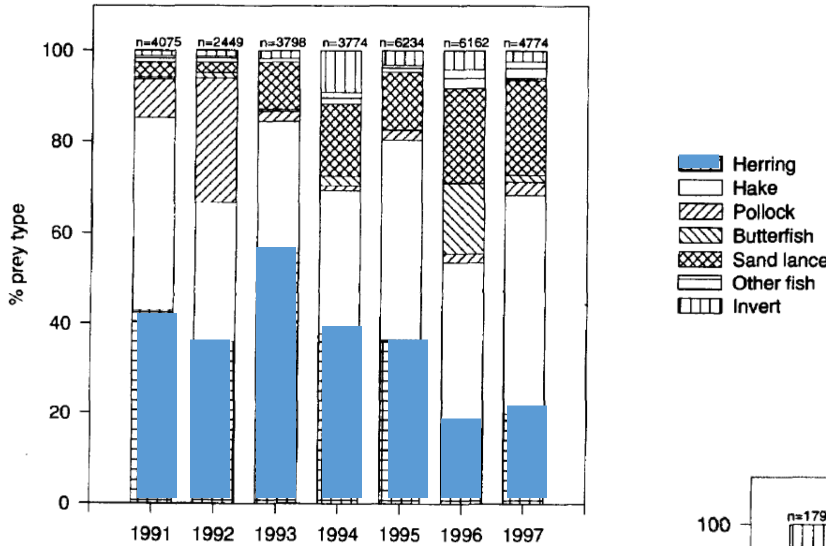


Figure 1. Variation in Common Tern chick diet between years 1991-1997.

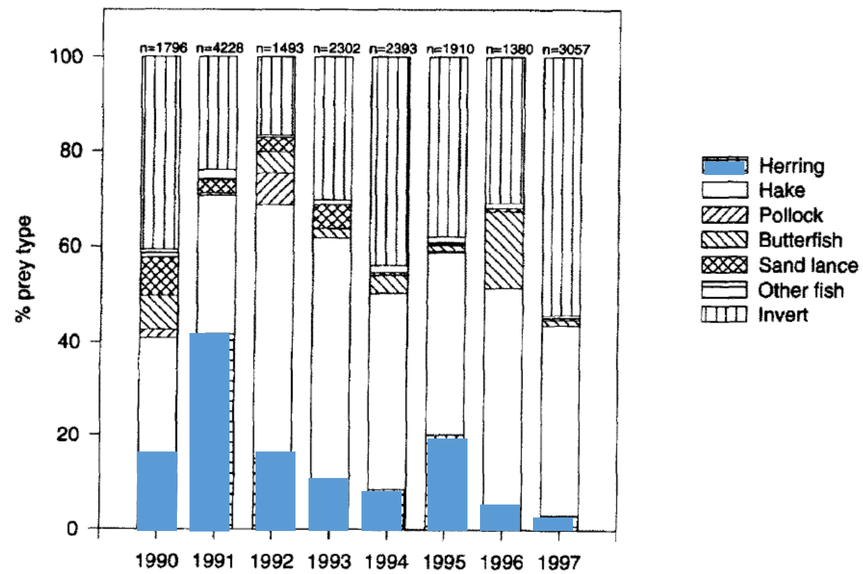
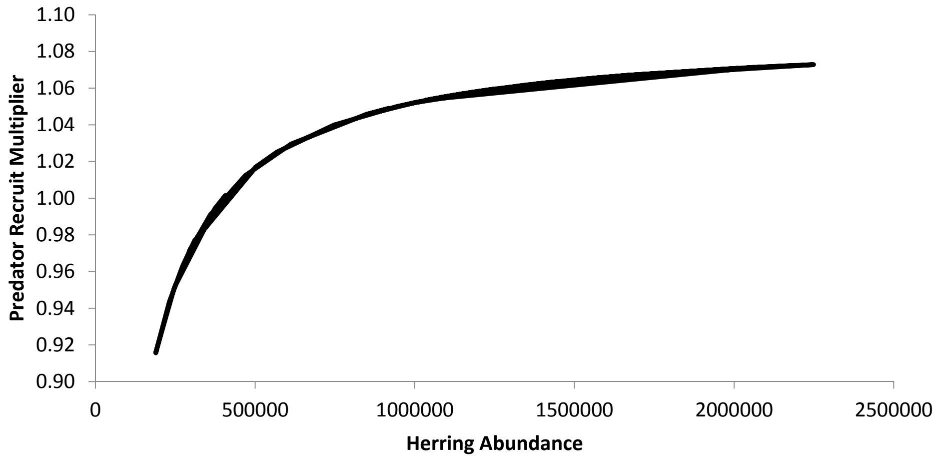
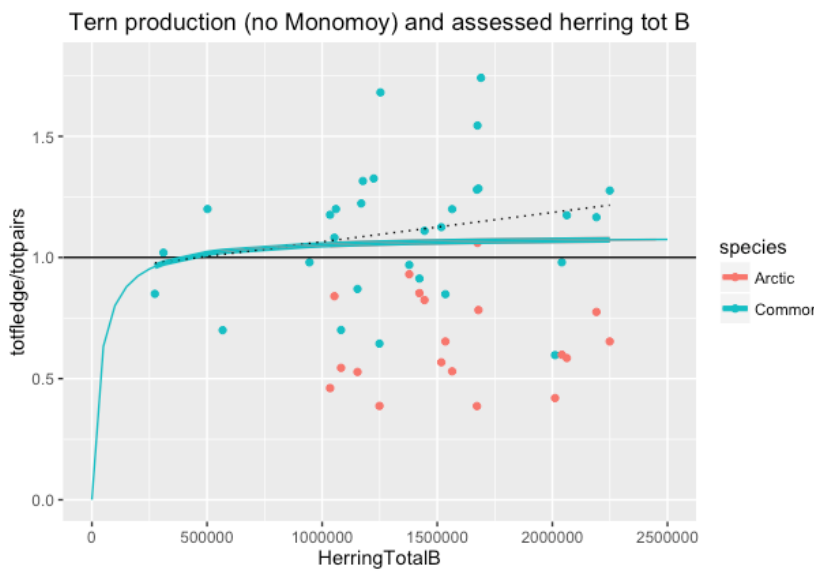


Figure 2. Variation in Arctic Tern chick diet between years 1990-1997.

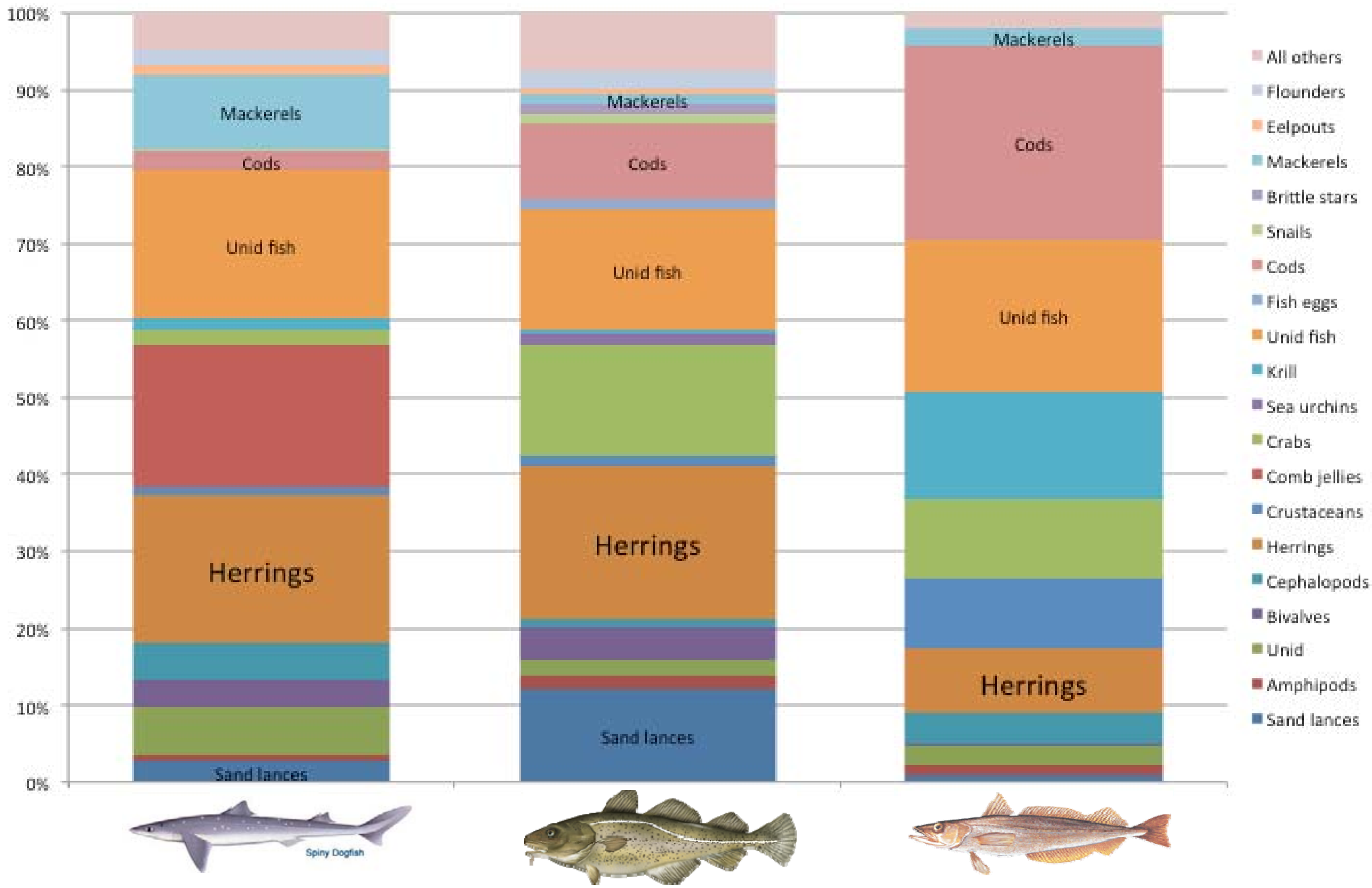
Herring → Common tern



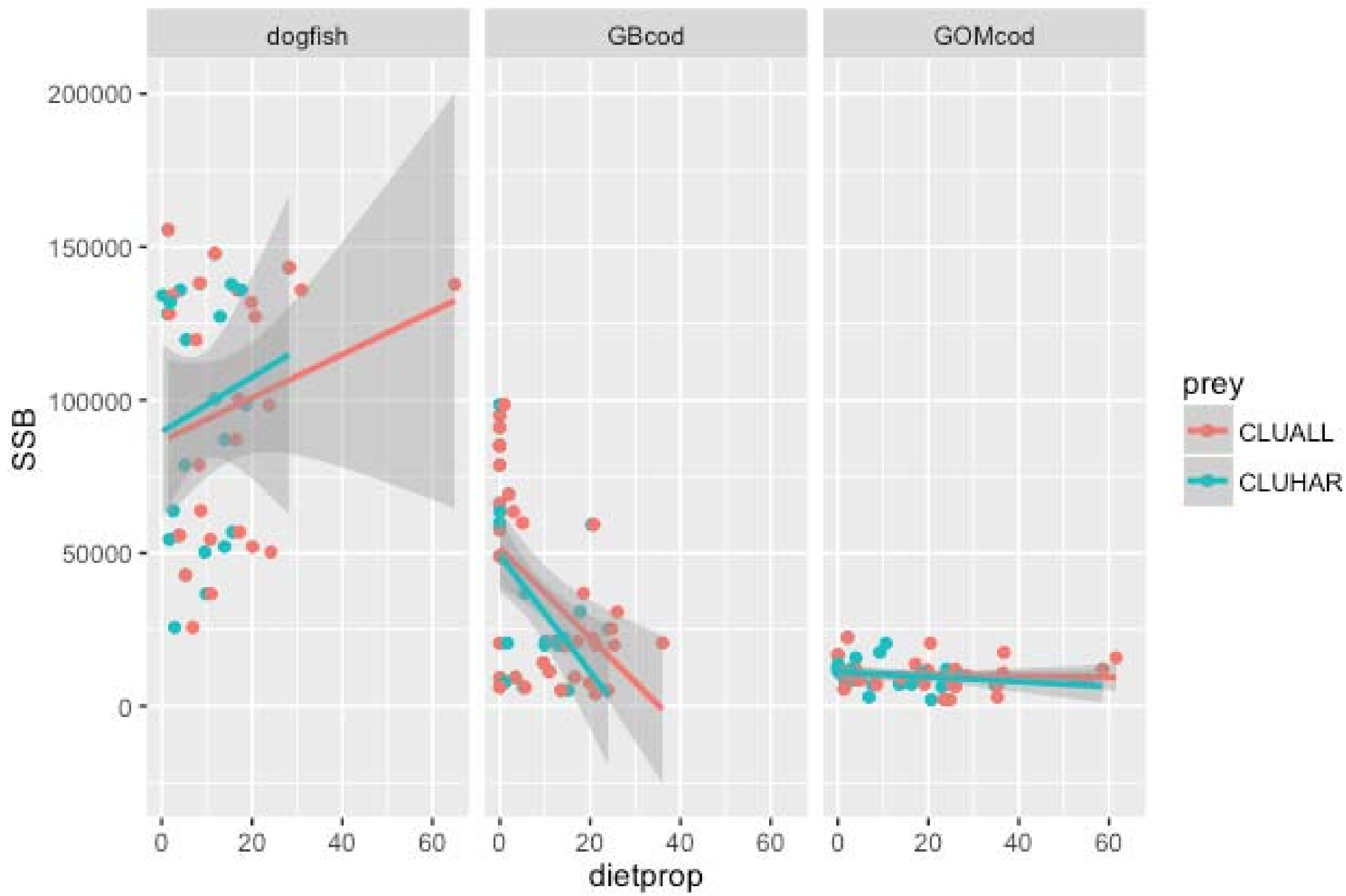
Modeled relationship:
Common tern productivity is improved when herring total biomass above a threshold (400,000 t). Productivity diminishes below this threshold.



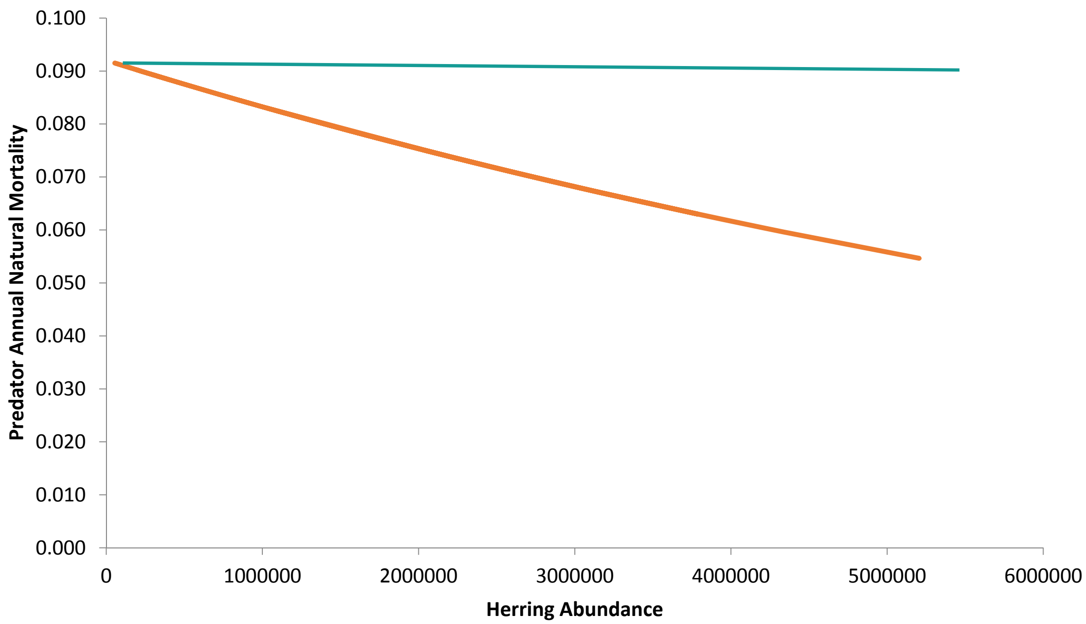
Top groundfish predators of herring (NEFSC, 1972-2015)



Dogfish, Georges Bank cod and Gulf of Maine cod all ate herring in proportion to herring abundance, 1972-2015. However, increased herring in diet was positively related to spawning stock biomass only for dogfish.



Herring → Dogfish



- The dogfish relationship assumes herring abundance improves dogfish survival because no clear relationship was found with recruitment or growth.
- Increased survival may not be the mechanism for the observed positive influence of herring in diet on the dogfish population.

Predator Modeling Summary

- Our models are designed for evaluating alternative herring control rules, not predator stock assessment and population prediction.
- We caution against generalizing results for these particular predators to other predators, as population parameters and herring relationships differ.
- Although we selected predators with high herring diet proportions, observed predator population responses to **herring alone** do not dominate dynamics, and our herring→predator models reflect that.
- Predator responses to **aggregate prey dynamics** are likely to be much clearer than responses to individual prey in the Northeast US ecosystem given its food web structure.

Herring Output Metrics – From Workshop #1

- Spawning Stock Biomass & SSB relative to SSB_{MSY} & $SSB_{unfished}$
- Probability that
  - SSB < SSB_{MSY} & 0.5 SSB_{MSY} (Probability of overfished)
  - SSB < 0.3 $SSB_{unfished}$ & 0.75 $SSB_{unfished}$
- Probability that F > F_{MSY} (Probability of overfishing)
- Yield and yield relative to MSY
- Interannual yield variation
- Probability that Atlantic herring fishery closes
- Proportion of the herring population that is age-1
- Amount of herring dying due to natural mortality

Predator Output Metrics

Predator Metrics:

- Frequency that dogfish are not overfished
- Frequency that tern production >=1
- Frequency that tuna weight > average

Output Metrics

Economic

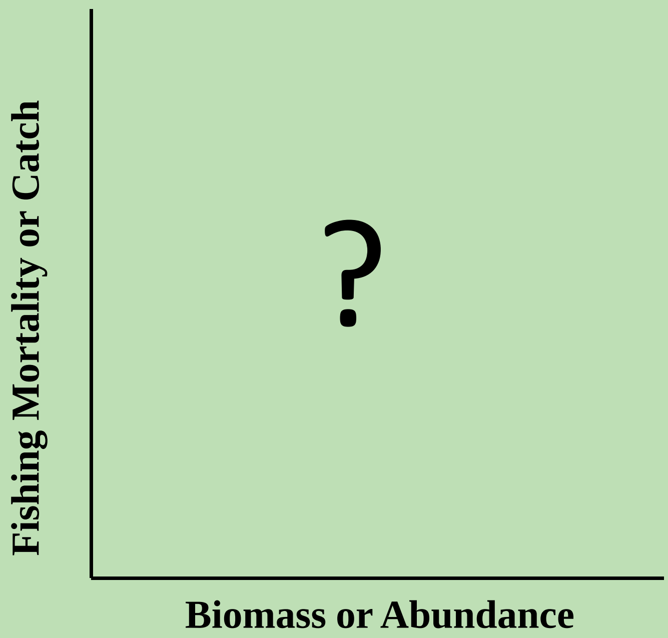
- Yield: output of the herring model
- Net revenue = (price*yield) – cost
- Stability = the degree to which net revenue was "stable" or "streaky" (i.e., fairly steady over time vs. booms and busts)

- Net revenue and stability demonstrate similar tradeoffs as herring yield and variation in yield, and so not presented in detail

Pause for Questions on Part I?

Data and methods developed for MSE models (herring, predator and economic)

Part II –Analysis of Potential Control Rules



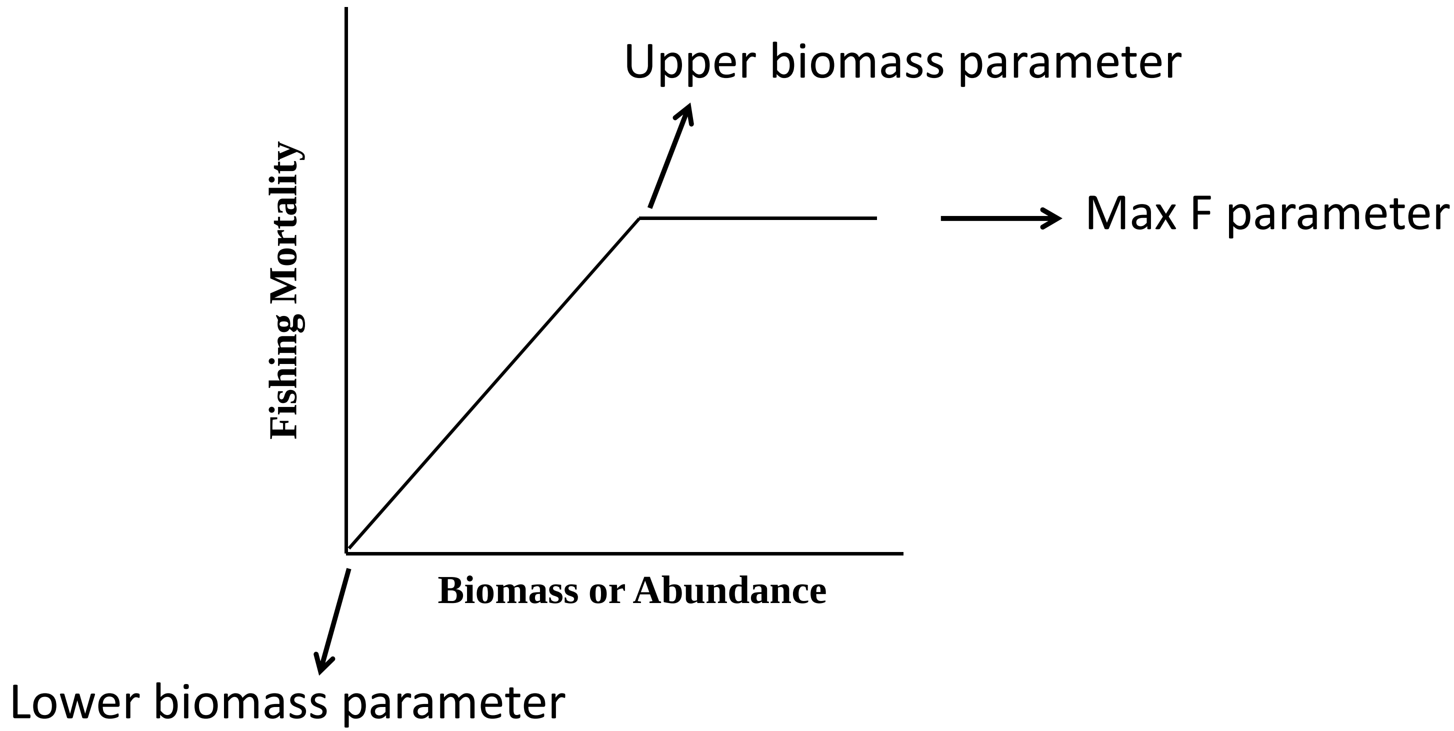
Six Control Rule Types presented at Workshop #2

1. Biomass based
2. Biomass based with 3 year block
3. Biomass based with 5 year block
4. Biomass based with 3 year block and 15% restriction
5. Constant catch
6. Conditional constant catch with max F = 0.5Fmsy

Control Rules

biomass based

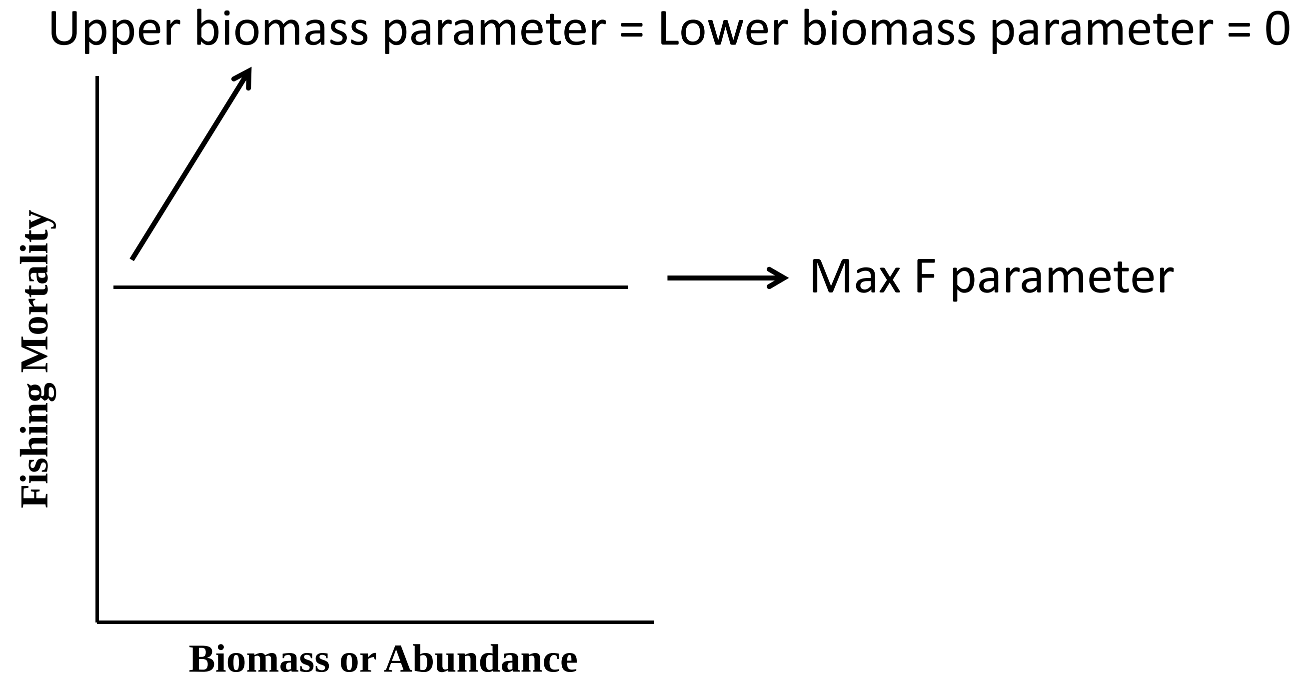
Three ‘parameters’ with many variants



Control Rules

biomass based

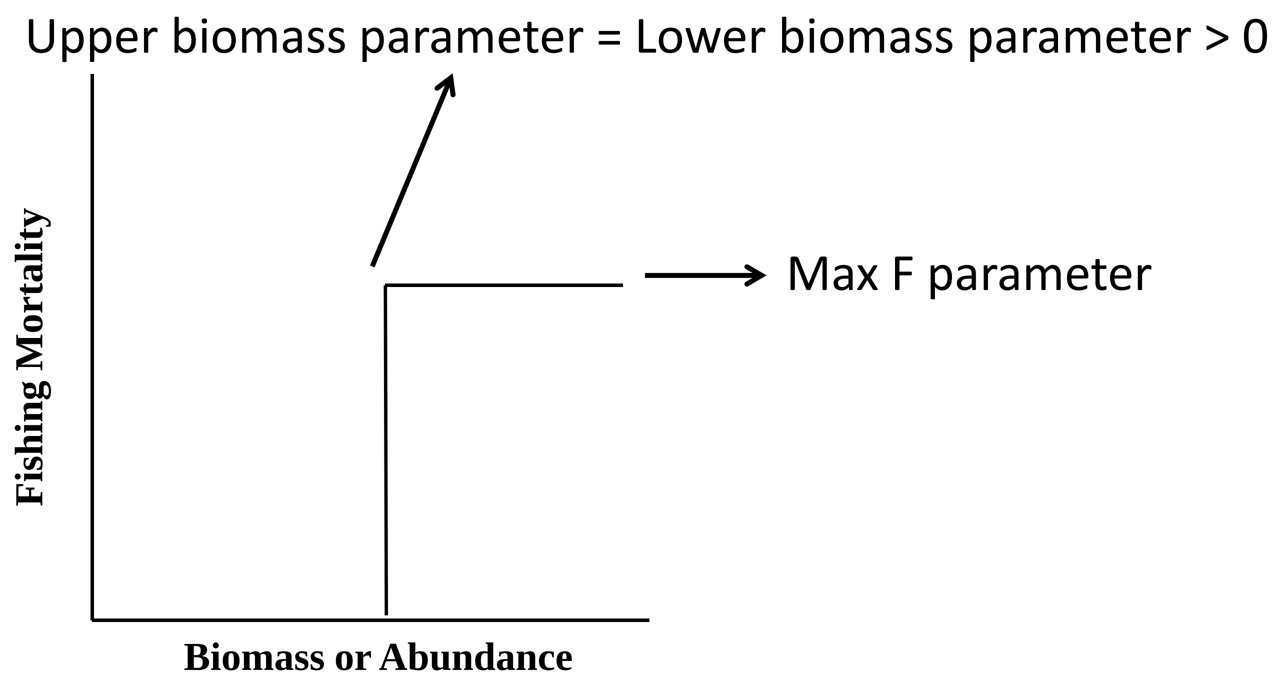
Three 'parameters' with many variants



Control Rules

biomass based

Three ‘parameters’ with many variants



Control Rules

biomass based

Three 'parameters' with many variants

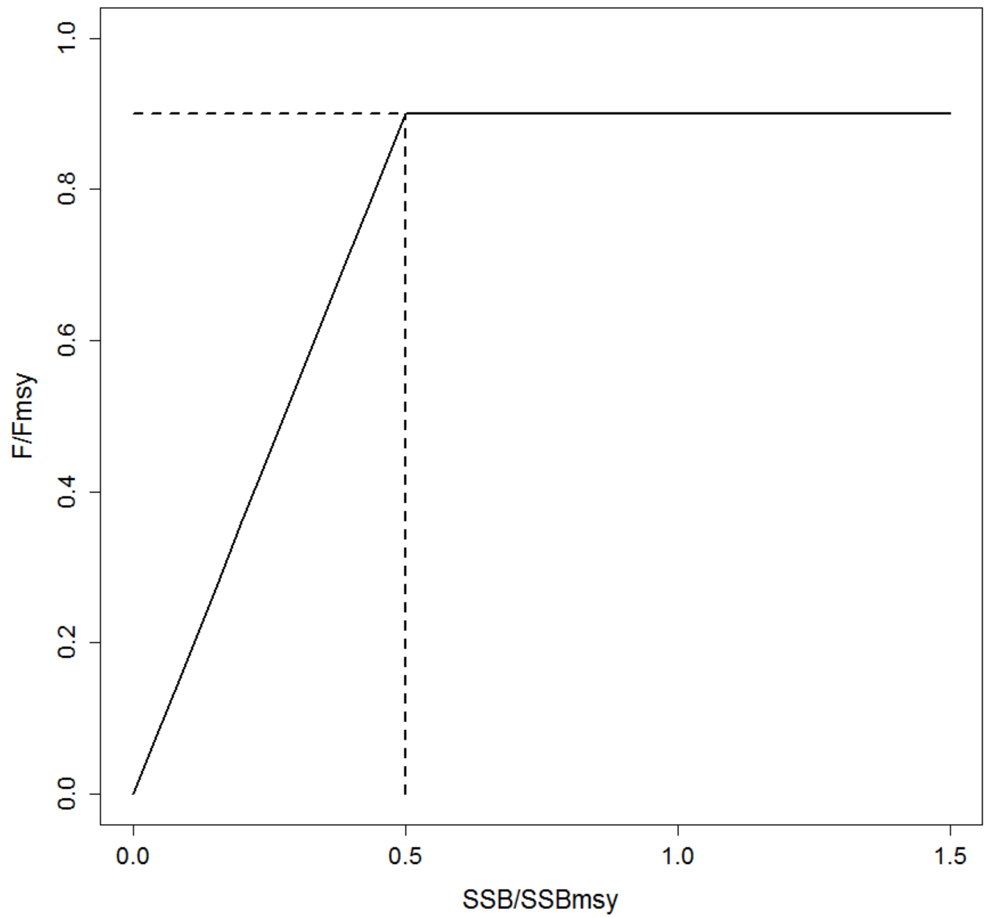
Evaluated 16 different values for each biomass threshold ranging from 0 to 4x Bmsy

Evaluated 10 different values for maximum F ranging from 0.1 to 1.0x Fmsy

1,360 combinations

Control Rules

status quo – biomass based with 3 year block

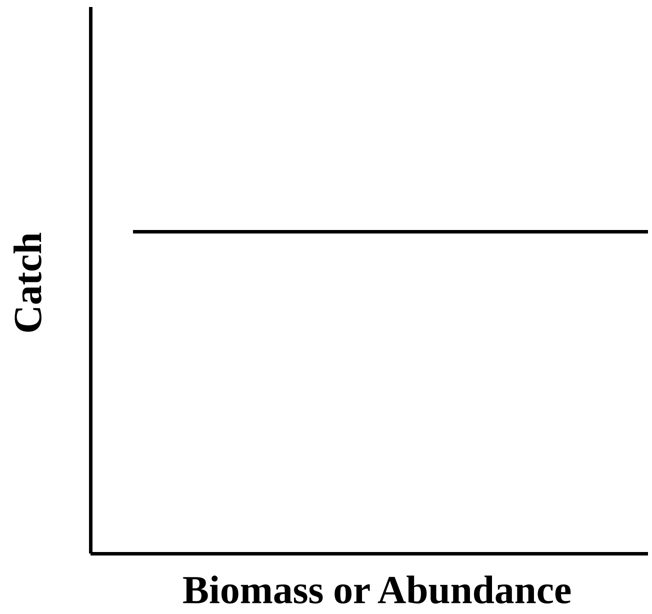


Control rules

Constant Catch

One parameter

Evaluated 10 different values ranging from 0.1 to 1x MSY

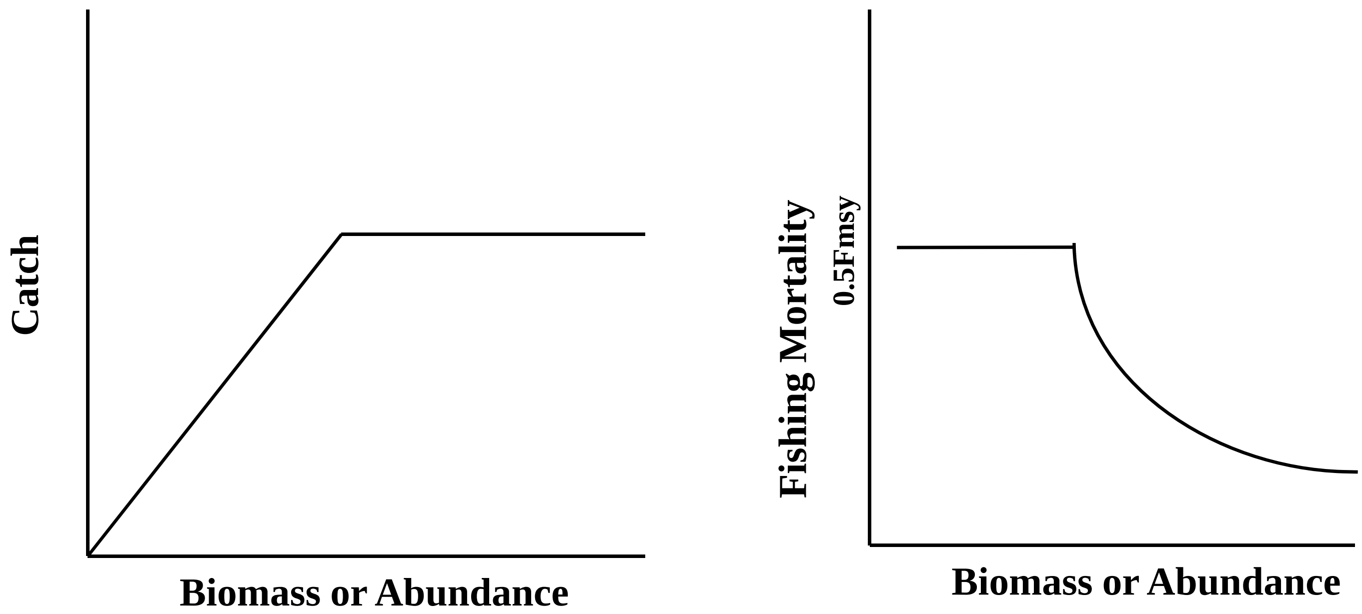


Control Rules

Conditional Constant Catch

Two parameters

Evaluated 10 different values ranging from 0.1 to 1x MSY with max F of 0.5Fmsy

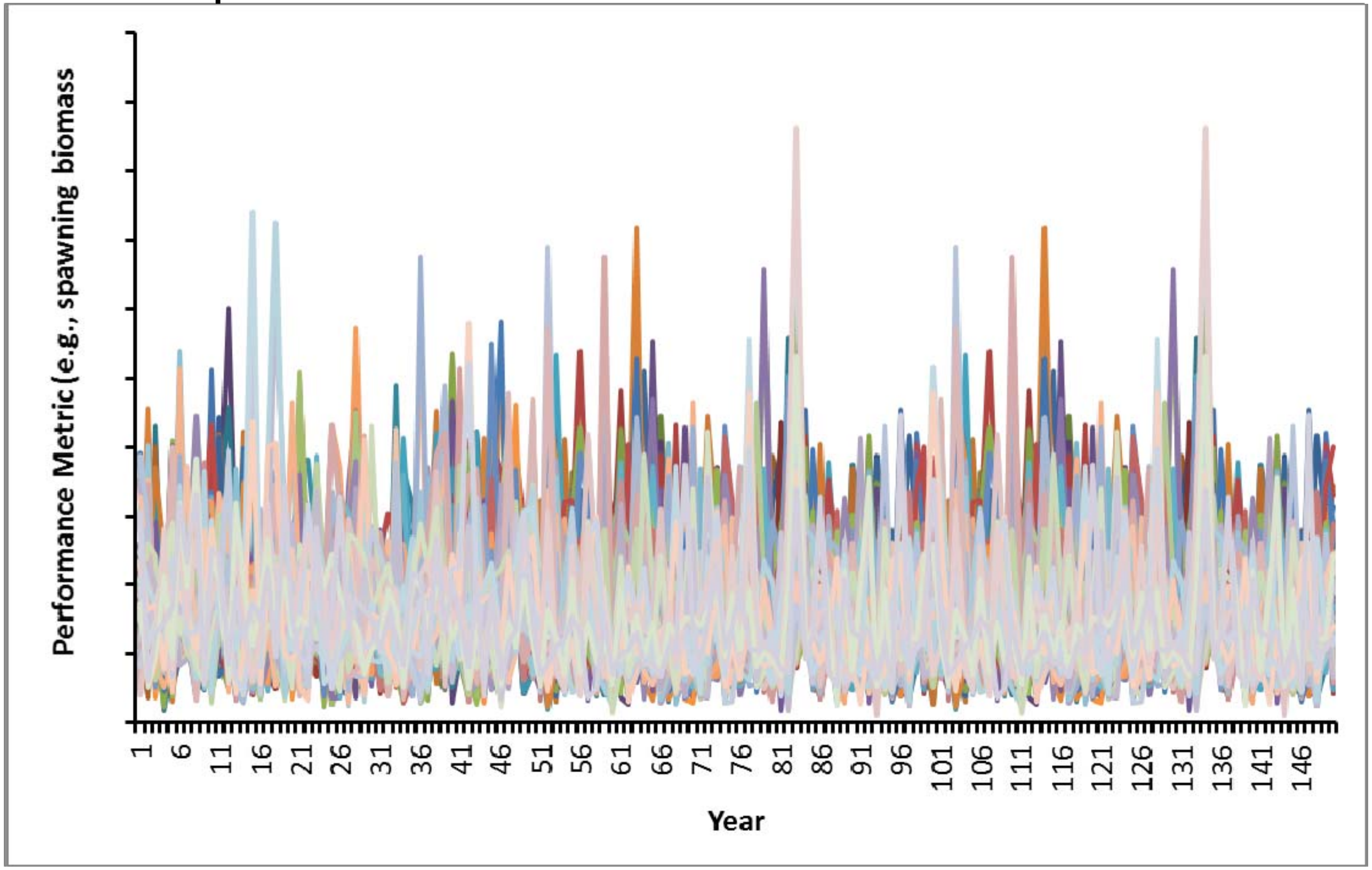


Control Rule Types and Shapes

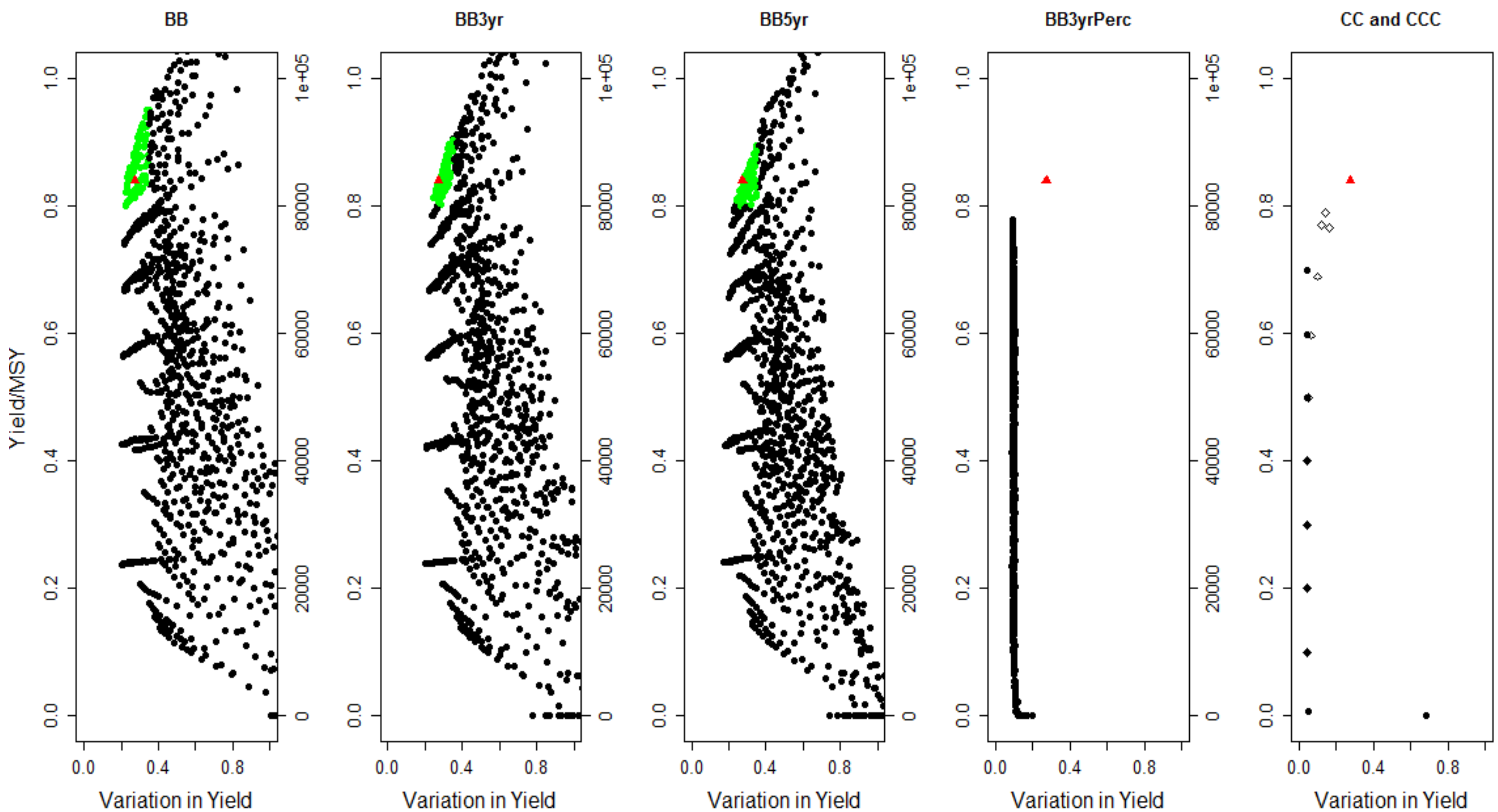
Biomass based	1,360 alternatives
Biomass based with 3 year block	1,360 alternatives
Biomass based with 5 year block	1,360 alternatives
Biomass based with 3 year block and 15% restriction	1,360 alternatives
Constant catch	10 alternatives
Conditional constant catch with max F = 0.5Fmsy	10 alternatives
	5,460 alternatives
	x 8 operating models
	43,680

Control Rules

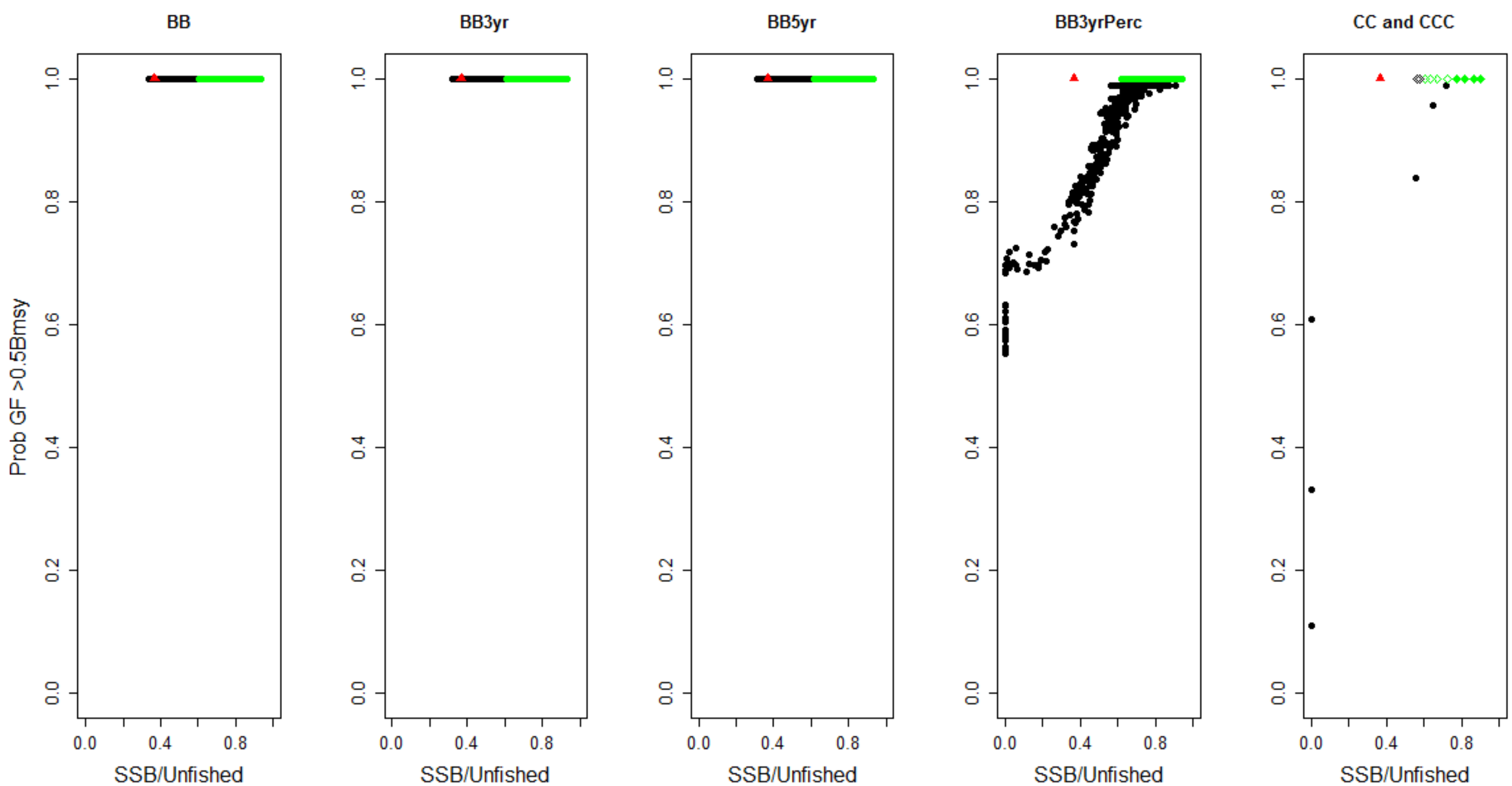
For each operating model, each control rule alternative was simulated for 150 years and this was repeated for 100 simulations



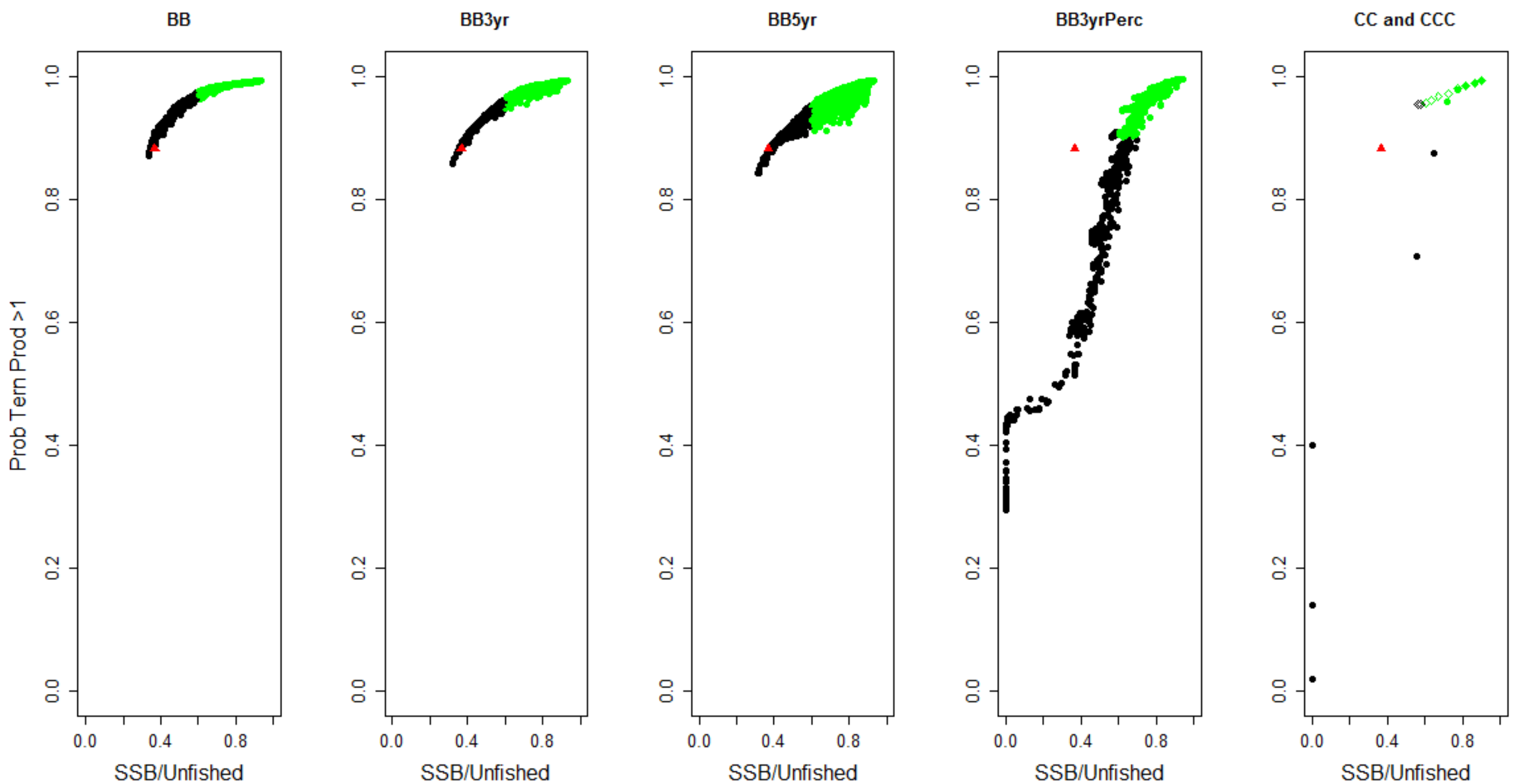
Prelim Results – Herring Yield vs Stability



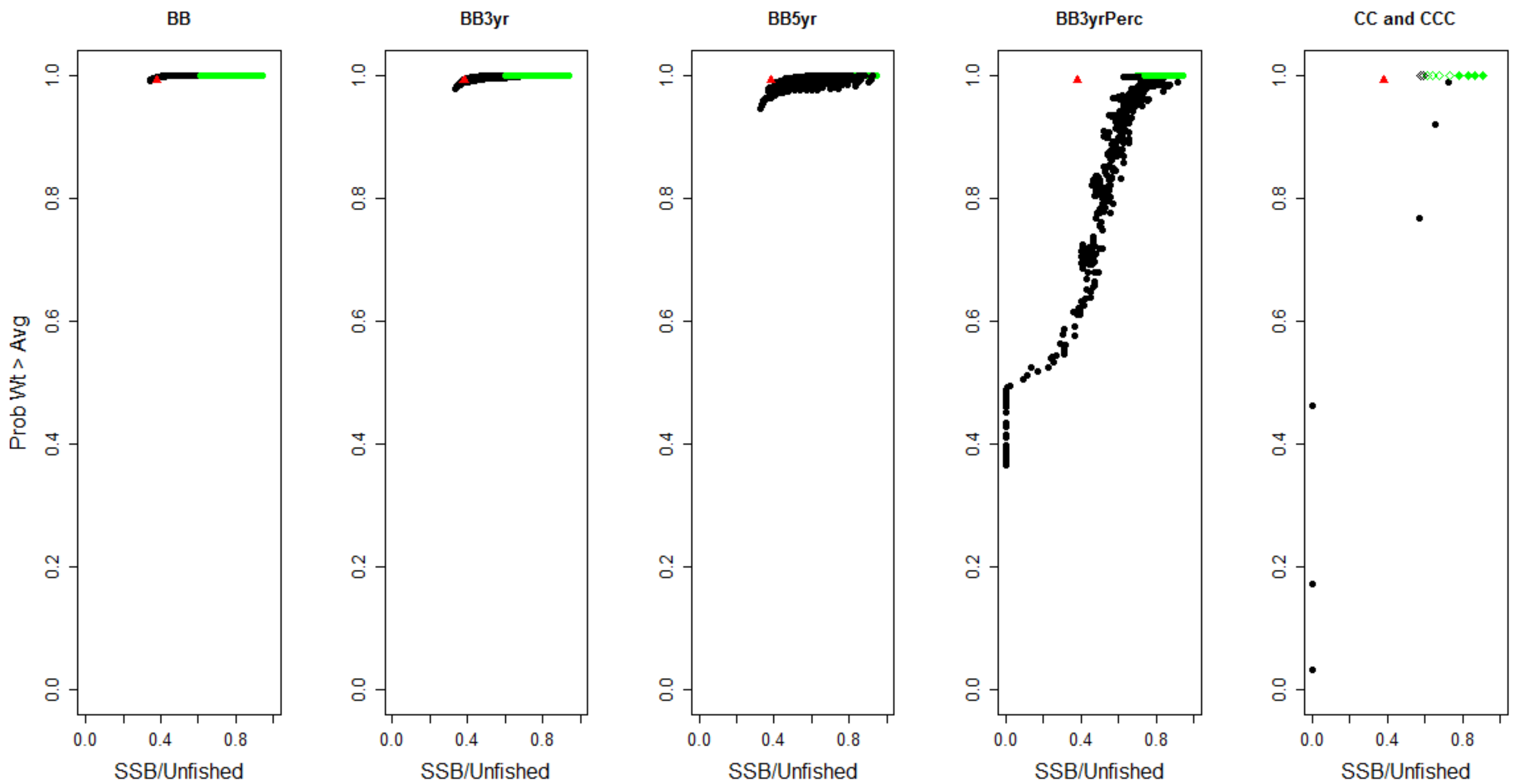
Frequency Dogfish > 0.5Bmsy vs herring SSB



Frequency tern prod > 1.0 vs herring SSB



Frequency tuna good condt'n vs herring SSB good herring growth



Post Workshop #2

- At workshop: less support for BB with 15% restriction and CC/CCC
  - Too much yield lost for short-term stability, poor performance elsewhere
  - More likely to require short-term deviations in application

- Post workshop: Herring AP and Committee tasked with:

  1) identifying priority metrics and tradeoffs; and

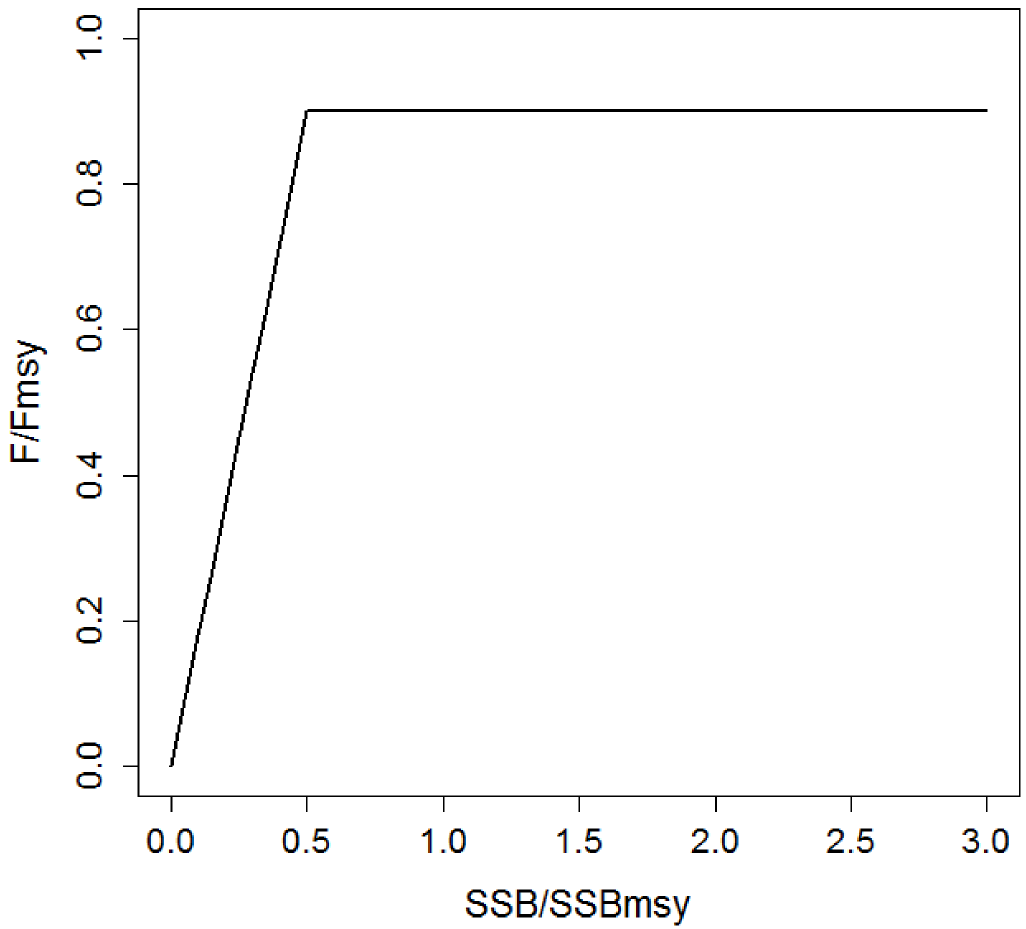
  2) identifying a reasonable number of CR alternatives.

- Herring PDT prepared 4 example control rule shapes, and evaluated their performance for a handful of possible metrics.

Control Rules

Biomass based	1,360 alternatives
Biomass based with 3 year block	1,360 alternatives
Biomass based with 5 year block	1,360 alternatives
~~Biomass based with 3 year block and 15% restriction~~	~~1,360 alternatives~~
~~Constant catch~~	~~10 alternatives~~
~~Conditional constant catch with max F = 0.5Fmsy~~	~~10 alternatives~~
	4,080 alternatives
	x 8 operating models
	~~43,680~~ 32,640

Let’s Compare 4 CRs



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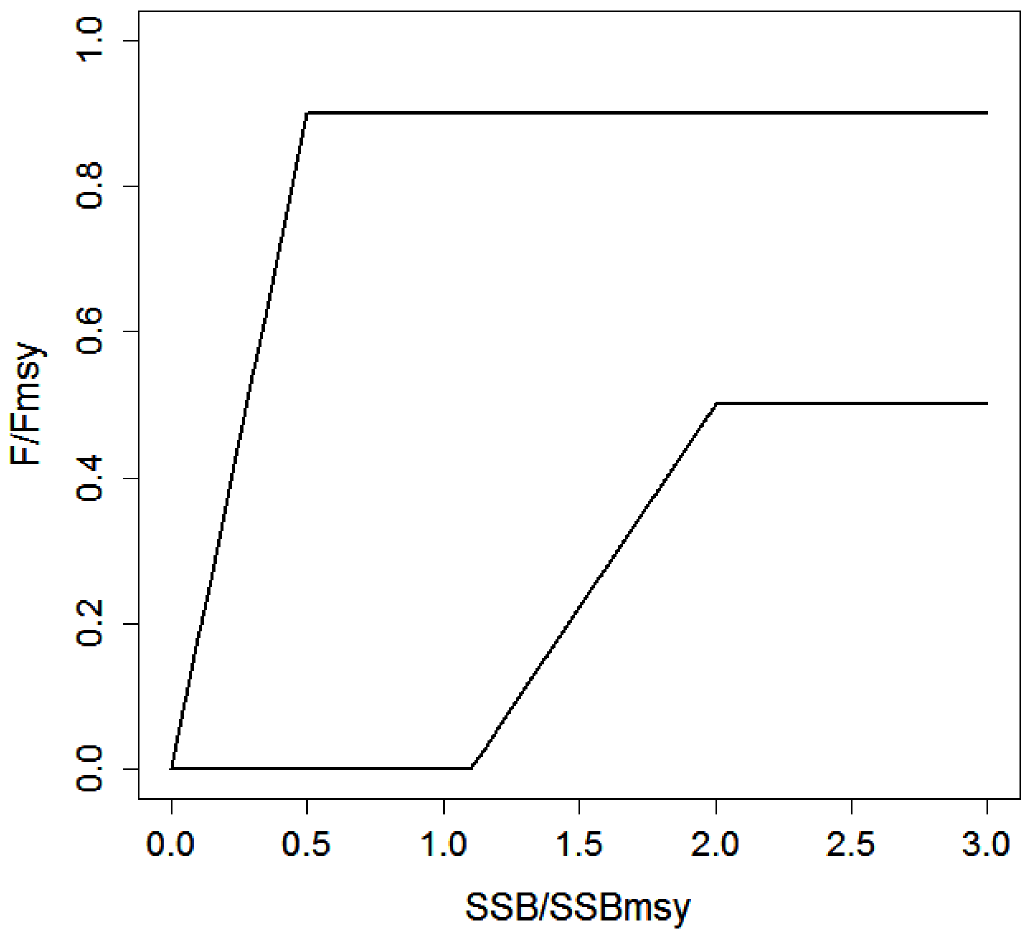

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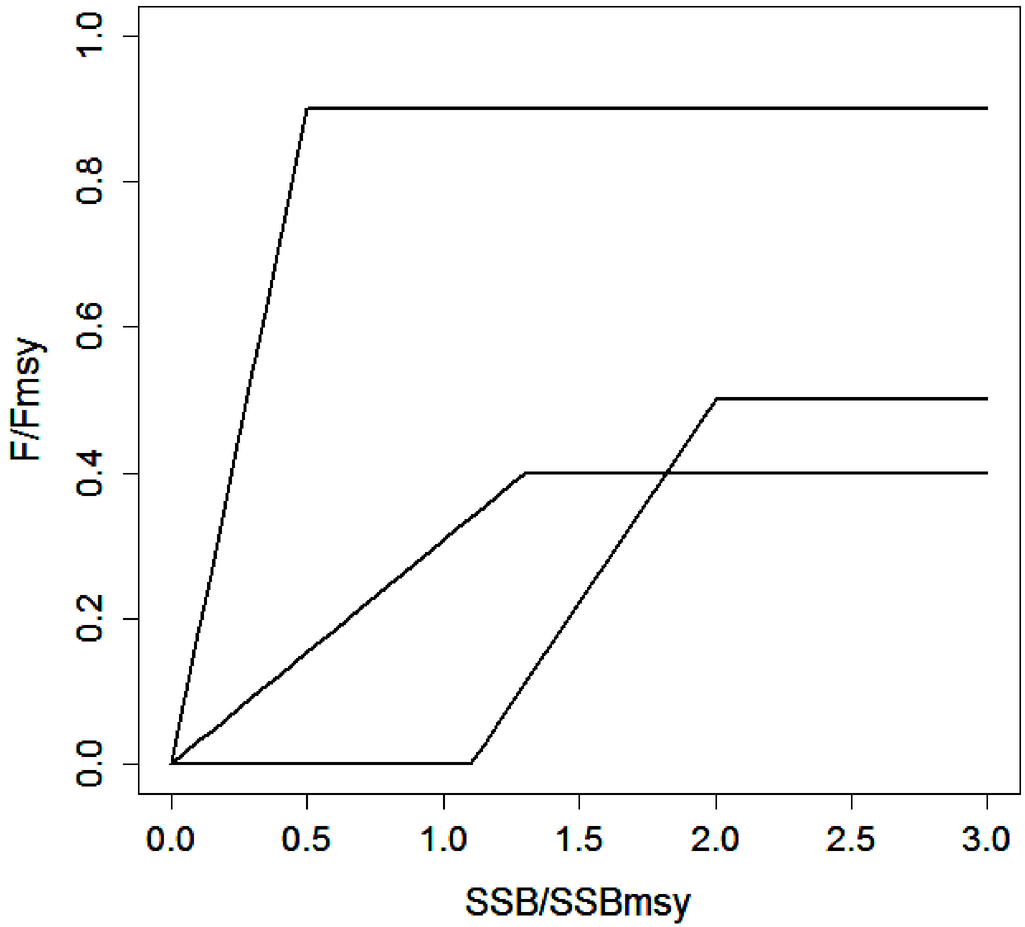

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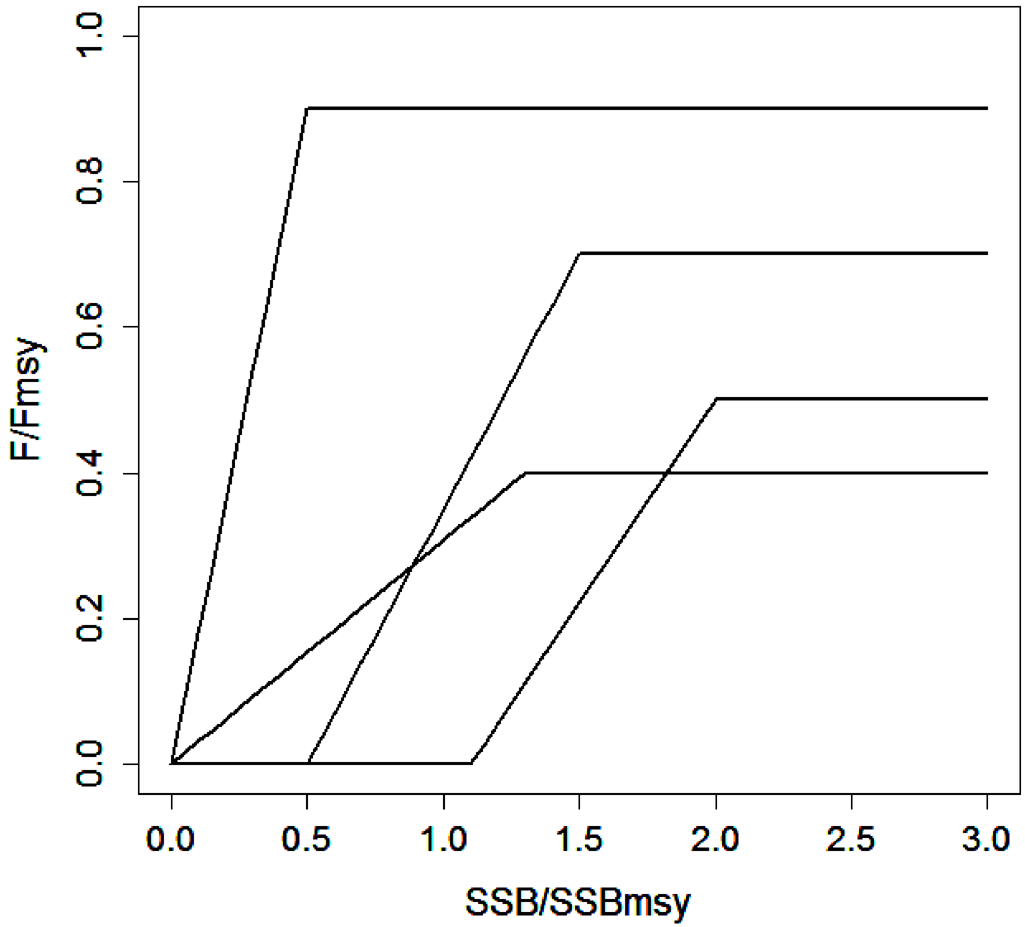


Let's Compare 4 CRs

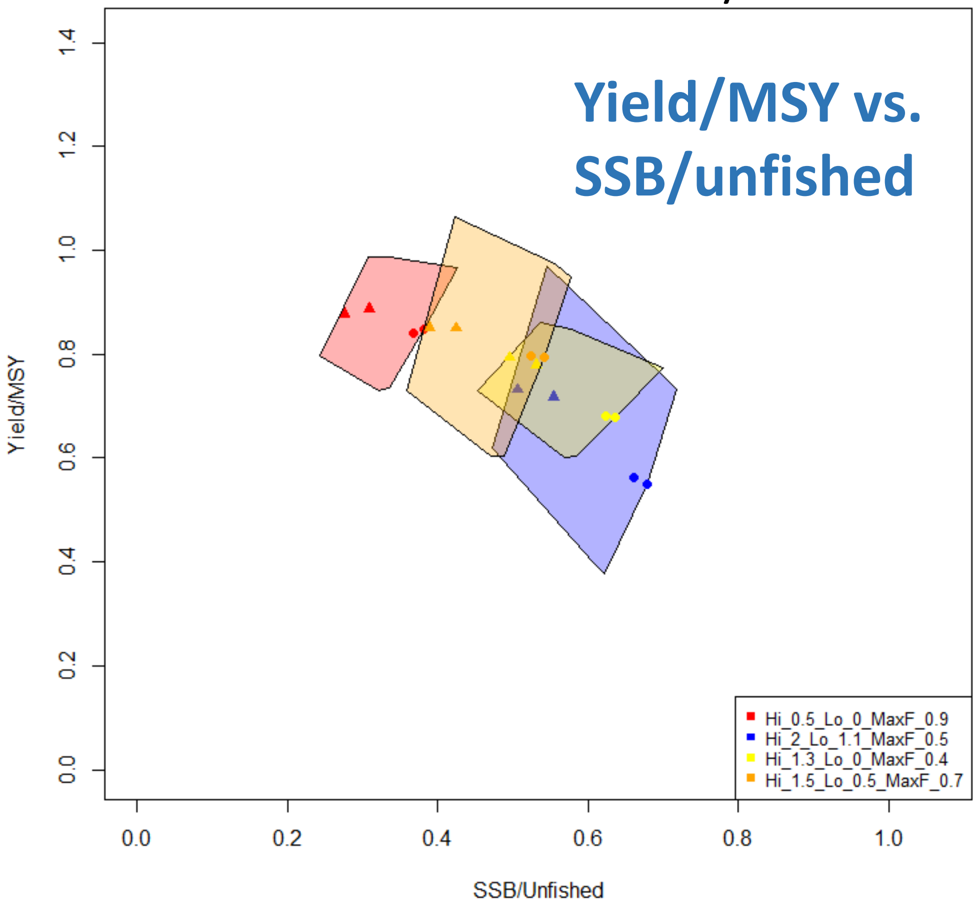
1. Examine tradeoffs and uncertainty in tradeoffs
2. Examine effect of assessment bias
3. Examine effect of annual ABC, 3 year blocks, and 5 year blocks

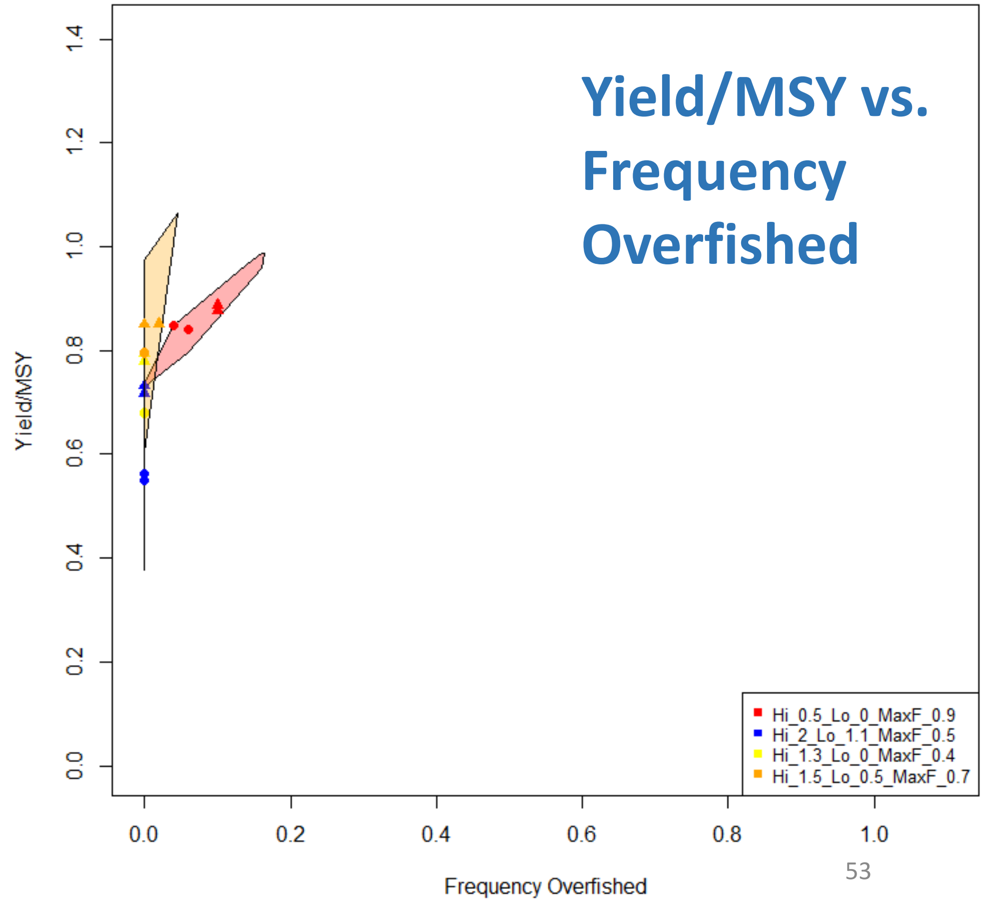
1. Examine tradeoffs and uncertainty in tradeoffs

Note some CRs more robust than others

Let's Compare 4 CRs

all with 3 year block – unbiased assessment



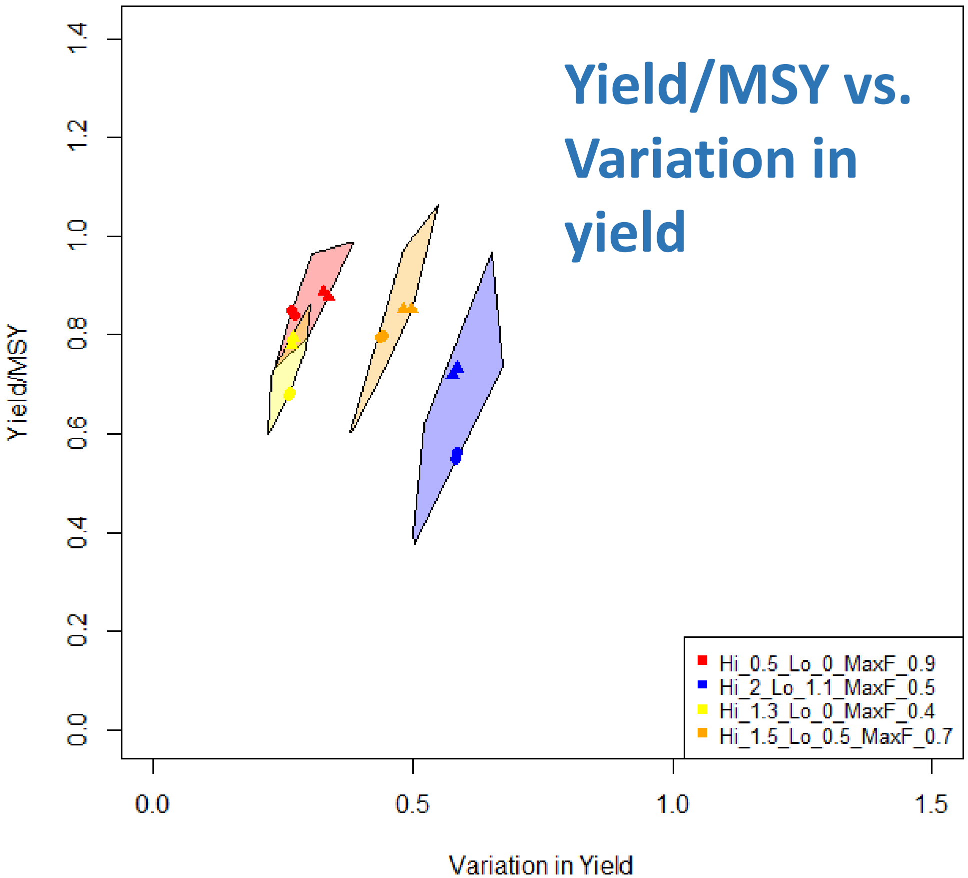


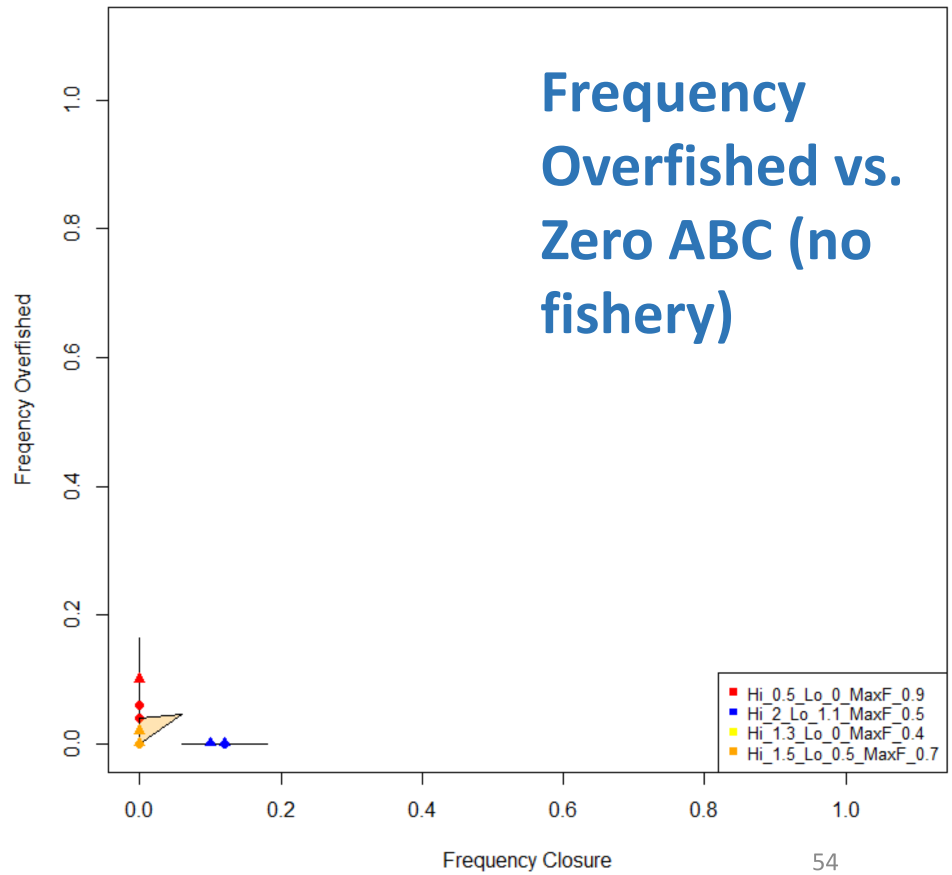
1. Examine tradeoffs and uncertainty in tradeoffs

Results more certain here

Let's Compare 4 CRs

all with 3 year block – unbiased assessment



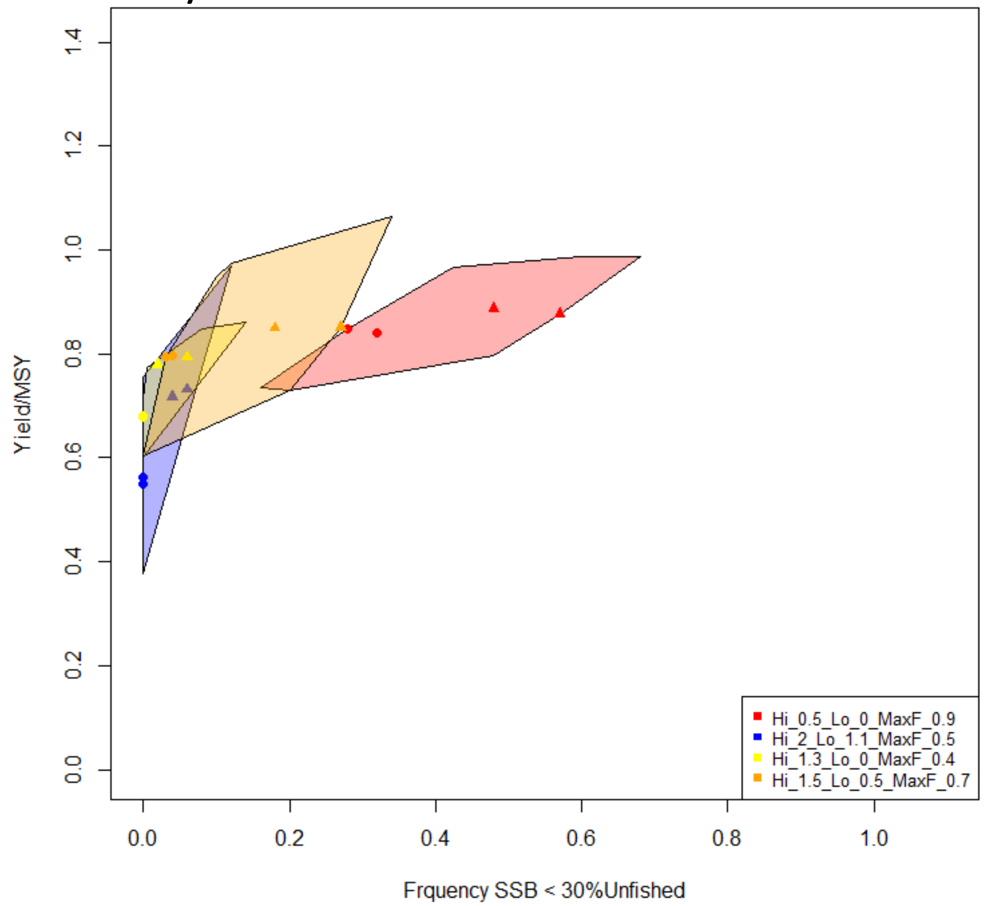


Note some CRs more robust than others

1. Examine tradeoffs and uncertainty in tradeoffs

Let’s Compare 4 CRs

all with 3 year block – unbiased assessment



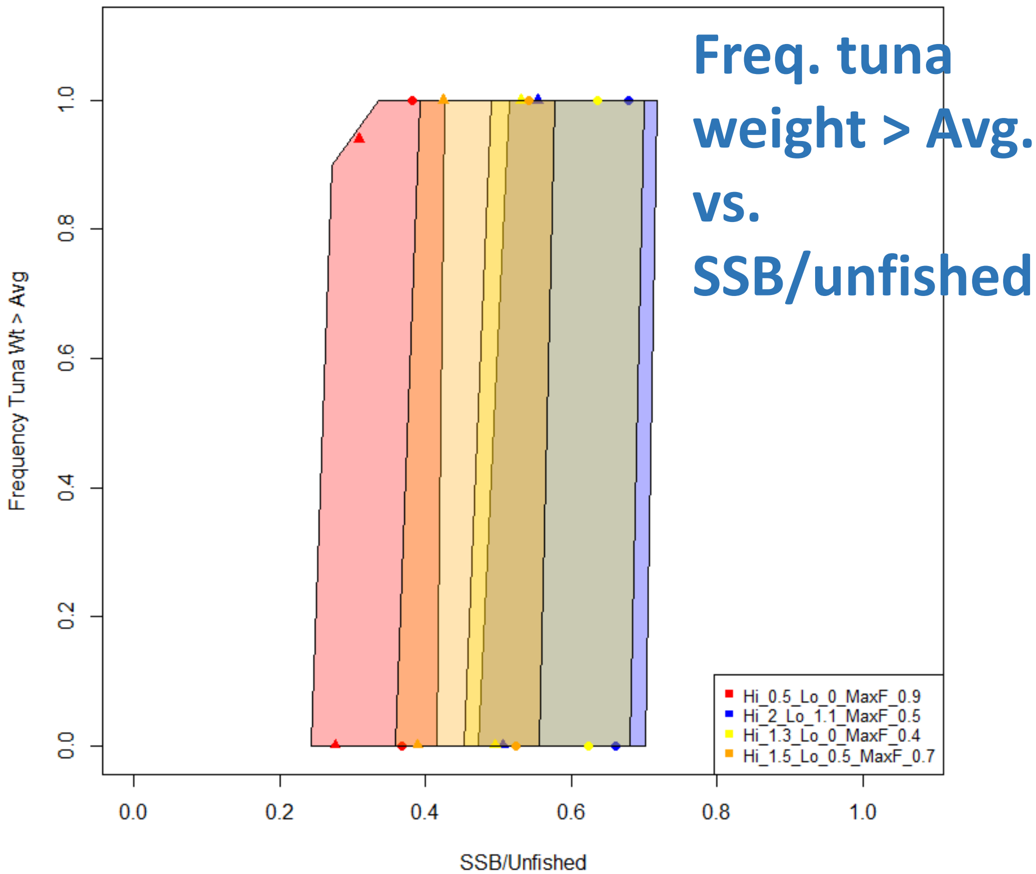
Yield/MSY vs. Frequency SSB <30% unfished

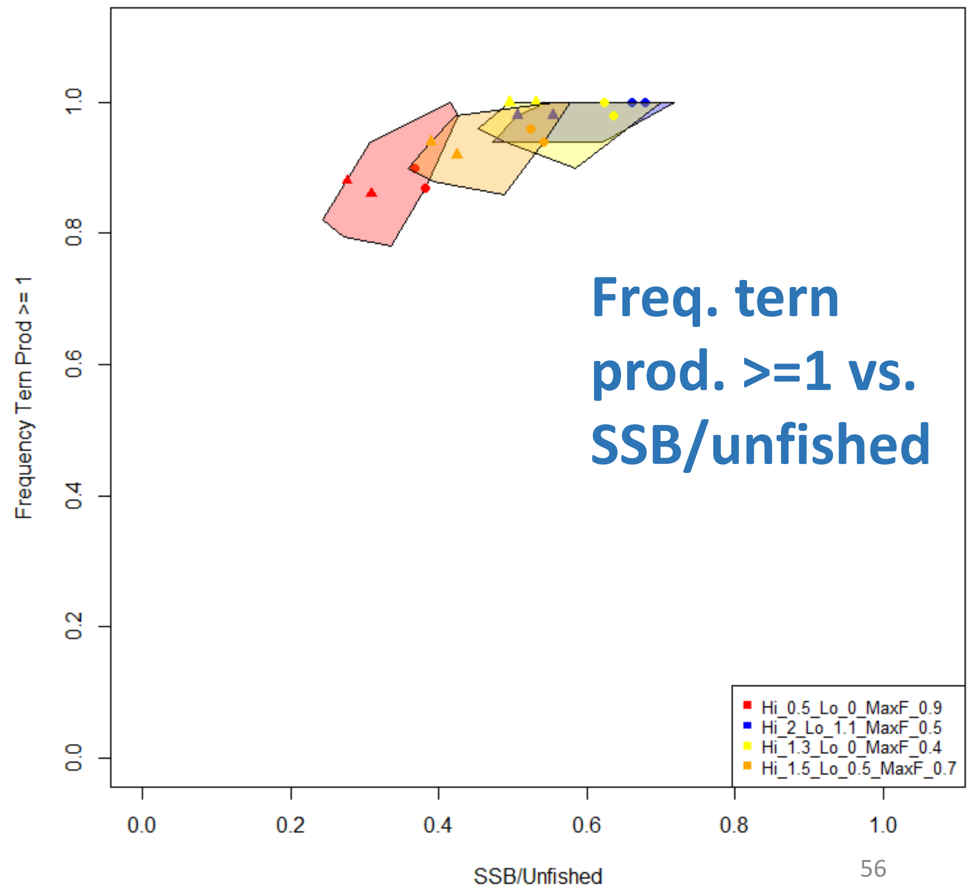
1. Examine tradeoffs and uncertainty in tradeoffs

Note some CRs more robust than others

Let’s Compare 4 CRs

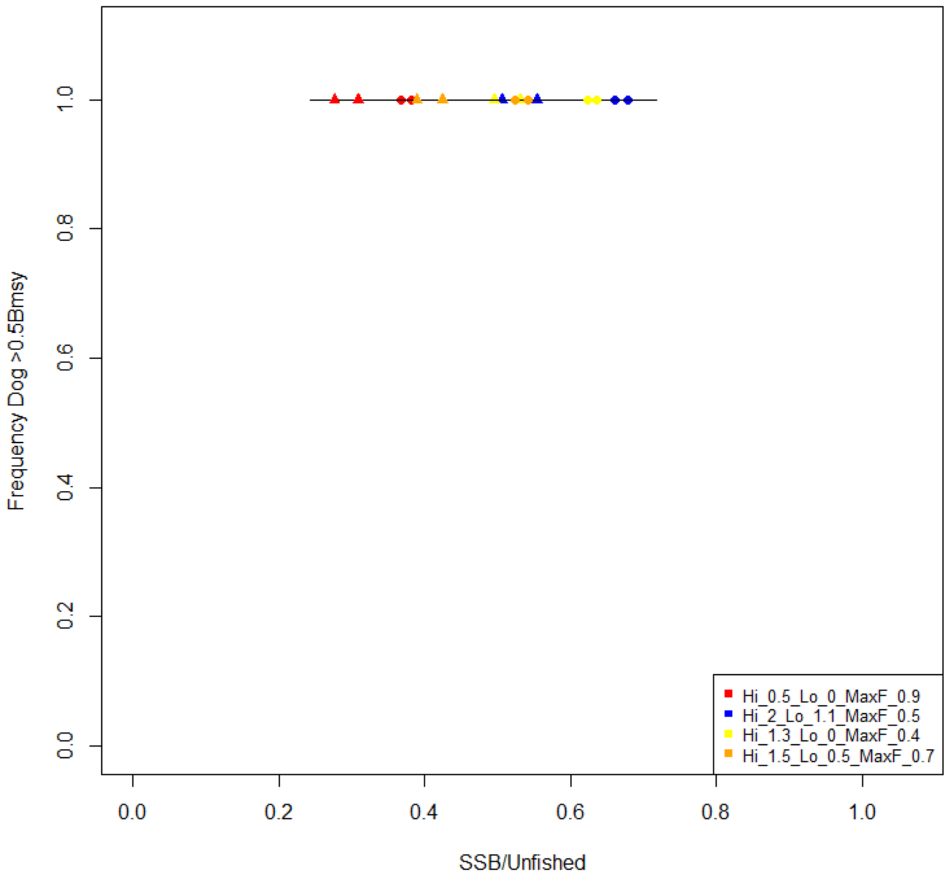
all with 3 year block – unbiased assessment





Let's Compare 4 CRs

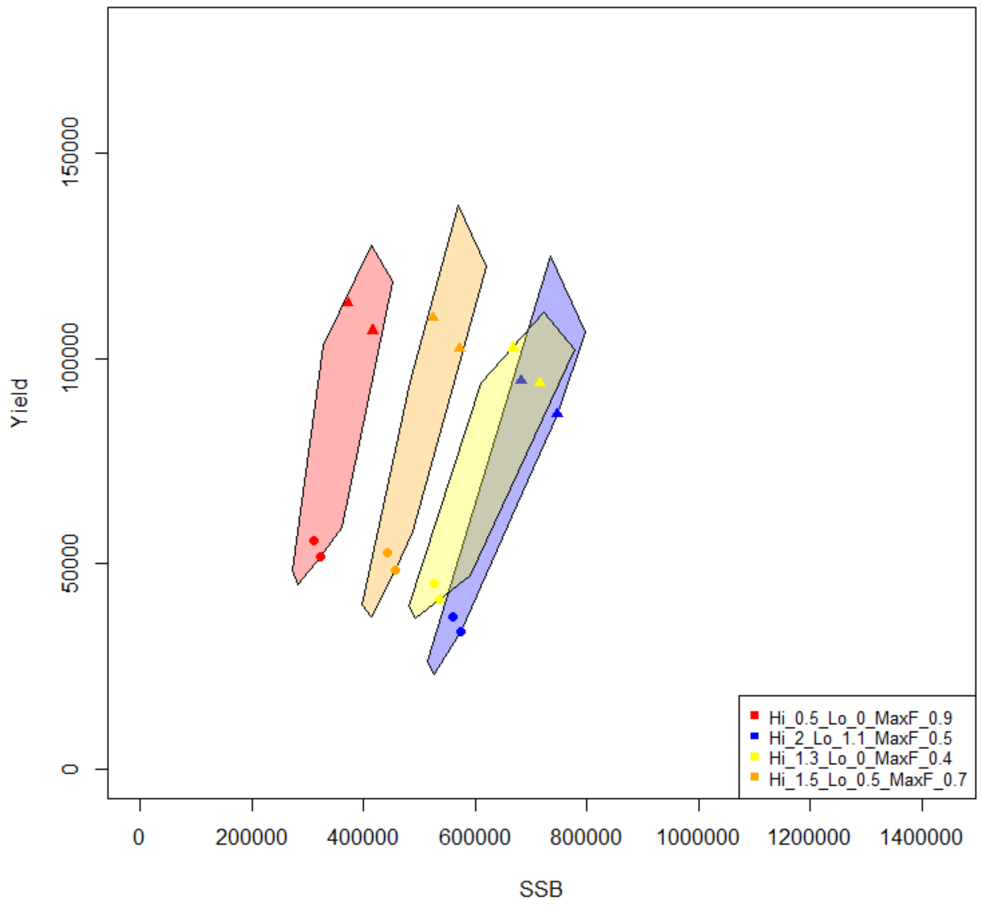
all with 3 year block – unbiased assessment



Frequency dogfish>0.5Bmsy vs. SSB/unfished

1. Examine tradeoffs and uncertainty in tradeoffs

Let’s Compare 4 CRs
all with 3 year block – unbiased assessment



Herring Yield vs. SSB

Let’s Compare 4 CRs

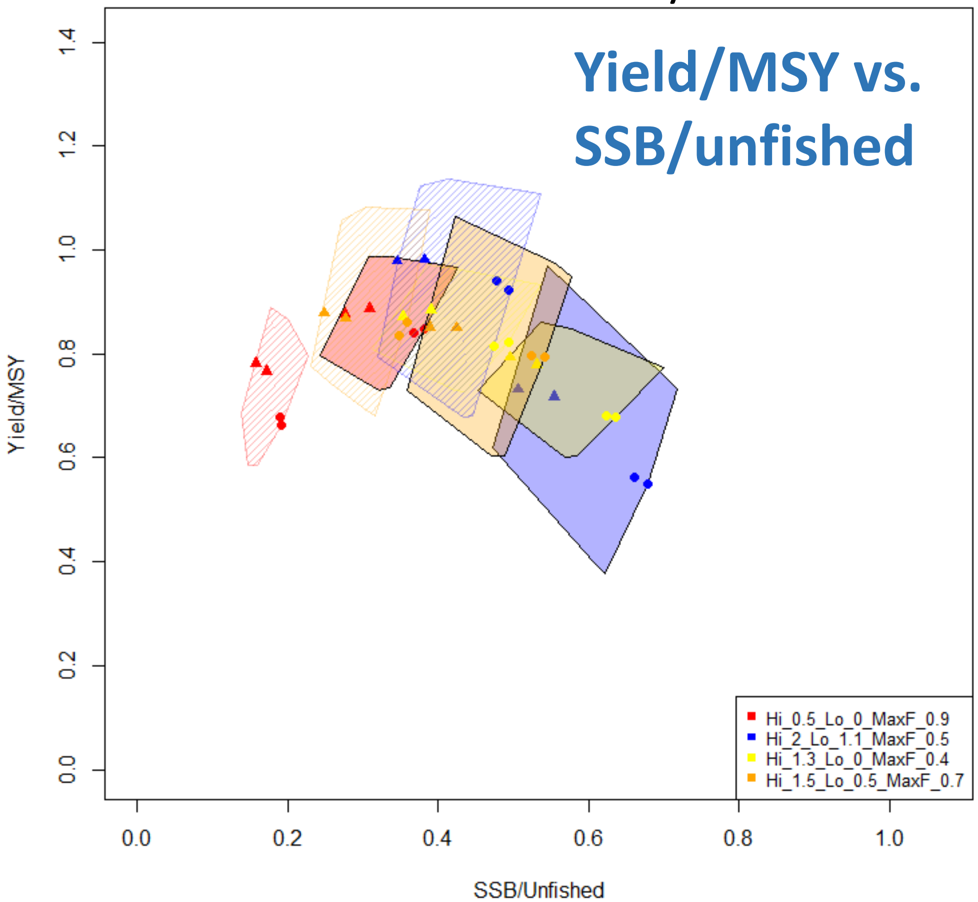
- What metrics/tradeoffs do you value most?
  - For example, if you highly value yield then you likely favor CRs with certainty in high amounts of yield, but do you get “acceptable” performance for other metrics?

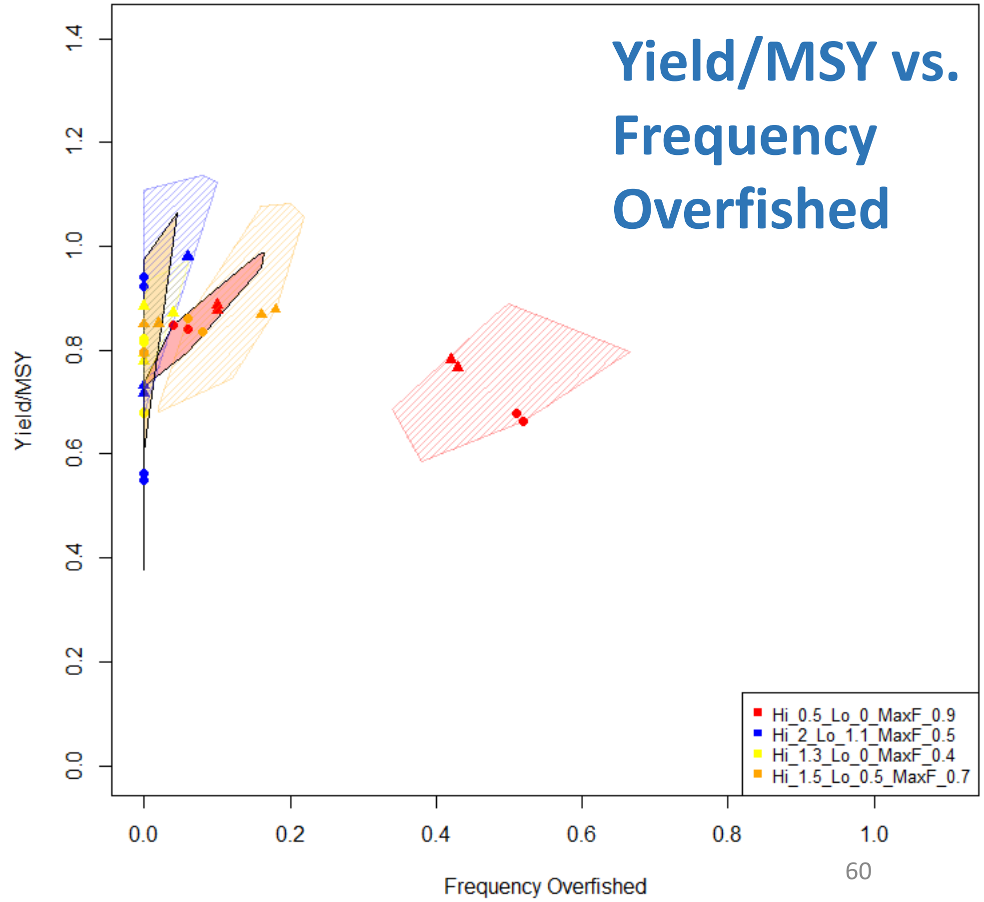
2. Examine effect of assessment bias

Note some CRs more robust than others, esp. Freq. Overfished

Let's Compare 4 CRs

all with 3 year block – effect of assessment bias





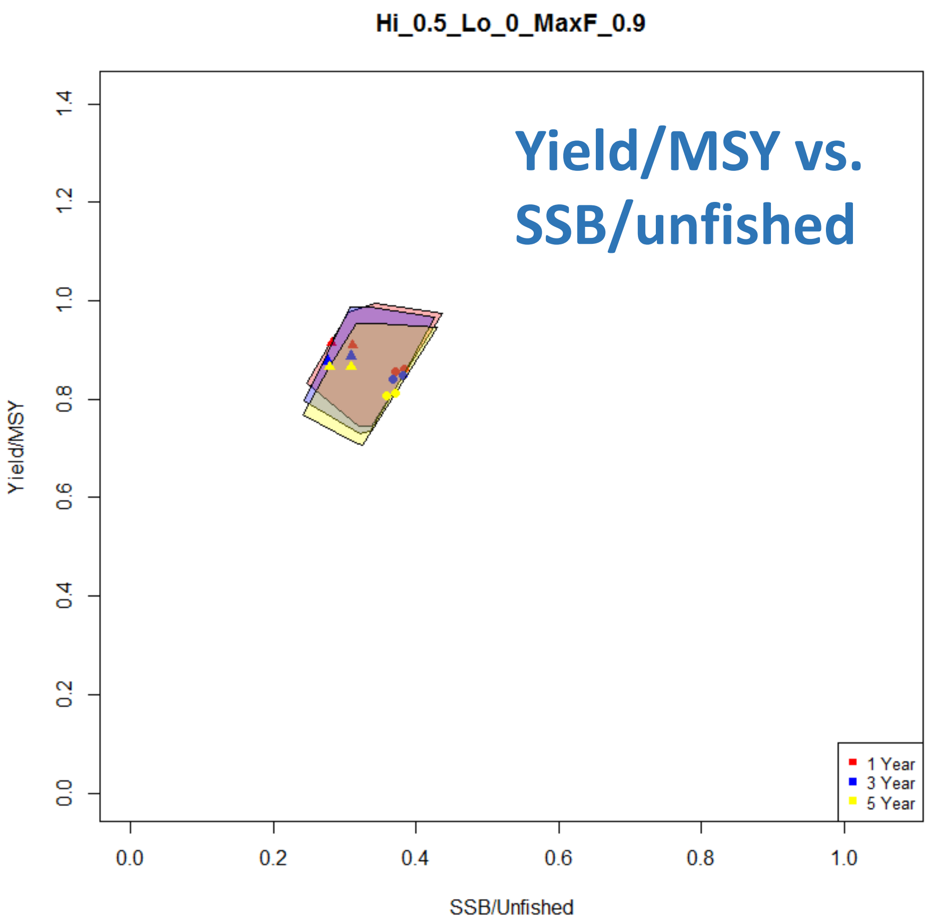
Let’s Compare 4 CRs

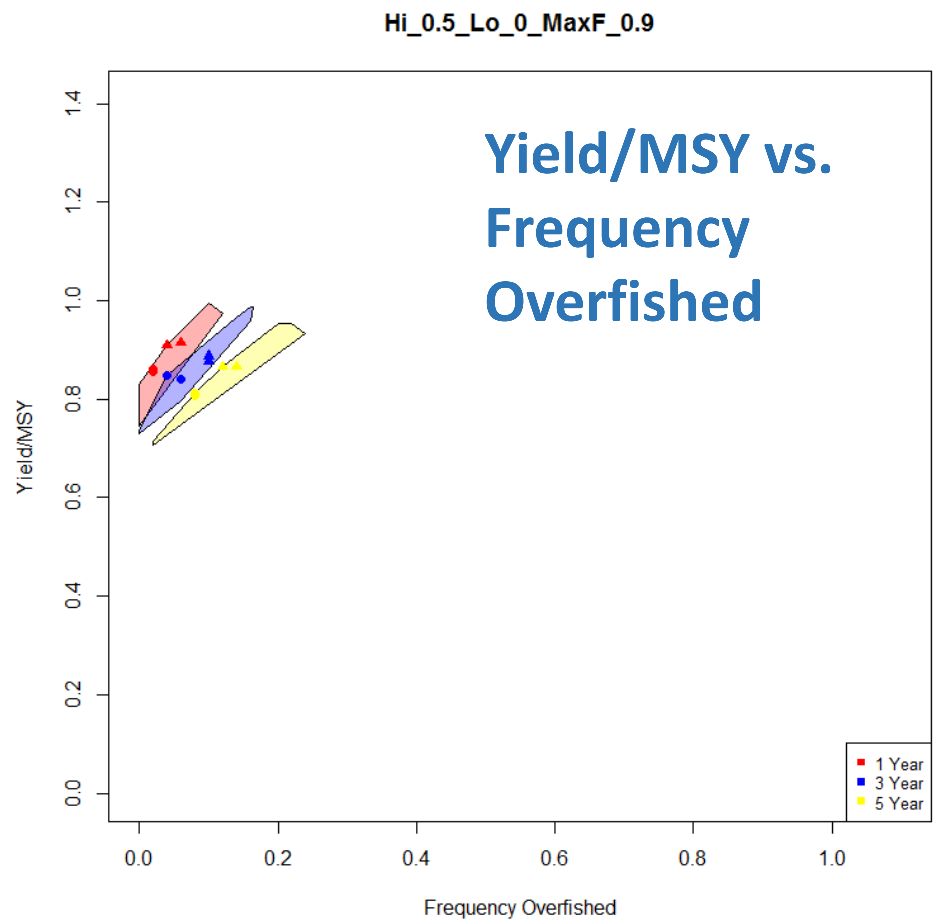
- Relying solely on biased results may duplicate other processes
  - We make adjustments for bias (e.g., retrospective adjustments)
  - We have peer review
  - We have an SSC
- Robustness to bias, which did vary among CRs, desirable

Longer blocks cost yield and SSB

3. Examine effect of annual ABC, 3 year blocks, and 5 year blocks

Status Quo CR – comparing 1, 3, and 5 years





Let's Compare 4 CRs

- Is the short-term stability of longer blocks worth the cost in: yield, long-term variation in yield, frequency of overfished, decrease in frequency of desired tern production?
- What is industry's preferred planning horizon?

Other Considerations

- Other tradeoffs of interest?
- Identifying or refining CR alternatives can by achieved by:
  - Specifying preferred performance for various metrics
  - Moving CR parameters (Hi and low thresholds and Max-F); “What if?”

Pause for Questions on Part II?

Preliminary analyses of potential control rule alternatives