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# RESTORE FFO-2023 - Actionable Science

Building next-generation diagnostic and forecasting capacity to achieve management objectives by increasing stock assessment accuracy and throughput.

Nathan Vaughan – Vaughan Analytics

GMFMC SSC  
August 1<sup>st</sup> 2024



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RESTORE grants

NA21NOS4510182 & NA23NOS4510311

## Project Team

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## Project Monitors

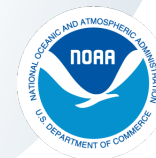
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## Collaborators

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# Goals for today's discussion

- Introduce our project to SSC members
- Review initial results from recent work
- Discuss implications of these results and key decision points for implementation
- Discuss SSC member preferences for
  - Future project updates
  - Research integration into stock assessment advice
  - Avenues for feedback
- Foster discussion on additional future research priorities



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# Project overview

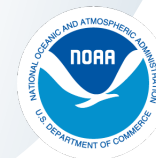
- Awarded 5 years of funding in October 2023
- Funding supports development of actionable research products that inform specific management decisions in the Gulf of Mexico
- Intended to facilitate the co-production of science between researchers, resource managers, and stakeholders
- Our goals are to develop and integrate improvements to existing stock assessment methods to inform OFL and ABC decision making for Gulf of Mexico fisheries
- Project will focus on three core areas for stock assessment improvement
  - Realism and accuracy of projections
  - Management advice throughput and robustness
  - Model interpretability and uncertainty quantification



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# Realism and accuracy of projections

- Projections are needed to estimate reference points and short term over fishing limits
- Simulations of the future constrained by many assumptions
  - Future dynamics of the fishery
    - Total effort and relative fleet participation
    - Selectivity and retention patterns
  - Future productivity of the stock
    - Recruitment rates
    - Natural mortality
    - Growth
  - Future ecosystem/environmental effects
    - Climate induced changes
    - Episodic mortality



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# Realism and accuracy of projections

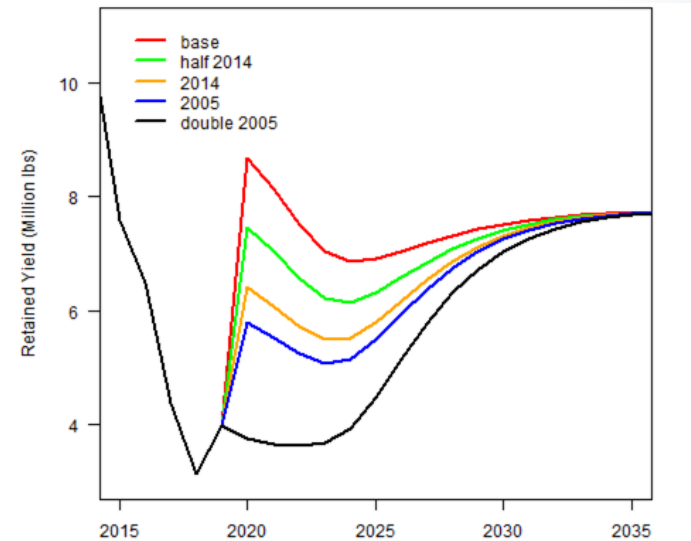
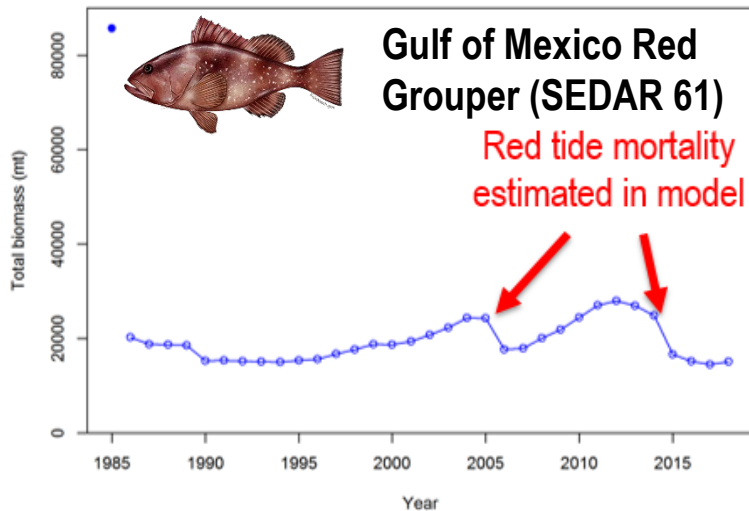
- Episodic mortality effects on benchmarks
  - Red tide and climate impacts
  - Red tide impact included in historic mortality and OFL estimates but not in benchmark calculations
  - Preliminary simulation analyses highlight decision points necessary for incorporation into management
- Selectivity dependent MSY
  - Fleet specific MSY (Tested for ICCAT YFT/BET)
  - Length/Age specific MSY
- Projecting discards
  - Impact of quotas and regulations on discard rates
  - Test methods to decouple discards from landings
- Other improvements as needs/issues/solutions are identified



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# Episodic mortality

- Previous efforts have focused on:
  1. Historical modeling of red tide events
  2. Short-term catch advice based on red tide mortality scenarios

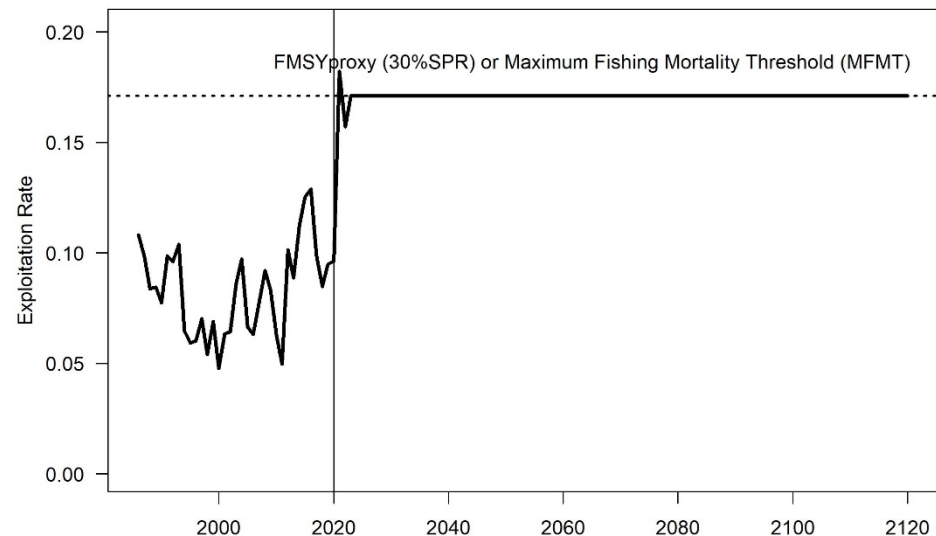
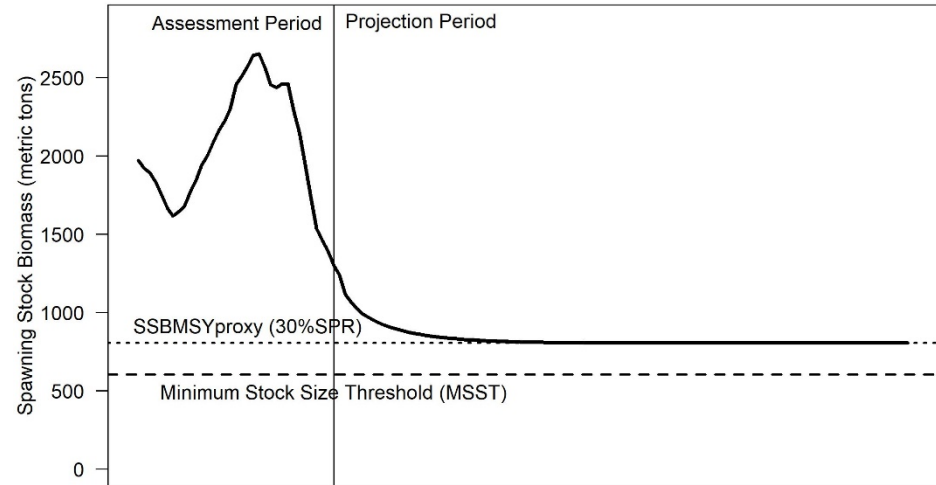


- No previous attempts to incorporate episodic events into reference points

# Projection approach for benchmarks

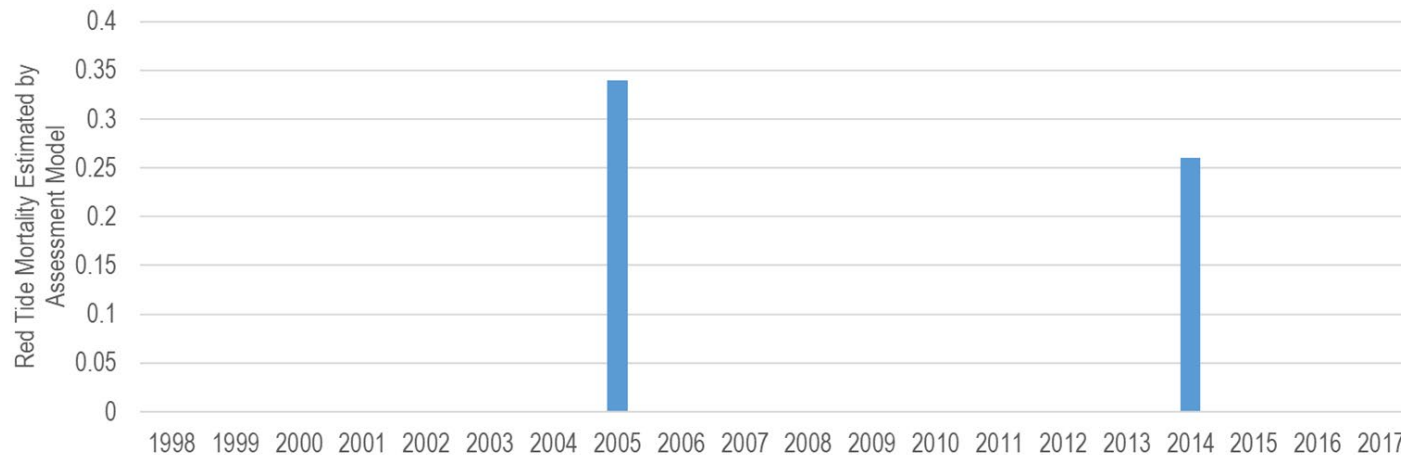
- 100-year equilibrium projection assuming:

Relative F	Average relative fishing mortality (apical F) over terminal 3 years
Selectivity	Fleet specific selectivity estimated over terminal 3 years
Retention	Fleet specific retention estimated over terminal 3 years
Recruitment	Derived from the model estimated Beverton-Holt stock-recruitment relationship
Interim Landings (2021-2022)	Landings estimates if available; if not, used 3-year average of most recent 3 years of landings
Allocation Ratio	Commercial and recreational sector allocations
Red Tide Mortality	Ignored in long-term projections



# Simulating future red tides: Red Grouper

- Historical red tide mortality estimates obtained from assessment model



- Quantitative red tide indices start in 1998 (using SeaWiFS), hard to quantify red tides prior

Year Range	Mean RTM
<b>1998-2017</b>	<b>0.030</b>
2000-2009	0.034
2010-2017	0.033
2015-2019	0.052



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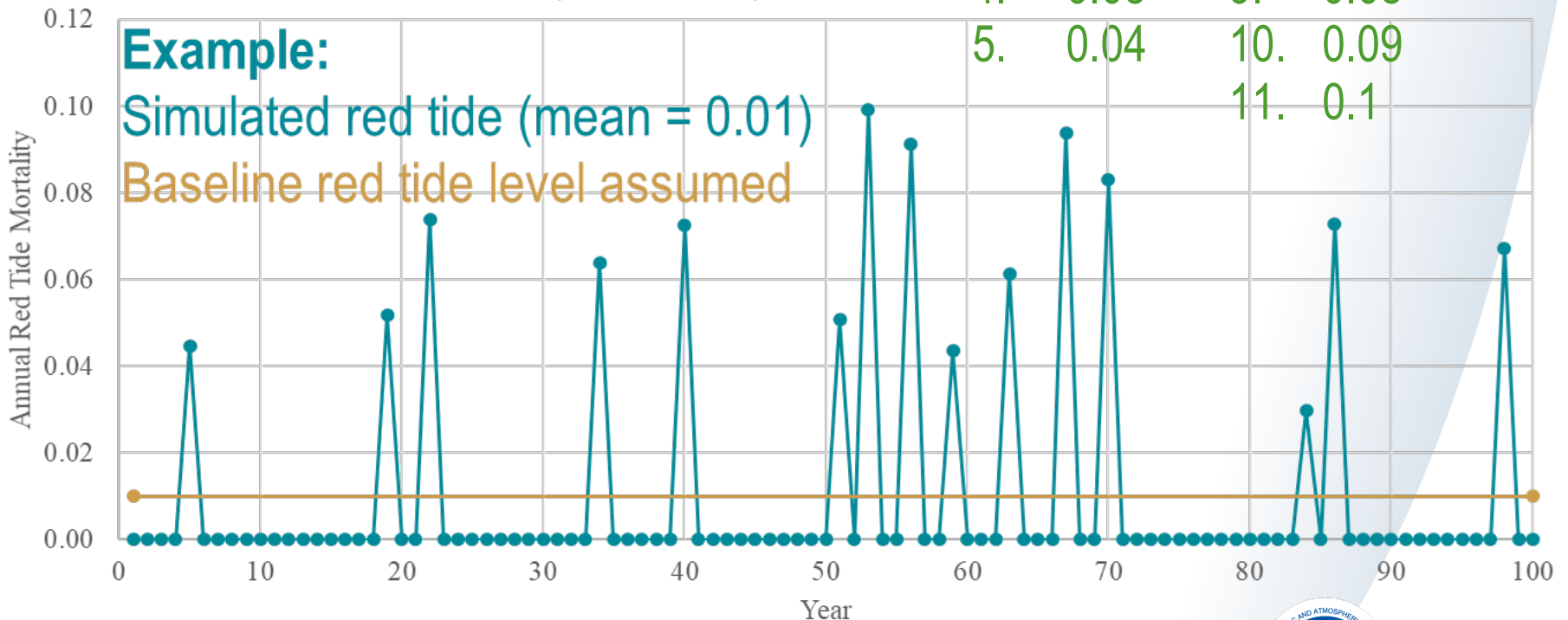
# Simulating future red tides: Red Grouper

- Future red tides:

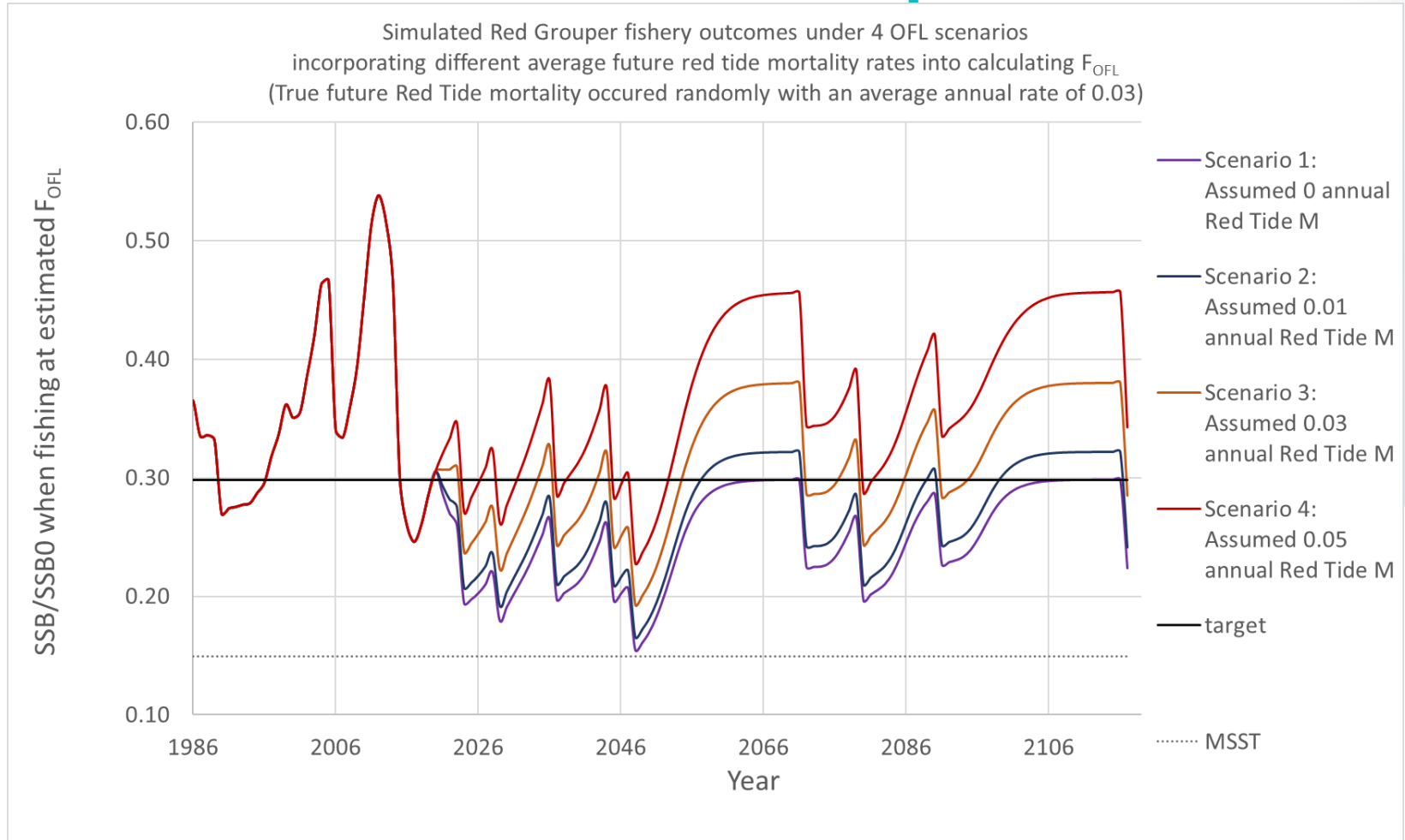
1. Mean of 0.01 (minimal)
2. Mean of 0.03 (actual)
3. Mean of 0.06 (2X actual)

- Baseline red tide levels:

- |         |          |
|---------|----------|
| 1. 0    | 6. 0.05  |
| 2. 0.01 | 7. 0.06  |
| 3. 0.02 | 8. 0.07  |
| 4. 0.03 | 9. 0.08  |
| 5. 0.04 | 10. 0.09 |
|         | 11. 0.1  |

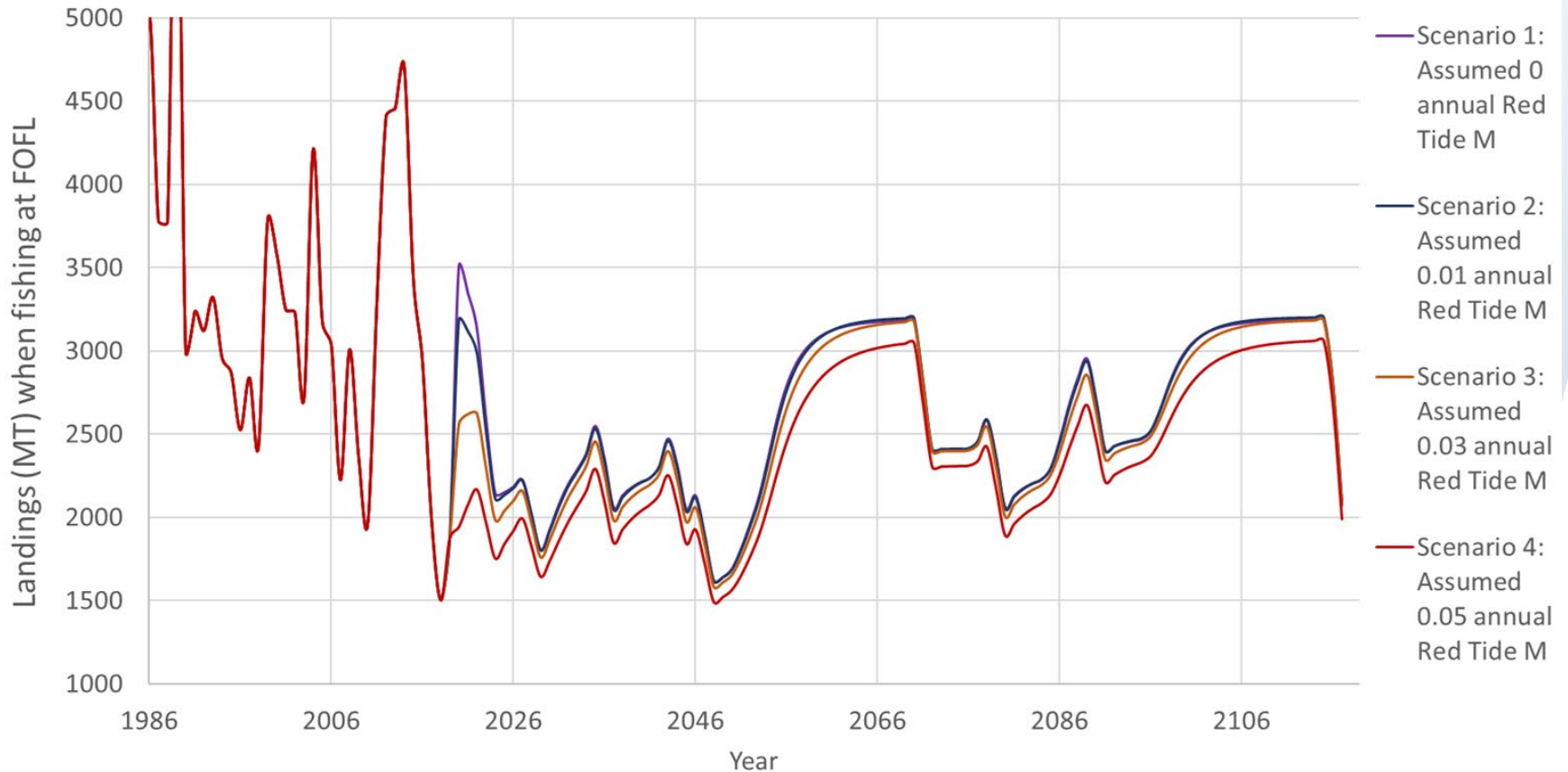


# Simulating future red tides: Red Grouper



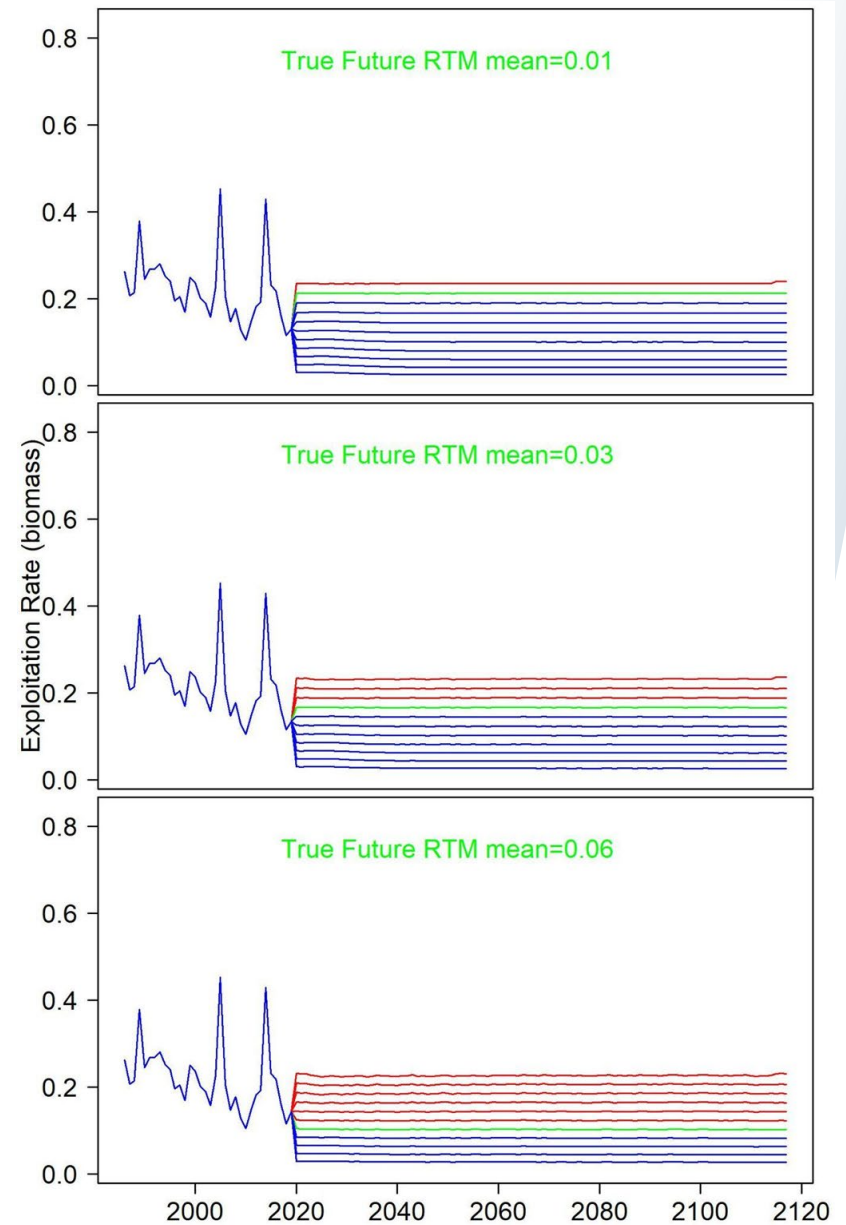
# Simulating future red tides: Red Grouper

Simulated Red Grouper fishery outcomes under 4 OFL scenarios  
incorporating different average future red tide mortality rates into calculating  $F_{OFL}$   
(True future Red Tide mortality occurred randomly with an average annual rate of 0.03)



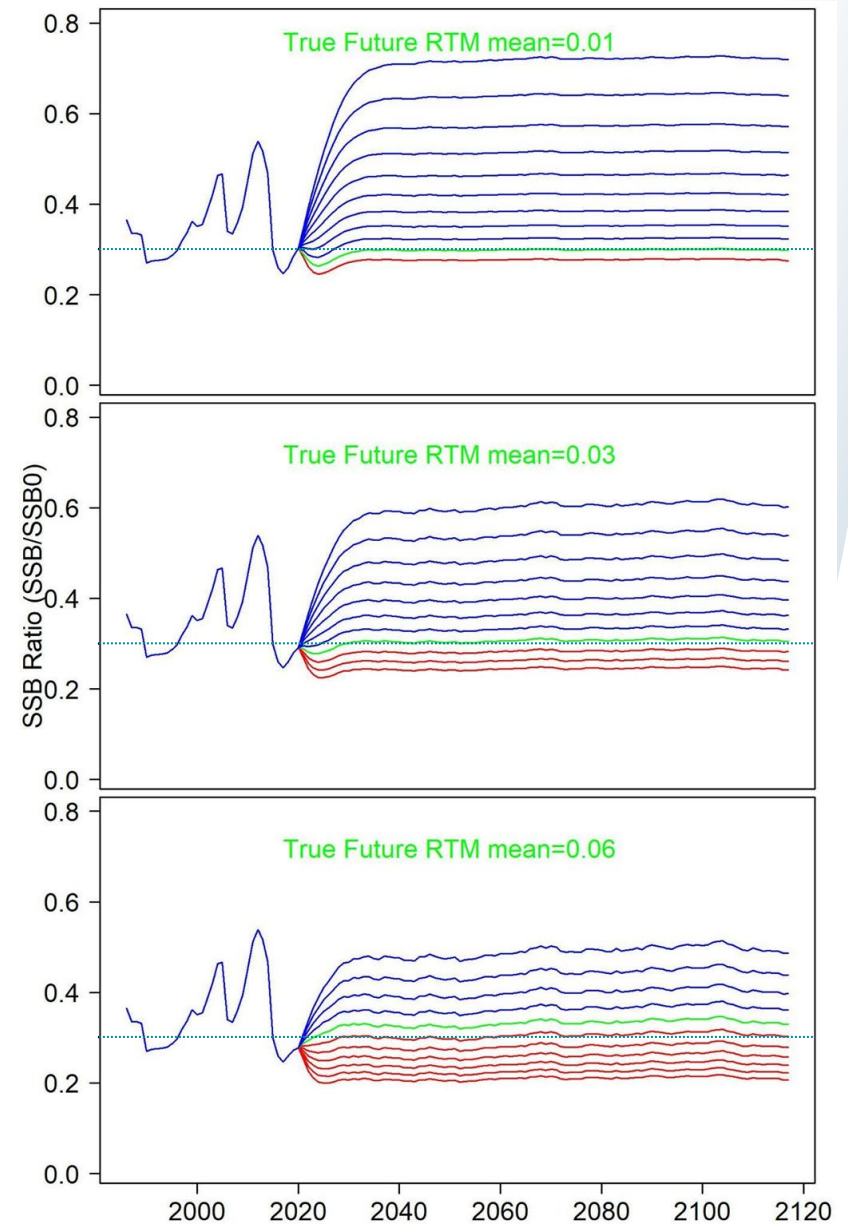
# Results – Red Grouper

- Exploitation rate (biomass)
  - Average across 500 simulations for each scenario
  - Constant F determined by baseline red tide assumption



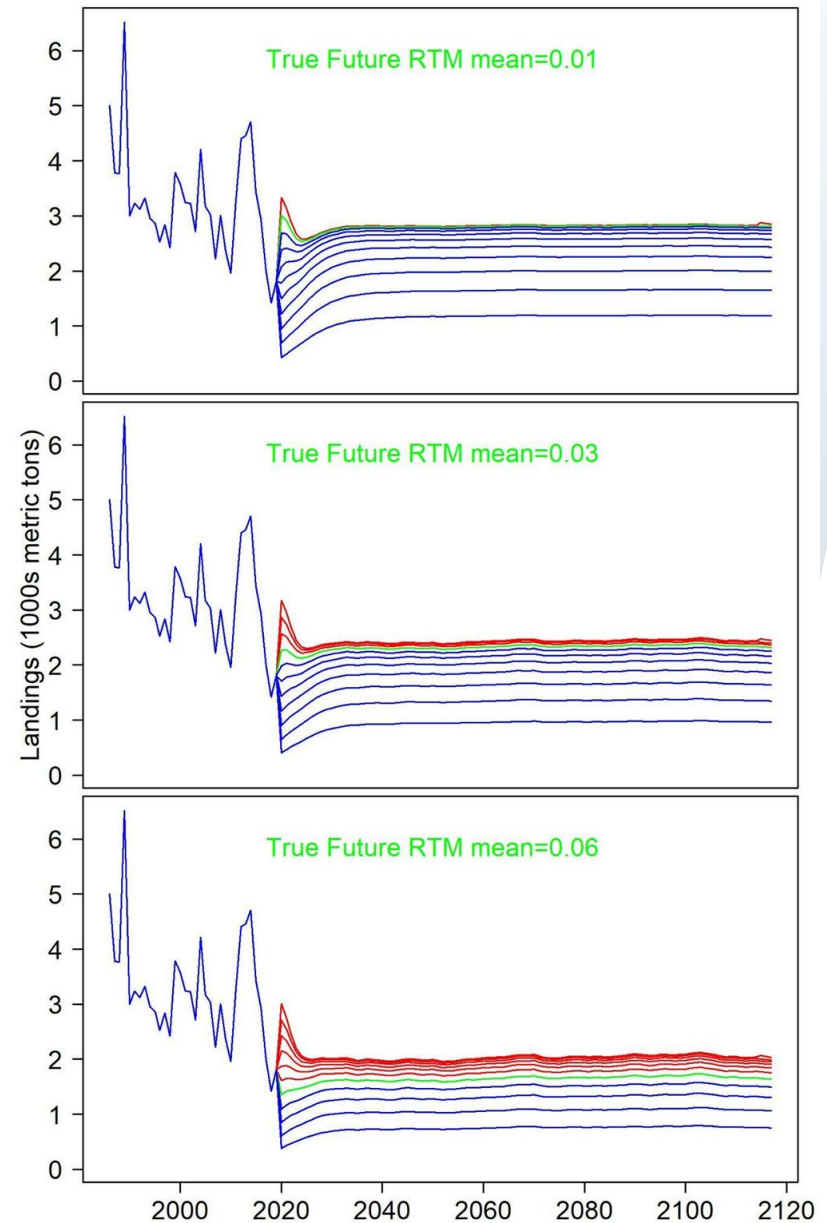
# Results – Red Grouper

- SSB Ratio
  - Average across 500 simulations for each scenario
  - Green scenario sum of baseline red tide F equal to sum of random red tide F



# Results – Red Grouper

- Landings
  - Average across 500 simulations for each scenario
  - Reduction in landings for first few years then similar between scenarios at or above optimal F



# Decision Points for Management

- Red tide mortality is currently parameterized as unmanaged episodic removals of large biomass similar to a bycatch fleet?
  - This depletes fished SSB relative to unfished SSB for calculating benchmarks
    - This would produce a theoretical zero sustainable yield under assumptions of extremely high  $F_{\text{red tide}} = F_{\text{OFL}}$
    - This is a similar scenario to high discard/bycatch fisheries
  - Changing red tide to a predator fleet or annual deviations in  $M$  would cause red tide to reduce fished and unfished SSB for calculating benchmarks
    - This would continue to estimate sustainable yield even under extremely high  $F_{\text{red tide}}$  resulting in extremely depleted SSB and potential stock collapse
- How this is setup will have large impacts on future OFL and stock status determinations



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# Decision Points for Management

- What are possible options for estimating future average red tide?
  - This approach shows potential for limiting the need to predict red tide frequency and annual severity prior to red tide events occurring but still requires a baseline average future mortality rate
  - We ran simulations ranging from much lower to twice recent historic averages. How to select a value for management is undetermined?
- What is the best way to implement this in projections?
  - Include average red tide mortality as done in simulation analysis for all projections
  - Quantify an equivalent increase in SPR proxy target assuming zero red tide (i.e. a ~SPR40% proxy may achieve ~SPR30% on average when average red tide mortality is 0.03, these numbers are just an example)



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# Analysis limitations

- This approach implements constant annual fishing mortality rates (i.e. catch follows red tide induced biomass reductions)
  - This was considered close to the outcome of annual interim OFL updates with minimal assumptions
  - Investigating fixed catch scenarios would require a more in depth MSE style simulation approach and assumptions regarding carryover/payback measures
- Results show more investigation is needed for how to calculate the baseline average to achieve target OFL proxy
  - Average annual  $F$  could to be replaced with geometric mean or sum of proportion removals which is being tested currently to improve predictability in results
- Simulations are also being completed for Gag grouper are there other species of particular concern for red tide mortality the SSC would like considered?



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# Selectivity based MSY

- The size/age structure of fishery landings is an important determining factor in the sustainability of those landings
- Stock assessments in the Gulf generally assume a fixed landings allocation between recreational and commercial sectors is maintained in the future
- Within sectors relative effort is assumed to remain constant among fleets
- This requires OFL calculations to be recomputed if a change in allocations is considered
- Achieved landings often diverge from these assumptions



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# Selectivity based MSY

## Fleet specific MSY

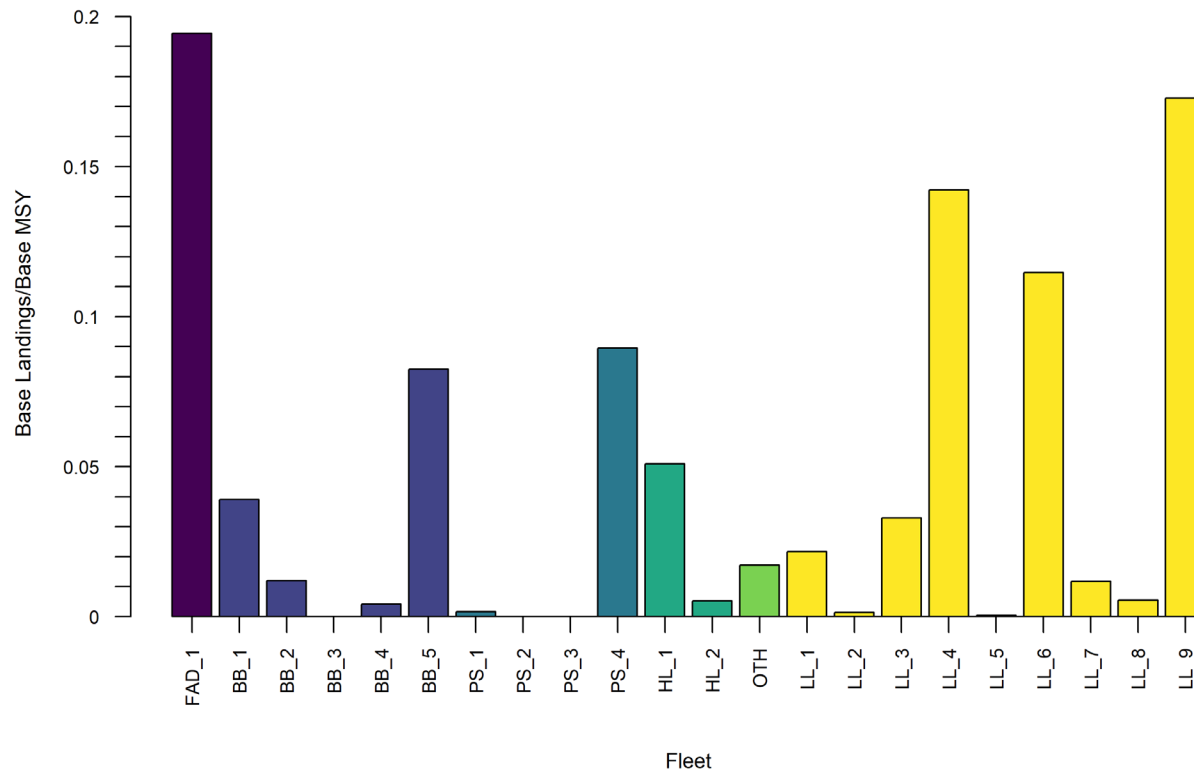
- Calculate MSY/OFL assuming only single fleet operating by running a projection for each fleet with all other fleets set at  $F=0$
- For all projections adjust single fleet  $F$  to achieve target spawning potential ratio MSY proxy such as SPR30%
- Compare to status quo landings at recent fleet relative  $F$  (i.e. no allocations scenario) or to current managed allocations
- Total fishery OFL can then be calculated such that the total proportion of fleet specific MSYs sums to 1.



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# Fleet specific MSY

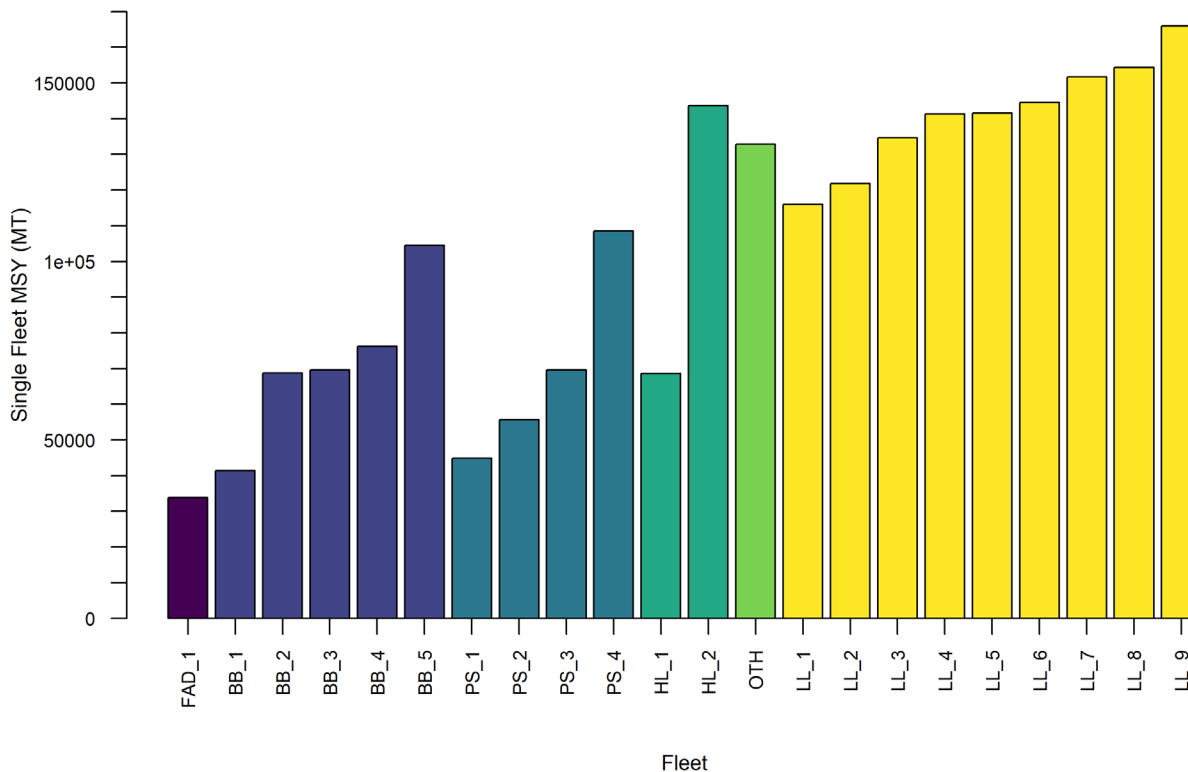
- Pilot study results applied to Bigeye tuna
  - Raw landings seem to be somewhat evenly distributed among multiple fleets



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# Fleet specific MSY

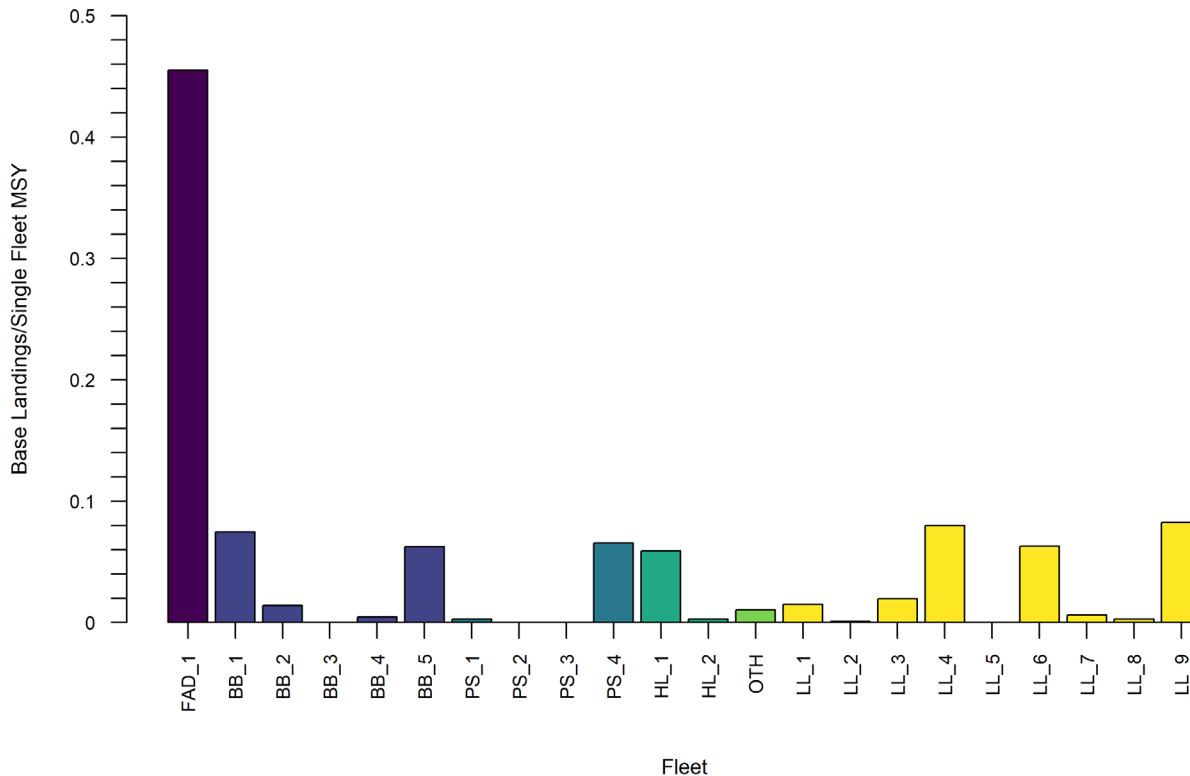
- Pilot study results applied to Bigeye tuna
  - Significant fleet specific variation in individual MSY estimates



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# Fleet specific MSY

- Pilot study results applied to Bigeye tuna
  - Dramatically changed impression of relative fleet impact



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# Fleet specific MSY

- Pilot study results applied to Bigeye tuna
  - Enabled quantification of relative landings value between fleets

Fleet A	Fleet B	4_PS	5_BB	8_BB	7_BB	6_BB	9_BB	21_PS	2_PS	1_PS	3_PS	20_HI	19_RF	22_O	13_O	10_Ja	12_Ja	14_O	16_CT	11_Ja	15_O	18_CT	17_CT
Fleet A	MSY	####	####	####	####	####	####	####	####	####	####	####	####	####	####	####	####	####	####	####	####	####	####
4_PS_FAD_9119	33844	1.00	1.22	2.03	2.06	2.25	3.09	1.33	1.65	2.06	3.21	2.03	4.24	3.92	3.43	3.60	3.98	4.17	4.18	4.27	4.48	4.56	4.90
5_BBPS_Ghana	41372	0.82	1.00	1.66	1.68	1.84	2.53	1.09	1.35	1.68	2.62	1.66	3.47	3.21	2.80	2.95	3.25	3.41	3.42	3.49	3.67	3.73	4.01
8_BB_North_Dakar_8119	68776.3	0.49	0.60	1.00	1.01	1.11	1.52	0.65	0.81	1.01	1.58	1.00	2.09	1.93	1.69	1.77	1.96	2.05	2.06	2.10	2.21	2.24	2.41
7_BB_North_Dakar_6280	69591.6	0.49	0.59	0.99	1.00	1.09	1.50	0.65	0.80	1.00	1.56	0.99	2.06	1.91	1.67	1.75	1.93	2.03	2.03	2.08	2.18	2.22	2.38
6_BB_South_Dakar	76150.6	0.44	0.54	0.90	0.91	1.00	1.37	0.59	0.73	0.91	1.43	0.90	1.89	1.74	1.52	1.60	1.77	1.86	1.86	1.90	1.99	2.03	2.18
9_BB_North_Azores	104478	0.32	0.40	0.66	0.67	0.73	1.00	0.43	0.53	0.67	1.04	0.66	1.38	1.27	1.11	1.17	1.29	1.35	1.36	1.38	1.45	1.48	1.59
21_PS_West	44902.8	0.75	0.92	1.53	1.55	1.70	2.33	1.00	1.24	1.55	2.42	1.53	3.20	2.96	2.58	2.71	3.00	3.15	3.15	3.22	3.38	3.44	3.69
2_PS_8690	55695.6	0.61	0.74	1.23	1.25	1.37	1.88	0.81	1.00	1.25	1.95	1.23	2.58	2.38	2.08	2.19	2.42	2.54	2.54	2.59	2.72	2.77	2.98
1_PS_6485	69627.4	0.49	0.59	0.99	1.00	1.09	1.50	0.64	0.80	1.00	1.56	0.99	2.06	1.91	1.67	1.75	1.93	2.03	2.03	2.08	2.18	2.22	2.38
3_PS_FSC_9119	108568	0.31	0.38	0.63	0.64	0.70	0.96	0.41	0.51	0.64	1.00	0.63	1.32	1.22	1.07	1.12	1.24	1.30	1.30	1.33	1.40	1.42	1.53
20_HI_BRA	68673.7	0.49	0.60	1.00	1.01	1.11	1.52	0.65	0.81	1.01	1.58	1.00	2.09	1.93	1.69	1.77	1.96	2.06	2.06	2.10	2.21	2.25	2.42
19_RR_West	143667	0.24	0.29	0.48	0.48	0.53	0.73	0.31	0.39	0.48	0.76	0.48	1.00	0.92	0.81	0.85	0.94	0.98	0.99	1.01	1.06	1.07	1.15
22_OTH	132803	0.25	0.31	0.52	0.52	0.57	0.79	0.34	0.42	0.52	0.82	0.52	1.08	1.00	0.87	0.92	1.01	1.06	1.07	1.09	1.14	1.16	1.25
13_Other_LL_N	116009	0.29	0.36	0.59	0.60	0.66	0.90	0.39	0.48	0.60	0.94	0.59	1.24	1.14	1.00	1.05	1.16	1.22	1.22	1.25	1.31	1.33	1.43
10_Japan_LL_N	121844	0.28	0.34	0.56	0.57	0.62	0.86	0.37	0.46	0.57	0.89	0.56	1.18	1.09	0.95	1.00	1.11	1.16	1.16	1.19	1.25	1.27	1.36
12_Japan_LL_S	134656	0.25	0.31	0.51	0.52	0.57	0.78	0.33	0.41	0.52	0.81	0.51	1.07	0.99	0.86	0.90	1.00	1.05	1.05	1.07	1.13	1.15	1.23
14_Other_LL_TRO	141271	0.24	0.29	0.49	0.49	0.54	0.74	0.32	0.39	0.49	0.77	0.49	1.02	0.94	0.82	0.86	0.95	1.00	1.00	1.02	1.07	1.09	1.17
16_CTP_LL_N	141570	0.24	0.29	0.49	0.49	0.54	0.74	0.32	0.39	0.49	0.77	0.49	1.01	0.94	0.82	0.86	0.95	1.00	1.00	1.02	1.07	1.09	1.17
11_Japan_LL_TRO	144525	0.23	0.29	0.48	0.48	0.53	0.72	0.31	0.39	0.48	0.75	0.48	0.99	0.92	0.80	0.84	0.93	0.98	0.98	1.00	1.05	1.07	1.15
15_Other_LL_S	151720	0.22	0.27	0.45	0.46	0.50	0.69	0.30	0.37	0.46	0.72	0.45	0.95	0.88	0.76	0.80	0.89	0.93	0.93	0.95	1.00	1.02	1.09
18_CTP_LL_S	154349	0.22	0.27	0.45	0.45	0.49	0.68	0.29	0.36	0.45	0.70	0.44	0.93	0.86	0.75	0.79	0.87	0.92	0.92	0.94	0.98	1.00	1.07
17_CTP_LL_TRO	165912	0.20	0.25	0.41	0.42	0.46	0.63	0.27	0.34	0.42	0.65	0.41	0.87	0.80	0.70	0.73	0.81	0.85	0.85	0.87	0.91	0.93	1.00



# Considerations for Management

- This type of approach could simplify decision making
  - By approving fleet specific OFL/ABC the SSC could finalize advice without needing to consider allocation decisions
- Could enable overfishing to be determined based on achieved landings rather than predicted allocation fractions
  - Does this concept work within the legal requirements of OFL/ABC/ACL definitions and enforcement capabilities
- Only been tested for equilibrium MSY not short term OFL



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# Size/age specific MSY

- Similar to the Global MSY concept in SS
- Calculate MSY/OFL assuming on a single size/age is selected for
- Provides estimate that is independent of population size/age composition
- Still early in conceptualization and needs further development
- Potential benefits of size/age specific OFL/ABC
  - Allow for more accurate representation of short term OFL/ABC accounting for current stock structure
  - Could prevent the trends we sometimes see of short term SSB declines in projections when fishing at  $F_{msy}$
  - Quantify the true cost of discard mortality on OFL/ABC



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# Discards in projections

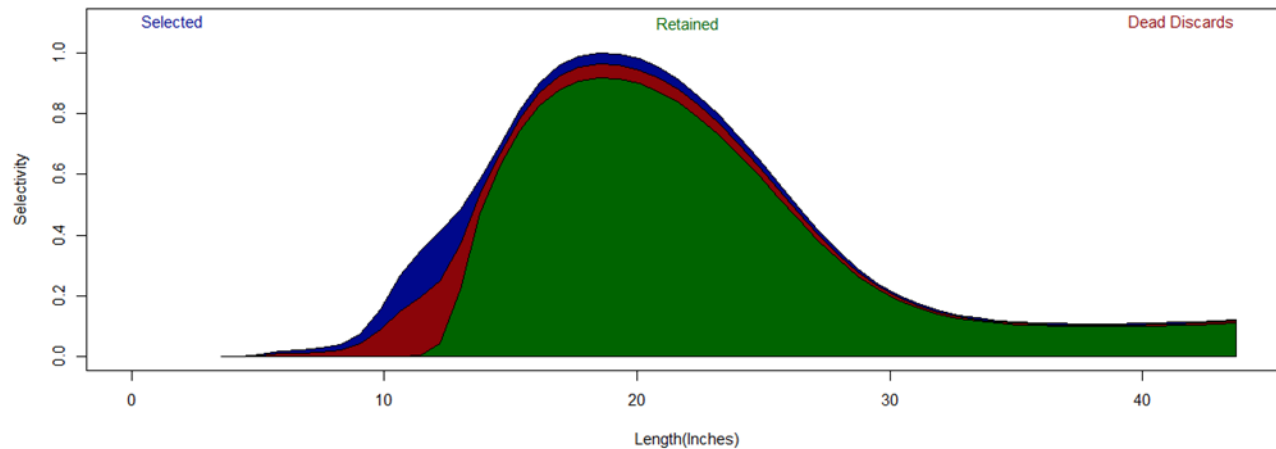
- Currently proportional to OFL fishing effort
- This assumption only holds if fishery participants are able and choose to 100% avoid landing a specific species during closed seasons.
- This is questionable given the diversity of experience and objectives represented within the fishery
- Assessments that directly model closed season discards such as red snapper show suggest selectivity overlap with other targeted species and/or catch and release effort are likely
- Current approaches therefore present a litigation risk for overfished/overfishing stocks particularly those under rebuilding plans that depend on significant landings reductions



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# Discards in projections

- Proportionality between landings and discards is an inherent aspect of how discards are modeled in Gulf stock assessments using retention functions



- Data and structural limitations make this the most practical approach for most Gulf stocks.
- Annual deviations in asymptotic retention represent a possible avenue to adjusting the proportional magnitude of discards to landings

# Discards in projections

- Possible to solution is to set fleet specific F in projections as proportion to recent average F and adjust asymptotic retention to achieve OFL

$$F_{\text{projected}} = X * F_{\text{recent\_mean}}$$

- The proportion X used would reflect the relative amount of effort reduction expected ranging from 1 being no reduction in effort to 0 being 100% avoidance of the species
  - How to set F proportion i.e. fishery targeting ability?
- Annual asymptotic retention rates would then be estimated to achieve annual total dead fish OFL targets



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# Considerations for Management

- This will require more explicit accounting of discard mortality in OFL/ABC limits due to changing discard fractions
  - This explicit accounting opens the door to more questions regarding how changes in discarding or discard mortality rate should be integrated into future quota allocations
- Could result in infinite rebuilding timelines i.e.  $F_{\text{Discard}} > F_{\text{OFL}}$ ?
  - What are the legal hurdles for dealing with this?



# Management advice throughput and robustness

- Completing a full assessment is a long process
  - 1-2 years of development and analysis
  - Terminal model year 2+ years old before completion
  - Management action is another year or more
- Limited SEFSC analyst capacity also means multiple years expected to elapse before a new assessment is completed
  - Prioritization often comes down to fishery value
- A lot of unobserved changes in the population can occur during this time
  - Episodic mortality
  - Recruitment variability
  - Changes in the fishery selectivity and landings



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# Interim assessment - Goal

Maximize throughput of robust management advice updates in a consistent way across species/assessments

- What does maximized throughput look like?
  - Data provision lag should be limiting factor to throughput
  - To some degree this is currently achieved based on interim calculation effort but limited by substantial pre-validation on species by species basis
- What is robust interim advice?
  - Results as similar to a new assessment as possible
  - Current interim assessments are limited by single data source biases
- What qualifies as consistent?
  - Utilize standardized methods that require minimal species specific expert decision making
  - Current methods are highly species specific with substantial expert judgment requirements to pre-select data sources



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# Interim assessment - Key features

- Able to integrate multiple data sources
  - Multiple indices of abundance
  - Recent landings data
- Quantifies prediction uncertainty of advice
  - Validate available sources of data to quantify accuracy and precision of each source for predicting OFL
  - Integrate available sources of data into unified OFL update with uncertainty
- Standardized implementation for new species
  - No expert judgement needed for data selection
  - Standardized analysis package to validate data sources and produce interim advice

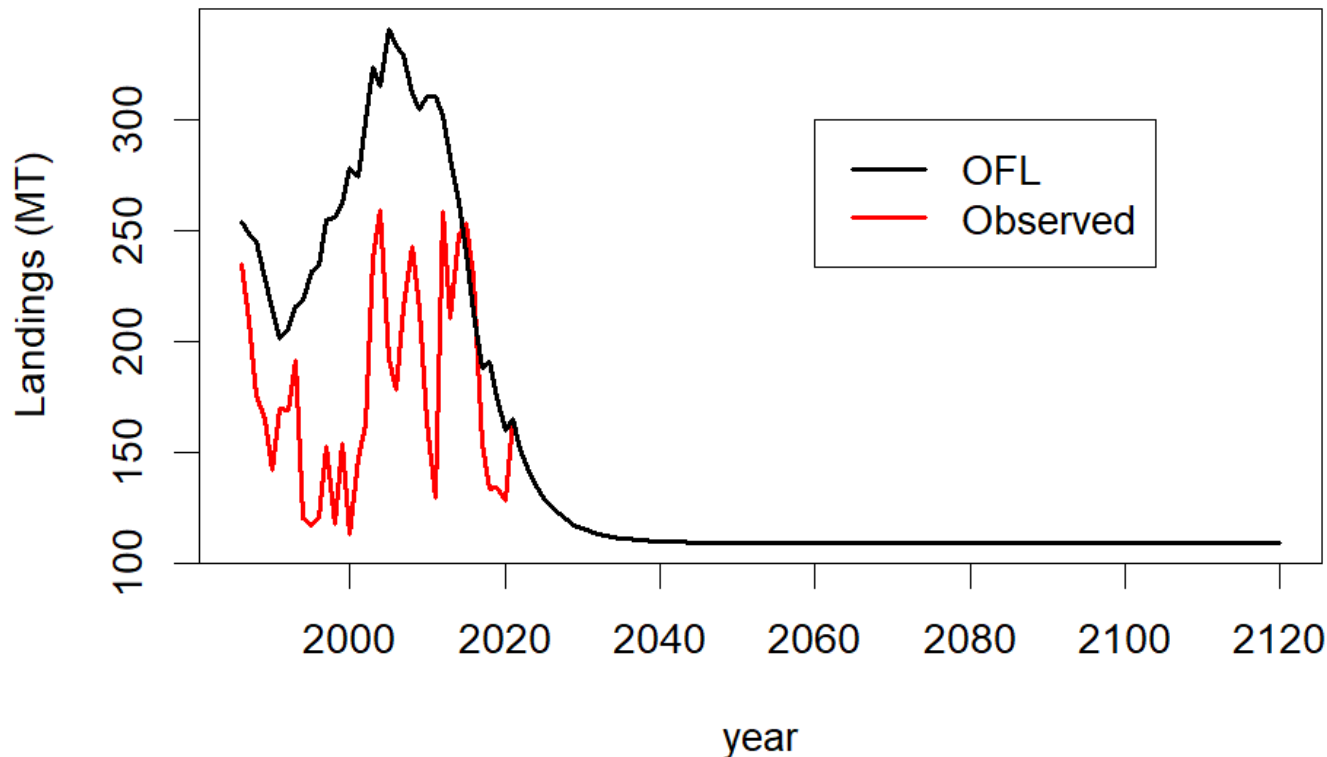


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# Interim assessments - Process

- Back calculate annual target OFL from most recent approved stock assessment utilizing estimated equilibrium  $F_{OFL}$  and historic catch and fishing mortality estimates

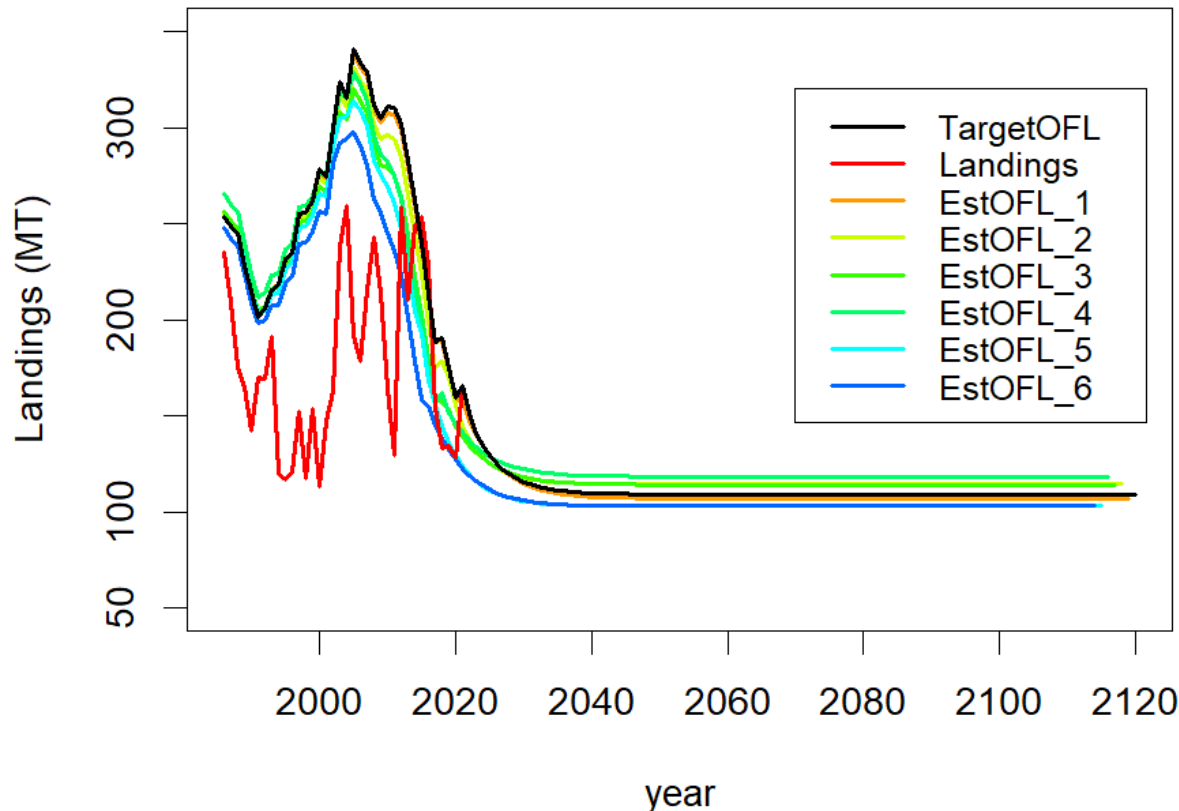
$$\text{TargetOFL}_y = \text{Catch}_y * (F_{OFL} / F_Y)$$



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# Interim assessments - Process

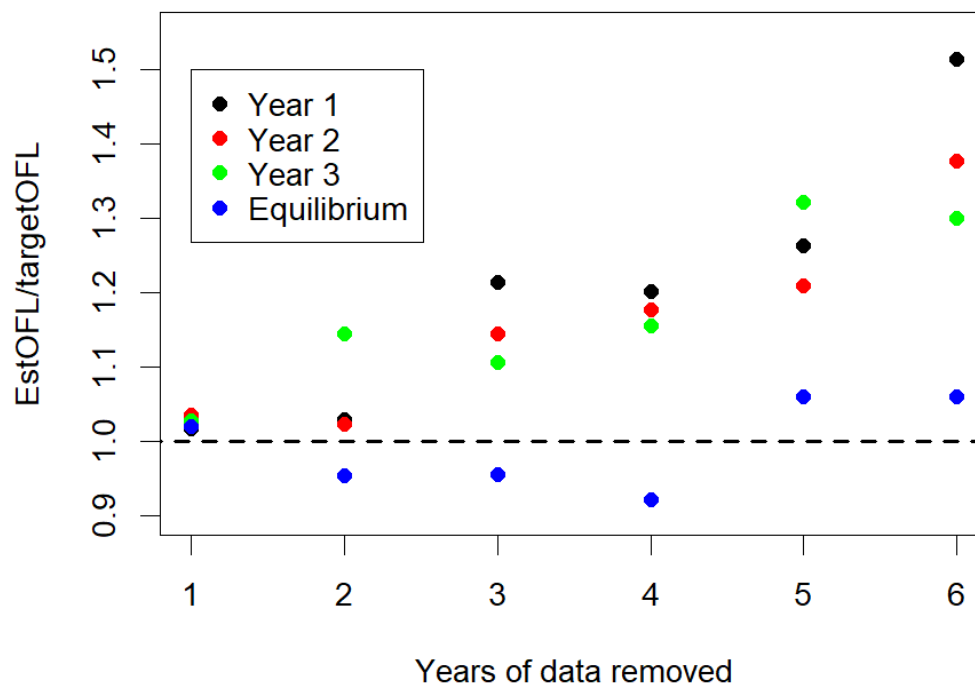
- Run hindcast stock assessments by removing one year of data at a time and re-estimating model. Model<sub>n</sub>
- Calculate vector of OFL estimates for each model EstOFL<sub>y,n,l</sub>
- Calculate adjusted OFL's incorporating known catch UpdateOFL<sub>y,n,l</sub>
- Calculate adjusted OFL's incorporation each index IndexOFL<sub>y,n,i,l,o</sub>



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# Interim assessments - Process

- Calculate the correction needed for each hindcast OFL to match target OFL.  $\text{TargetOFL}_y / \text{EstOFL}_{y,n,l}$ ,  $\text{TargetOFL}_y / \text{UpdateOFL}_{y,n,l}$ ,  $\text{TargetOFL}_y / \text{IndexOFL}_{y,n,i,l,o}$
- Calculate mean and standard deviation of the correction factors for each OFL estimate summing across hindcast runs for each estimate type and lag between assessment end year and prediction year.



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# Analysis limitations

- How to deal with retrospective bias and other patterns in results
  - Could this be used to adjust for predicted retrospective effects
  - In the EstOFL example would you take a mean, predict a bias based on years between assessments, or something else?
  - These results may be in part due to changes in relative effort between fleets in hindcast model runs
- Retrospective hindcasting limited to <20 years for almost all species
  - This still represents the most realistic result possible by avoiding the need to simulate index and population data
  - These results may be useful for informing future MSE parameterization of index and model uncertainty
- Method does not account for possible changes in model structure and assumes most recent assessment represents the truth
- Hindcasting analysis model still in development



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# Management advice throughput and robustness

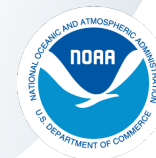
- Long term: Updates using partial data
  - Currently avoided due to potential bias
  - Will test using data predictions for missing observations
  - Requires prediction of individual data source biases
- Potential outcome: Continuum of assessment complexity
  - Simple interim external to baseline assessment
  - Update available data estimate recruitment/episodic mortality
  - Update available data and re-estimate subset of parameters
  - Complete new assessment



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# Model interpretability and uncertainty quantification

- Data specific parameter gradients
  - Quantify the influence of each data point on each model parameter
  - Assist model development by identifying
    - Causes of data conflicts
    - Time varying parameter trends
    - Model instability
  - Inform model review
- Test feasibility of ensemble approaches
  - Influence of fixed parameters
  - Stability of complex model structures
  - Compute time for multi-model inference
  - Automation potential

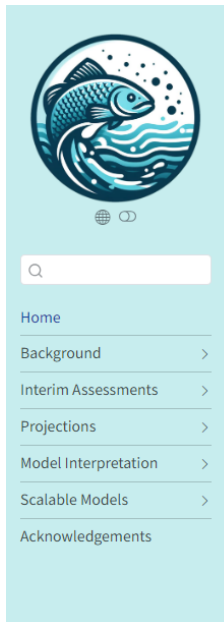


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# Project website

- Intended to provide a project overview and updates of progress as available for managers and stakeholders
- Will link to source code and results once analyses are complete
- Currently in development

<https://nathanvaughan-noaa.github.io/Roadmap/>



## A stock assessment improvement roadmap for the Gulf of Mexico

This website is intended to provide a living roadmap for planning and tracking research and development effort towards improving stock assessment methods and workflows in the Gulf of Mexico. This roadmap will maintain a dynamic record of ongoing and planned research carried out under a [5 year RESTORE FFO 2023 Actionable Science grant](#).

Providing a dynamic accounting of ongoing and planned research is intended to facilitate, agile development, responsive research prioritization, and collaboration opportunities with other research efforts as promoted through the [NMFS Open Science initiative](#). This roadmap is also intended to facilitate improved stakeholder and user awareness and engagement with ongoing research efforts and priorities, providing a basis for feedback and discussion.

### Disclaimer

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# Goals for today's discussion

- Introduce our project to SSC members Was this helpful?
- Review initial results from recent work incorporating red tide into benchmarks
  - Did providing this review of planned/in development/initial results help future decision making for the SSC?
- Discuss implications of these results and key decision points for implementation
  - With SEDAR88 in progress should we work to include red tide mortality into benchmark analyses for this assessment?
- Discuss SSC member preferences for
  - Future project updates
  - Research integration into stock assessment advice
  - Avenues for feedback
- Foster discussion on additional future research priorities



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# Thank you for your time

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