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Northwest Fisheries
Science Center

Processing and exploring assessment model output: lessons learned from a decade of work on the r4ss package

FANTASTIC!

Ian G. Taylor

Wellington, New Zealand, 8 November 2019
CAPAM workshop on next-gen assessment models

Outline

- Background on the assessment process
- Overview of the r4ss package
- Lessons learned
- Thoughts for the next generation of output processing

Note: this talk is from my perspective, not an attempt to cover the wide range of output processing tools used in stock assessment, including R packages for other models, GUI interfaces, etc.



Background on the assessment process

- Illustrated using 2019 stock assessment for Big Skate on U.S. west coast
- Age structure model using Stock Synthesis
- Limited data, not a very complex assessment



Status of Big Skate (*Beringraja binoculata*)
Off the U.S. Pacific Coast in 2019



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Vladlena Gertseva¹
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Joseph Bizzarro³

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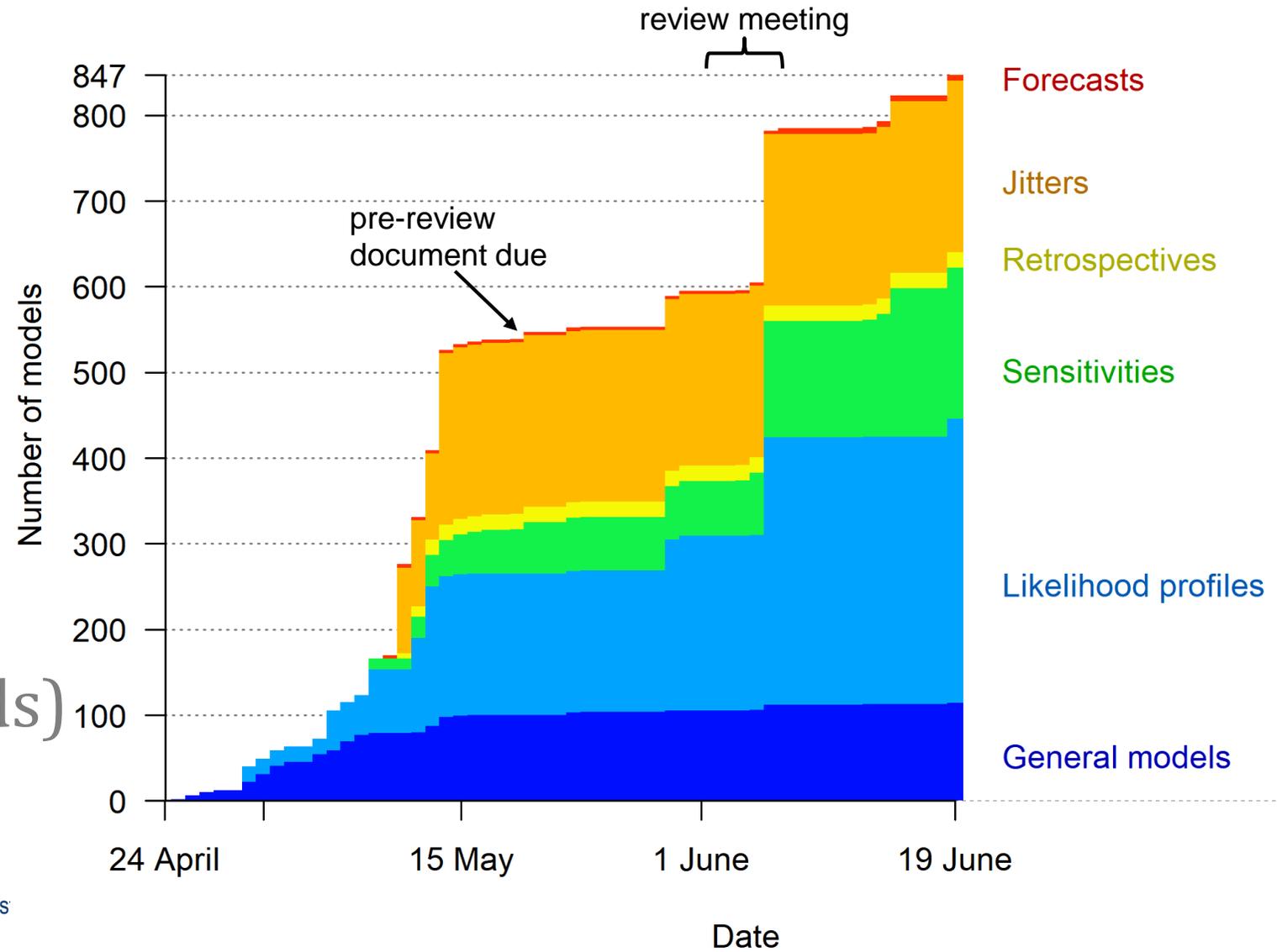
²Northwest Fisheries Science Center, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, 2032 S.E. OSU Drive Newport, Oregon 97365

³Southwest Fisheries Science Center, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, 110 Shaffer Road, Santa Cruz, California 95060



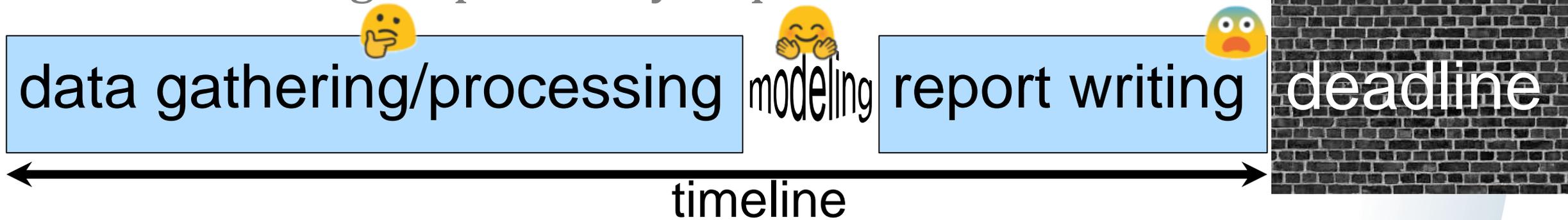
Background on the assessment process

- 847 different models run in 2 months
- 190 models run during 5-day review meeting
 - 7 new candidate models
 - 108 profile models
 - 72 sensitivity analyses
 - 3 forecasts
- 38,000 plots created (~200/mod × ~200 mods)
- Requires automation



Background on the assessment process

- The modeling step is always squeezed for time



- Making any repetitious task more efficient allows more time for the fun and valuable part of modeling: **discovery**

Background on the assessment process

“You spend 90% of your time trying to run the damn model and then the next 10% making plots and writing the report and whatnot and then you go home, drink a bottle of wine, and forget everything you just did”

-Ernesto Jardim

- Making any repetitious task more efficient allows more time for the fun and valuable part of modeling: **discovery**



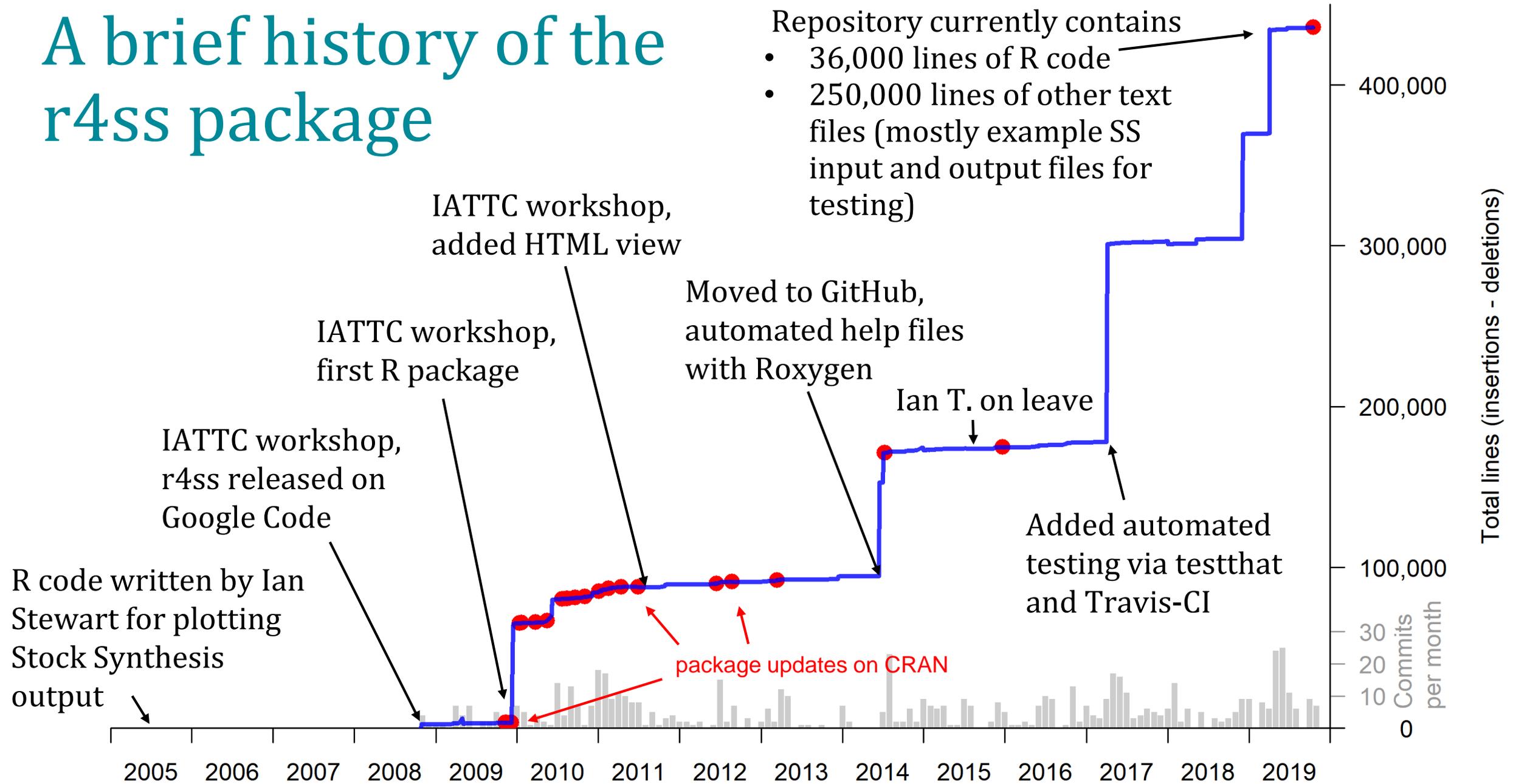
Overview of r4ss

- An R package* for processing output from Stock Synthesis
- Has many functions for manipulating input files
- Evolved over a long period to incorporate new functions and improve on existing elements
- Lots of old code still in place which would be written differently if developed today
- Available on the Comprehensive R Archive Network (CRAN) and GitHub github.com/r4ss/r4ss

*R package = a collection of functions and their documentation that are bundled together in an easy-to-install format



A brief history of the r4ss package



Example use

```
# install package from CRAN
install.packages('r4ss')

# or install from github
remotes::install_github('r4ss/r4ss')

# read the model output
replist <- SS_output(dir='c:/model/')

# make a bunch of plots
SS_plots(replist)
```



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SS Output

File | C:/ss/skates/models/bigskate99_new_prior_98percent_priorSD/plots/SS_...

Home Bio Sel Timeseries S-R Catch SPR Discard Mnwt Index Numbers Co

Home

SS version: 3.30.13.02-safe;_2019_05_08;_Stock_Synthesis_by_Rich

r4ss info:
Version: 1.35.3
Date: 2019-07-01
Built: R 3.5.1; ; 2019-07-02 16:50:34 UTC; windows
RemoteType: github
RemoteHost: api.github.com
RemoteRepo: r4ss
RemoteUsername: r4ss
RemoteRef: development
RemoteSha: 7d1dee002bc653fb8a00a6421d27f5919d44c309

Starting time of model: Thu Jun 6 09:43:03 2019

Warnings (from file warnings.sso):

#Foreign copyrights may apply. See copyright.txt for more information.
Thu Jun 6 09:43:02 2019

Block:2 13 ends in: 2030 after retroyr+1: 2019
Minimum size bin is: _20; which is >10cm, which is large for use as size-at-age 0
N warnings: 3
Number_of_active_parameters_on_or_near_bounds: 0

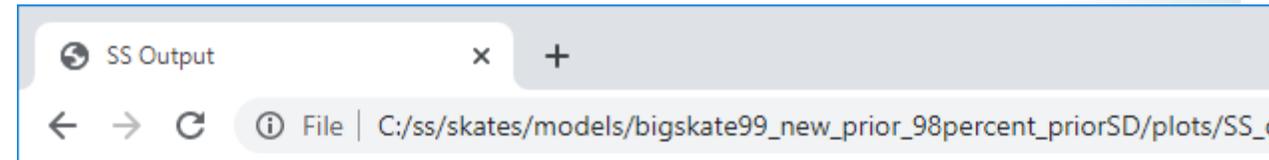
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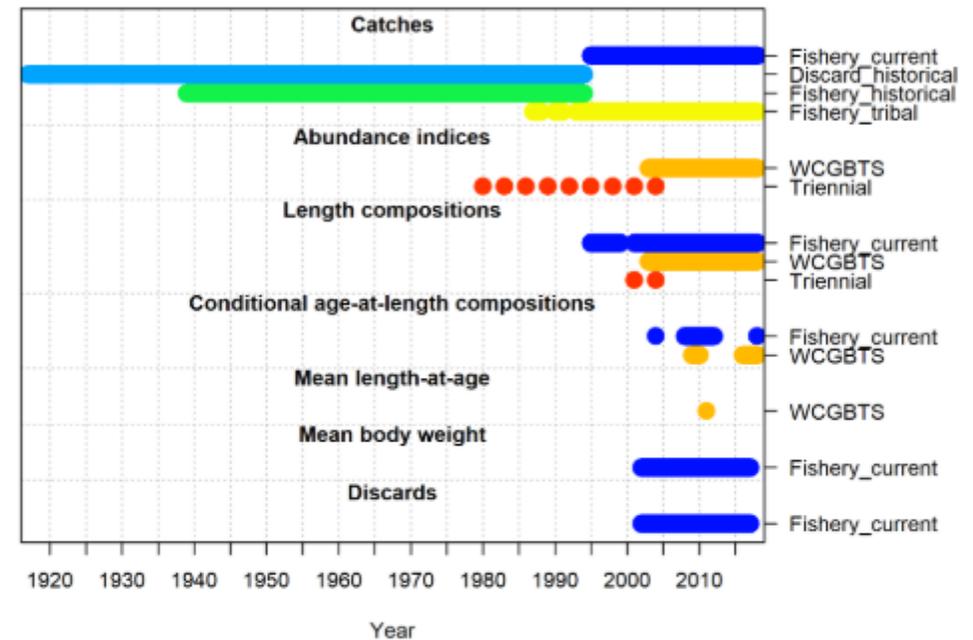
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Home Bio Sel Timeseries S-R Catch SPR Discard Mnwt Index Numbers Co

Data



Data presence by year for each fleet and data type
file: [data_plot.png](#)

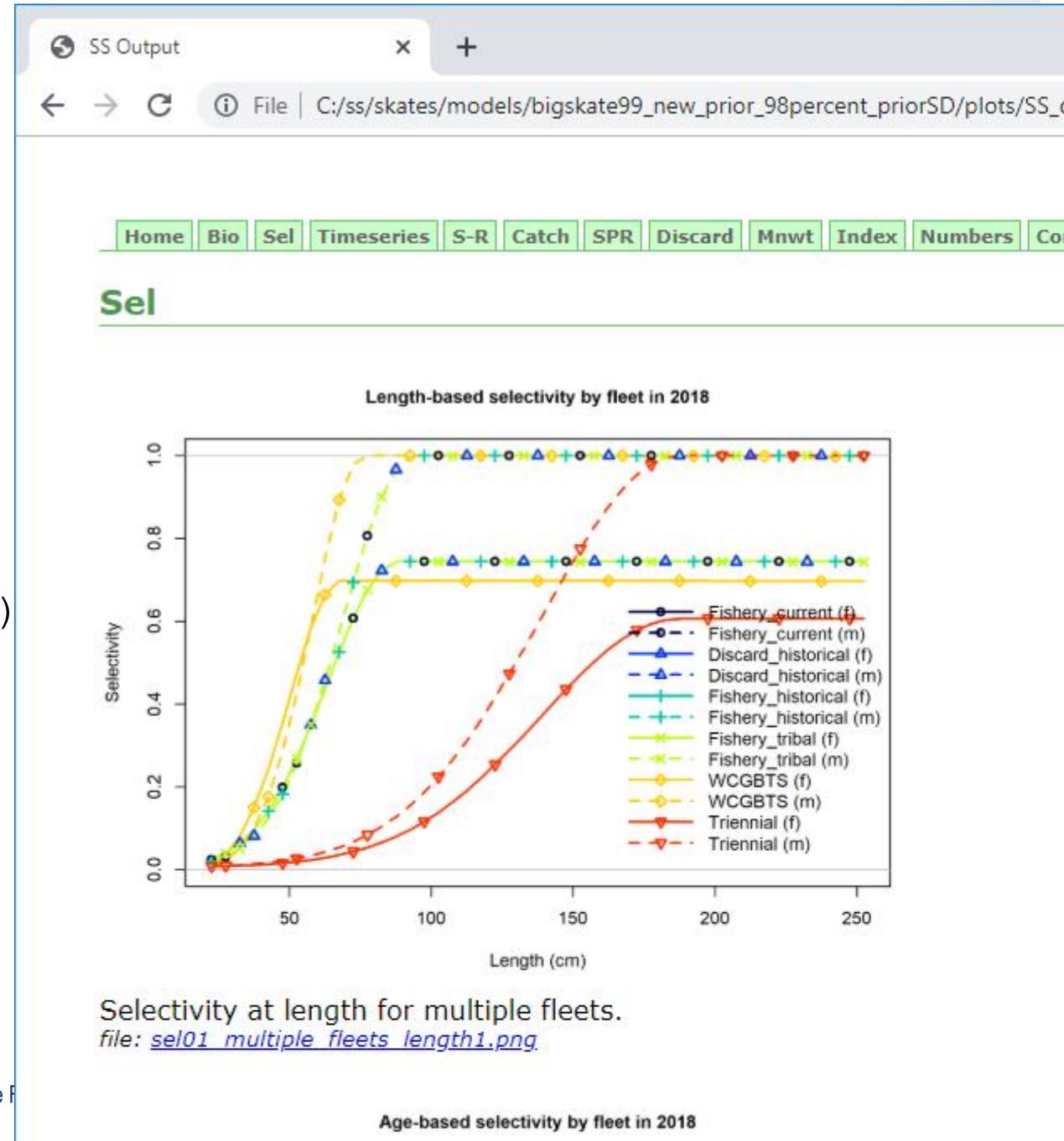
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Selectivity at length for multiple fleets.

file: [sel01_multiple_fleets_length1.png](#)

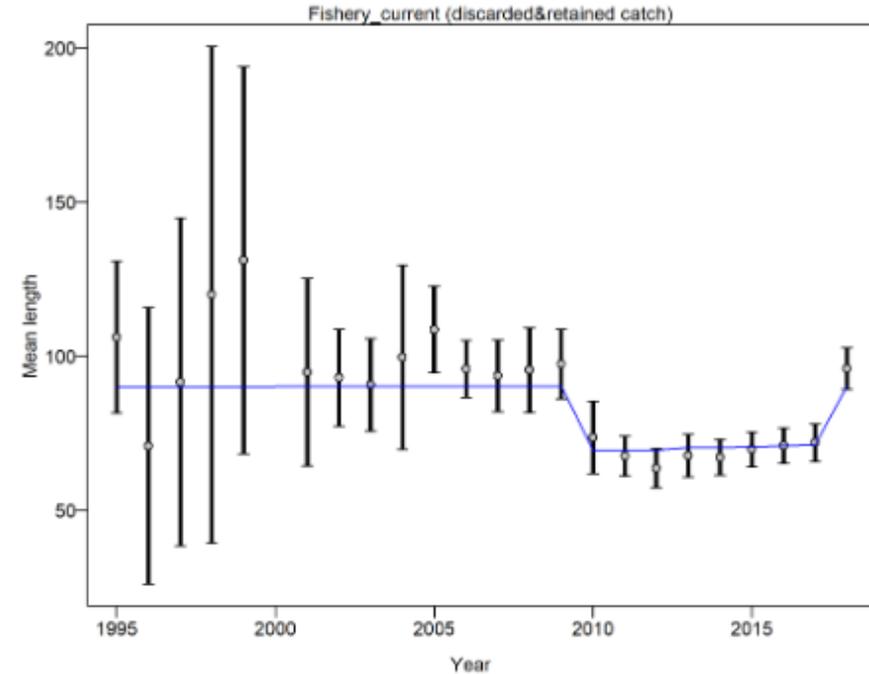
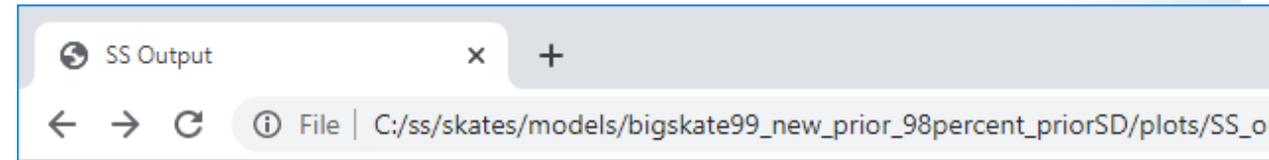
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Mean length for Fishery_current with 95% confidence intervals based on current Francis data weighting method TA1.8: thinner intervals (with capped ends) show adjusting sample sizes based on suggested multiplier (with 95% interval) for len Fishery_current:
1.0019 (0.6269-2.105)

For more info, see

Francis, R.I.C.C. (2011). Data weighting in statistical fisheries stock assessment. *Can. J. Fish. Aquat. Sci.* 68: 1124-1138. <https://doi.org/10.1139/f2011-025>

file: [comp_lenfit_data_weighting_TA1.8_Fishery_current.png](#)

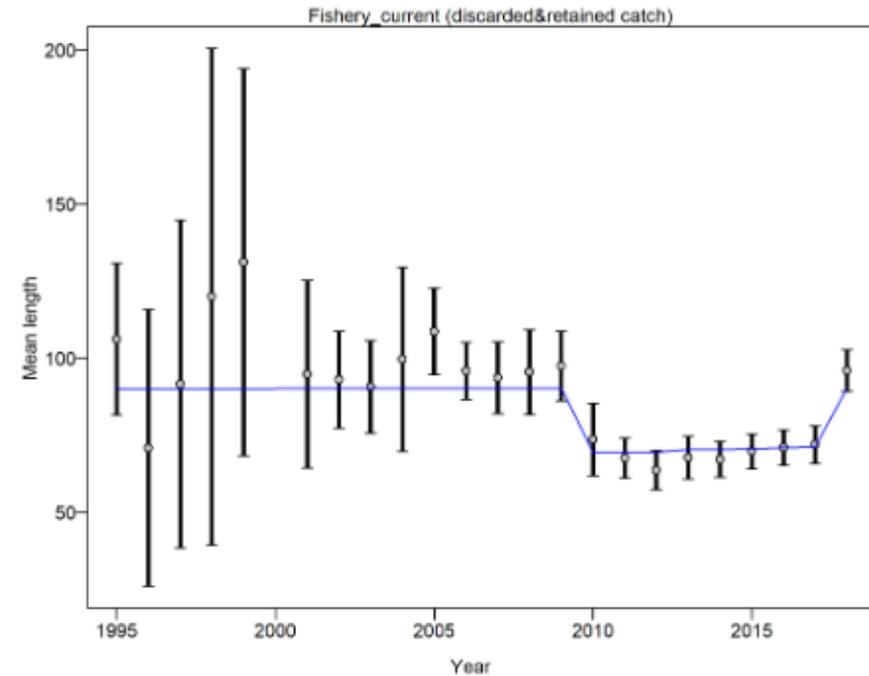
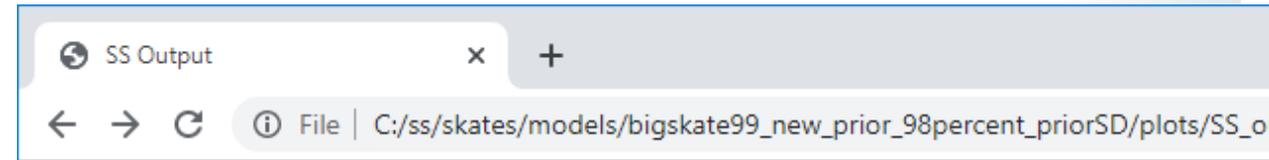
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file: [comp_lenfit_data_weighting_TA1.8_Fishery_current.png](#)

Adding diagnostic tables along with the plots

- Thanks to Christine Stawitz for adding HTML tables
- Allows color and other elements not available in Report text file

SS Output

File | C:/ss/skates/models/bigskate99_new_prior_98percent_priorSD/plots/SS_output_DiagnosticTables.html

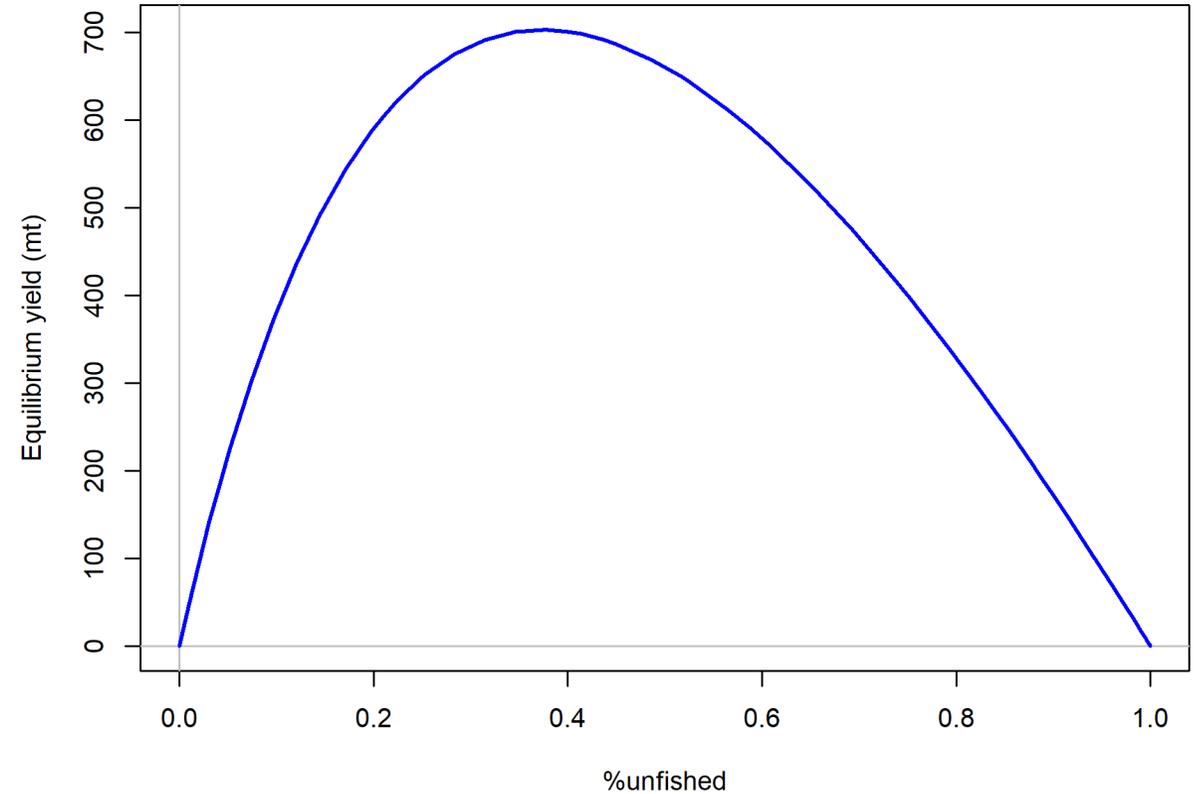
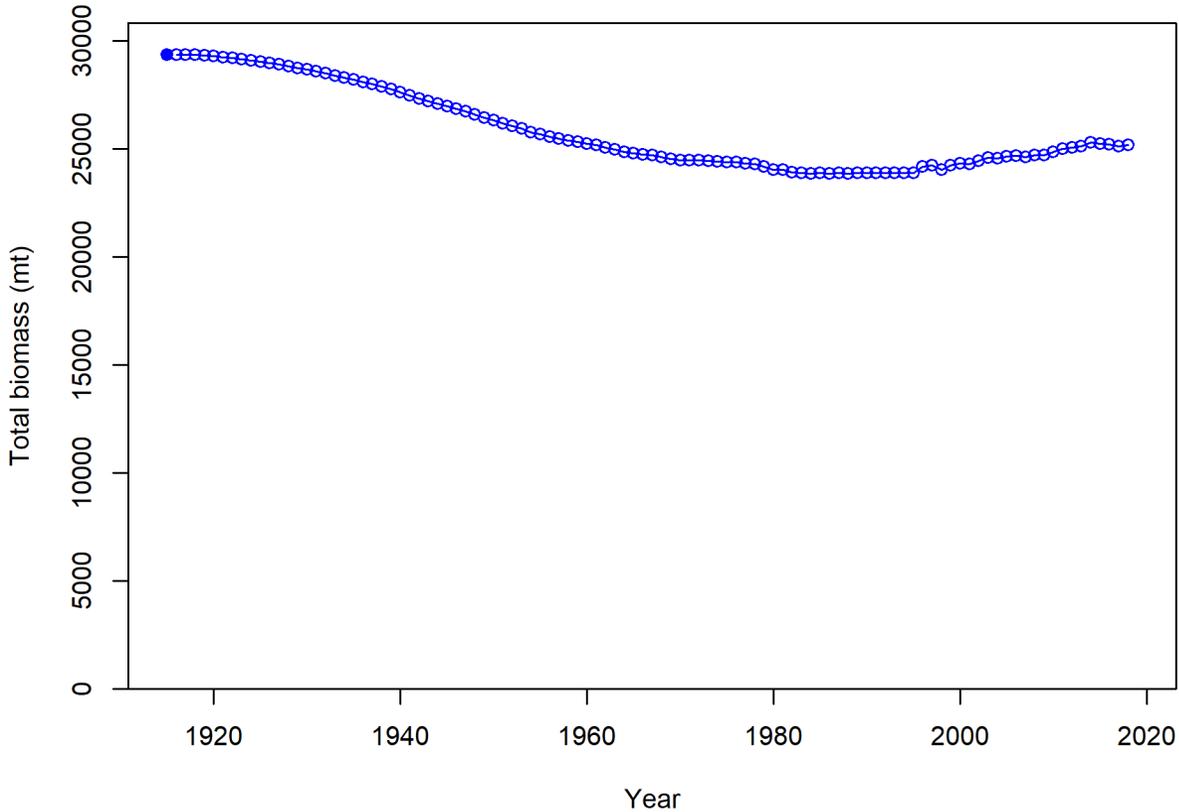
Home Bio Sel Timeseries S-R Catch SPR Discard Mnwt Index Numbers CompDat LenComp AgeComp A@LComp Mean@A Yield Data DiagnosticTables

DiagnosticTables

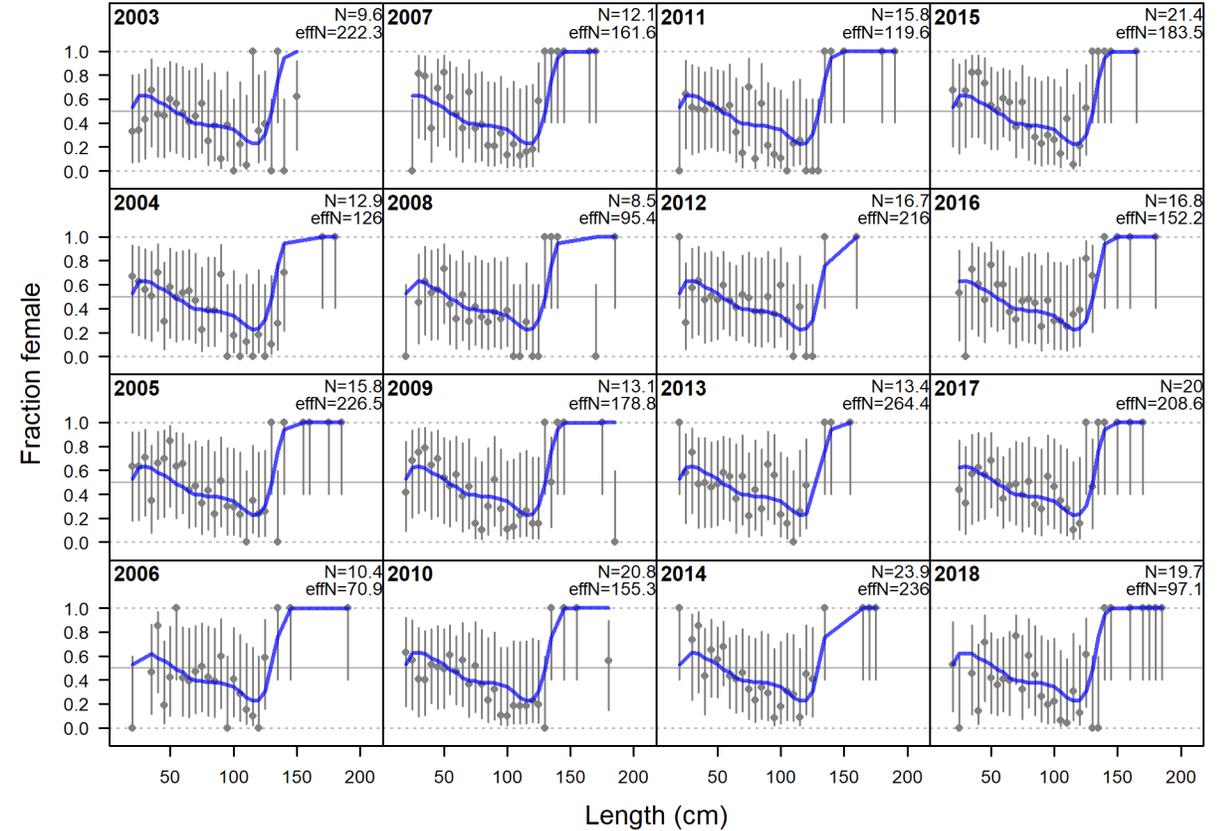
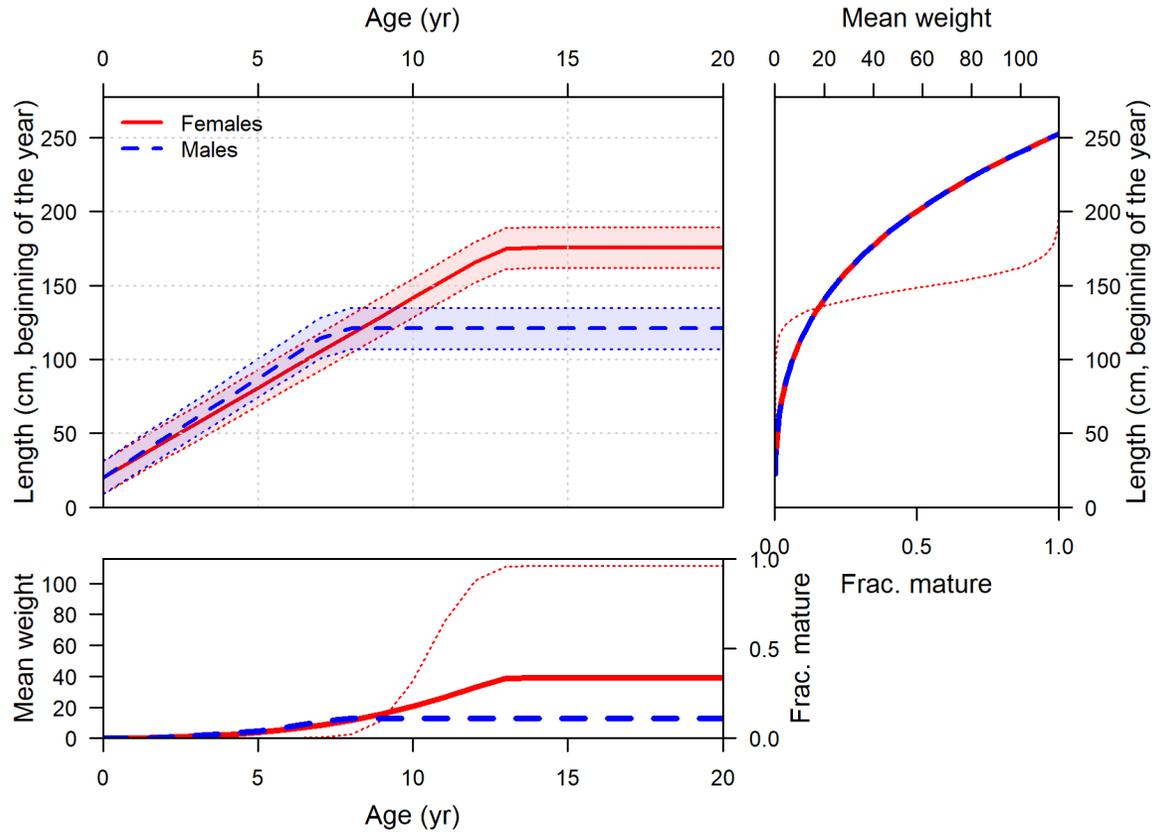
	Value	Phase	Min	Max	Init	Status	Parm_	StDev	Gradient	Pr_type	Prior	Pr_SD	Pr_Like	A
NatM_p_1_Fem_GP_1	0.449208	3	0.100	0.6	0.3785780	OK	0.0305510	2.15827e-06	Log_Norm	-1.02165	0.438	0.1277320	O	
L_at_Amin_Fem_GP_1	20.082100	2	10.000	40.0	20.3220000	OK	1.0314100	-1.77539e-06	No_prior	NA	NA	NA	O	
Linf_Fem_GP_1	175.663000	2	100.000	300.0	178.3980000	OK	4.0044900	2.44607e-06	No_prior	NA	NA	NA	O	
VonBert_K_Fem_GP_1	12.140700	1	0.005	30.0	11.9546000	OK	0.3580360	-6.15757e-06	No_prior	NA	NA	NA	O	
Cessation_Fem_GP_1	5.610090	3	0.100	10.0	2.5000000	OK	11.8509000	-2.95656e-08	No_prior	NA	NA	NA	O	
SD_young_Fem_GP_1	5.702740	5	1.000	20.0	5.6843500	OK	0.9011410	-1.12396e-06	No_prior	NA	NA	NA	O	
SD_old_Fem_GP_1	7.084120	5	1.000	20.0	7.8667600	OK	0.9204520	1.80901e-07	No_prior	NA	NA	NA	O	
Linf_Mal_GP_1	-0.373076	2	-1.000	1.0	-0.3939010	OK	0.0251082	-6.7119e-07	No_prior	NA	NA	NA	O	
VonBert_K_Mal_GP_1	0.100981	3	-10.000	20.0	0.1248620	OK	0.0339790	-4.02467e-05	No_prior	NA	NA	NA	O	
SR_LN(R0)	8.904690	3	5.000	15.0	9.0000000	OK	0.3734850	-7.43111e-06	No_prior	NA	NA	NA	O	
LnQ_base_WCGBTS(5)	-0.403308	1	-2.000	2.0	0.0000000	OK	0.3154050	-3.23638e-06	Normal	-0.35500	0.326	0.0109793	O	
Q_extraSD_WCGBTS(5)	0.163264	1	0.000	2.0	0.1000000	OK	0.0573576	-3.63615e-07	No_prior	NA	NA	NA	O	
LnQ_base_Triennial(6)	-1.252400	1	-10.000	2.0	0.0000000	OK	0.7431200	-1.48995e-06	No_prior	NA	NA	NA	O	
Q_extraSD_Triennial(6)	0.365954	1	0.000	2.0	0.1000000	OK	0.1464040	2.552e-07	No_prior	NA	NA	NA	O	
LnQ_base_Triennial(6)_BLK1repl_100F	0.034511	1	7.000	0.0	0.0000000	OK	0.7412080	1.08774e-06	No_prior	NA	NA	NA	O	

Gallery: simple but necessary plots

Total biomass (mt)



Gallery: complex plots that are hopefully useful



Navigating a sea of plots

- Initially plots were in the R GUI window (Windows only)
- PDF option added facilitated saving results, navigating among them, and other platforms
- HTML view facilitates browsing PNG image files
 - Inspired by MFCL Java viewer which Simon Hoyle showed me in 2011
 - Image files with consistent names facilitates the use of RMarkdown or LaTeX templates for reports
- Convenience of browsing among plots in browser raises limit on tolerable number of plots
 - ~200 plots for U.S. west coast Big Skate assessment (pretty basic model)
 - ~750 plots for U.S. west coast Canary Rockfish assessment (complex model with 3 areas, lots of fleets, lots of data)

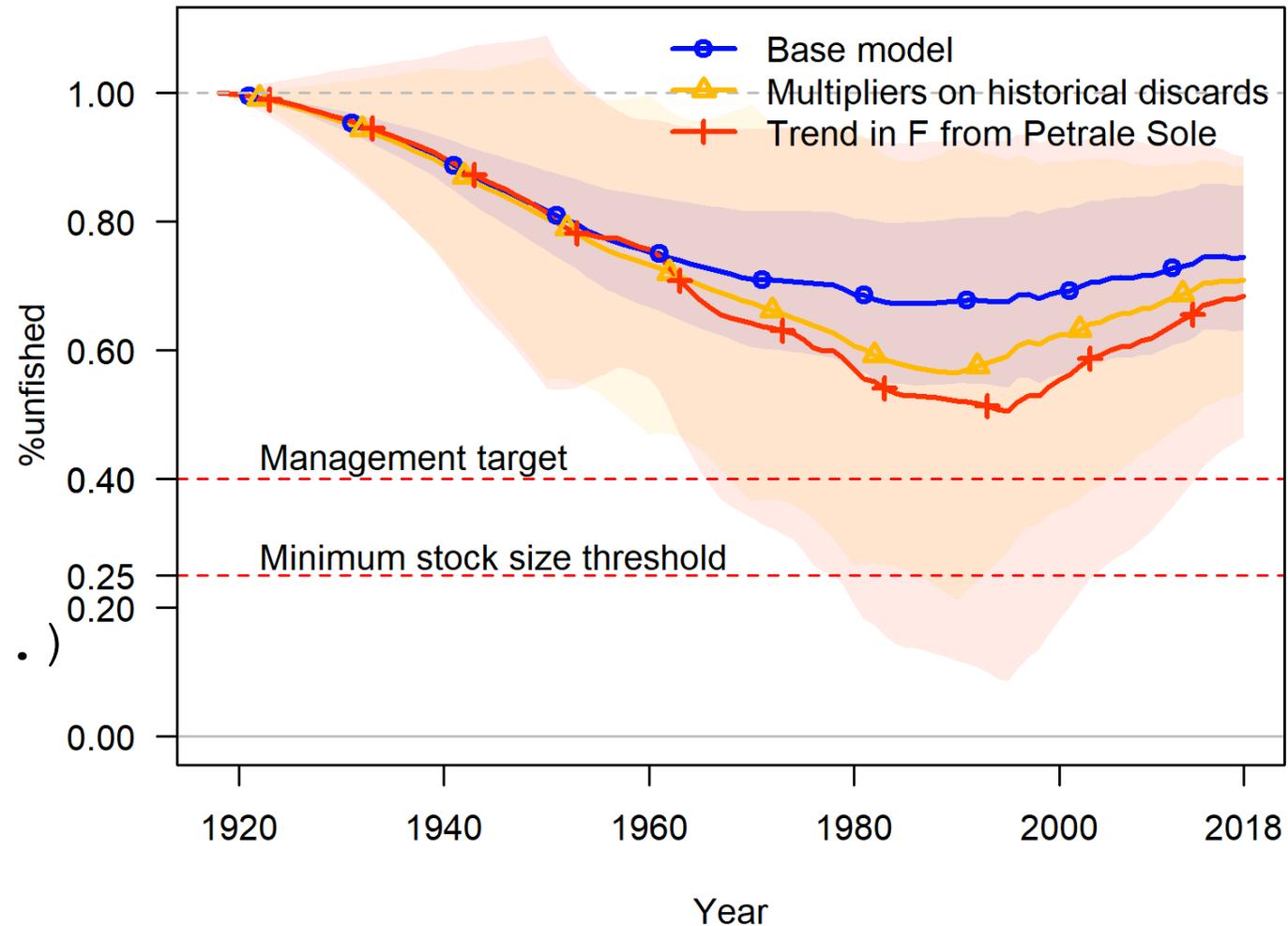


Comparing multiple models

```
# read models
mod1 <- SS_output(...)
mod2 <- SS_output(...)
mod3 <- SS_output(...)

# create summary of results
mod.sum <- SSsummarize(
  list(mod1, mod2, mod3))

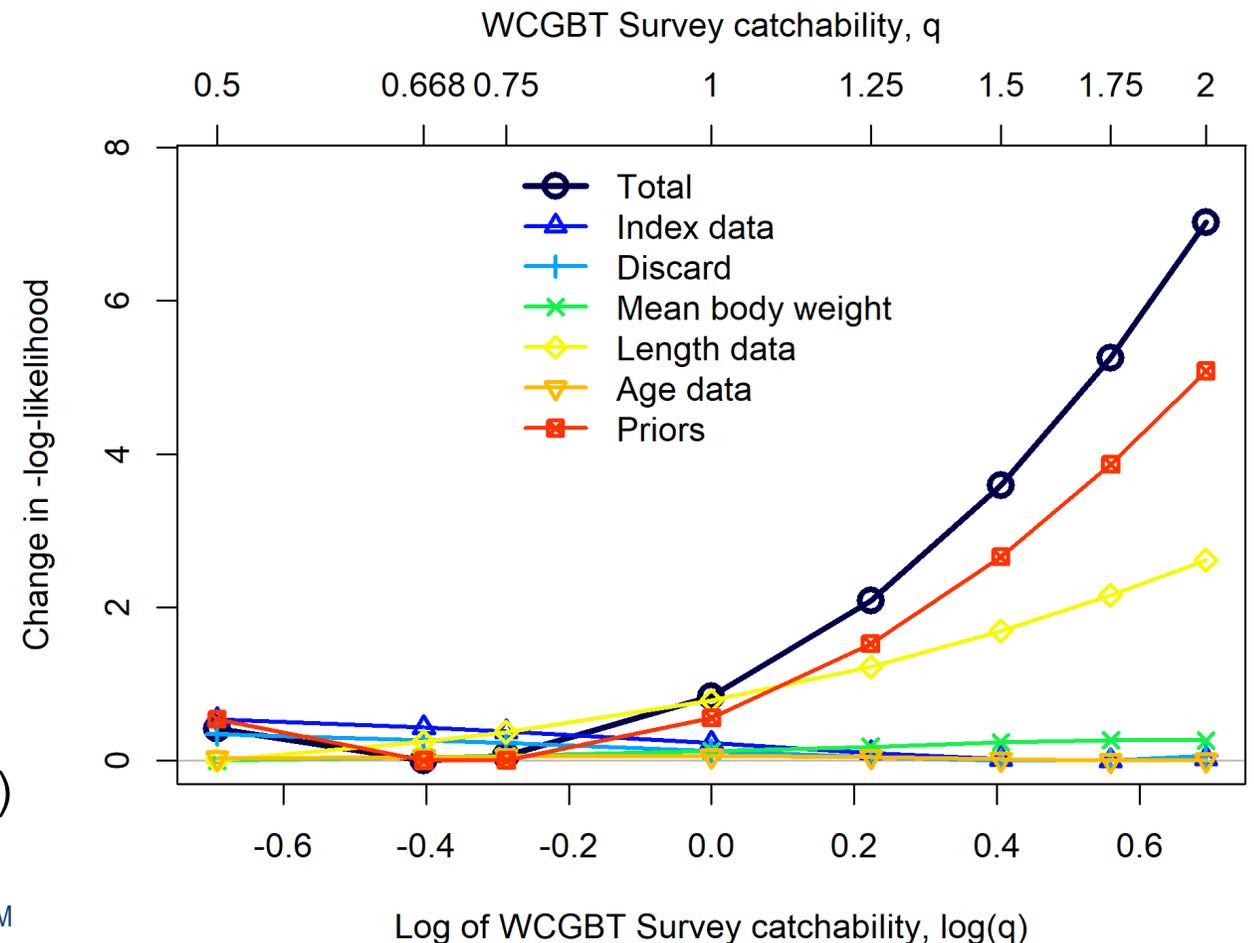
# plot comparisons
SSplotComparisons(mod.sum, ...)
```



Interaction of input files and output processing

Likelihood profile created by iteratively changing control file, re-running the model, and plotting the aggregated results

```
# run profile
SS_profile(...)
# read all results
profilemodels <-
  SSgetoutput(...)
# summarize results
profile.sum <-
  SSsummarize(profilemodels)
# make plot
SSplotProfile(profile.sum, ...)
```



A few thoughts on writing assessment reports

- Automated tools to create figures from model output facilitate the use of templates for report writing
 - Big Skate assessment report was written in R Markdown (thanks Melissa Monk, Chantel Wetzel, and Andi Stephens)
github.com/iantaylor-NOAA/BigSkate_Doc/
 - Takes ~10 minutes to update *most* of the 27 tables and 81 figures for new model
- Efficient report writing buys valuable time for model exploration
- Automated tools for report writing can reduce errors





Photo: André Sampaio, https://commons.wikimedia.org/wiki/File:Pra%C3%A7a_Cant%C3%A3o.jpg

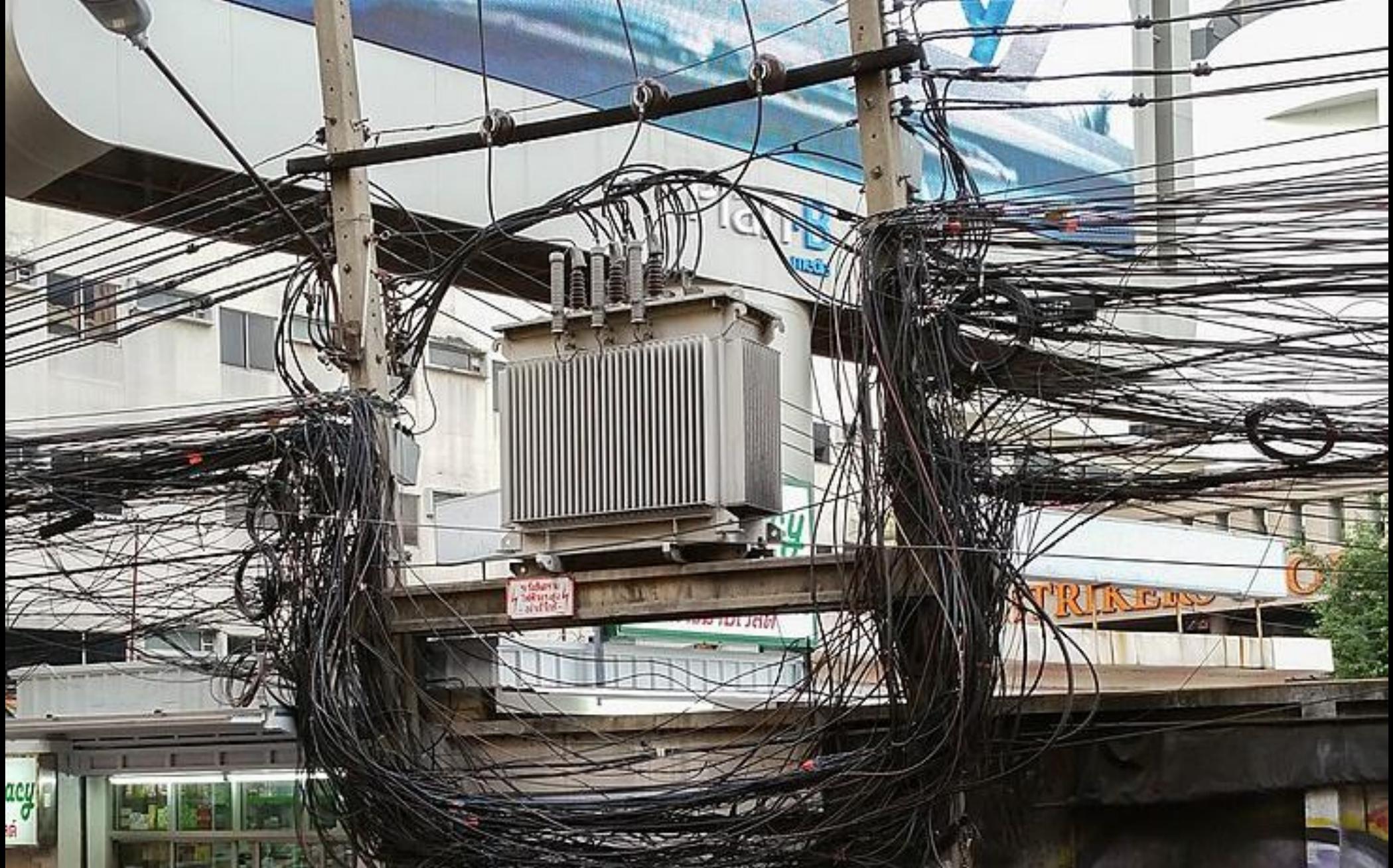


Photo: User:Photogoddle <https://commons.wikimedia.org/wiki/File:Transformer.jpg>

Challenges of the r4ss approach

- No proper design (the bazaar rather than the cathedral)
- Maintaining compatibility with many versions of SS (going back to 3.24 from 2012 *because it's still in use*)
- Depends on busy people
- Most contributors lack formal training in software development
- Technical debt built up over many years is hard to pay back
- Easier to start over than try to implement large-scale changes (like switching to ggplot or adapting to a next generation model)



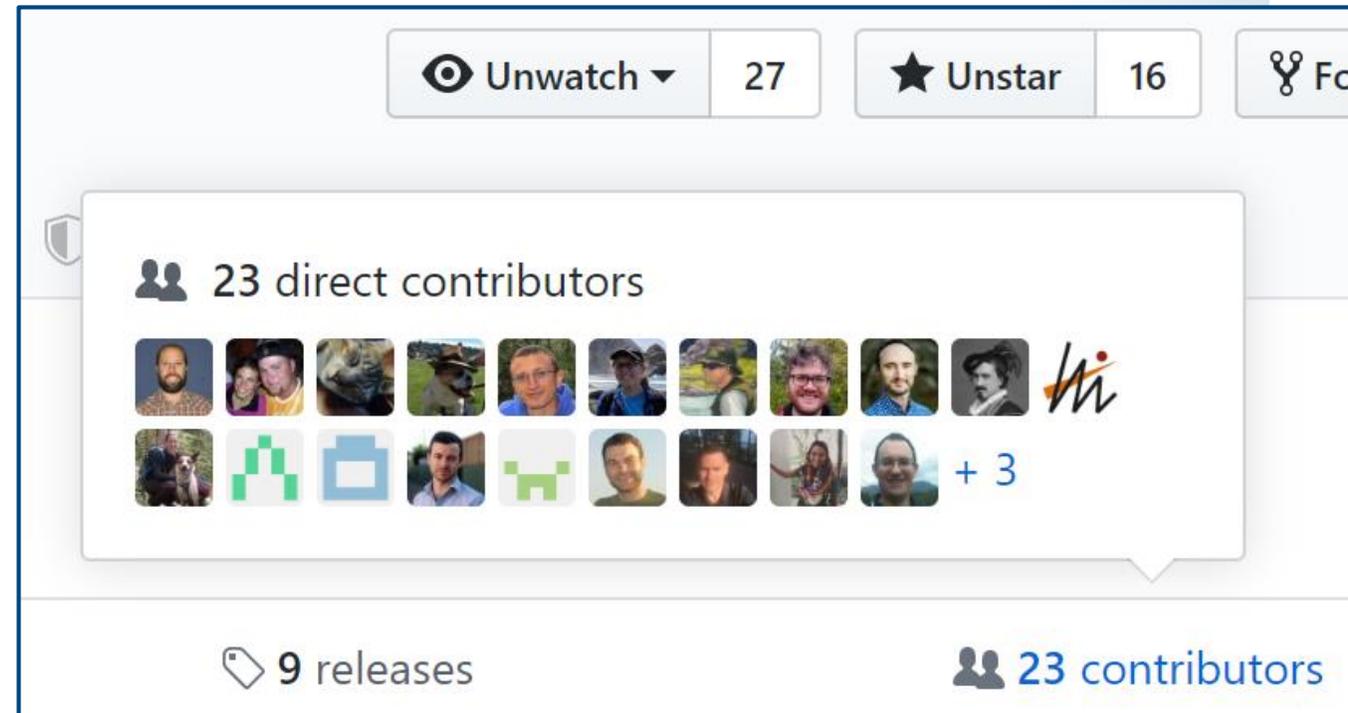
Keys to successes of r4ss

- Widespread use of Stock Synthesis
 - Large pool of users and potential contributors
 - Greater time investment in development is justified
- The R language
 - Widely used among fisheries scientists
 - Supportive community:
reshamas.github.io/why-women-are-flourishing-in-r-community-but-lagging-in-python
- Open source model
- Not the only way to explore Stock Synthesis output (doesn't have to work for everybody)



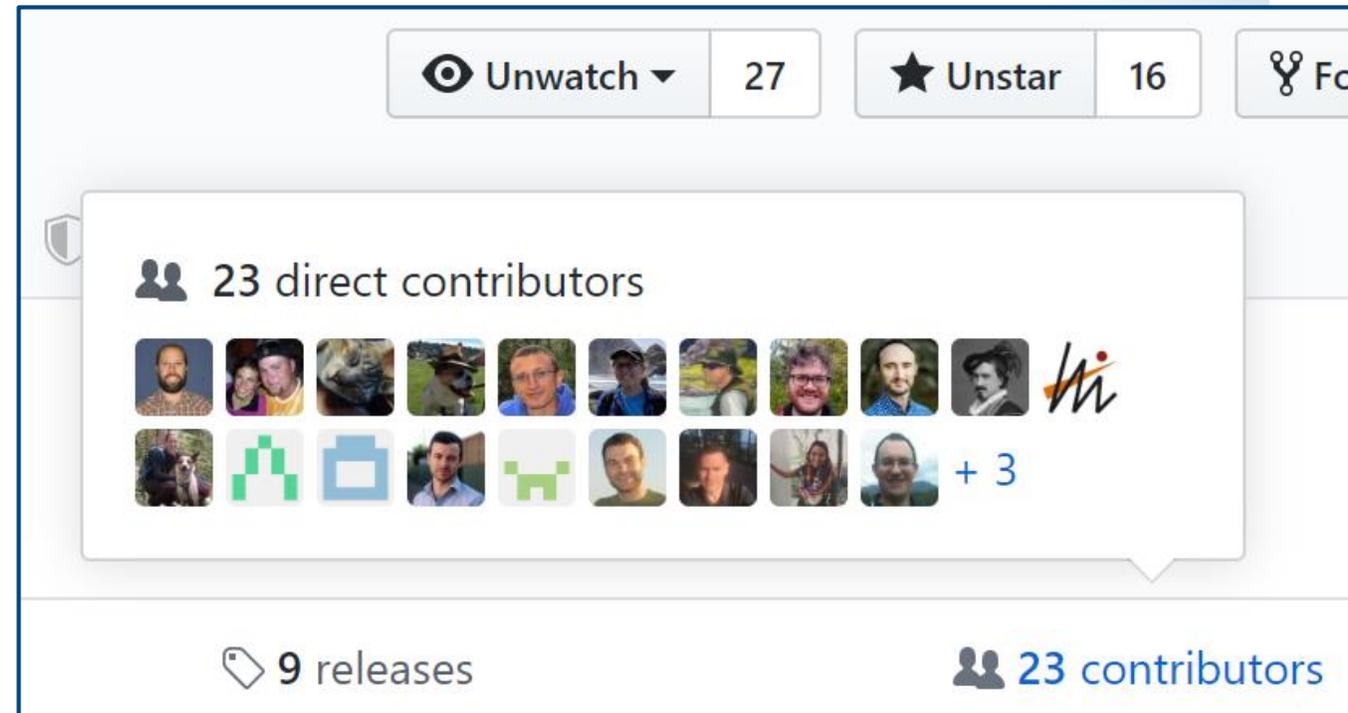
Benefits of open source for model output

- Visualizing model results is both art and science
- The right framework makes it easy to include contributions from many people
- Much more powerful than what any individual or committee could think up



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“If I give it to Ian and a thousand people ignore it, then I feel like I could have made a difference.” -André Punt

A few thoughts about diversity in the stock assessment community

- The stock assessment models we use were mostly developed by white men
- The next generation of stock assessment scientists has much higher representation of women
- The racial diversity of the assessment community remains much lower than the larger societies in which we work
- The next generation of stock assessment models will be stronger if they are developed with input from a more diverse community of scientists
- Strong evidence that diverse perspectives make science more powerful (e.g. AlShebli et al. 2018

<https://www.nature.com/articles/s41467-018-07634-8>

The screenshot shows the 'People' page of The Punt Lab website. It features a large grid of photos of lab members on the left and a list of names with titles on the right. The list includes:

- Andre Punt, Principal Investigator
- John Best, Graduate Student
- Charlotte Boyd, Past Postdoctoral ...
- Mala Sosa Kapur, Graduate Student
- Castin Allen Akselrud, Graduate Student
- Amanda Faig, Postdoctoral Fellow
- Kristin Privitera-Johns, Graduate Student
- Cecilia O'Leary, Postdoctoral Fellow
- Lee Cronin-Fine, Graduate Student
- Claudio Castillo-Jordan, Postdoctoral Fellow
- Jon Reum, Past Postdoctoral ...
- Grant Adams, Graduate Student
- Madison Shipley, Graduate Student
- Christine Stawitz, Past Postdoctoral ...
- Margaret Siple, Postdoctoral Fellow

Women make up 53% of past and present grad students and postdocs affiliated with the Punt Lab

Suggestions for processing the output from the next generation of stock assessment models

- Develop open source R packages
- Be inclusive & support contributions from a broad community
 - Include people with experience developing and testing R packages
 - Include people who are involved in the production assessments
 - Provide a clear framework, but don't be too rigid
 - Try to budget about ~1 day per week for the next 10 years for maintenance and improvements
- Don't try to make it perfect, make it easy to keep getting better



Acknowledgements

- NIWA and CAPAM
- Simon Hoyle and Mark Maunder
- Rick Methot
- Kelli Johnson and Chantel Wetzel
- Countless users of the r4ss package
- **r4ss package co-authors**

Ian Stewart, Allan Hicks, Tommy Garrison, Andre Punt, John Wallace, Chantel Wetzel, James Thorson, Yukio Takeuchi, Kotaro Ono, Cole Monnahan, Christine Stawitz, Teresa A'mar, Athol Whitten, Kelli Johnson, Robbie Emmet, Sean Anderson, Gwladys Lambert, Megan Stachura, Andrew Cooper, Andi Stephens, Neil Klaer, Carey McGilliard, Iago Mosqueira, Watal Iwasaki, Kathryn Doering, and Andrea Havron



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