Management strategy evaluation of United States Caribbean yellowtail snapper (*Ocyurus chrysurus*): Advancing management advice for United States Caribbean fish stocks

SEDAR 103

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Background – US Caribbean Fisheries Management

- The Caribbean Fishery Management Council is responsible for managing 179 fish species
- Fisheries management advice in the US Caribbean is challenged by data limitations
- Island-based fisheries management spreads the limited data thin – sample sizes are already relatively small, and made smaller by making one assessment into 2-3

Background – Past Stock Assessments

- Four stocks across the three islands were identified as having enough data to conduct a stock assessment using traditional methods, e.g., statistical catch-at-age models (SEDAR 2016, Sagarese et al. 2018, Stevens et al. 2019)

- Only two of these species (Queen triggerfish, spiny lobster) actually had enough data for an integrated stock assessment model to produce estimates to inform management advice (SEDAR 2019, SEDAR 2022a,b, SEDAR 2025a,b,c)
  - Spawning potential ratio-based biological reference points, e.g., F_X
  - Mean recruitment (R_0) is the most important scale parameter

- Stock assessments of St. Thomas/St. John and Puerto Rico yellowtail snapper and St. Croix stoplight parrotfish could not generate estimates to inform management advice (SEDAR 2025d,e)

Background – Confronting Uncertainty

- Effects of data limitations and model uncertainty have large been explored through sensitivity runs and model diagnostics (SEDAR 2025a,b,c,d,e)

- CFMC expressed concerns in 2024 about recruitment failure/nonstationarity in Southeast US snapper/grouper stocks potentially occurring in the US Caribbean

- When uncertainty threatens the integrity of the current management approach, a management strategy evaluation (MSE) is justifiable (Walter et al. 2023)

Background - MSE

- Closed-loop simulation framework that:
  - Seeks to model the entire socio-ecological management system
  - Is designed to stress test alternative management procedures (MP) against a range of uncertainties
  - Can evaluate MP performance against a set a pre-defined objectives (Butterworth and Punt 1999, Punt et al. 2016)

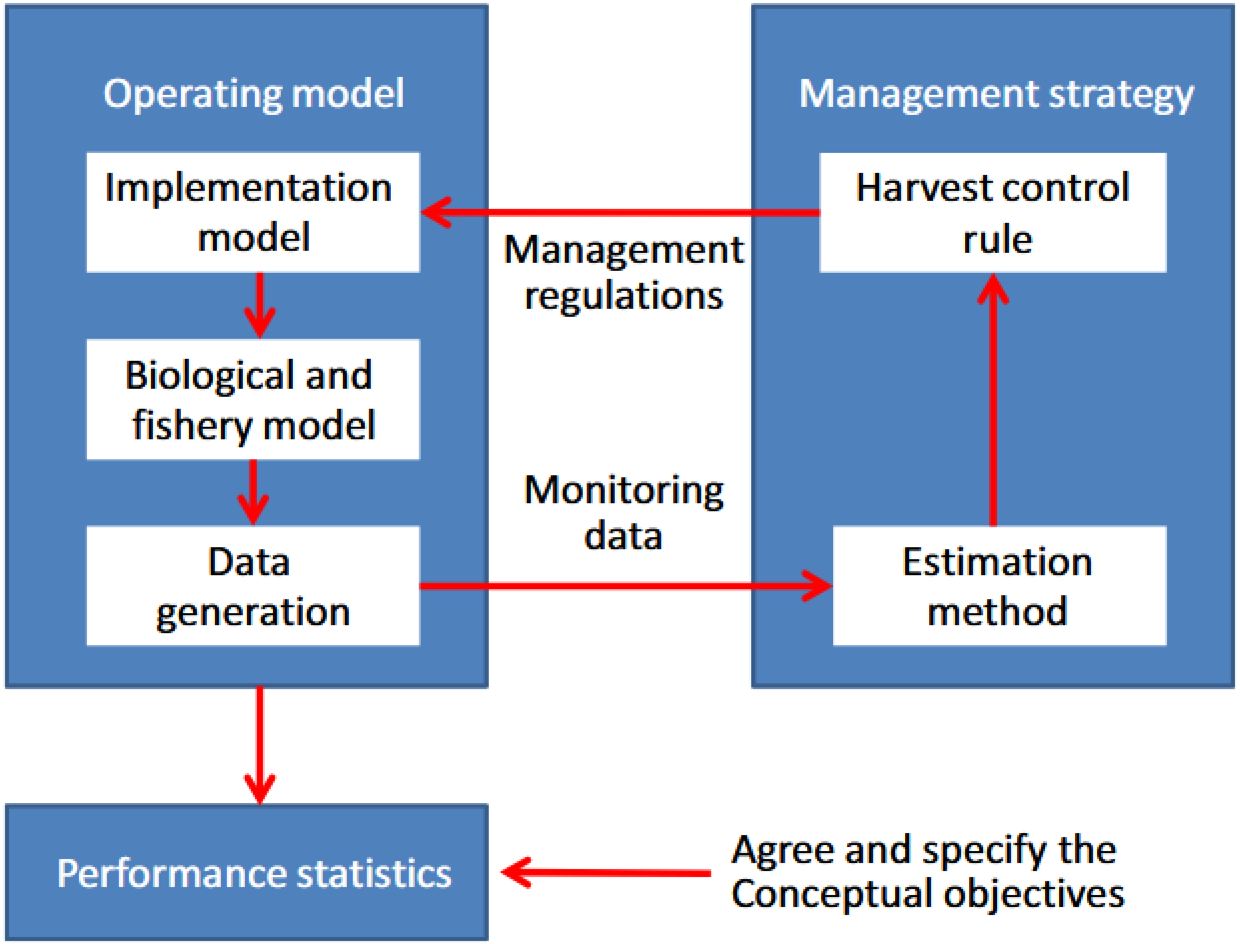


Figure from Punt et al. 2016

Background – MSE in the US Caribbean

- Before enough data were available to pursue statistical catch-at-age methods, SEFSC analysts conducted a “desk” MSE for SEDAR 46 for queen triggerfish, spiny lobster, yellowtail snapper, and stoplight parrotfish (SEDAR 2016, Sagarese et al. 2018)

- Used DLMtool R (Carruthers and Hordyk 2018) to condition simulations on available data, and tested generic, data-limited empirical MPs (Geromont and Butterworth 2015) to determine if adaptive data-limited MPs could outperform the constant catch HCR that was used for those stocks at that time (SEDAR 2016, Sagarese et al. 2018)

- Empirical MPs, e.g., iTarget, an MP based on a target level of relative abundance, outperformed the constant catch HCR by protecting more of the spawning stock while achieving comparable yields (SEDAR 2016, Sagarese et al. 2018)

Background - Research question and goals of the exercise

- Question: what MPs are a suitable path forward for the US Caribbean's data-limited stocks, or those for which data is more plentiful, but stock assessment has not been able to produce reference points for management?

- Goals:
  - Evaluate model-based MPs, an index-based empirical MP, a constant catch MP, and a model-based MP that is effectively ignored (market-driven fishing behavior) over a range of recruitment scenarios
  - Identify tradeoffs between MPs where they may occur
  - Evaluate the relative long-term risk associated with each MP at the scale of the entire US Caribbean management system

Methods – Size Structured MSE Framework

- "Desk" MSE for US Caribbean yellowtail snapper (*Ocyurus crysurus*) as proof-of-concept exercise

- Used MSE tool developed by Damiano et al. (2024); uses size-structured stock assessment model developed by Cao et al. (2017) – written in AD Model Builder (Fournier et al. 2012)

- Areas-as-fleets approach to modeling each island platform (Hurtado-Ferro et al. 2014)

- Used life history parameters and estimates of fishing mortality (*F*) and recruitment (mean, deviations) from SEDAR 84 (SEDAR 2025d,e) to generate simulated data during 2012-2022

Methods – (Additional) MSE Assumptions

- 16 size bins at 3-centimeter (cm) increments from 3-48cm fork length for consistency with SEDAR 84 (2025d,e)
- Growth modeled using a growth transition matrix based on von Bertalanffy growth function parameters (Chen et al. 2003, Cao et al. 2017)
- Natural mortality constant over size and time
- One fishery-independent survey based on the National Coral Reef Monitoring Program (NCRMP) Reef Visual Census (RVC) – assumed an uninterrupted time series as if index was standardized using a model-based method that could interpolate missing values, e.g., spatiotemporal models like VAST or sdmTMB
  - Data technically only available for PR and STTJ during 2012-2016 then every other year (Grove et al. 2021)
- Survey has dome-shaped selectivity for consistency with SEDAR 84 (2025d,e)
- “Fleets” have logistic selectivity
- Low sample sizes for both fishery-dependent and independent size composition; survey CV 0.25

Methods - Management Procedures (MPs)

- Six MPs
- Model-based: F30, 75% of F30, F30 with B-thresh – all threshold HCRs
- Data-limited empirical: iTarget

$$F_{targ} = F_{apex} * \left[1 + \left(\frac{I_{rec} - I_{ref}}{I_{targ} - I_{ref}}\right)\right]$$

if $I_{rec} \geq I_{ref}$

$$F_{targ} = F_{apex} * \left[\frac{I_{rec}}{I_{ref}}\right]^2 \text{ if } I_{rec} < I_{ref}$$

- Constant catch: Catch avg
- Market-based fishing: Random walk F

$F_{y+1} = F_y + \alpha$

MP	Description
F30	Stock is fished at F_{30}
75% F30	Stock is fished at 75 percent of F_{30}
F30 with B-thresh	Stock is fished at F_{30}; if spawning stock biomass is reduced below the MSST, fishing stops until the next stock assessment is completed
iTarget	Stock is fished at a projected rate of F based on the historical mean and adjusted using a version of the iTarget formula tuned to the index of relative abundance (see Equations 1 and 2)
Catch avg	Stock is fished at the average rate of F achieved during 2017-2020
Random walk F	Stock is fished at a rate of F determined by a random walk

Methods – Study Design

- Three recruitment scenarios (operating models):
  - Average recruitment
  - 50% of average recruitment (below average recruitment)
  - Nonstationary mean recruitment: random mean recruitment is drawn before every assessment cycle – saved one random vector of means for all MPs tested
- All MPs projected 30 years into the future
  - 18 unique OM x MP combinations
  - "Assessment" occurs every 6 years (5 assessments per simulation)
  - 200 iterations for model sampling error
  - Stochastic deviations from mean recruitment – saved and used across all OMs for comparable study design
- If estimation model failed to converge (no inverted Hessian or exceeds maximum gradient), results were tossed out and model was re-run
- Sensitivity analyses conducted (not shown here because they need to be re-run…)

Methods - MSE Objectives and Performance Metrics

- Avoid overfishing
  - Maximum fishing mortality threshold = *Fmax,* a proxy for *F* at maximum sustainable yield (MSY) when MSY-based reference points are not available

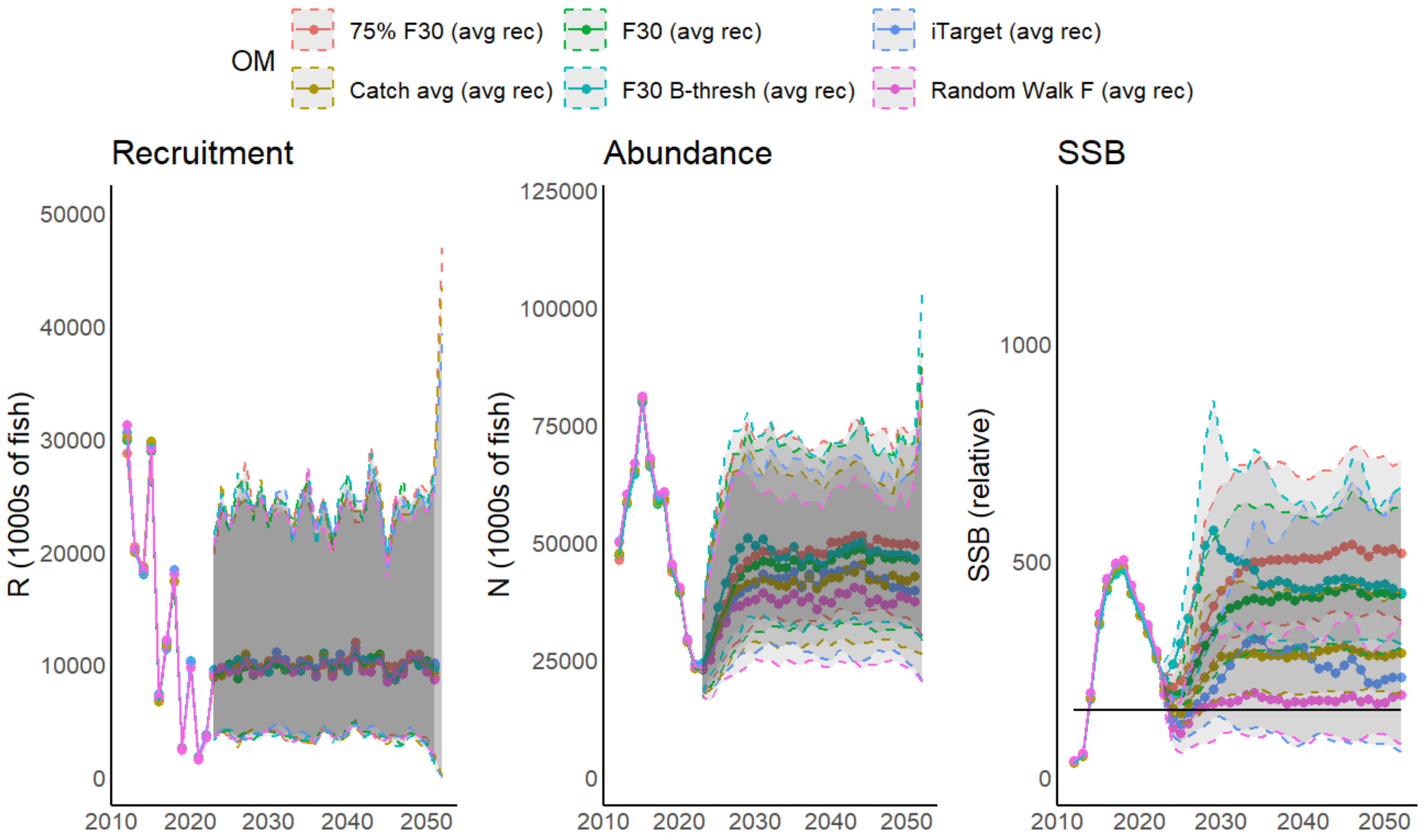
- Avoid overfished status
  - Minimum stock size threshold = 0.5*SSB* from the historical period (assumed a proxy for SSB_{MSY})

- Achieve pretty good yield
  - Percent change in mean long-term total catch from mean historical total catch (which we implicitly assume is ~*MSY*)

- Optimize number of plate-sized fish
  - Mean proportion of population within the plate-sized range (~10-14 inches) available to the fisheries

Results – Population Dynamics in an average recruitment scenario

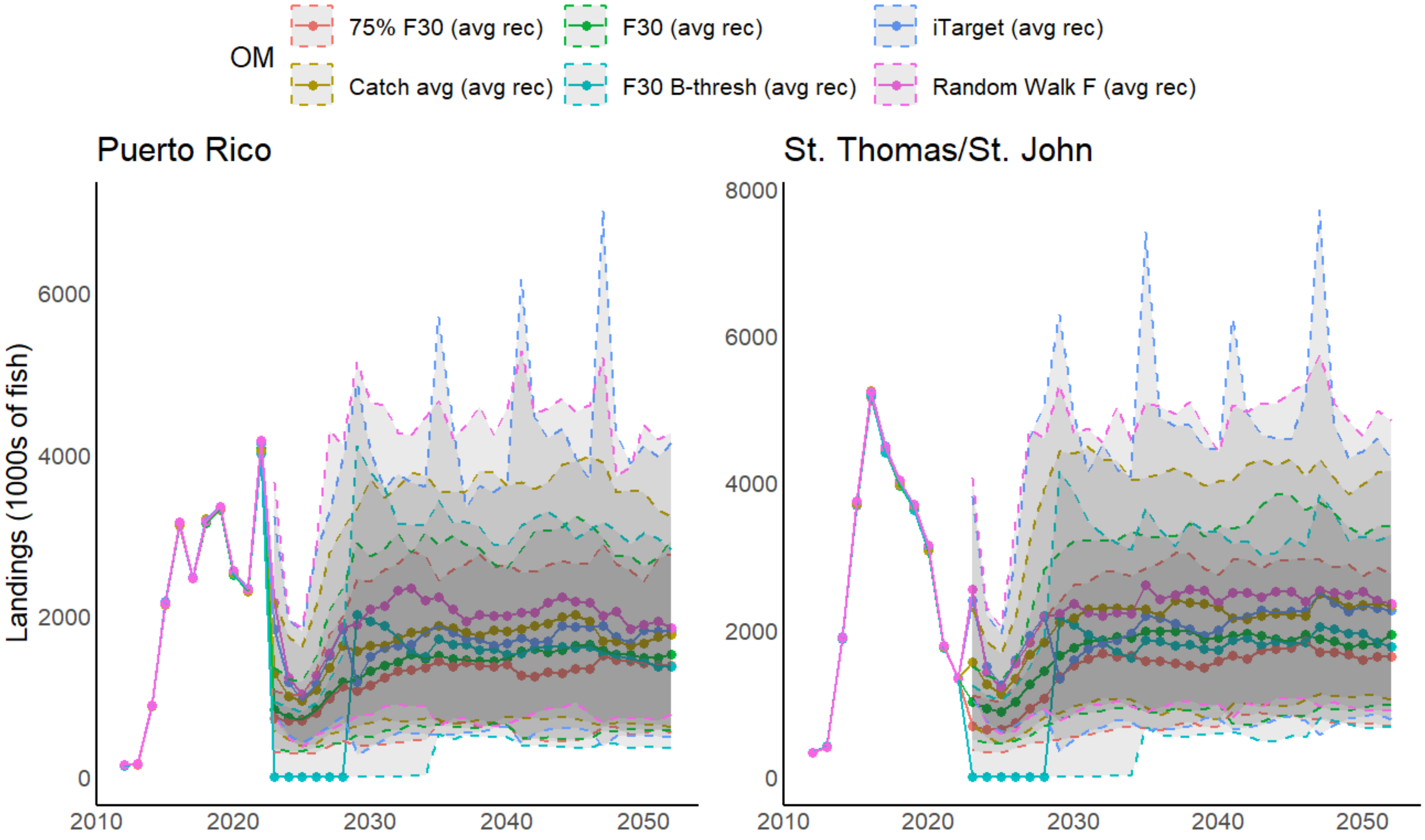
- All model-based MPs maintain abundance and SSB at the highest levels
- iTarget and Catch Avg perform similarly
- RW F most aggressive



Results – Landings by island in an average recruitment scenario

- Very little difference in median catch across MPs

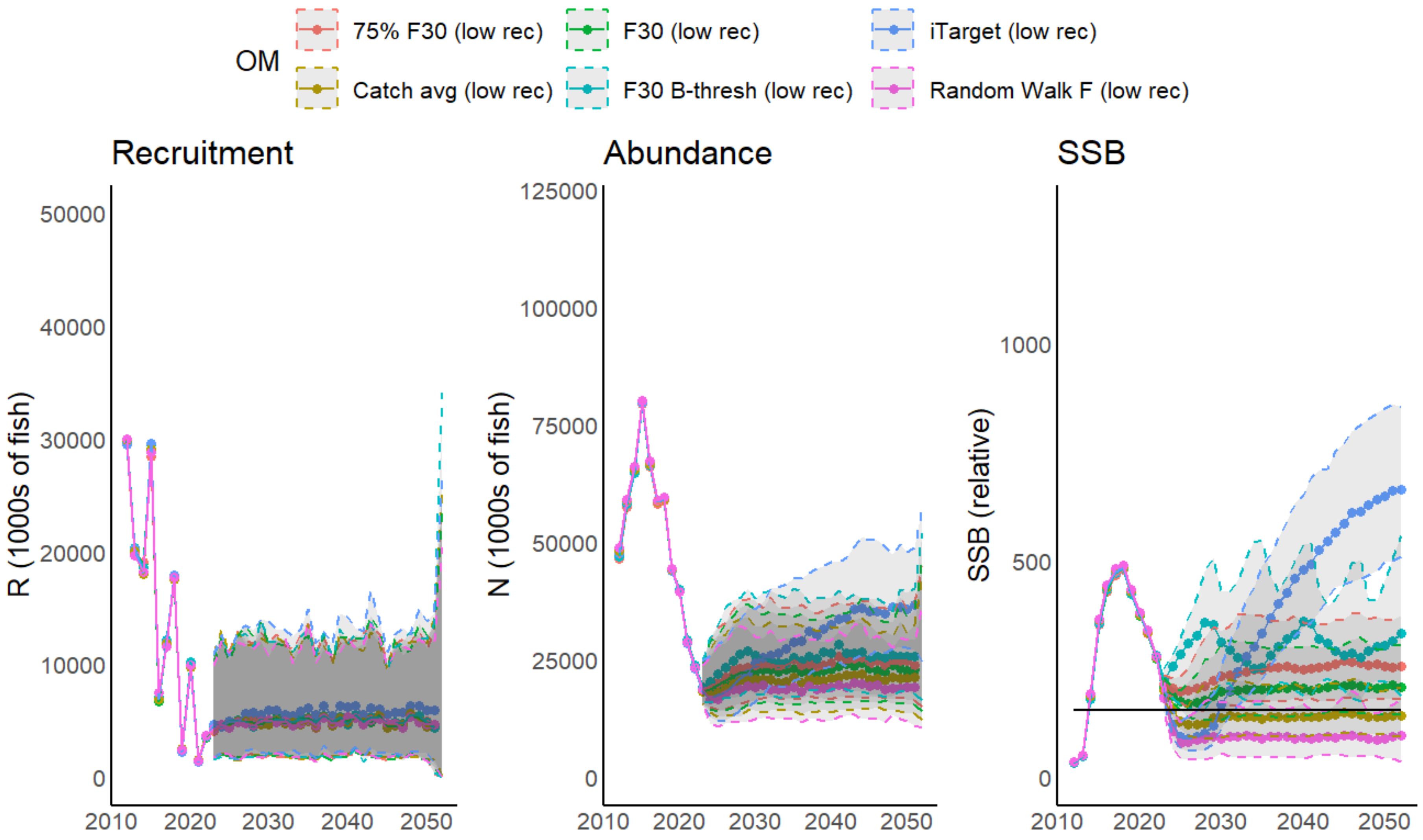
- Range of yields are comparable to historical period for model-based, 90% quantiles higher for others



Results – Population Dynamics in a below average recruitment scenario

- Results are similar to average recruitment scenario…

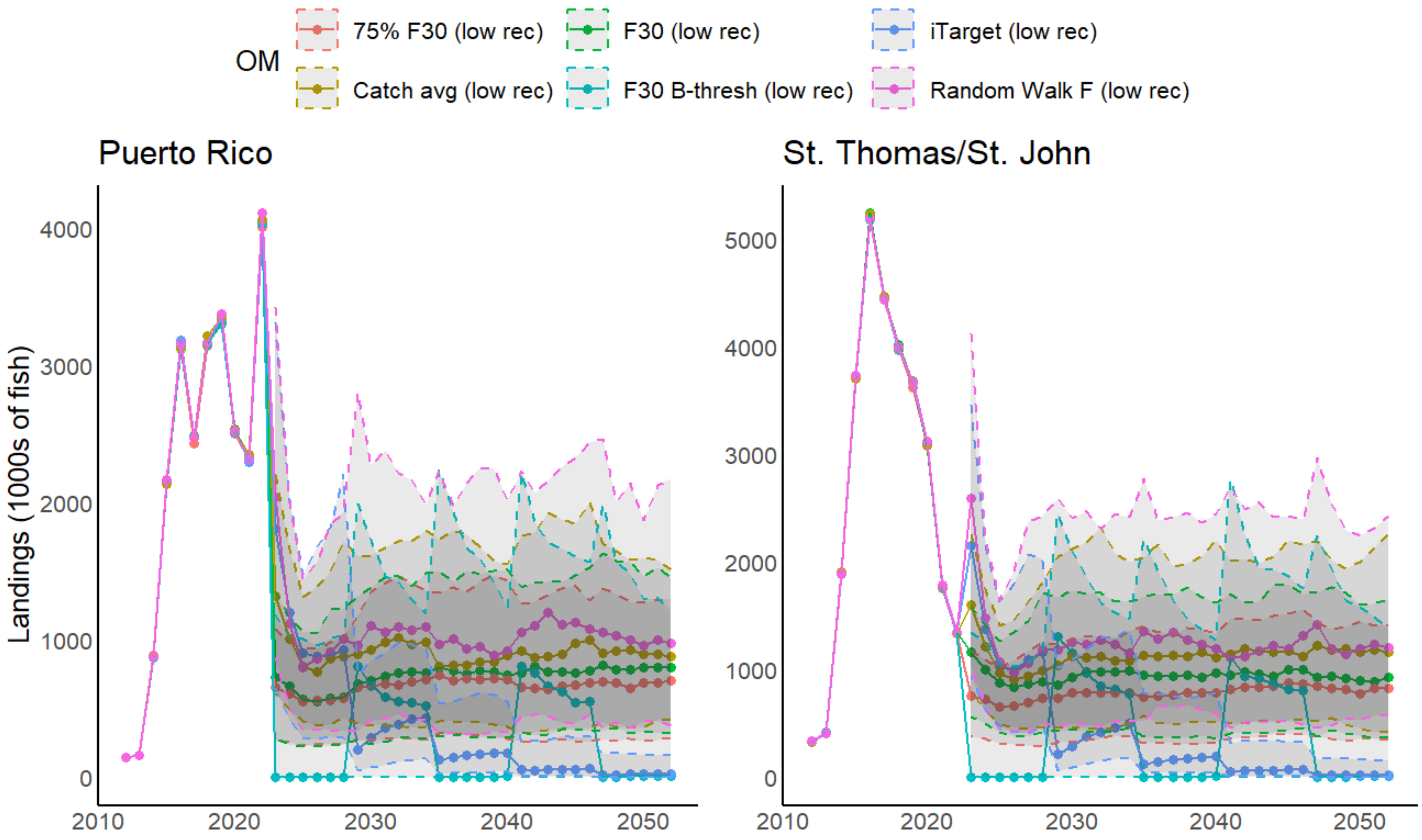
- But iTarget produces much higher abundance and SSB*



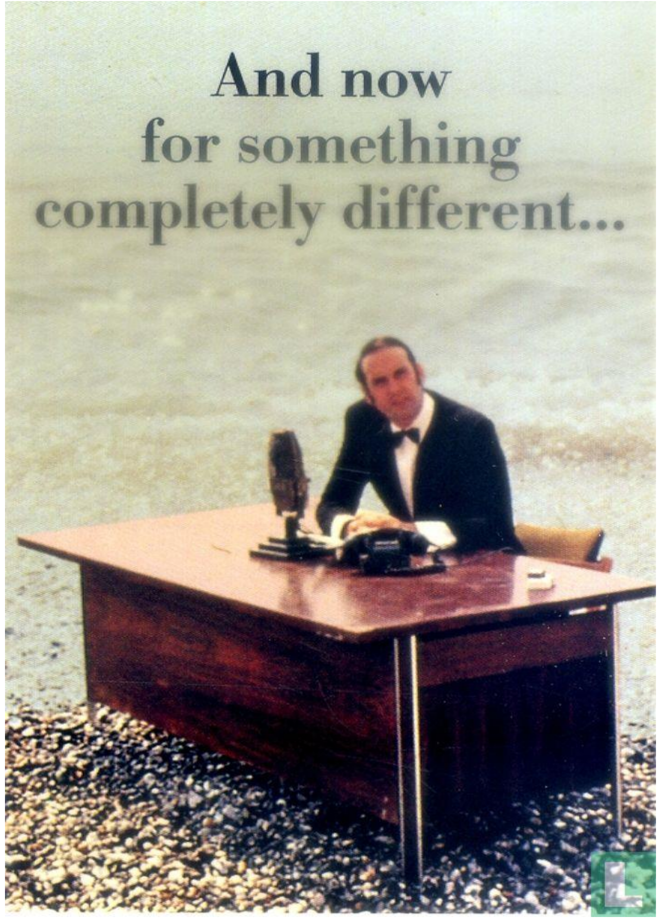
Results – Landings by island in a below average recruitment scenario

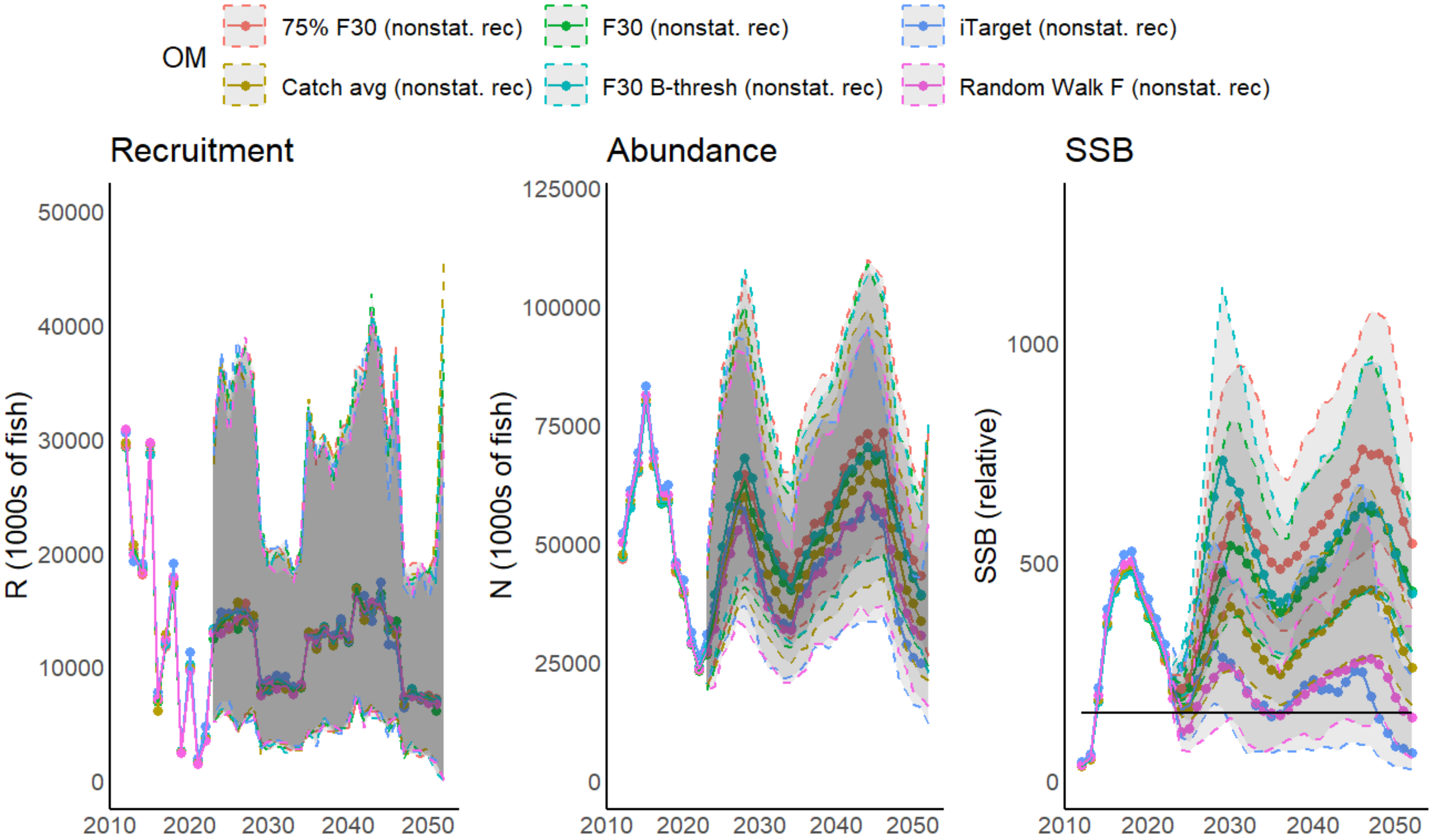
- Because iTarget keeps defaulting to the second condition, which reduces *F* each assessment cycle

- Historic yields only possible if management advice is ignored (RW F)



Results – Population Dynamics in a nonstationary mean recruitment scenario

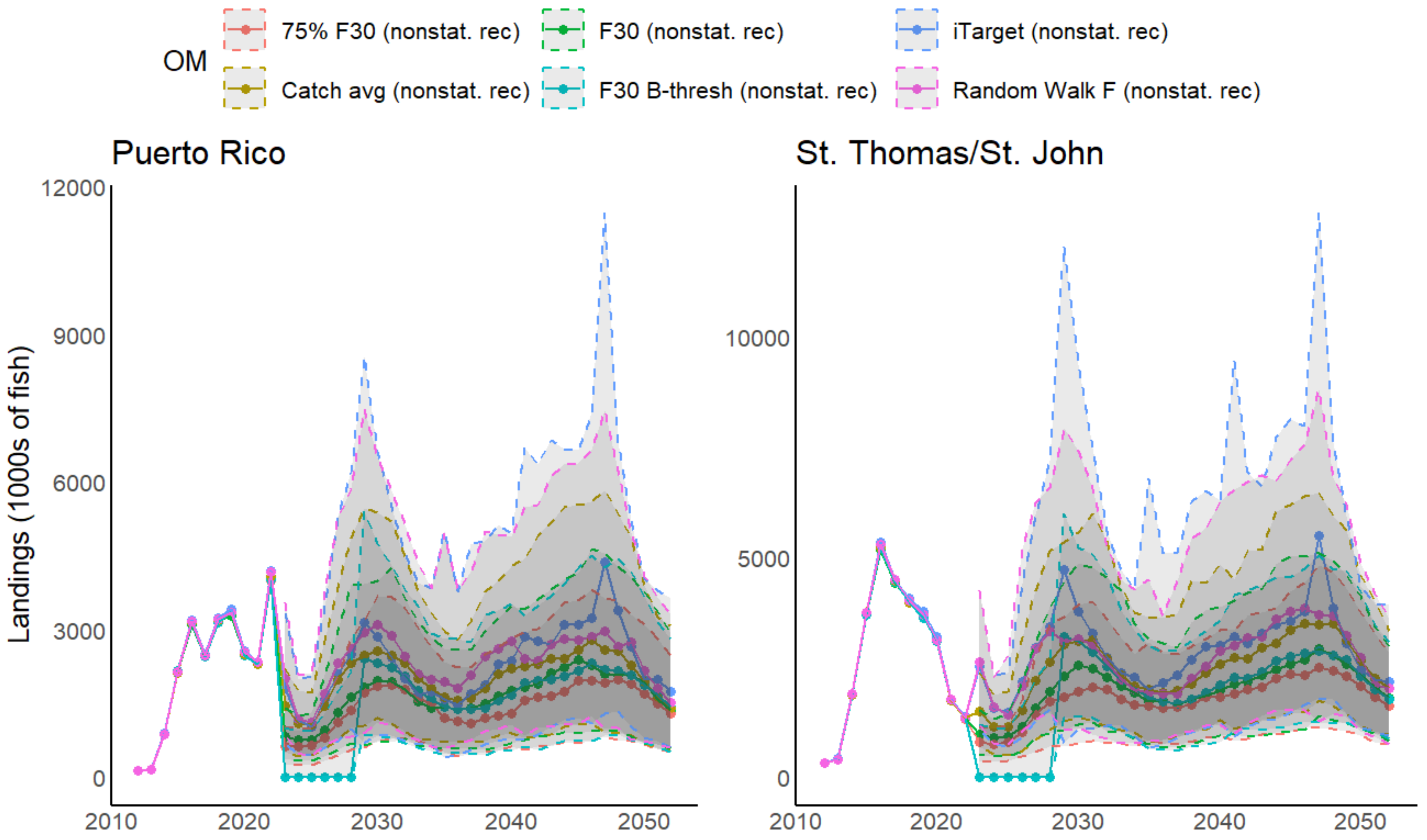




Results – Landings by island in a nonstationary mean recruitment scenario

- All MPs track with the changes in mean recruitment

- iTarget and RW F compete for most aggressive MP in this scenario



Results - Tradeoffs in an average recruitment scenario

- Model-based MPs avoid overfishing/overfished status entirely while maintaining the highest proportion of plate-size fish
- iTarget has a high P(overfishing), but low P(overfished)
- Random walk F achieves the highest catch, but highest P(overfishing), lowest proportion of plate-sized fish

MP	P (Overfishing)	P (Overfished)	Mean total catch/ historical catch	Mean proportion plate-sized
F30	0.00	0.00	0.70	0.33
75% F30	0.00	0.00	0.62	0.36
F30 with B-thresh	0.00	0.00	0.64	0.33
iTarget	0.58	0.11	0.82	0.25
Catch avg	0.25	0.28	0.83	0.28
Random walk F	0.86	0.22	0.85	0.22

Results - Tradeoffs in a below average recruitment scenario

- Comparable tradeoffs to average recruitment scenario
- 75% F30 sacrifices a small portion of catch to avoid P(overfishing), P(overfished)
- iTarget doesn't perform as intended due to unachievable target abundance

MP	P (Overfishing)	P (Overfished)	Mean total catch/ historical catch	Mean proportion plate-sized
F30	0.00	0.33	0.35	0.33
75% F30	0.00	0.00	0.31	0.35
F30 with B-thresh	0.00	0.00	<0.01	0.36
iTarget	0.19	0.09	0.01	0.41
Catch avg	0.28	0.10	0.41	0.28
Random walk F	0.86	0.53	0.44	0.22

Results - Tradeoffs in a nonstationary mean recruitment scenario

- Model-based MPs are the least risky
- iTarget and Random Walk F are comparably aggressive/risky
  - Results based on terminal year when recruitment is lowest during projections
- Catch Avg performance was kind of a surprise

MP	P (Overfishing)	P (Overfished)	Mean long-term catch/ historical catch (out of 1.0)	Mean proportion plate-sized (out of 1.0)
F30	0.00	0.00	0.65	0.36
75% F30	0.00	0.00	0.60	0.41
F30 with B-thresh	0.00	0.00	0.65	0.37
iTarget	0.77	0.21	0.78	0.17
Catch avg	0.22	0.00	0.70	0.30
Random walk F	0.87	0.11	0.71	0.24

Discussion – Main Takeaways

- HCRs that used model-based SPR proxies like F_x, with only one exception, avoided overfishing and overfished status entirely while achieving pretty good yield and maintaining a higher number of target size fish
    - To be expected; it's doing what it was designed to do: reduce the SSB to the target level. Evidence that these proxies are generally robust to recruitment nonstationarity (Shertzer et al. *in review*)
    - Closing the fishery in response to exceeding a biomass threshold does not really buy anything in the long-term

- The iTarget algorithm chosen for this exercise was tuned to be (too) aggressive and performed as such.
    - Below average recruitment would be considered "exceptional circumstances" for this MP
    - Can be further tuned to balance tradeoffs; add 1.5 scalar (or something like it) from *iTarget1* back in

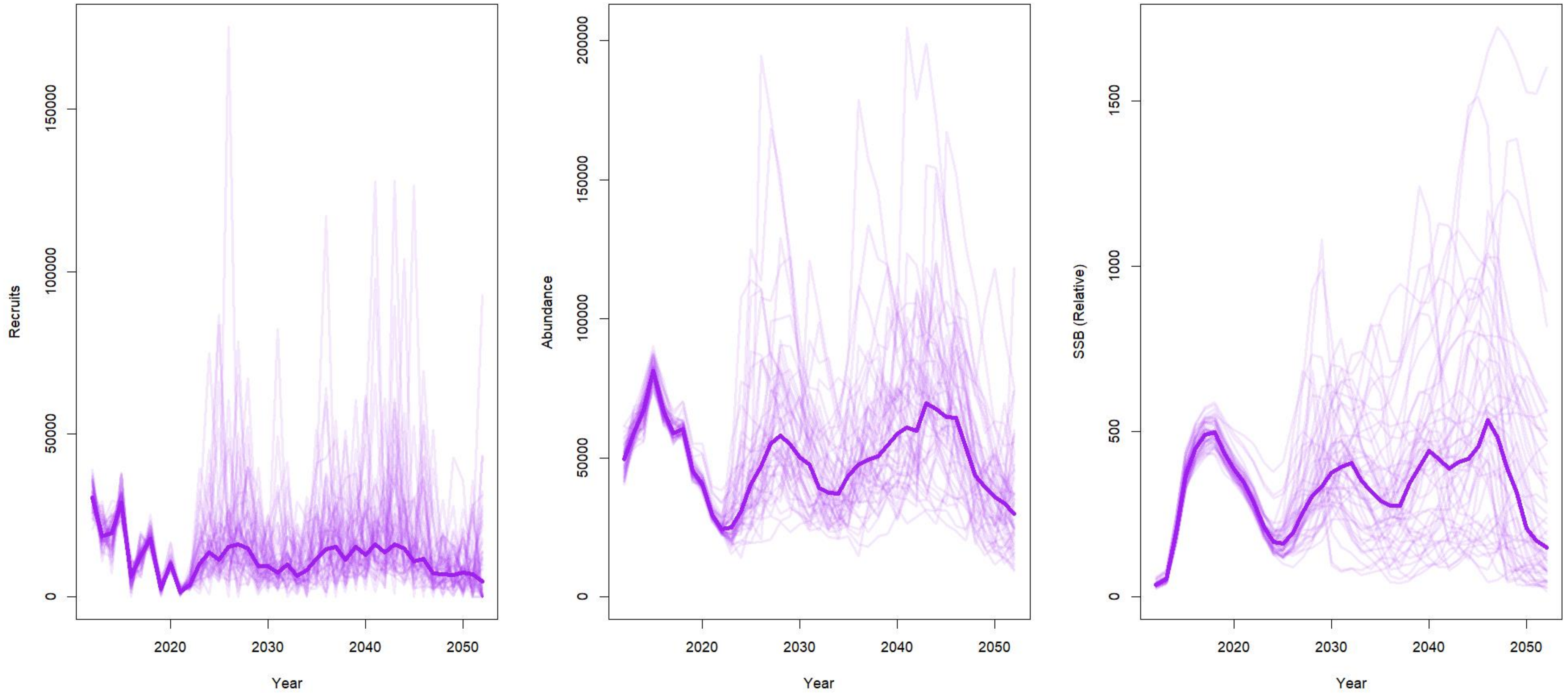
- Catch Avg (constant catch) performance was surprising in the nonstationary mean recruitment scenario
    - This may be incidental rather than an indication of true robustness

- The market-driven fishing modeled using Random Walk F produced the highest P(Overfishing) for not that much more yield
    - Whether the simulated pattern is accurate to reality is not clear, and would greatly benefit from stakeholder input for future modeling of MP

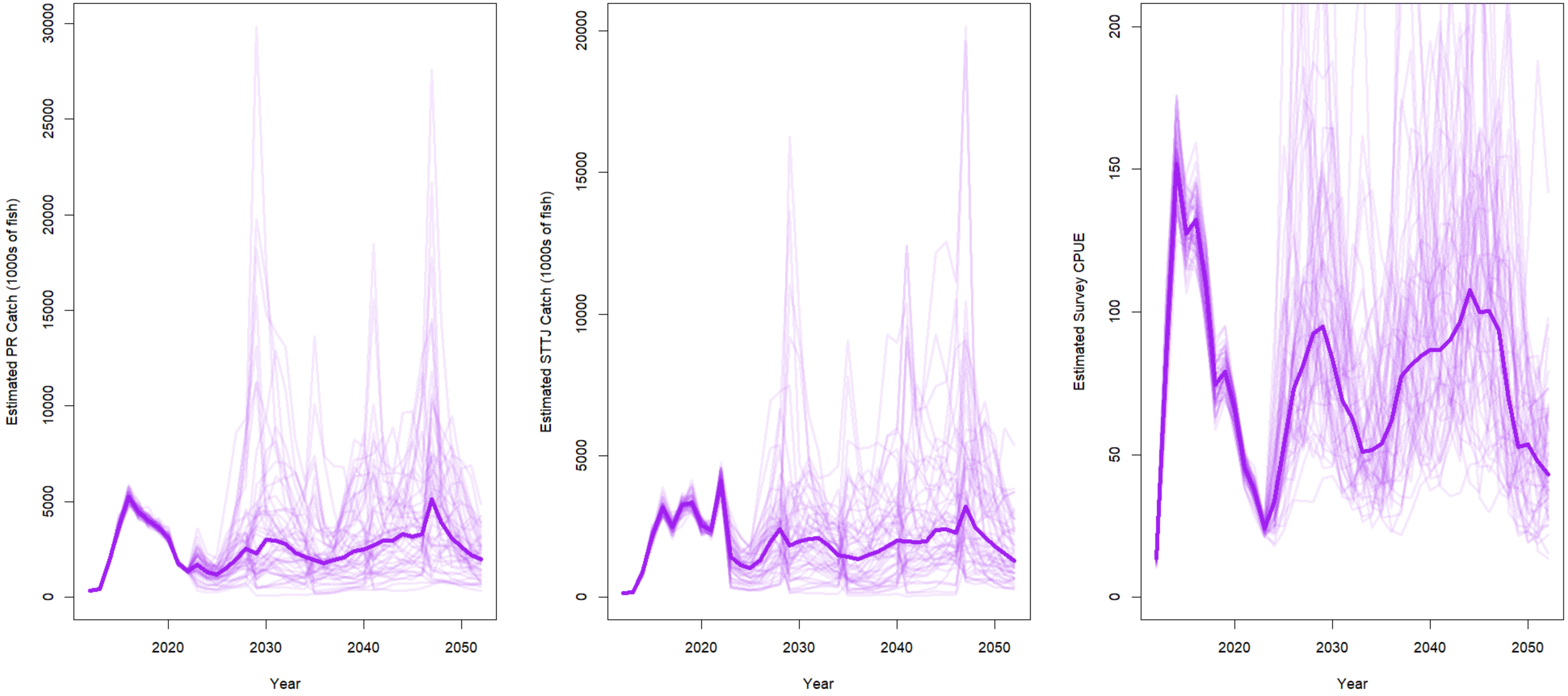
Discussion – A Quick Investigation of iTarget with alternate tuning - I

- (Re)introduced scalar such that target = 1.2 * pretty good relative abundance
- 50 iterations of iTarget MP with nonstationary mean recruitment
- Results are more what I would have expected and demonstrate an important point made during last US Caribbean MSE: generic empirical MPs need to be tuned to achieve a reasonable balance across objectives (Sagarese et al. 2018)

Discussion – A Quick Investigation of iTarget with alternate tuning - II



Discussion – A Quick Investigation of iTarget with alternate tuning - III



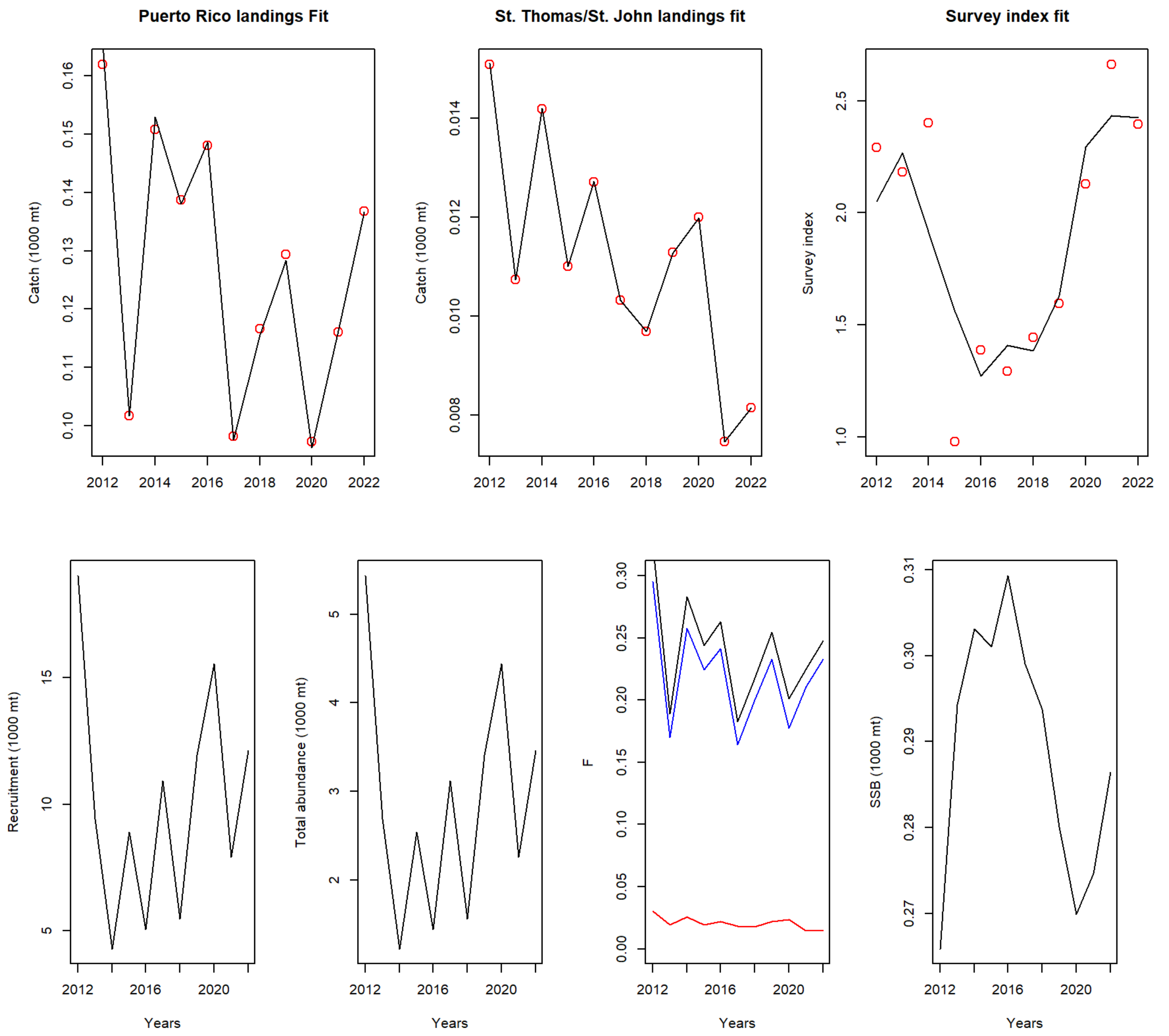
Discussion - Caveats

- Many simplifying assumptions
- Projections manage to *F* instead of catch. Therefore, they are better interpreted as input (effort) controls; still feasible in data-limited situations (MacPherson et al. 2022)
- OMs not conditioned directly on data – data were simulated based on model estimates
    - Doing so makes STTJ landings comparable to PR, when they are much smaller in reality
- Using an areas-as-fleets approach precludes our ability to investigate localized depletion
- Desk MSEs are practical and simpler but don't get the socialization, and stakeholder feedback and participation and buy-in
    - Fishery objectives are assumed instead of solicited directly
- Relatively steep learning curve to do MSE – size structured MSE software is not user-friendly

Discussion – Additional (Spicy?!) Takeaway

- Combining data across island platforms and using the areas-as-fleets assessment approach allows data to be leveraged more optimally

- We fit the size structured assessment model to the actual data from SEDAR 84 during 2012-2022 and it produced results fairly consistent with the OM-generated data
    - Secret bonus product of this exercise



FishPath Categorization

Assessment Category: abundance indicators, population dynamics model, risk analysis, size-based

Assessment Output: Fishing rate, stock status (sort of)

Management Measure: Effort limits

Assessment Tier: Extremely data-poor, Mid, High, at least with respect to MPs that can be tested

Thank you!

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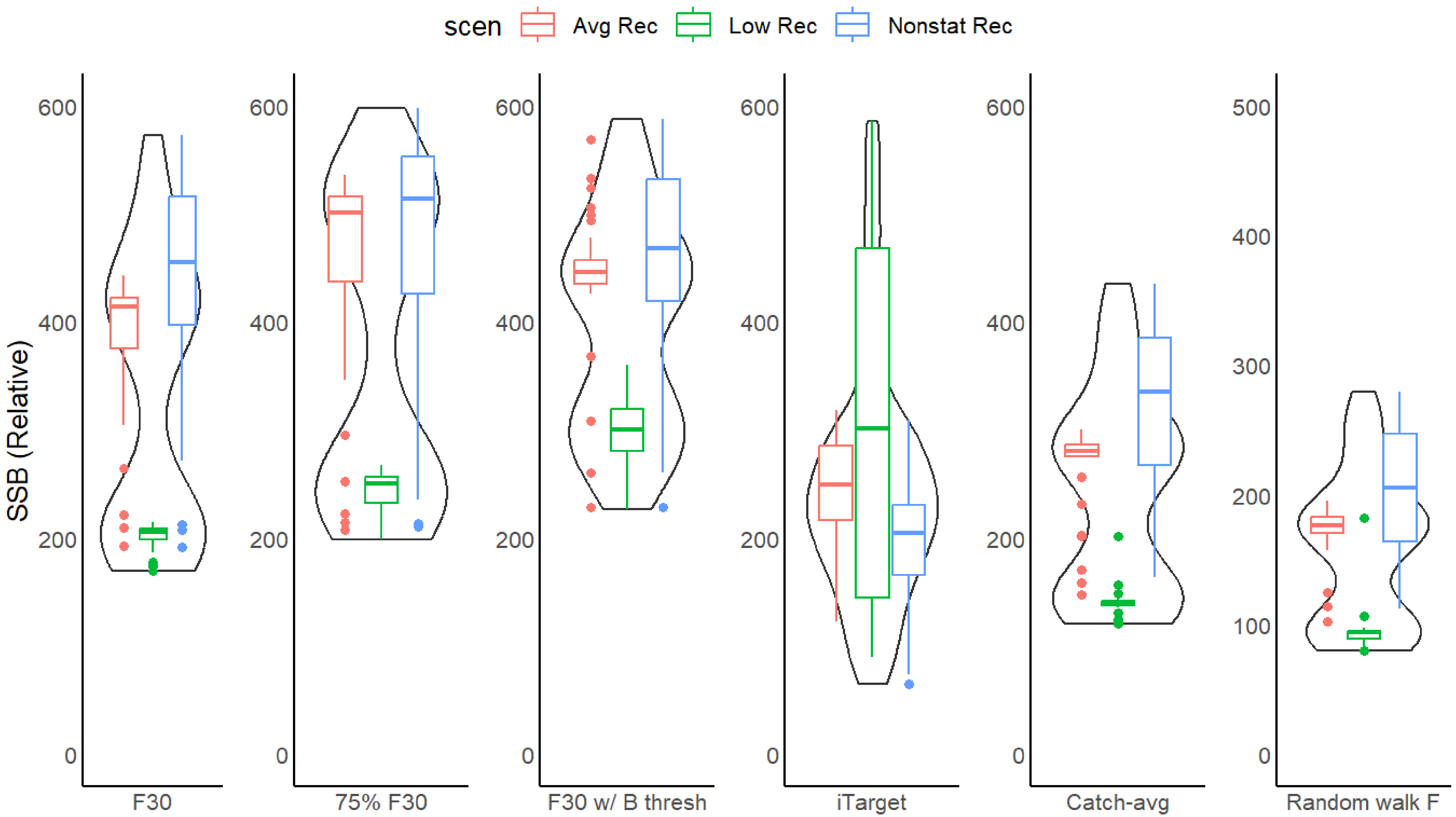
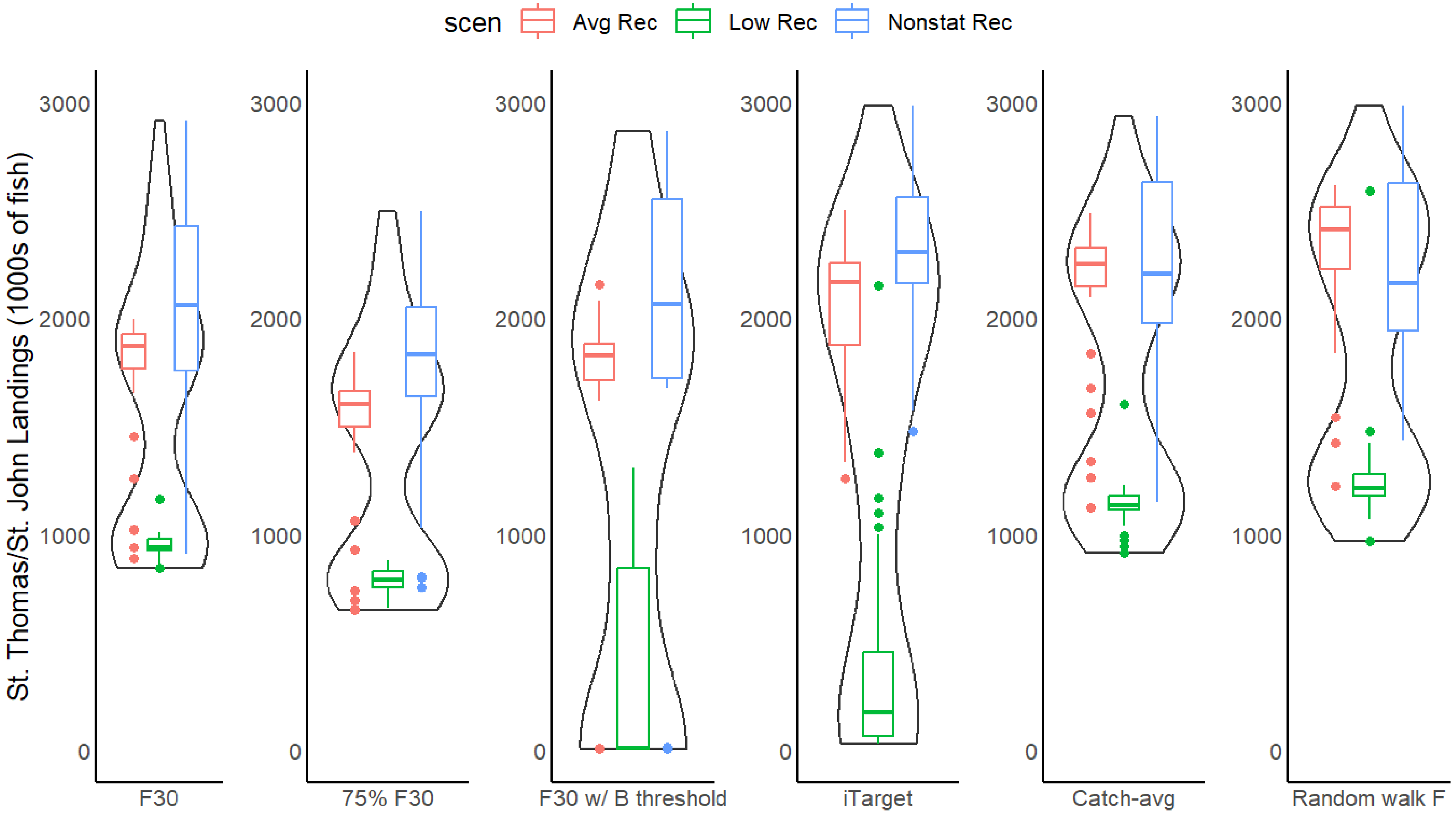
Violin plots – SSB (relative)



Violin plots – STTJ Landings (relative)



Violin plots – PR Landings (relative)