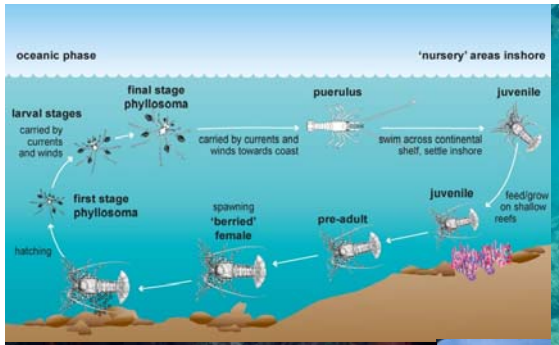





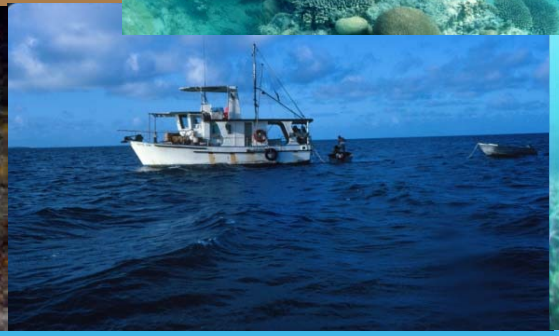

Developing a Harvest Strategy for the Torres Strait tropical rock lobster (TRL) fishery – vers 2

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August 2016

CSIRO Oceans and Atmosphere
www.csiro.au

Australian Fisheries Management Authority

Outline

- Recap re draft Harvest Strategy agreements
- Empirical (data-based) Harvest Control Rule (HCR) explained
- Example application using past data
- Feedback from TRLRAG
- Feedback from Nokome Bentley
- Alternative HCR candidates and their performance
- Deciding on rules for closure
- Reviewing data-based trigger and limit reference points
- Exceptional circumstances clauses
- Sensitivity Analyses
- Discount factors for tiered system (eg more/fewer surveys)

Australia's National Harvest Strategy Guidelines

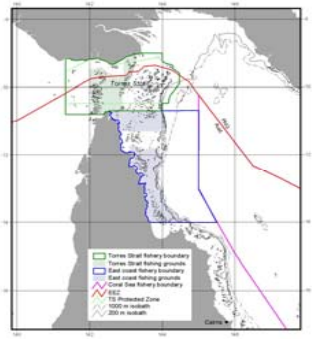
Harvest Strategy: "a framework that specifies the pre-determined management actions in a fishery necessary to achieve the agreed ecological, economic and/or social management objectives."

A key principle is that fishery managers, fishers and key stakeholders utilise pre-agreed (and preferably pre-tested) rules as to how to adjust management recommendations given updates of data and/or model outputs

http://www.agriculture.gov.au/fisheries/domestic/harvest_strategy_policy

Revised TRL Harvest Strategy Timeline under Quota Management

March	July	Aug/Sept	Oct	Nov	End Nov	Season opening - Dec
Update catch, catch at age, survey and TIB & TVH CPUE information	Stock assessment model every 3 yrs?		Bilateral catch sharing meeting – move ??	Conduct Preseason survey and analyse data	~~Rerun assessment OR~~ apply empirical HCR	Final TAC



Recent Catches

Year	TiB	TVH	PNG	TS_Total	Aus_TAC	Catch as % of TAC
2004	211	481	182	874		
2005	345	545	228	1118		
2006	143	135	142	420	471	89%
2007	267	269	228	764	842	91%
2008	207	100	221	528	751	70%
2009	135	91	161	387	450	86%
2010	182	279	293	754	853	88%
2011	201	503	165	869	803	108%
2012	151	370	174	695	964	72%
2013	127	362	108	597	871	69%
2014	132	273	261	666	616	108%
2015	151	152	416*	719	769	93%?
			or 192t	495		65%

2016 TAC = 796t

Harvest Strategy Components

(1) Indicators (data from the fishery; Docket books & Logbooks)

(2) Monitoring (agreed protocols to get data; Population surveys, Size/age monitoring)

(3) Reference points (targets and limits; Stock biomass, Fishing mortality)

(4) Method of assessment (Stock assessment, Catch per Unit of Effort (CPUE) standardisation)

(5) Decision rules (agreed rules for setting catch levels; called Harvest Control Rules)

(3) Final Agreed (by TRLRAG) Harvest Strategy Reference points (targets and limits)

B_{targ} =0.65Bsp(0)

Bsp(0) is assumed to be the model-estimate of spawning biomass in 1973 (start of the fishery)

Btarg has been chosen by TRLRAG as a proxy for BMEY

B_{lim} (0.5Btarg) =0.32Bsp(0)

If LRP is triggered 2 years out of the most recent 3 year period, then the fishery is closed

F_{targ} – estimated by model to keep stock around B_{targ} =0.15

$B_{threshold}$ /$B_{trigger}$ - Biomass level below which more stringent rules for calculating TAC are applied =0.48Bsp(0)

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(5) Harvest Control Rules (HCR)

Traditional Approach

- Model analyses fishery data and assesses current status and productivity of the resource
- "**Best assessment**" provides RBC (Recommended Biological Catch)
- Reference-point HCR informs TAC recommendation and management action

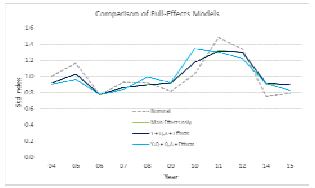
HCR Approach

- A **formula** for recommending the TAC, based on pre-specified data inputs
- **Empirical**, uses the data directly e.g recent upward or downward trends in abundance indices used directly as feedback ⇒ TAC changes in the same direction
- Tested by **simulation** to provide appropriate trade-offs, taking into account range of uncertainties

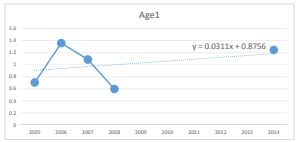
How do we develop an empirical HCR?

1. **Management Objectives** – what are we trying to achieve?

2. **Data inputs** - Decide what data will be used and available in time for input to HCR formula each year: Need Catch, CPUE (TVH), CPUE (TIB) and Preseason survey data (0+, 1+) before end November



3. **Alternative Rules/Formulae = HCR candidates** - Consider some different ways of using trends/updates in some or all of these data to adjust the RBC upwards or downwards



4. **Simulation testing using Operating Model (OM)** – How well do different HCR candidates perform in terms of meeting objectives: quantify using **Performance Statistics** to show trade-offs, risk to resource, average RBC

(RBC = Recommended Biological catch)

How do we develop an empirical HCR cont?

5. **Stakeholder feedback** – key performance measures, preferred trade-offs, tuning to achieve objectives, action needed to avoid penalties (eg if insufficient data) or want a bonus (eg do more surveys, increase precision and accuracy of data inputs)

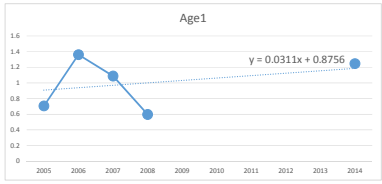
6. **Final HCR or set of candidate HCRs** – Additional tuning to optimise performance, and test robustness using a range of tests

7. **Agreement re HCR formula to apply** – Use formula to recommend TAC once Preseason survey data available (unless there are exceptional circumstances)

8. **Stock assessment every 3 years** – Comprehensive check on resource – is recalibration of HCR needed?

Simple example…

All data collected, checked and analysed
Preseason 1+ numbers are 10% greater than previous average



HCR: TAC = (1+p) * Average Catch
TAC = (1+0.1) * 680 = 748 t

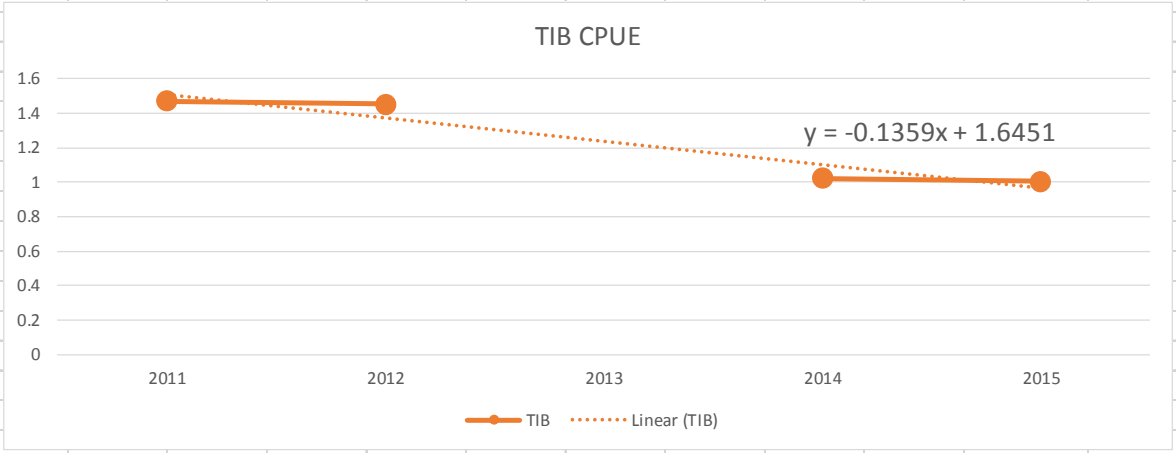
Using this rule, we pre-tested that average catches and catch rates would be reasonably high, inter-annual variability acceptable and low risk of depletion of lobster population

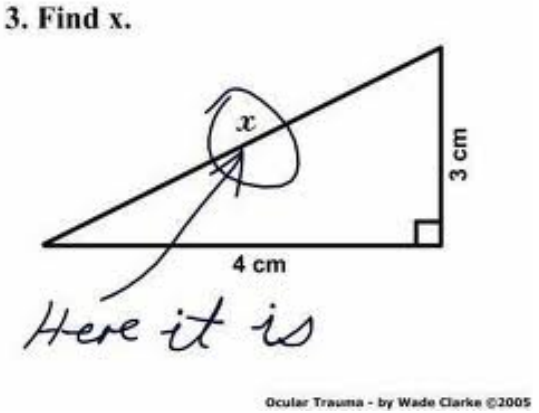
After 3 years, we conduct a stock assessment as a double -check, e.g. if the resource has dropped below the target level, adjust the HCR so that it ensures some rebuilding over the next 3 years

Easy to do the maths and use the final formula!

EXCEL SPREADSHEET CALCULATIONS

			wts	0.15	0.15					0.6	0.1
	TVH		TIB	slopeTVH	slopeTIB		Age1		Age0	slope_pre1	slope_pre0
2005	1.468256	2005	1.150579			2005	0.706113	2005	1.716919		
2006	0.701436	2006	0.86629			2006	1.361401	2006	0.541224		
2007	0.990124	2007	0.96345			2007	1.087655	2007	0.813392		
2008	0.888407	2008	0.997269			2008	0.597608	2008	0.926754		
2009	0.652056	2009	1.028565	-0.1445	-0.0113	2009		2009			
2010	1.233647	2010	1.311098	0.0726	0.0955	2010		2010			
2011	1.931844	2011	1.468828	-0.0113	0.1325	2011		2011			
2012	1.425147	2012	1.453196	0.2353	0.1352	2012		2012			
2013	1.243556	2013		0.1375	0.1432	2013		2013			
2014	0.951777	2014	1.022412	-0.1252	-0.0837	2014	1.247222	2014	1.061155	0.0311	-0.0136
2015	0.615251	2015	1.004475	0.3107	-0.1359	2015	1.589523	2015	0.940556	0.0433	0.0356





Summary re HCR

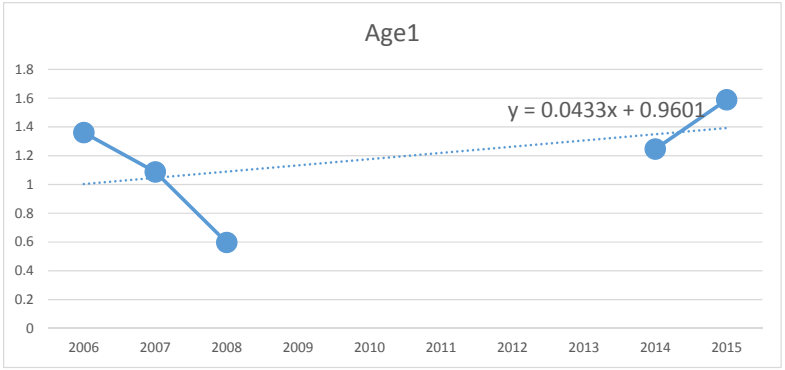
- Compare and select between candidate HCRs that perform satisfactorily
- Challenge and compare performance with robustness tests
- Can tune candidate HCRs to have the same average catch, and then compare risk and other performance measures OR can tune to have the same risk and compare what the average catch will be under each
- Stakeholders select between candidate HCRs based on clear criteria
- Useful to focus on few key performance statistics

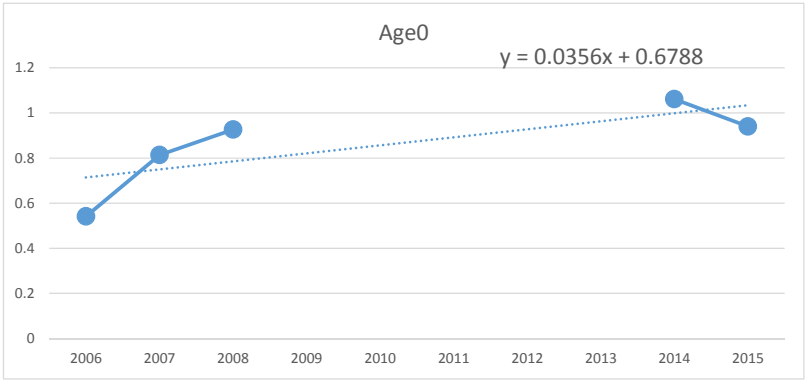
Greatest advantages are probably:

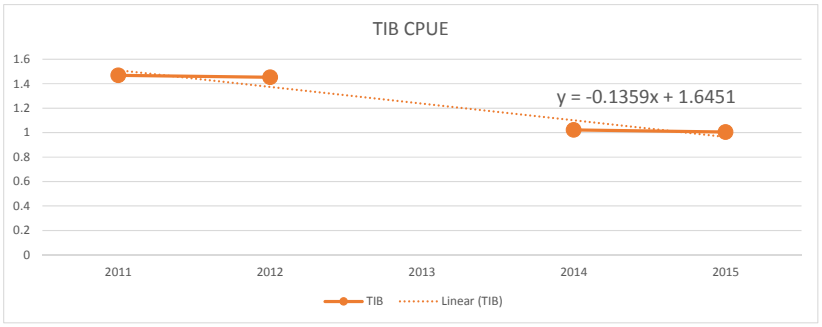
- **A sound basis for setting TACs without compromising resource status**
- **Properly addressing concerns about scientific uncertainty through simulation testing to ensure that feedback secures reasonably robust performance across a range of plausible alternative resource dynamics**

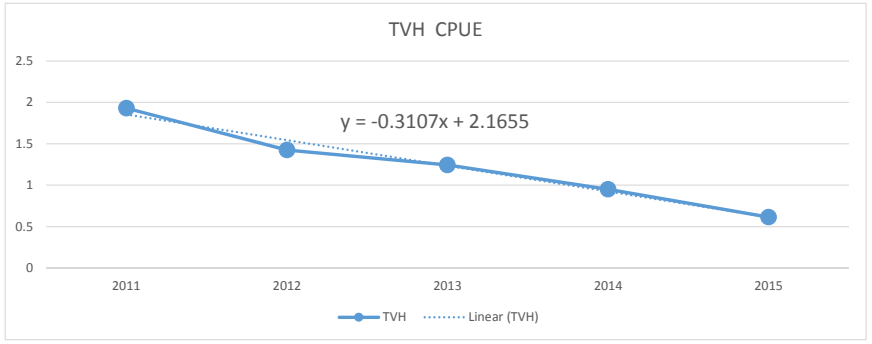
HCR regression slope example using both preseason survey indices and CPUE indices

TAC (2016) = 756 t





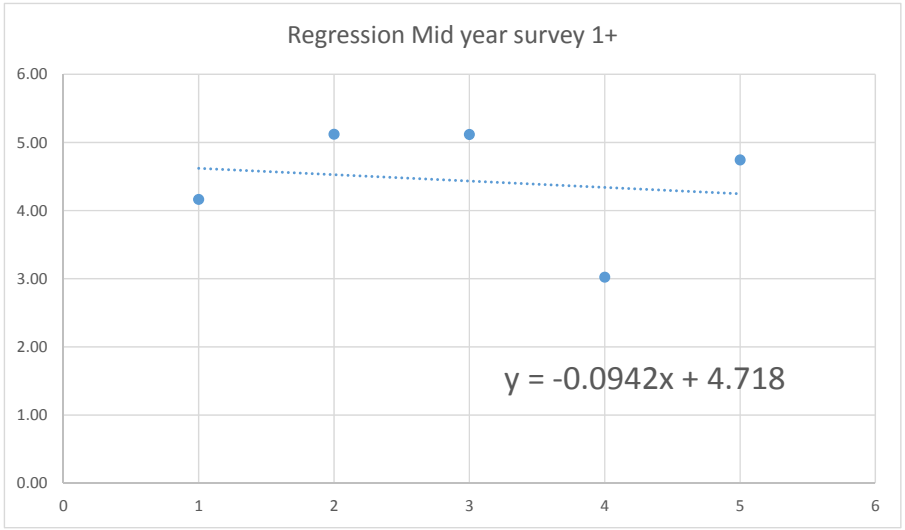




$$TAC_y = 0.6 \cdot \left(1 + s_y^{presurv,1}\right) \cdot \bar{C}_{y-4,y} + 0.1 \cdot \left(1 + s_y^{presurv,0}\right) \cdot \bar{C}_{y-4,y} + 0.15 \cdot \left(1 + s_y^{CPUE,TVH}\right) \cdot \bar{C}_{y-4,y} + 0.15 \cdot \left(1 + s_y^{CPUE,TIB}\right) \cdot \bar{C}_{y-4,y}$$

Excel Spreadsheet Example will be available

	Data				
Catch cohort	Pre 0+	Mid 1+	Pre 1+		Slope of last 5 yr midyr survey
1986					
1987					
1988					
1989					
1990		1.66			
1991		3.54			
1992		3.95			
1993		5.08			
1994		2.34			0.2891
1995		5.64			0.2591
1996		3.50			-0.0350
1997		3.35			-0.2310
1998		3.97			0.0966
1999		1.78			-0.7255
2000		3.49			-0.1574
2001		3.06			-0.1040
2002		1.24			-0.4187
2003		2.51			-0.0796
2004		2.83			-0.1880
2005		2.72			0.0908
2006		1.19	1.69		0.0127
2007	2.14	5.41	2.94		0.4155
2008	0.75	3.83	2.69		0.4694
2009	0.97	2.09	1.33		0.1379
2010	1.21	3.44			0.1172
2011		4.17			-0.2877
2012		5.12			0.4657
2013		5.12			0.7746
2014		3.02			0.0127
2015		4.74	2.90		-0.0942



Feedback from Nokome Bentley

1.Initial trials using the preseason 0+ index to derive a preliminary/forecast TAC

- ***This does indeed look useful but obviously caution is needed given the very low number of data points (slide 58)***

2. Modifying the code to add separate implementation errors

- ***Implementation errors for each sector seems like a good idea.***

3. In the next round of testing, I'll likely use 4 operating models to integrate results over

- ***It would be good to look at different values of autocorrelation in recruitments. This is likely to highly influential for HCR performance - particularly if there is a clause to close the fishery if biomass falls below 0.32B0 in 2 out of 3 years. Perhaps calculate the autocorrelation in the model's estimated rec devs and simulate that value +/- 50%.***
- ***Do you have a perf stat summarizing the frequency of fishery closure?***

Feedback from Nokome Bentley cont.

4.There was general support for including all 4 indices...Any comments re weightings?

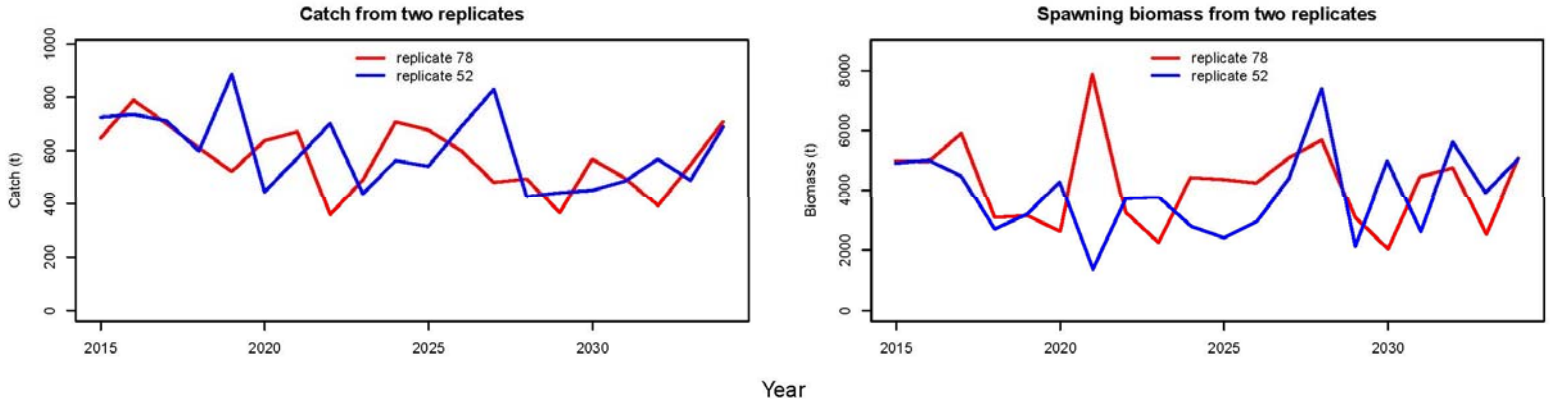
- ***I think that the choice of weightings should really be determined by MSE results - i.e. run a range of different weightings and see which gives best perf stats. I would be surprised if weightings of less than 0.6 for preseason 1+ would perform well.***
- ***The simple slope rule just using preseason 1+ seems the easiest to understand and I would be surprised if adding in the other indices or catch averages helps improve performance. I would certainly encourage this HCR to be further tested with a range of slopes and max catches.***

5.Agreed to focus on current situation first where we only have preseason survey; as next step will do testing for other tiers to quantify how much better we could do with a midyear survey added, or alternatively what the penalties are if missing or poor data inputs

- ***This would be an interesting and important step to test alternative tiers of info.***

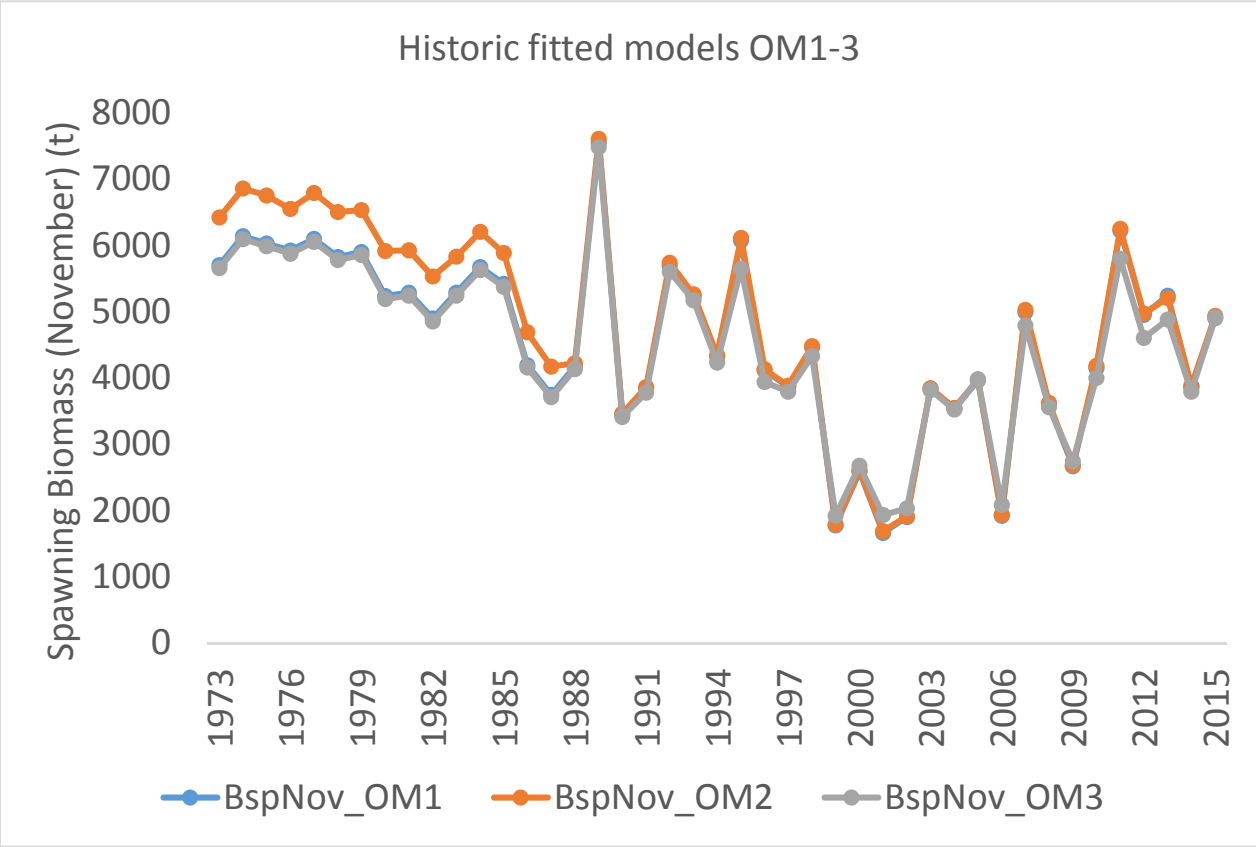
Operating Model

- Stock assessment model
- Explore uncertainties re model specification and fit to data
- Generate "future" survey and CPUE data, with observation error added
- Use same random numbers to test every candidate HCR



Generate 200 replicates = plausible future trajectories

Reference Set of 4 Operating Models (OMs)



1. Base
2. Different stock-recruit steepness h
3. Hyperstability = 1
4. Autocorrelated poor recruitment

200 replicates
x 4 Oms = 800 simulations

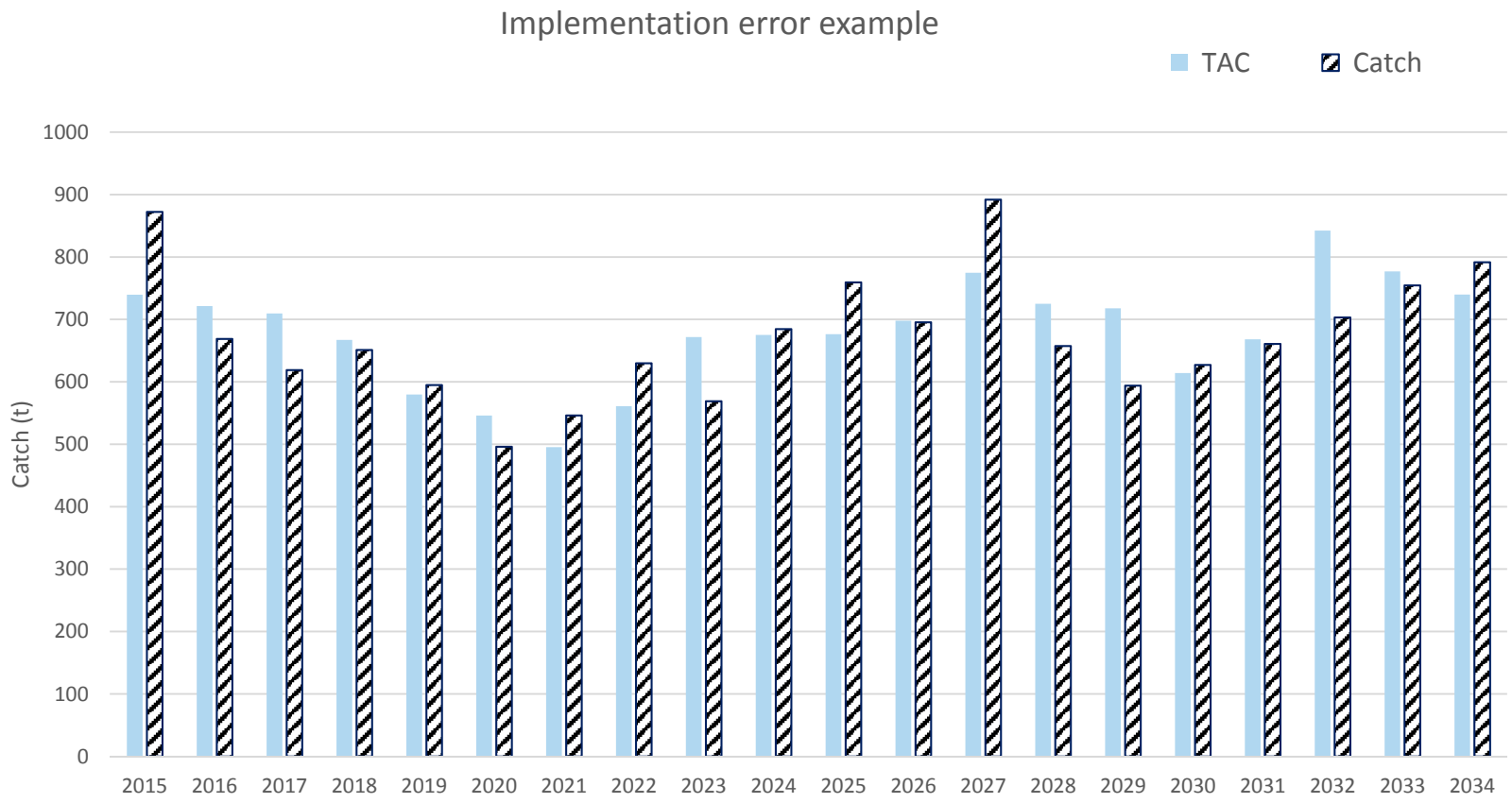
Quantifying Uncertainty

Several types of Uncertainty:

- **Process uncertainty** (e.g. recruitment variability, stock-recruit relationship, natural mortality)
- **Observation uncertainty** (e.g. surveys, measured by CVs* for abundance estimates).
- **Model uncertainty** (do alternative models fit the data adequately?)
- **Estimation uncertainty** – given a model and some data, how well do the data determine the parameters (and predictions) of the model
- **Implementation uncertainty** – given a management decision, how well is it enforced or implemented?

CV = Coefficient of Variation = Std Deviation/Mean

Implementation uncertainty



Random example from single realisation

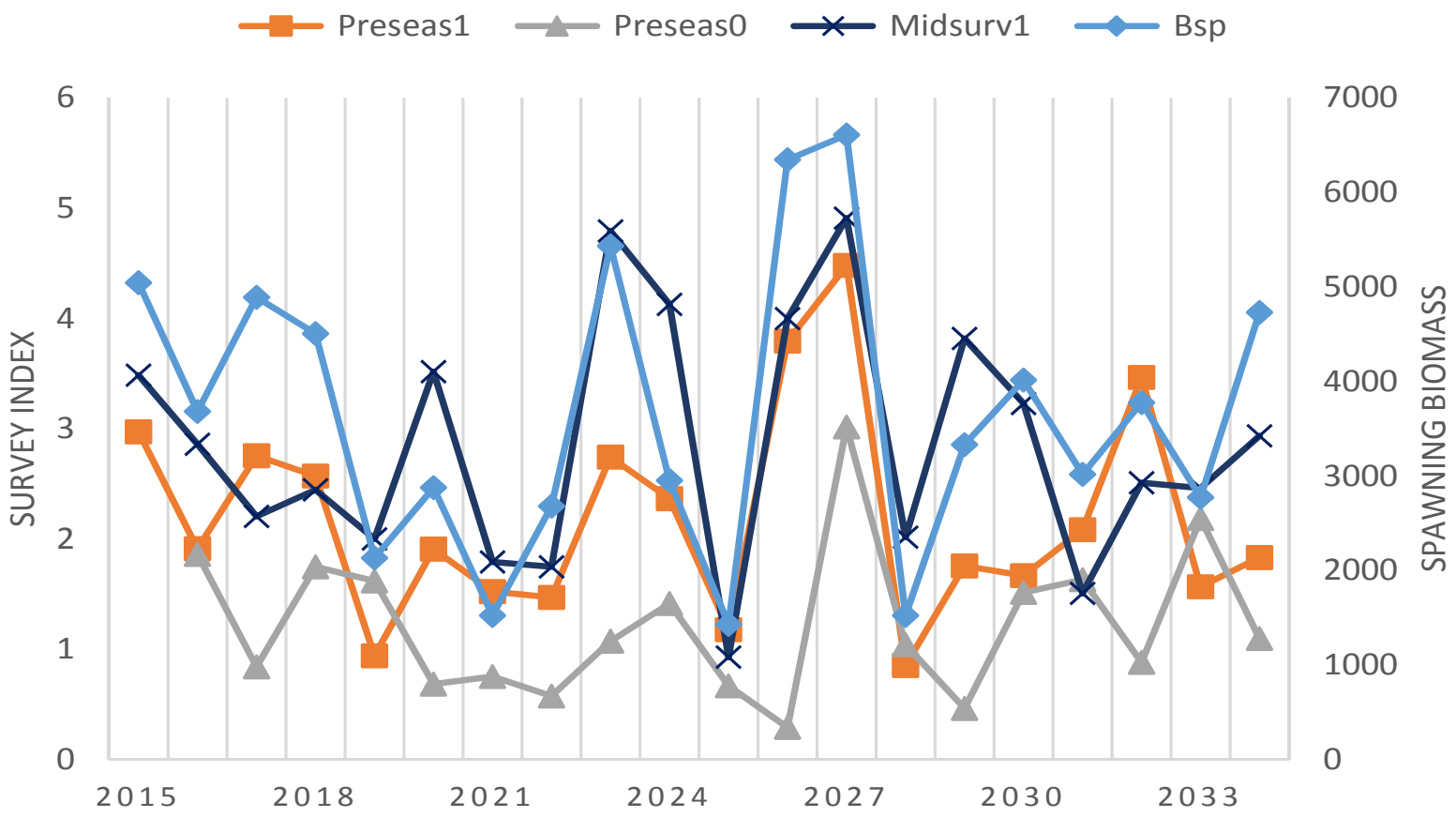
Different implementation error magnitudes for each of the three sectors based on recent observed catches, and hence base case values are set at σ(TIB) (0.06), σ(TVH) (0.04) and σ(PNG) (0.1)

Year	Catch	Catch_TIB	Catch_TVH	Catch_PNG	TAC-Catch_actual	TAC
2015	860.326	322.688	238.254	299.384	-91.3262	769
2016	741.626	283.353	219.54	238.733	38.673	780.299
2017	668.417	256.438	201.122	210.857	64.0464	732.464
2018	710.379	270.427	207.388	232.565	11.7605	722.14
2019	698.723	265.005	201.202	232.516	-12.0248	686.698
2020	582.892	223.013	173.483	186.396	38.6679	621.56
2021	644.757	243.179	182.001	219.577	-41.1621	603.595
2022	599.696	225.854	168.423	205.419	-45.1733	554.522
2023	550.313	211.53	166.875	171.908	64.58	614.893
2024	705.677	267.884	203.877	233.916	-6.49961	699.177
2025	768.477	289.408	215.794	263.276	-58.1303	710.347
2026	679.866	258.415	197.348	224.102	1.59127	681.457
2027	756.608	284.356	210.969	261.282	-69.0552	687.553
2028	712	272.452	212.04	227.508	48.4021	760.402
2029	629.369	242.28	192.034	195.055	84.918	714.287
2030	708.714	268.889	204.342	235.484	-9.99769	698.717
2031	582.965	221.702	169.557	191.706	4.23174	587.197
2032	556.773	214.215	169.493	173.065	71.467	628.24
2033	742.493	282.749	217.042	242.702	14.6933	757.186
2034	712.088	269.206	202.685	240.197	-31.8324	680.255

Example of model output for a single replicate, showing the difference between the TAC and the actual catch when assuming implementation error, and example values for individual sectors from a single replicate (from 200) for OM1

Observation Uncertainty

1 realisation



Performance Statistics

Resource status-related

- $B^{sp}_{2034} / B^{sp}_{2015}$ the expected median spawning biomass at the end of the projection period, relative to the current 2015 level.
- $B^{sp}_{2034} / B^{sp}_{1973}$ the expected median spawning biomass at the end of the projection period, relative to the starting (1973) level (used as a proxy for K).

Tuned to target level; avoid Blim

- Risk of depletion: percentage of all individual runs that ended below (a) 32% and (b) 48% of Unfished biomass

How risky?

Utilisation-related

- Average catch: $\overline{C} = \frac{1}{20}\sum C_y$ over 2015 to 2034.

Average / target level

- Catch variability $\frac{1}{20}\sum C_y / \overline{C}$

How variable?

- Implementation error – difference between TAC and actual catch over the projection period

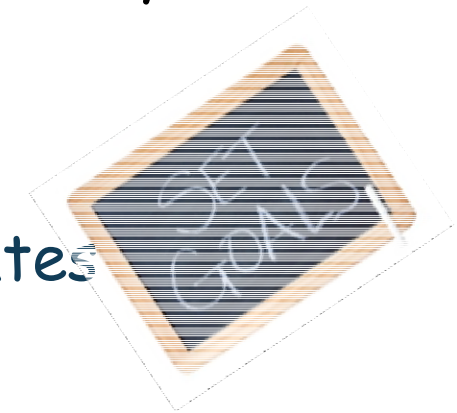
Other examples also provided for stakeholder input and consideration

Comparing Performance Statistics

- Key variables
- Biomass
- Catch and AAV (Annual average variability)
- Risk

Results:

- Medians of 800 stochastic replicates
- 70th / 90th and 10th percentiles
- Range of values
- Average and trend over years



Robustness tests – your inputs needed

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HCR Candidates

	Name	Description	Details	Forecast
1	HCR1	Constant Catch 600		
2	HCR2	Constant Catch 800		
3	HCR3	Constant Catch 400		
4	HCR4	Pre1	(1+ln(slope_Pre))*Catch_ave_5yrs	0.85
5	HCR5	Pre2	(1+ln(slope_Pre))*Catch_ave_3yrs	0.85
6	HCR6	Pre3	(1+(slope_Pre))*Catch_ave_5yrs	0.85
7	HCR7	Pre4	(1+(slope_Pre))*Catch_ave_3yrs	0.85
8	HCR8	All (Pre1, Pre0, CPUE_TVH, CPUE_TIB)	(slopes last 5 yrs); Catch_ave_5yrs; weightings(Pre1;Pre0;CPUE_TVH;CPUE_TIB)=(0.6;0.1;0.15;0.15)	0.85
9	HCR9	All (Pre1, Pre0, CPUE_TVH, CPUE_TIB)	(slopes last 5 yrs); Catch_ave_5yrs; weightings(Pre1;Pre0;CPUE_TVH;CPUE_TIB)=(0.8;0.1;0.05;0.05)	0.85
10	HCR10	All (Pre1, Pre0, CPUE_TVH, CPUE_TIB)	Ln(slopes last 5 yrs); Catch_ave_5yrs; weightings(Pre1;Pre0;CPUE_TVH;CPUE_TIB)=(0.6;0.1;0.15;0.15)	0.85
11	HCR11	All (Pre1, Pre0, CPUE_TVH, CPUE_TIB)	Ln(slopes last 5 yrs); Catch_ave_5yrs; weightings(Pre1;Pre0;CPUE_TVH;CPUE_TIB)=(0.8;0.1;0.05;0.05)	0.85
12	HCR12	No PreSeas	(slopes last 5 yrs); Catch_ave_5yrs; weightings(Pre1;Pre0;CPUE_TVH;CPUE_TIB)=(0.0;0.0.0;0.5;0.5)	0.85
	Revised HCR			
13	RHCR1	All (Pre1, Pre0, CPUE_TVH, CPUE_TIB)	Ln(slopes last 5 yrs); Catch_ave_5yrs; weightings(Pre1;Pre0;CPUE_TVH;CPUE_TIB)=(0.6;0.1;0.15;0.15)	1
14	RHCR2	All (Pre1, Pre0, CPUE_TVH, CPUE_TIB)	(slopes last 5 yrs); Catch_ave_5yrs; weightings(Pre1;Pre0;CPUE_TVH;CPUE_TIB)=(0.6;0.1;0.15;0.15)	1
15	RHCR3	All (Pre1, Pre0, CPUE_TVH, CPUE_TIB)	Ln(slopes last 5 yrs); Catch_ave_5yrs; weightings(Pre1;Pre0;CPUE_TVH;CPUE_TIB)=(0.6;0.3;0.05;0.05)	1
16	RHCR4	All (Pre1, Pre0, CPUE_TVH, CPUE_TIB)	(slopes last 5 yrs); Catch_ave_5yrs; weightings(Pre1;Pre0;CPUE_TVH;CPUE_TIB)=(0.6;0.3;0.05;0.05)	1
17	RHCR5	All (Pre1, Pre0, CPUE_TVH, CPUE_TIB)	Ln(slopes last 5 yrs); Catch_ave_5yrs; weightings(Pre1;Pre0;CPUE_TVH;CPUE_TIB)=(0.8;0.1;0.05;0.05)	1
18	RHCR6	All (Pre1, Pre0, CPUE_TVH, CPUE_TIB)	Ln(slopes last 5 yrs); Catch_ave_5yrs; weightings(Pre1;Pre0;CPUE_TVH;CPUE_TIB)=(0.7;0.2;0.05;0.05)	0.85
19	RHCR7	All (Pre1, Pre0, CPUE_TVH, CPUE_TIB)	Ln(slopes last 5 yrs); Catch_ave_5yrs; weightings(Pre1;Pre0;CPUE_TVH;CPUE_TIB)=(0.7;0.1;0.1;0.1)	0.85
20	RHCR8	All (Pre1, Pre0, CPUE_TVH, CPUE_TIB)	Ln(slopes last 5 yrs); Catch_ave_5yrs; weightings(Pre1;Pre0;CPUE_TVH;CPUE_TIB)=(0.5;0.1;0.2;0.2)	0.85
21	RHCR9	All (Pre1, Pre0, CPUE_TVH, CPUE_TIB)	Ln(slopes last 5 yrs); Catch_ave_5yrs; weightings(Pre1;Pre0;CPUE_TVH;CPUE_TIB)=(0.41;0.21;0.19;0.19) - **inverse of sigma**	0.85
22	RHCR10	All (Pre1, Pre0, CPUE_TVH, CPUE_TIB)	Ln(slopes last 5 yrs); Catch_ave=**665t;** weightings(Pre1;Pre0;CPUE_TVH;CPUE_TIB)=(0.6;0.1;0.15;0.15)	1
23	RHCR11	All (Pre1, Pre0, CPUE_TVH, CPUE_TIB)	Ln(slopes last 5 yrs); Catch_ave_5yrs; weightings(Pre1;Pre0;CPUE_TVH;CPUE_TIB)=(0.6;0.1;0.15;0.15); HOCKEY RULE	1
24	RHCR12	Constant Catch 700		

HCR Alternative Candidates

1. Constant Catch (e.g. 400t/yr) – doesn't perform well

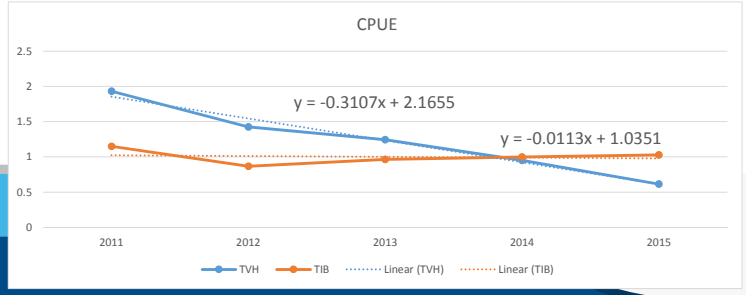
2. Simple slope – based on latest Preseason survey index relative to mean value – showed previously doesn't perform well

3. Regression slope applied to last 5 years' Preseason 1+, 0+, CPUE data with different relative weightings for different series

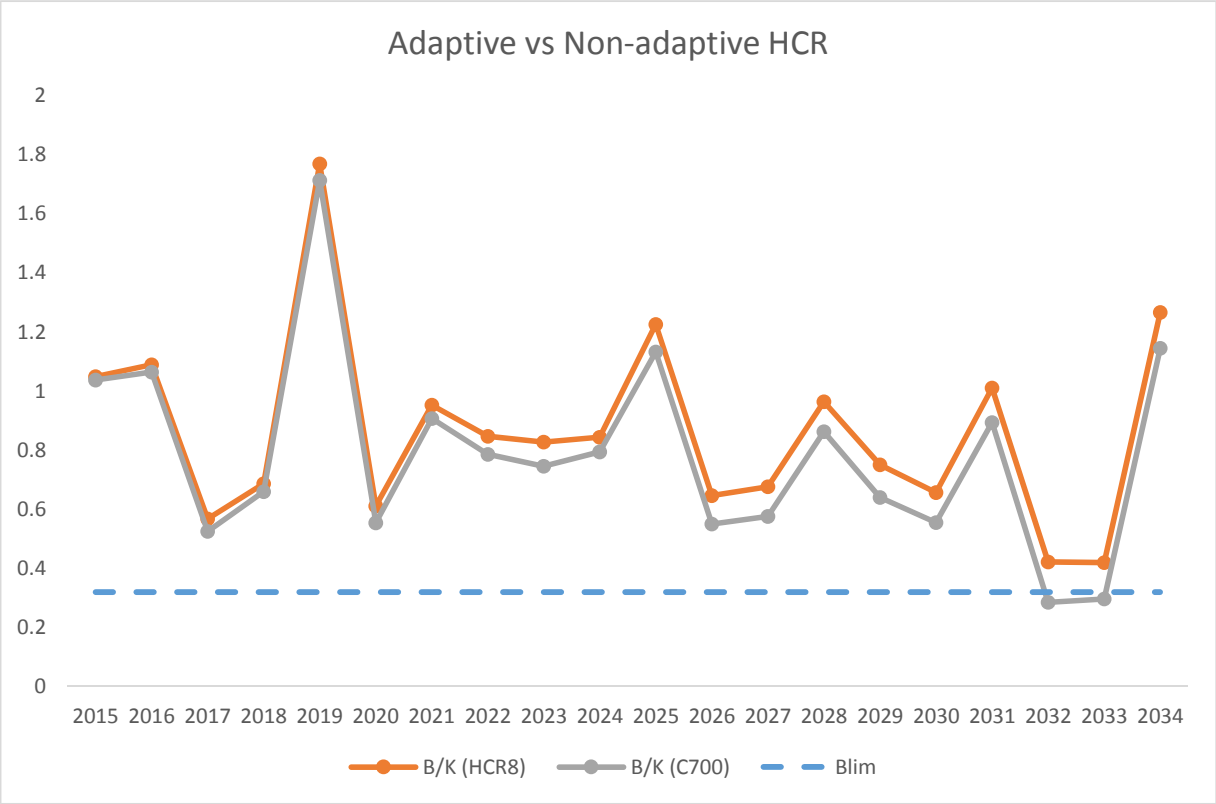
4. Log regression slope – as above but take natural logarithm of indices to dampen variability

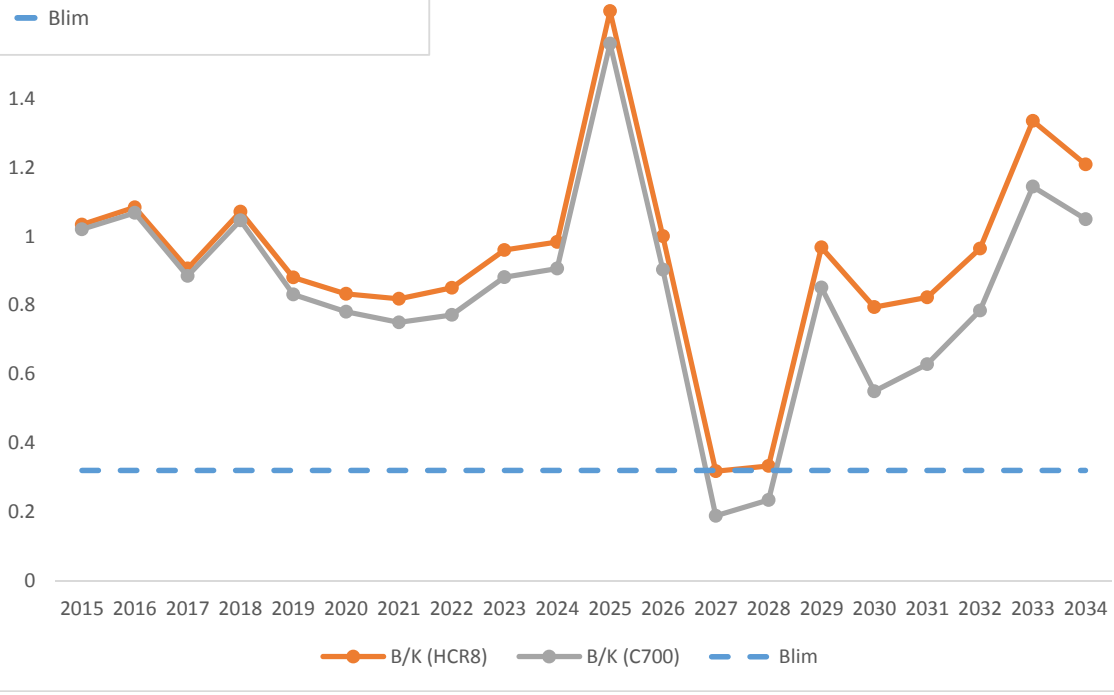
5. Add constraints (limit on upper and lower levels/changes)

6. Add empirical reference points - optional



Adaptive HCR vs non-adaptive

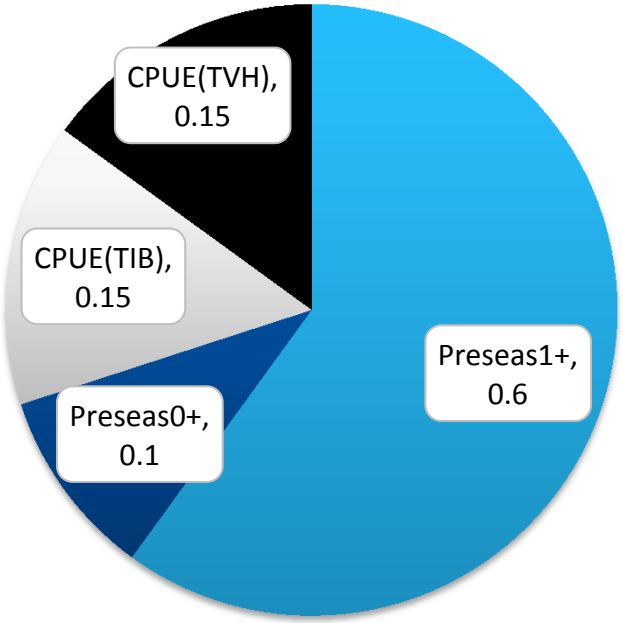




Results

Example rHCR1:

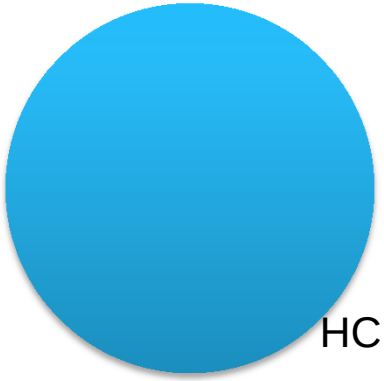
Regression slope example; log of slopes; all indices (pre1+, pre0+, CPUE_TVH, CPUE_TIB) with default weightings (0.6, 0.1, 0.15,0.15)



Relative weightings of each data series in contributing to calculating RBC (Recommended Biological Catch) in formula

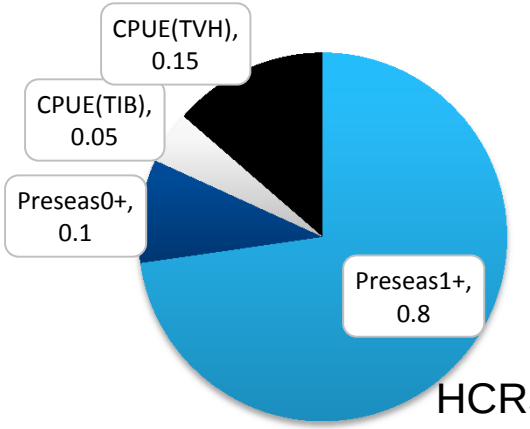
Range of alternative weightings tested

ONLY PRESEASON 1+



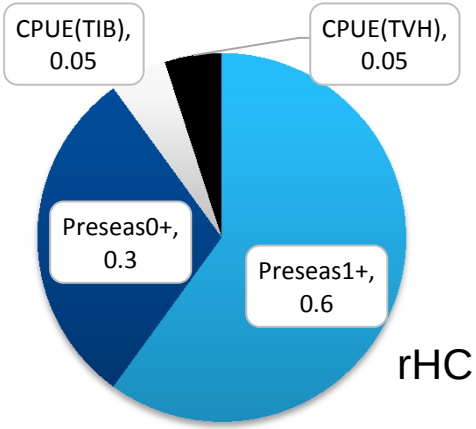
HCR4

HIGH PRESEASON 1+

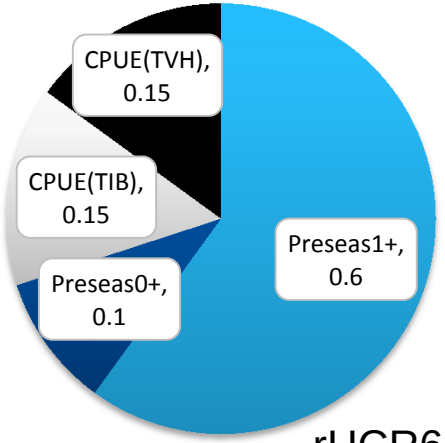


HCR5

MORE PRESEASON 0+

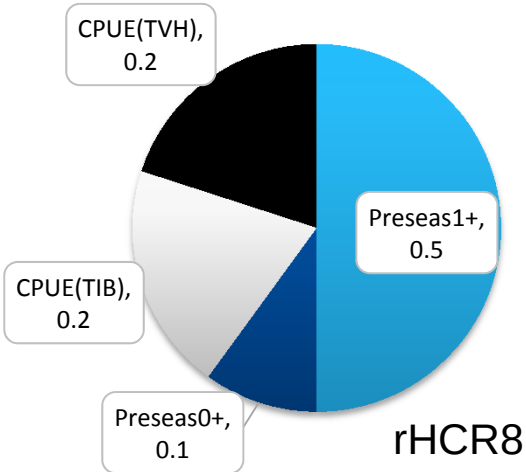


rHCR6



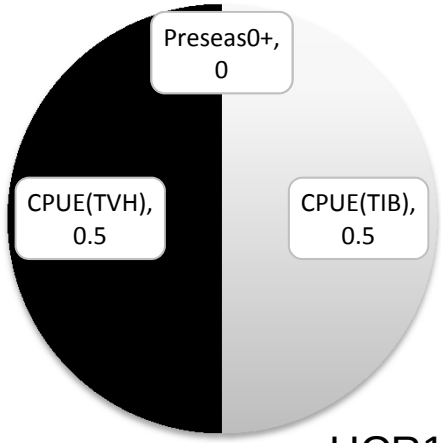
rHCR6

BALANCED OPTION



rHCR8

HIGHER CPUE WEIGHTING

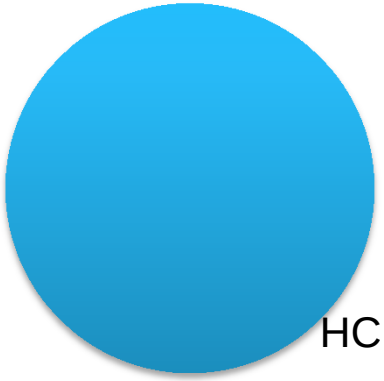


HCR12

NO PRESEASON

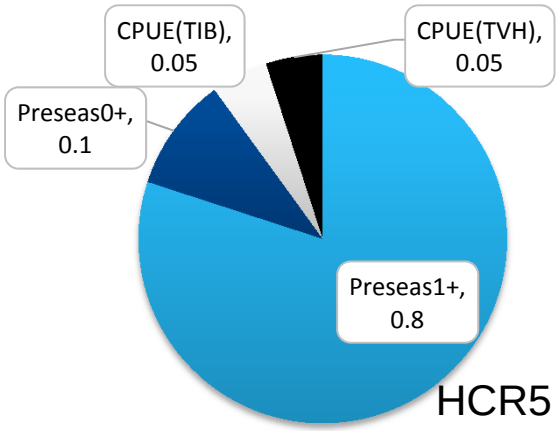
Range of alternative weightings tested

ONLY PRESEASON 1+



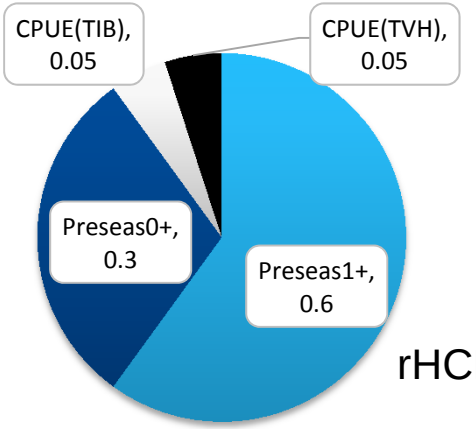
HCR4

HIGH PRESEASON 1+

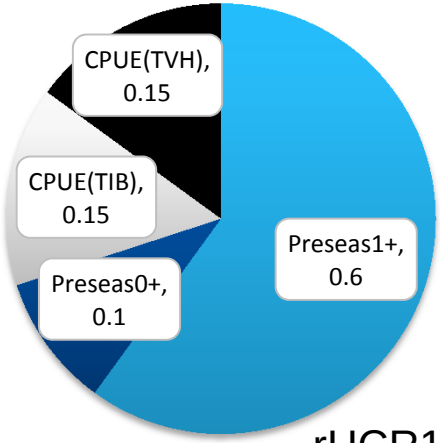


HCR5

MORE PRESEASON 0+

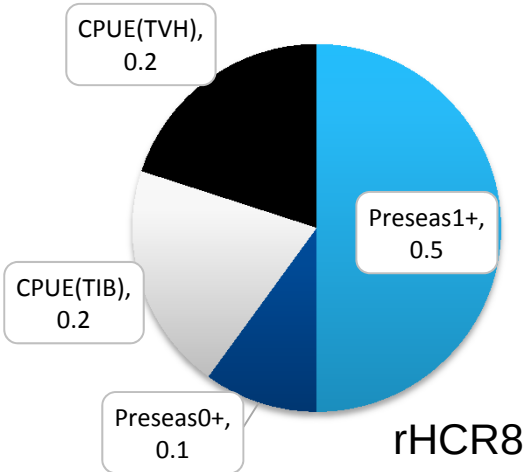


rHCR3



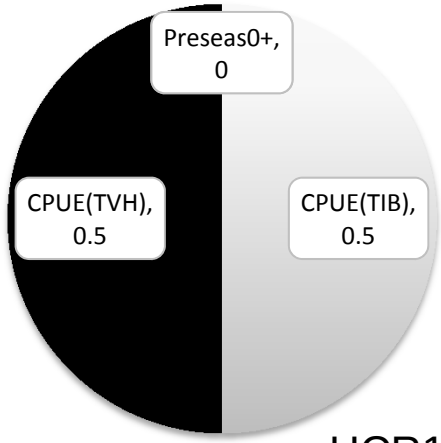
rHCR1

BALANCED OPTION



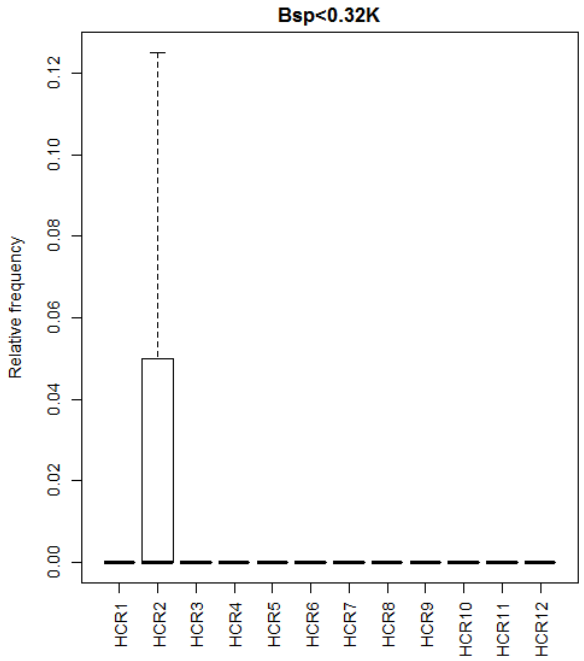
rHCR8

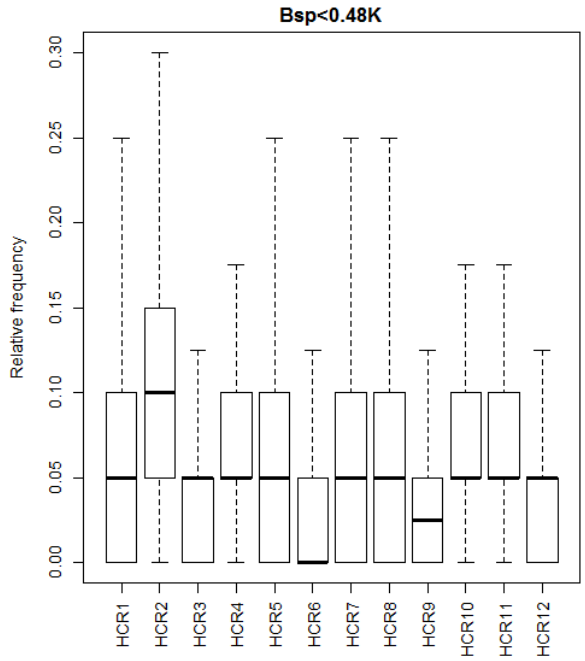
HIGHER CPUE WEIGHTING

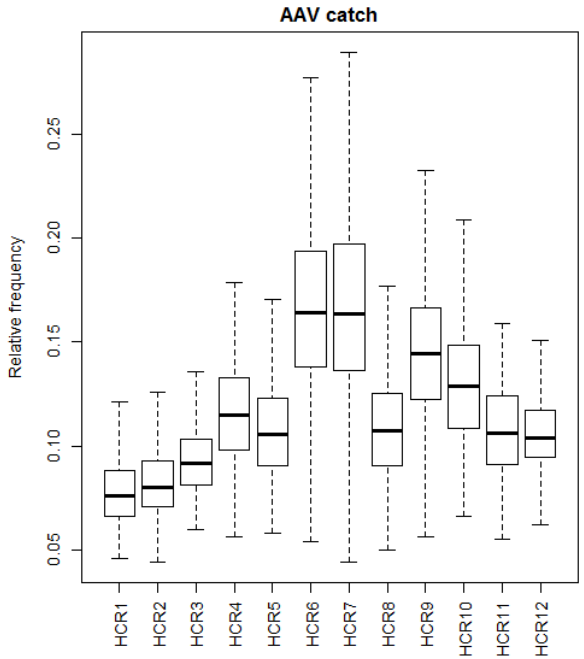


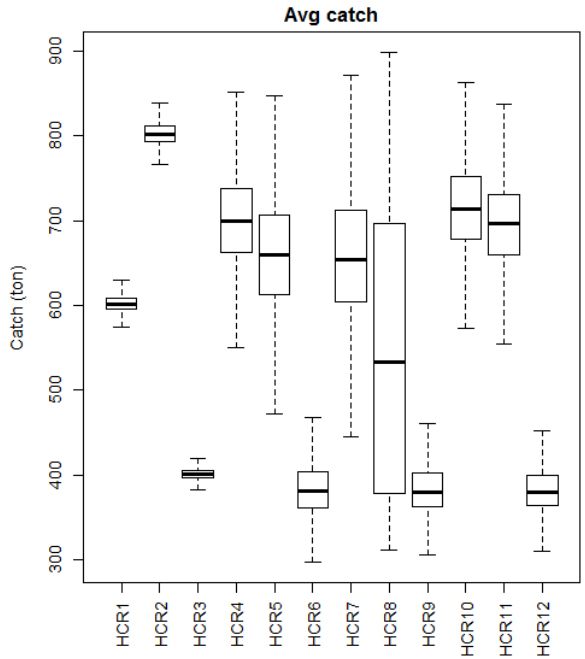
HCR12

NO PRESEASON









HCR initial set

1-3 (Constant Catch) –risky or poor performance

4-5 (Preseason only) –not bad but higher risk than some others

6-7 (Preseason only) –high AAV with no log and low catch

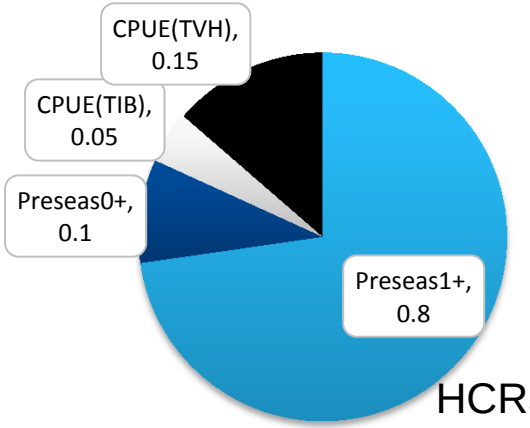
12 (NO Preseason) – worst performance

Range of alternative weightings tested

ONLY PRESEASON 1+

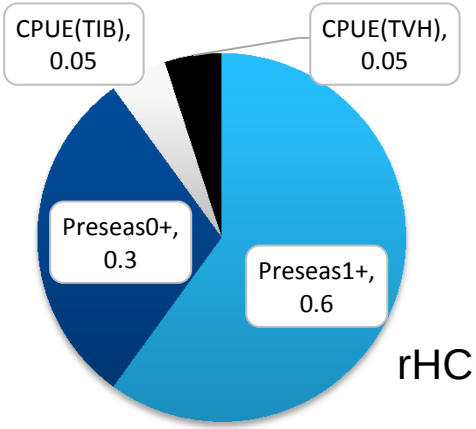
HCR4

HIGH PRESEASON 1+

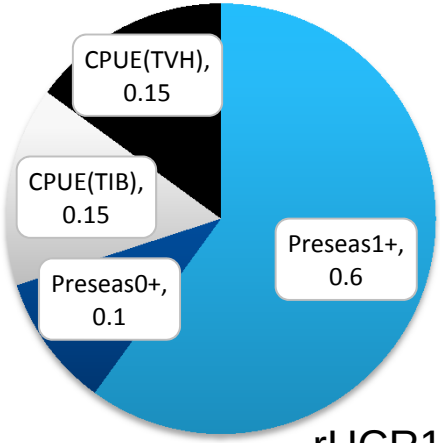


HCR5

MORE PRESEASON 0+

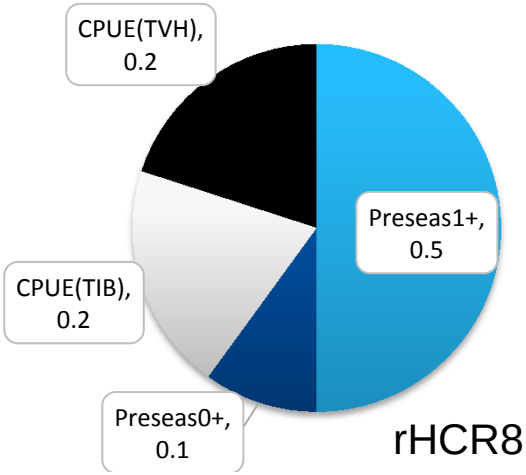


rHCR3



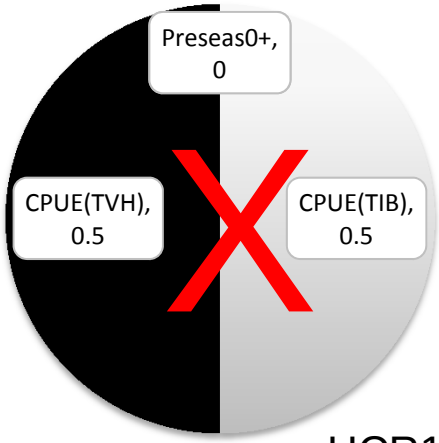
rHCR1

BALANCED OPTION



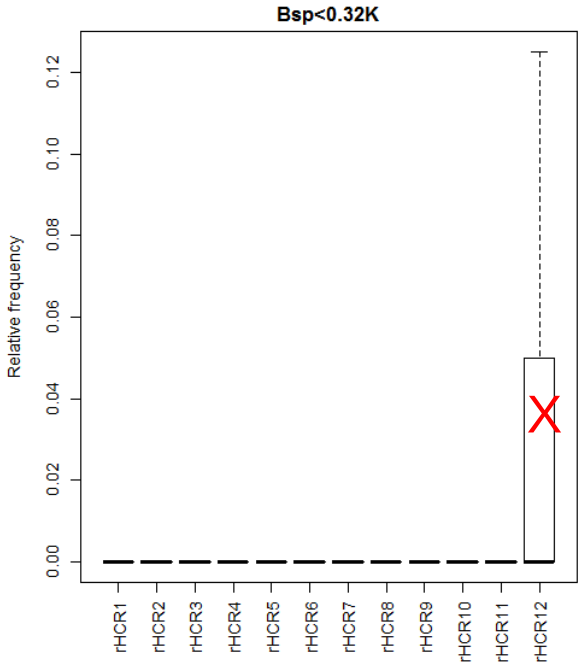
rHCR8

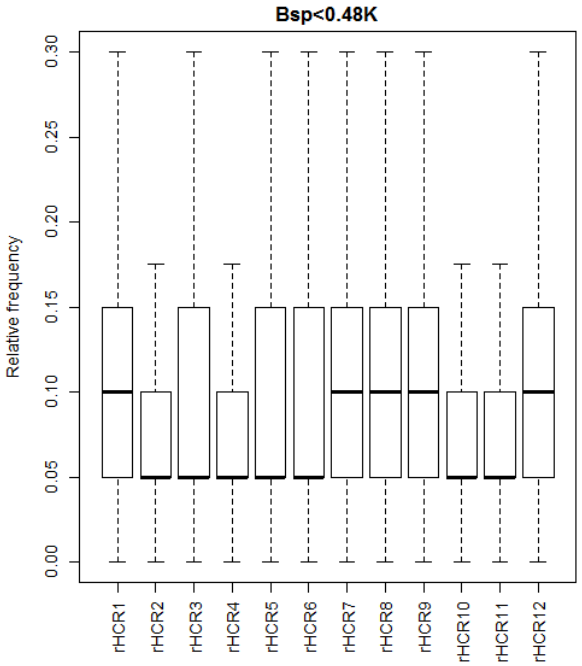
HIGHER CPUE WEIGHTING

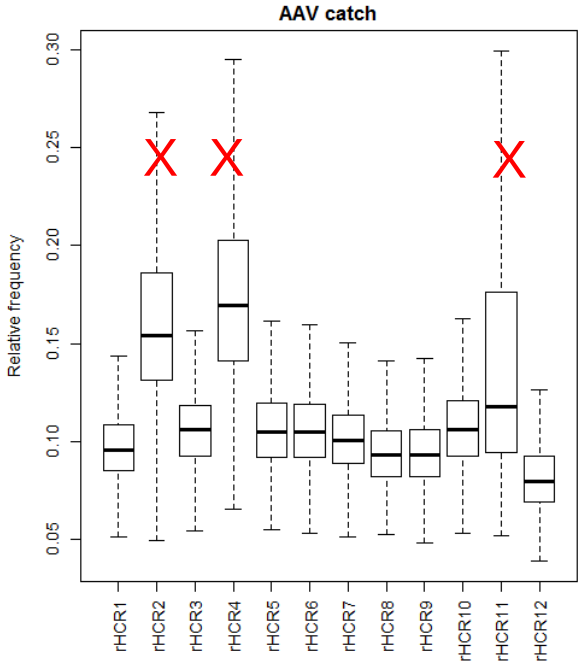


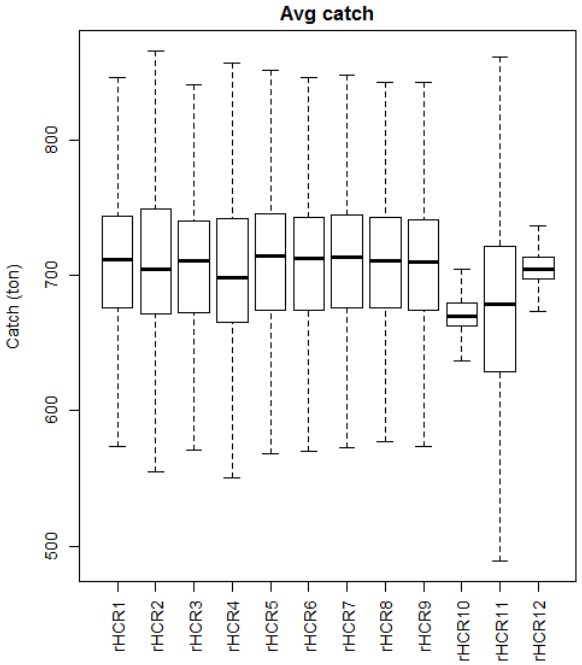
HCR12

NO PRESEASON







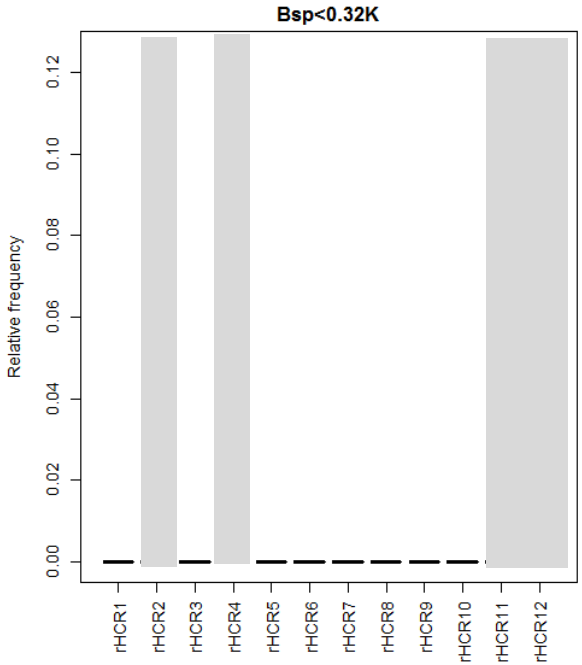


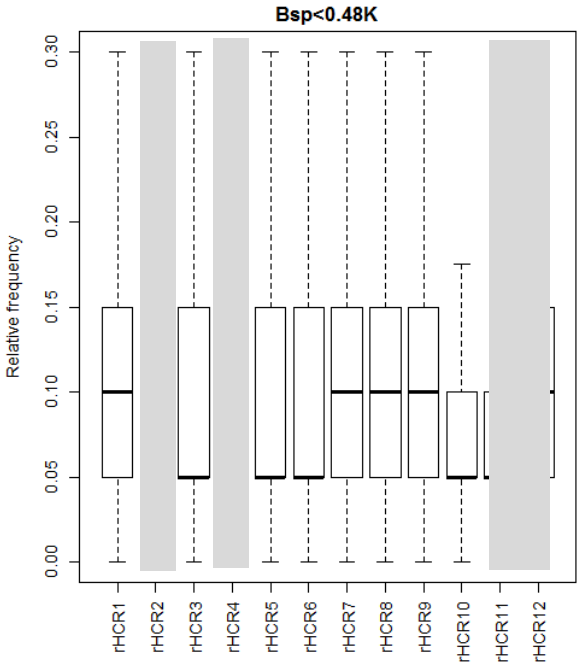
X LOSERS

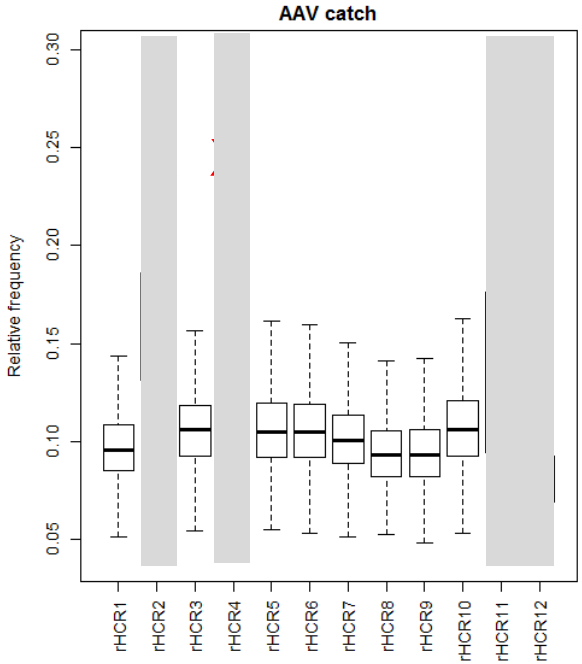
2 & 4 (no log) – too variable

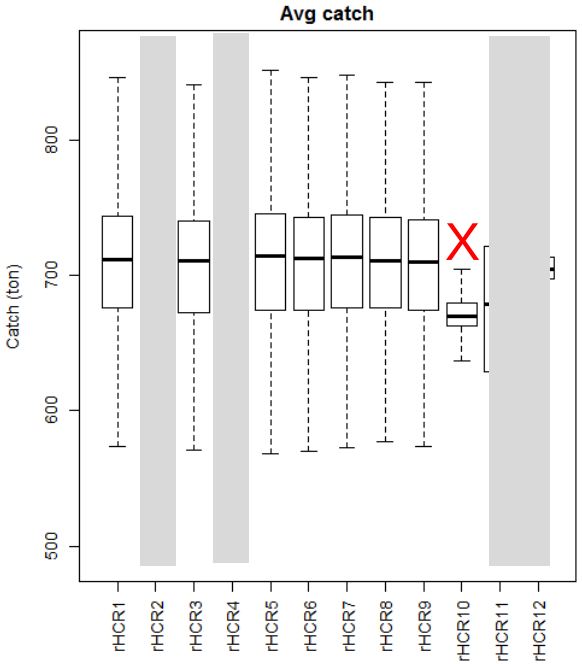
11(hockey rule based on survey values) – too variable

12 (constant catch) – too risky



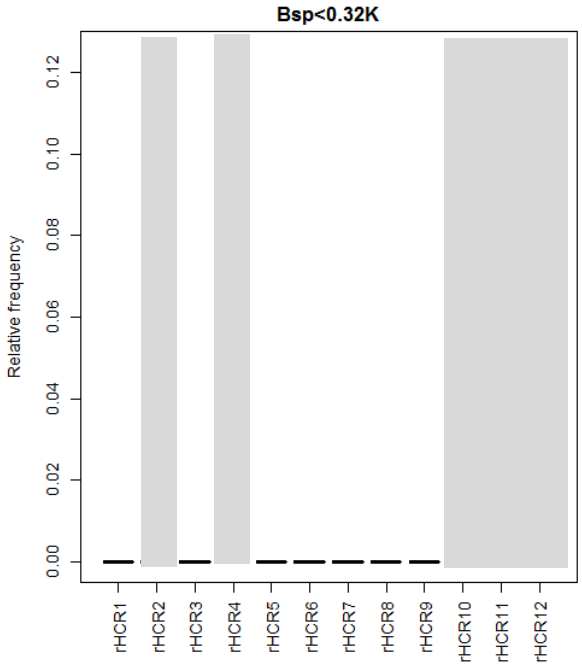


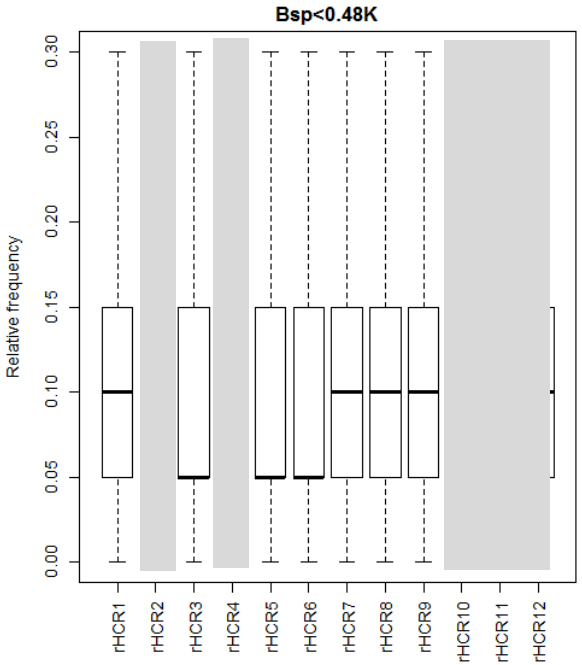


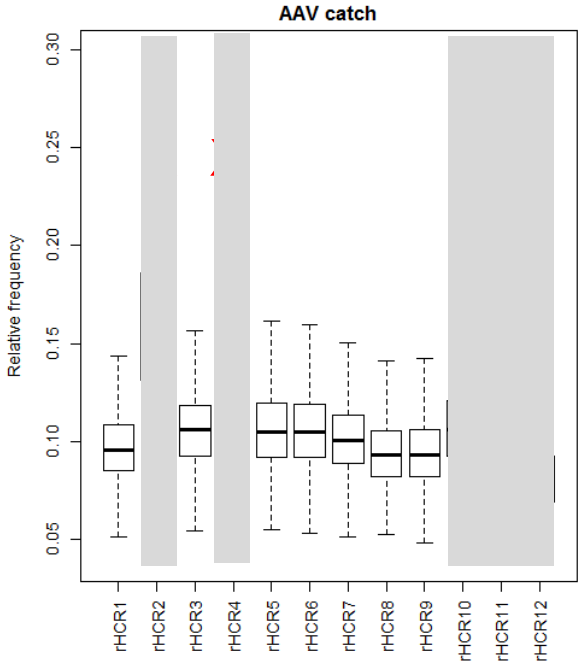


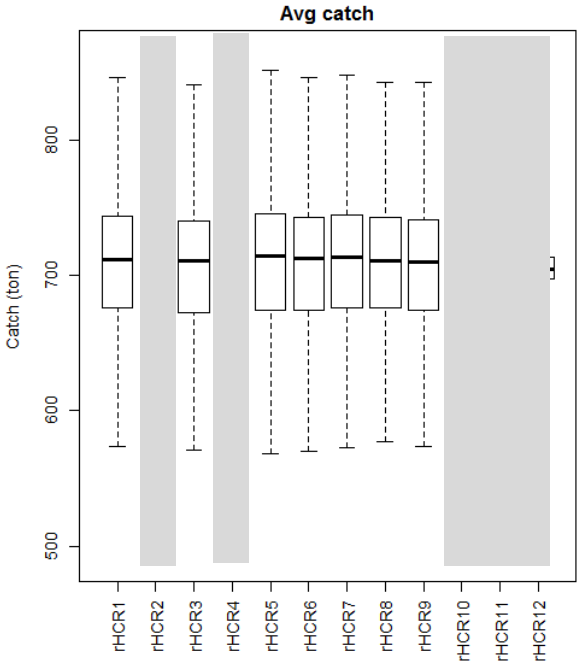
X MORE LOSERS

10 (constant average catch) – too low









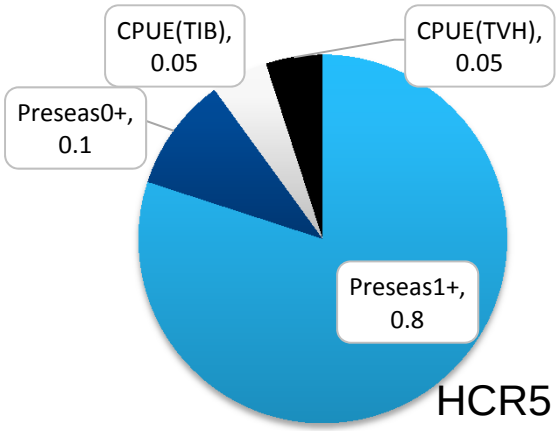
POTENTIAL CANDIDATES

Slightly more risky for similar catch:
1 ; 7; 8 ; 9

Slightly lower risk:
3 (Higher Preseas 0+)
5 (Higher Preseas 1+)
6 (Higher Preseas)

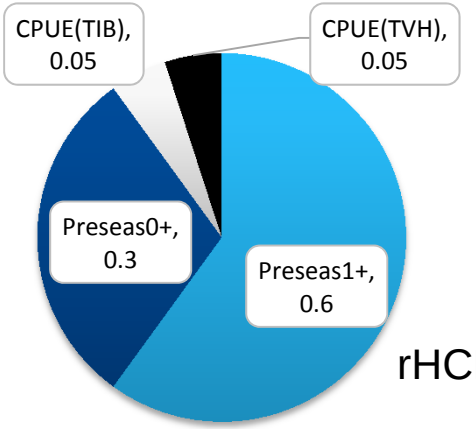
Range of alternative weightings tested

HIGH PRESEASON 1+



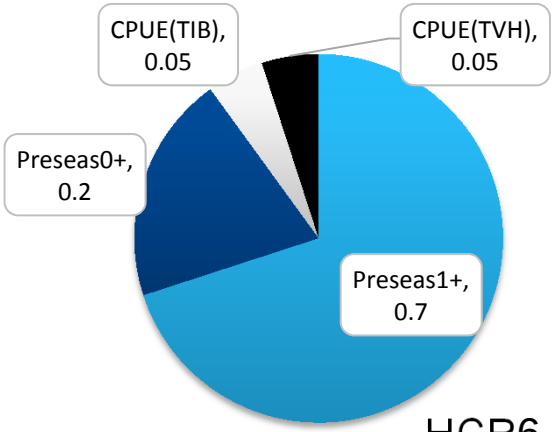
HCR5

MORE PRESEASON 0+

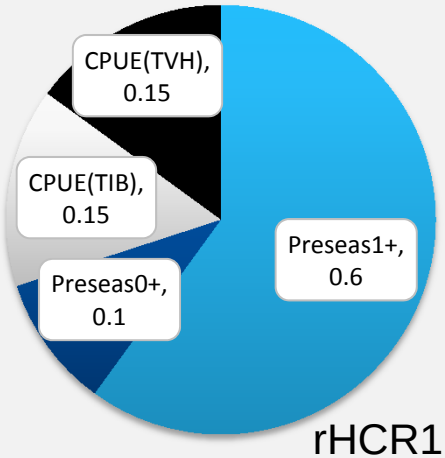


rHCR3

But recently reduced no. survey sites so more uncertain?



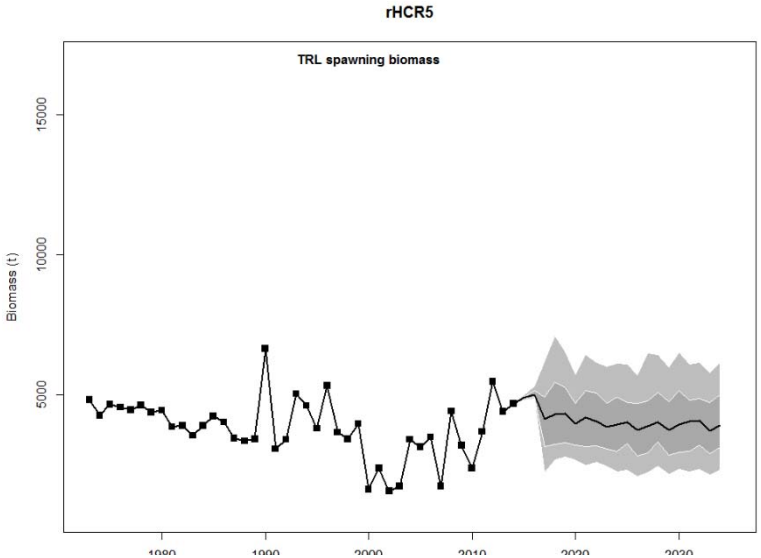
HCR6

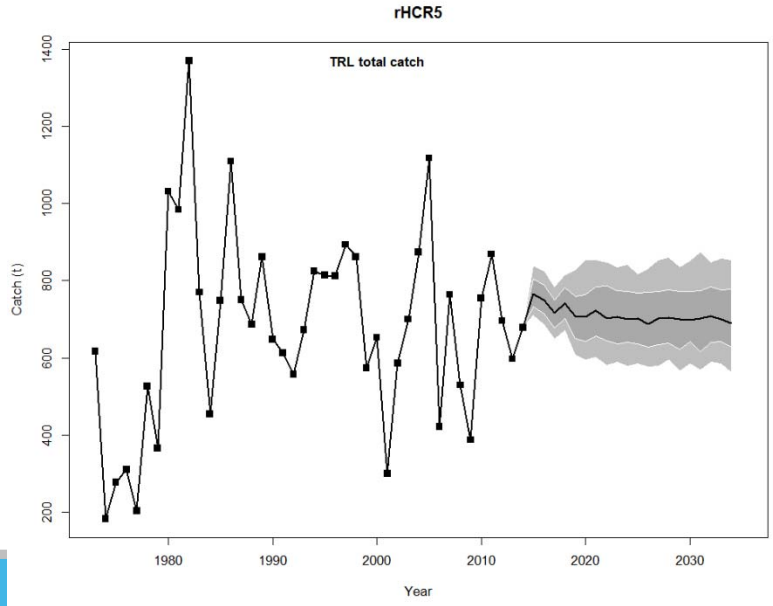


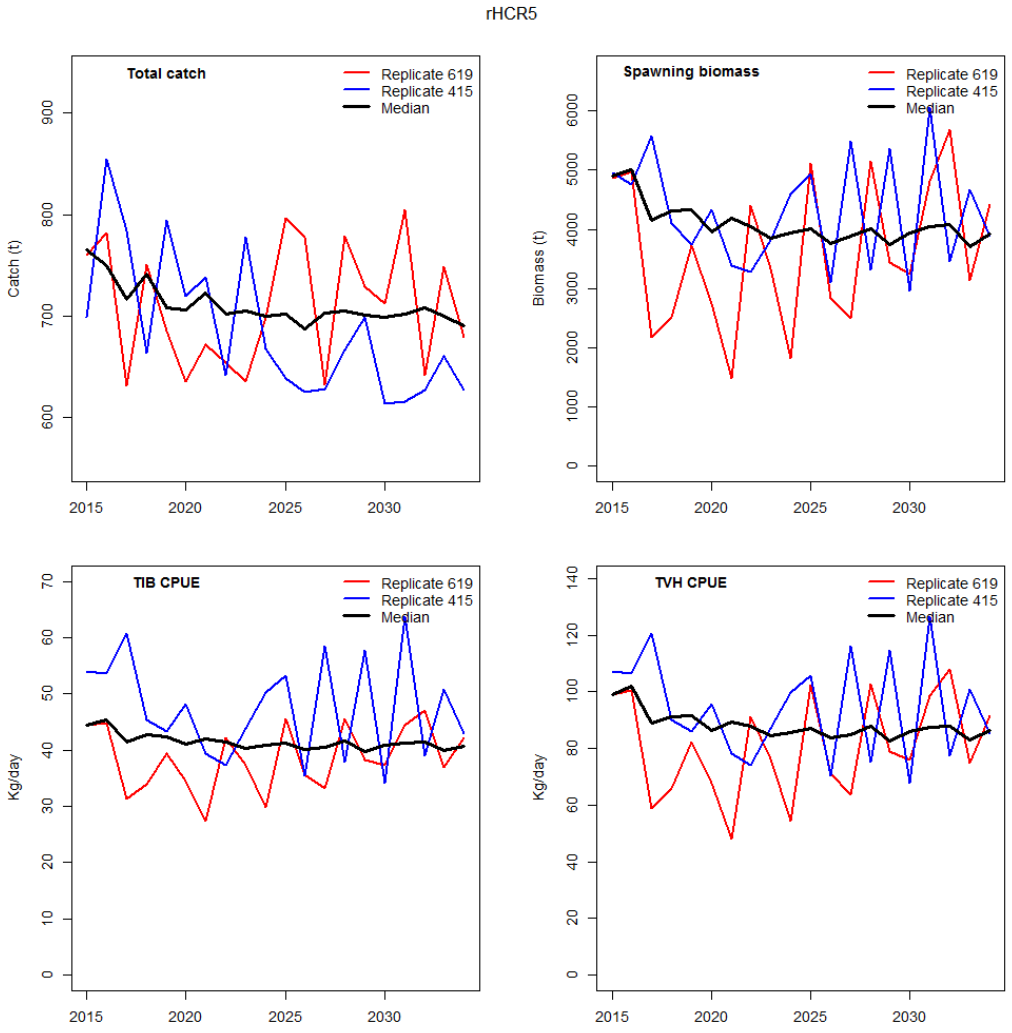
rHCR1

BALANCED OPTION

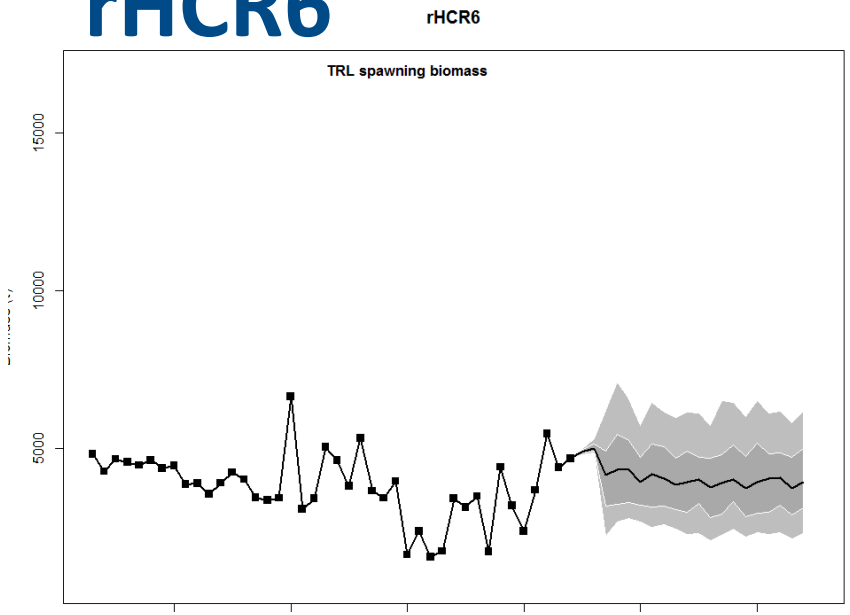
rHCR5

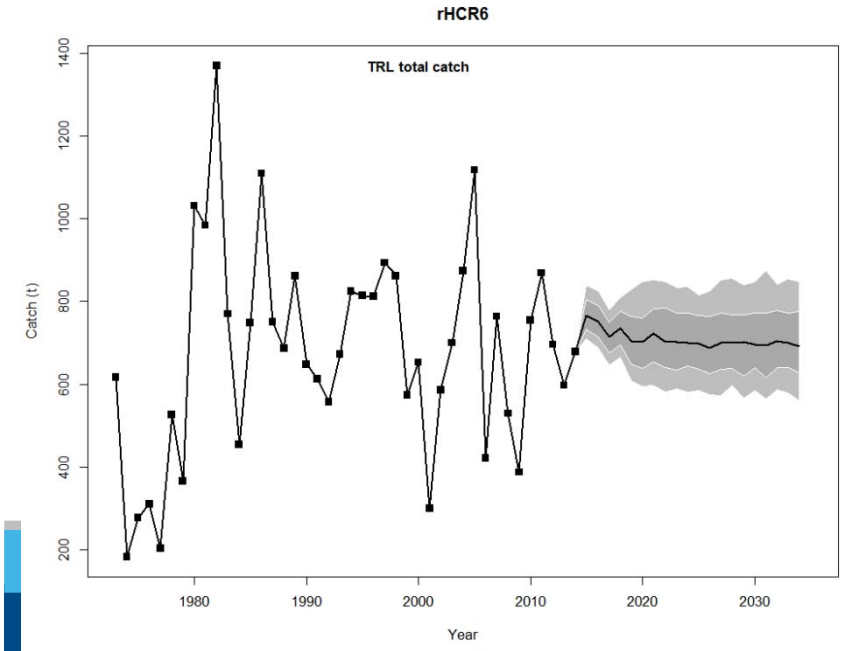

rHCR5
TRL spawning biomass
Biomass (t)
5000
10000
15000

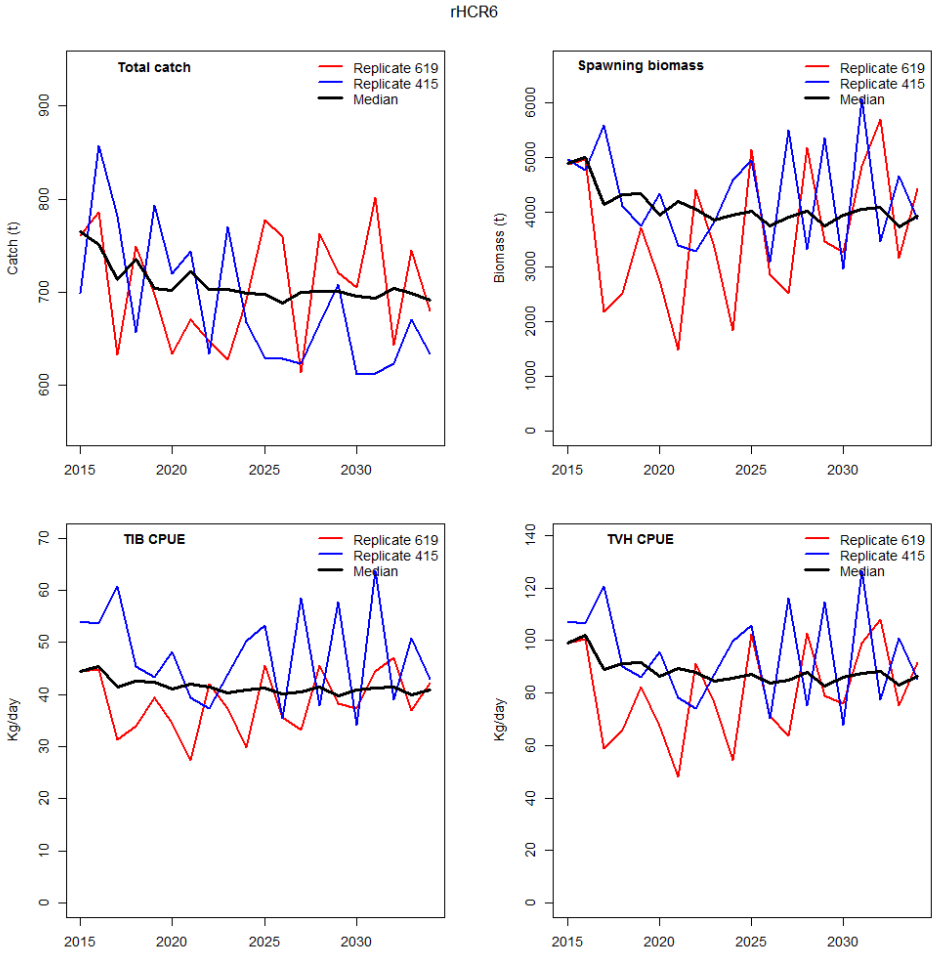

rHCR5
TRL total catch
Catch (t)
200
400
600
800
1000
1200
1400
1980
1990
2000
2010
2020
2030
Year

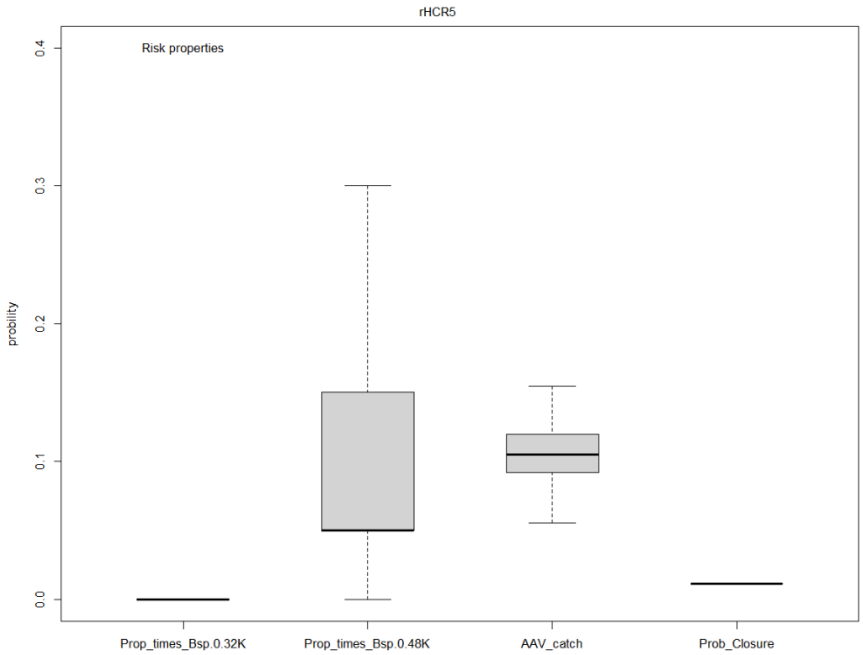

rHCR5
Total catch
Replicate 619
Replicate 415
Median
Catch (t)
600
700
800
900
2015
2020
2025
2030
Spawning biomass
Biomass (t)
0
1000
2000
3000
4000
5000
6000
TIB CPUE
Kg/day
0
10
20
30
40
50
60
70
TVH CPUE
0
20
40
60
80
100
120
140

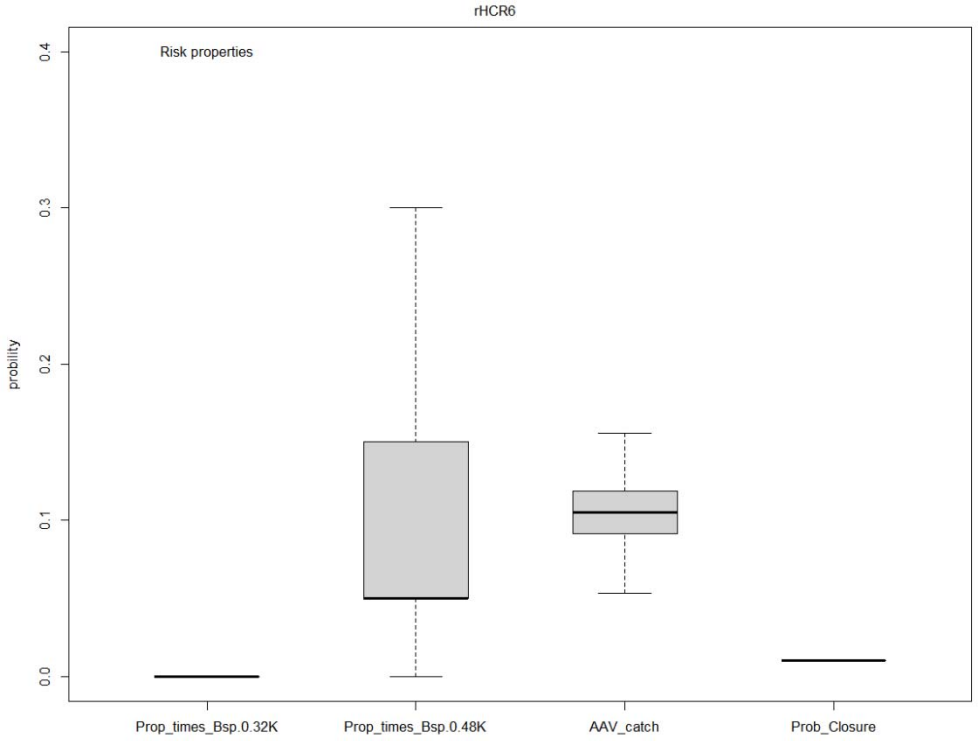
rHCR6


rHCR6
TRL spawning biomass
15000
10000
5000

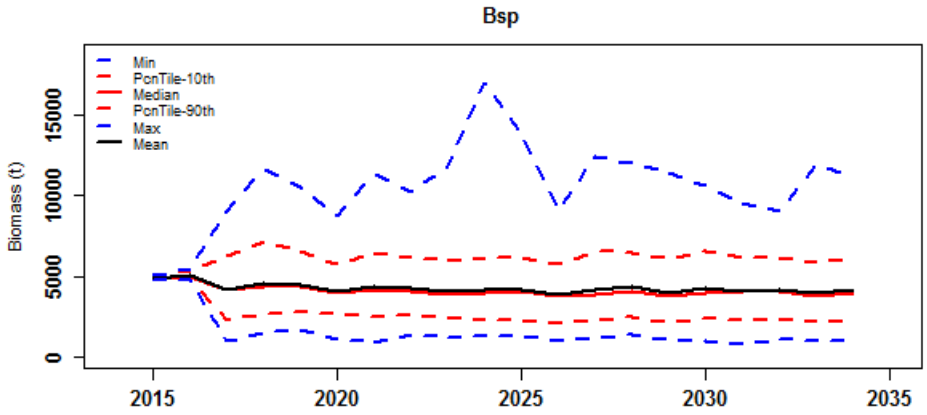

rHCR6
TRL total catch
Catch (t)
200
400
600
800
1000
1200
1400
1980
1990
2000
2010
2020
2030
Year

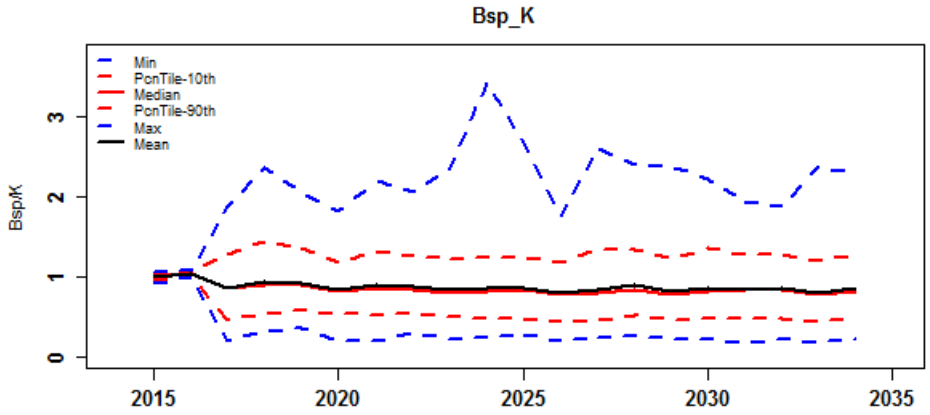

rHCR6
Total catch
Replicate 619
Replicate 415
Median
Catch (t)
600
700
800
900
2015
2020
2025
2030
Spawning biomass
Replicate 619
Replicate 415
Median
Biomass (t)
0
1000
2000
3000
4000
5000
6000
2015
2020
2025
2030
TIB CPUE
Replicate 619
Replicate 415
Median
Kg/day
0
10
20
30
40
50
60
70
2015
2020
2025
2030
TVH CPUE
Replicate 619
Replicate 415
Median
Kg/day
0
20
40
60
80
100
120
140
2015
2020
2025
2030

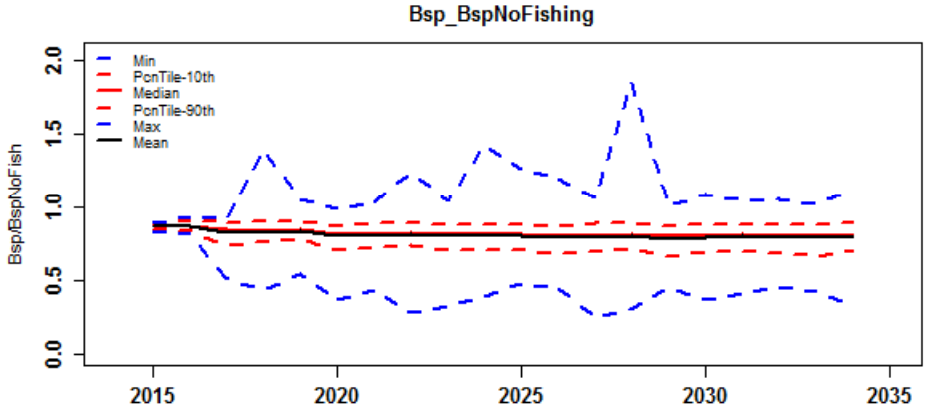

rHCR5
Risk properties
probility
0.0
0.1
0.2
0.3
0.4
Prop_times_Bsp.0.32K
Prop_times_Bsp.0.48K
AAV_catch
Prob_Closure

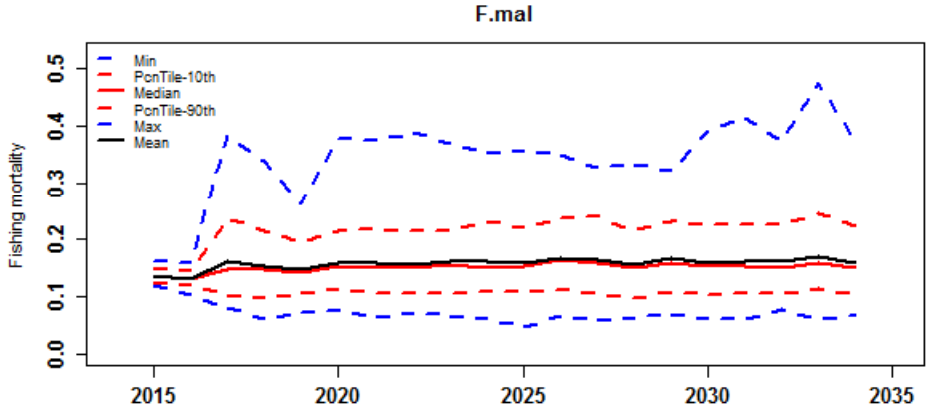

rHCR6
Risk properties
probility
0.0
0.1
0.2
0.3
0.4
Prop_times_Bsp.0.32K
Prop_times_Bsp.0.48K
AAV_catch
Prob_Closure

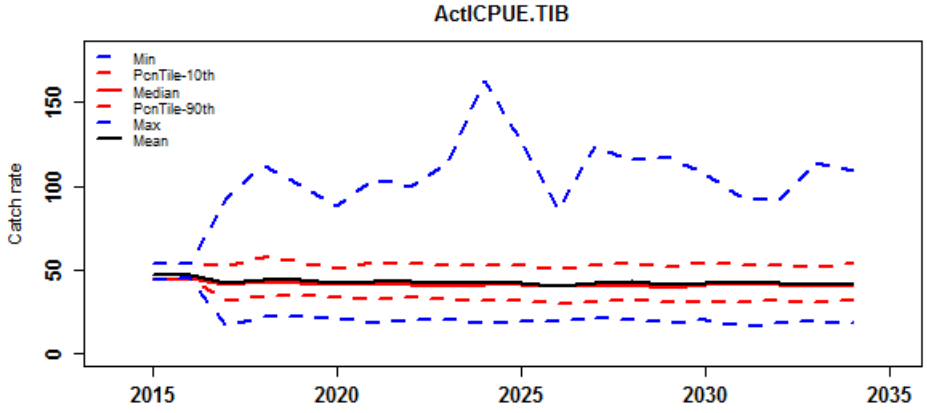
rHCR6

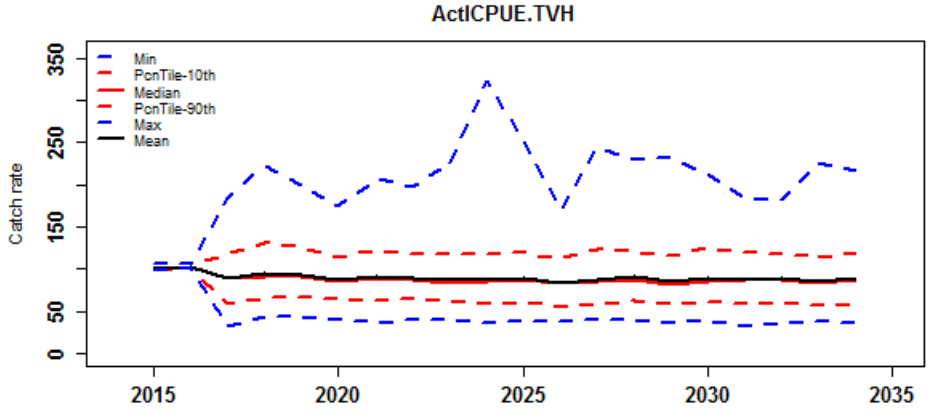

Bsp
Min
PcnTile-10th
Median
PcnTile-90th
Max
Mean
Biomass (t)
0
5000
10000
15000
2015
2020
2025
2030
2035


Bsp_K
Min
PcnTile-10th
Median
PcnTile-90th
Max
Mean
Bsp/K
0
1
2
3
2015
2020
2025
2030
2035

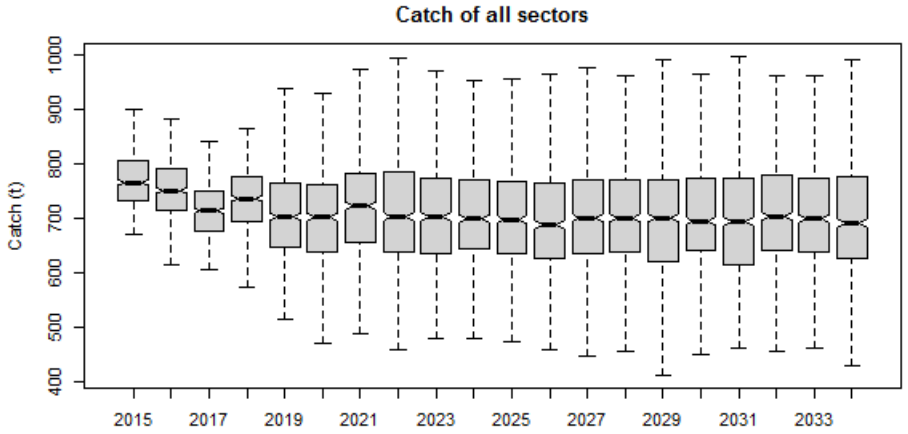

Bsp_BspNoFishing
Min
PcnTile-10th
Median
PcnTile-90th
Max
Mean
Bsp/BspNoFish
0.0
0.5
1.0
1.5
2.0
2015
2020
2025
2030
2035

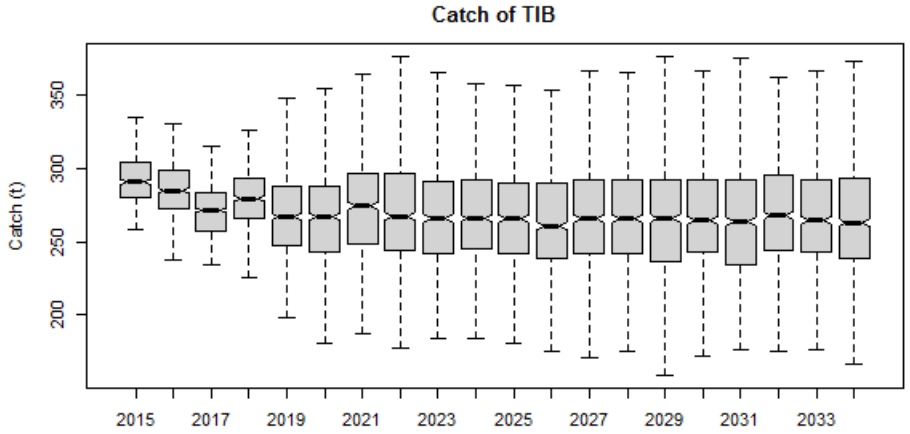

F.mal
Min
PcnTile-10th
Median
PcnTile-90th
Max
Mean
Fishing mortality
0.0
0.1
0.2
0.3
0.4
0.5
2015
2020
2025
2030
2035

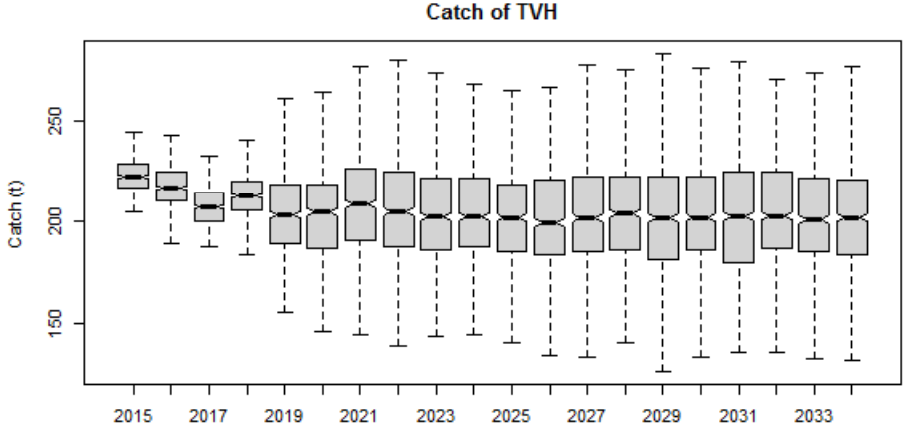

ActICPUE.TIB
Min
PcnTile-10th
Median
PcnTile-90th
Max
Mean
Catch rate
0
50
100
150
2015
2020
2025
2030
2035

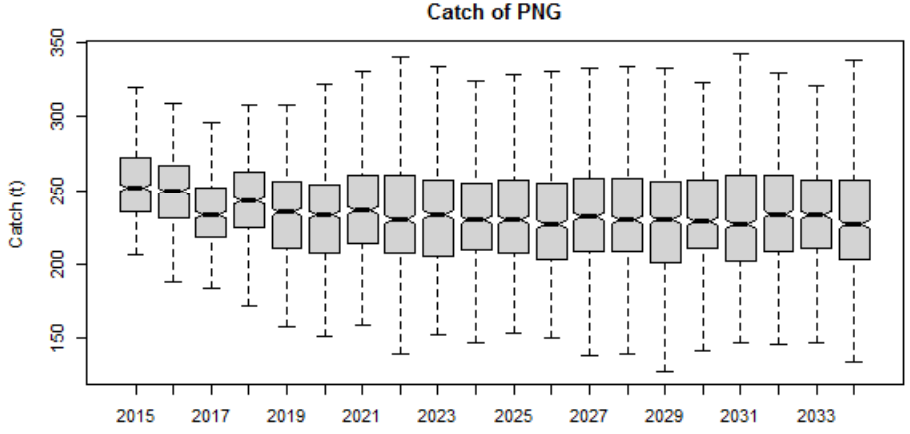

ActICPUE.TVH
Min
PcnTile-10th
Median
PcnTile-90th
Max
Mean
Catch rate
0
50
150
250
350
2015
2020
2025
2030
2035

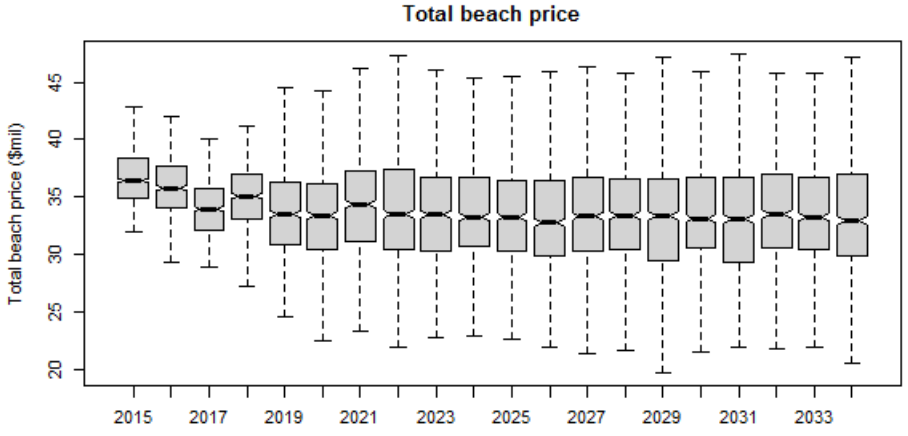
rHCR6

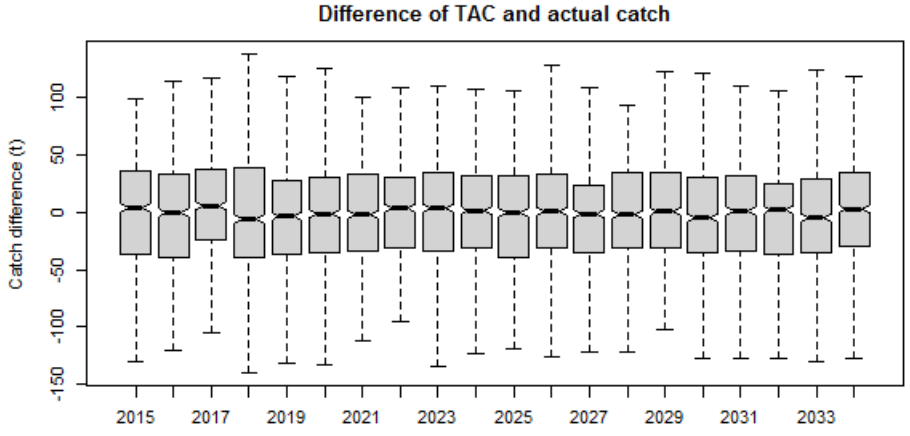

Catch of all sectors
Catch (t)
400
500
600
700
800
900
1000
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033


Catch of TIB
Catch (t)
200
250
300
350
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033

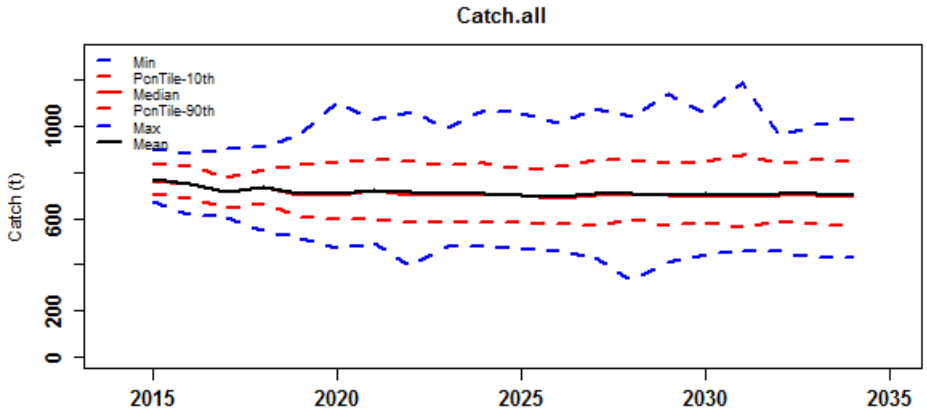

Catch of TVH
Catch (t)
150
200
250
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033

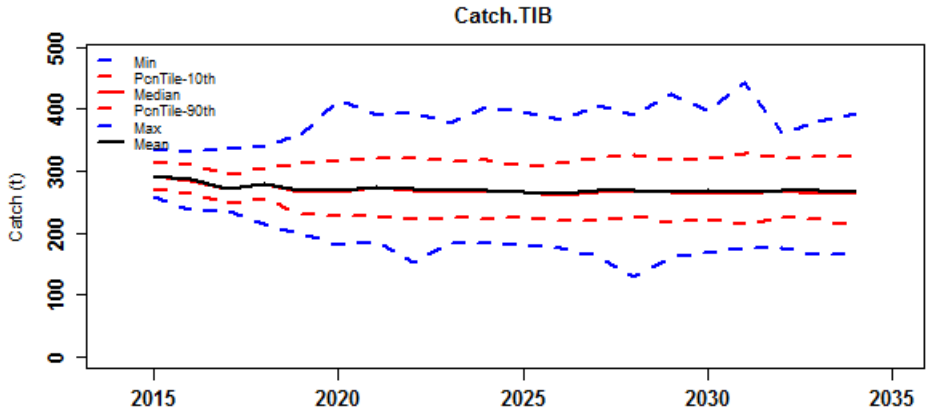

Catch of PNG
Catch (t)
150
200
250
300
350
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033

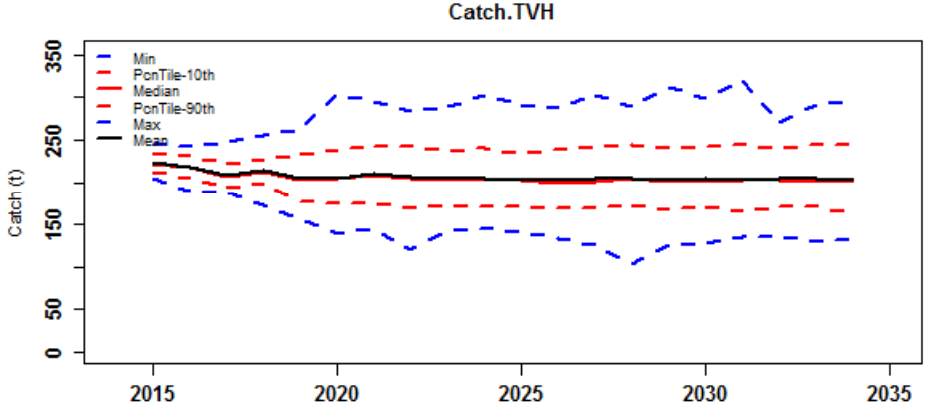

Total beach price
Total beach price ($mil)
20
25
30
35
40
45
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033

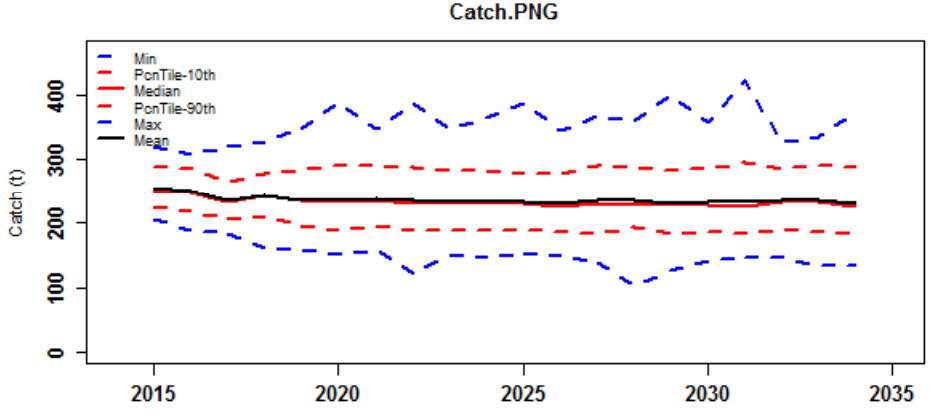

Difference of TAC and actual catch
Catch difference (t)
-150
-100
-50
0
50
100
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033

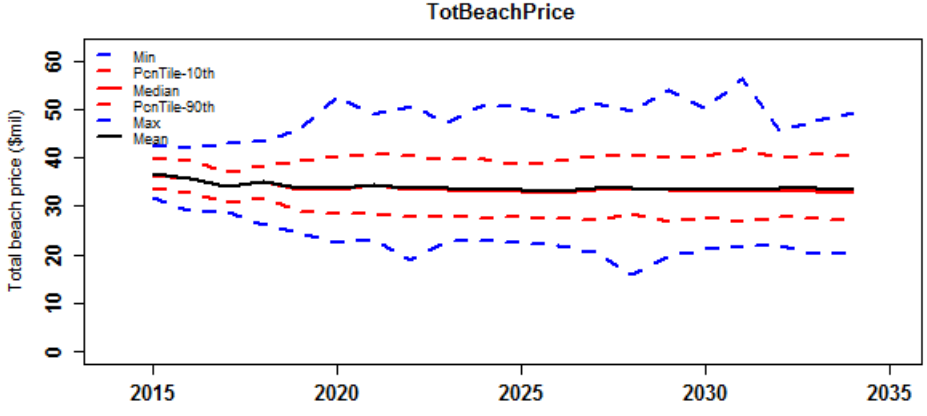
rHCR6

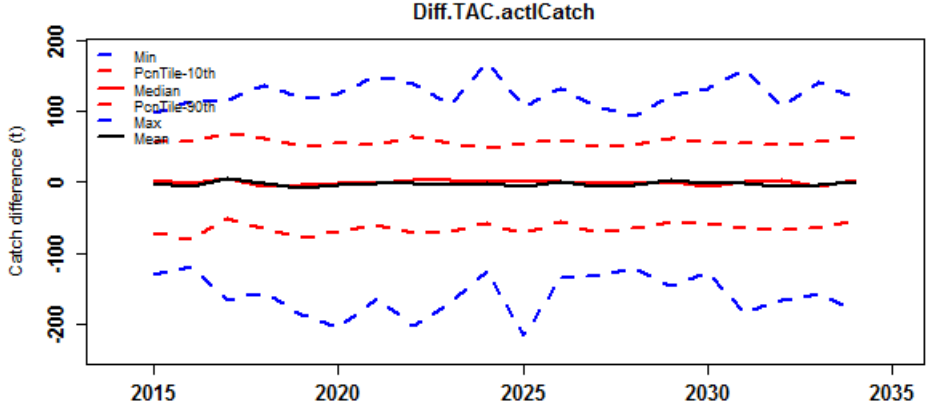

Catch.all
Min
PcnTile-10th
Median
PcnTile-90th
Max
Mean
Catch (t)
0
200
600
1000
2015
2020
2025
2030
2035


Catch.TIB
Min
PcnTile-10th
Median
PcnTile-90th
Max
Mean
Catch (t)
0
100
200
300
400
500
2015
2020
2025
2030
2035

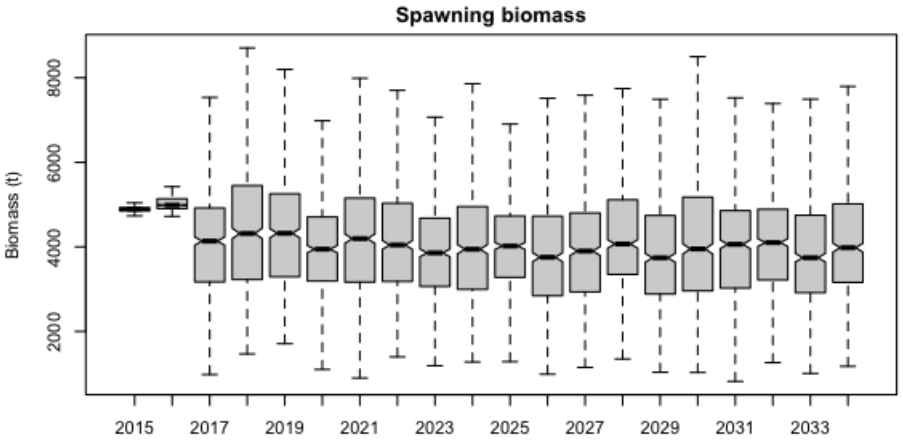

Catch.TVH
Min
PcnTile-10th
Median
PcnTile-90th
Max
Mean
Catch (t)
0
50
150
250
350
2015
2020
2025
2030
2035

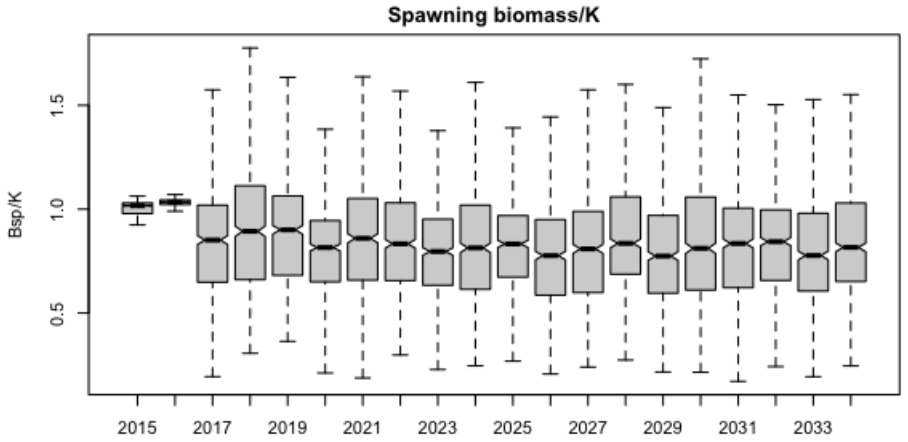

Catch.PNG
Min
PcnTile-10th
Median
PcnTile-90th
Max
Mean
Catch (t)
0
100
200
300
400
2015
2020
2025
2030
2035

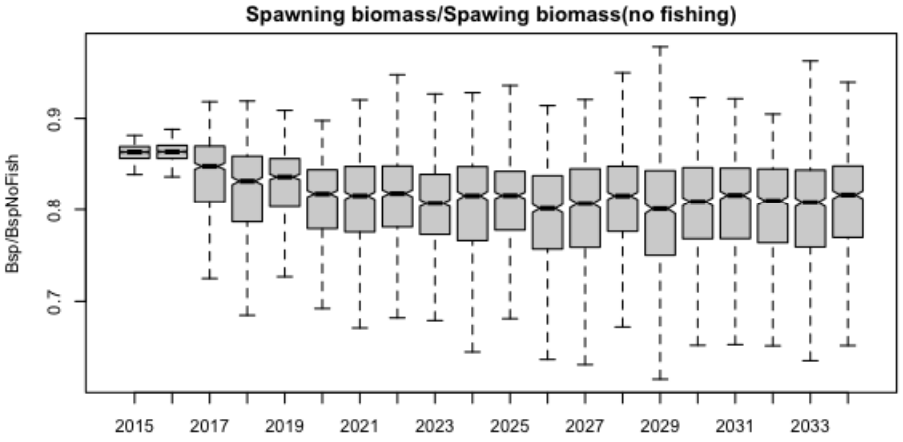

TotBeachPrice
Min
PcnTile-10th
Median
PcnTile-90th
Max
Mean
Total beach price ($mil)
0
10
20
30
40
50
60
2015
2020
2025
2030
2035

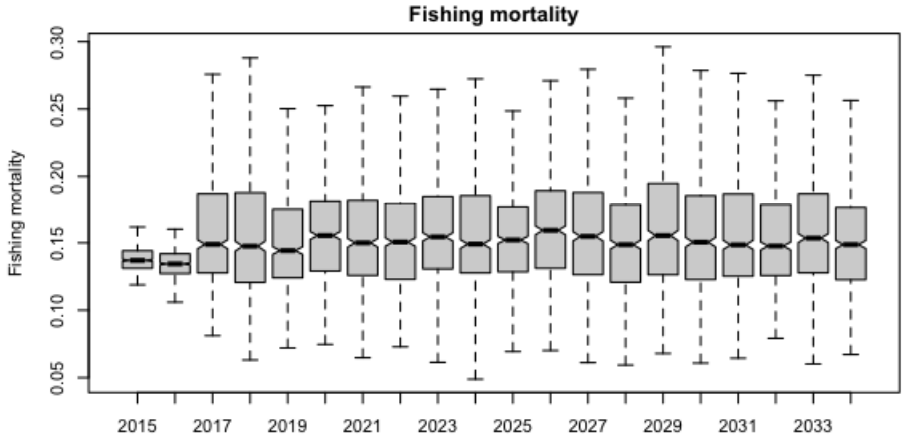

Diff.TAC.actlCatch
Min
PcnTile-10th
Median
PcnTile-90th
Max
Mean
Catch difference (t)
-200
-100
0
100
200
2015
2020
2025
2030
2035

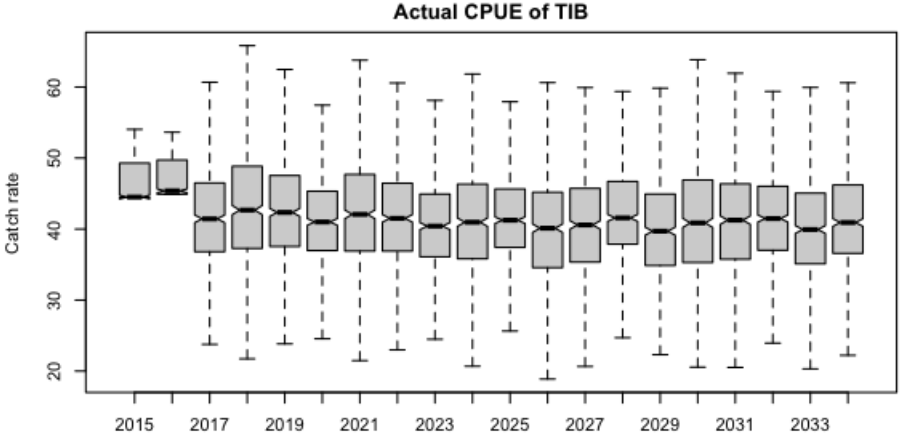
rHCR6rev

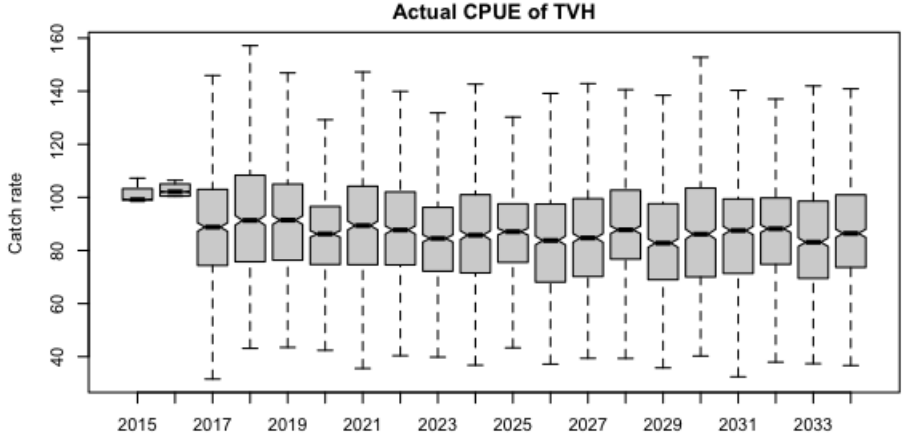

Spawning biomass
Biomass (t)
2000
4000
6000
8000
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033


Spawning biomass/K
Bsp/K
0.5
1.0
1.5
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033

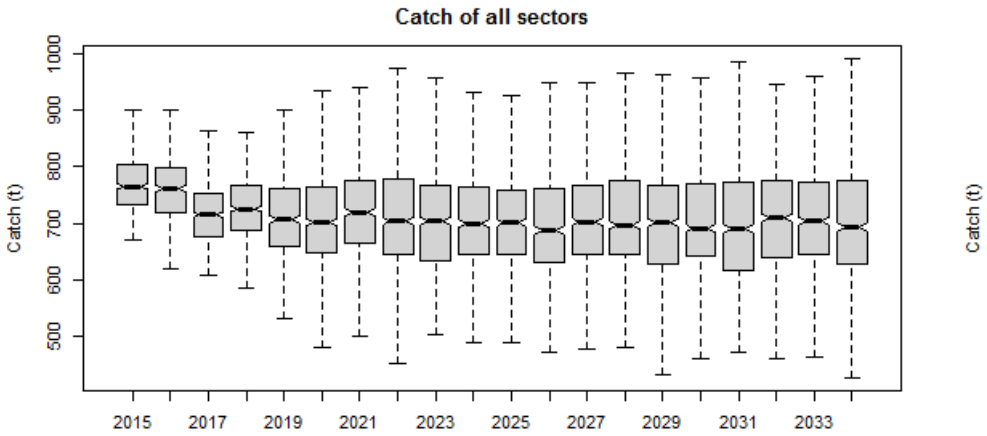

Spawning biomass/Spawing biomass(no fishing)
Bsp/BspNoFish
0.7
0.8
0.9
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033


Fishing mortality
Fishing mortality
0.05
0.10
0.15
0.20
0.25
0.30
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033

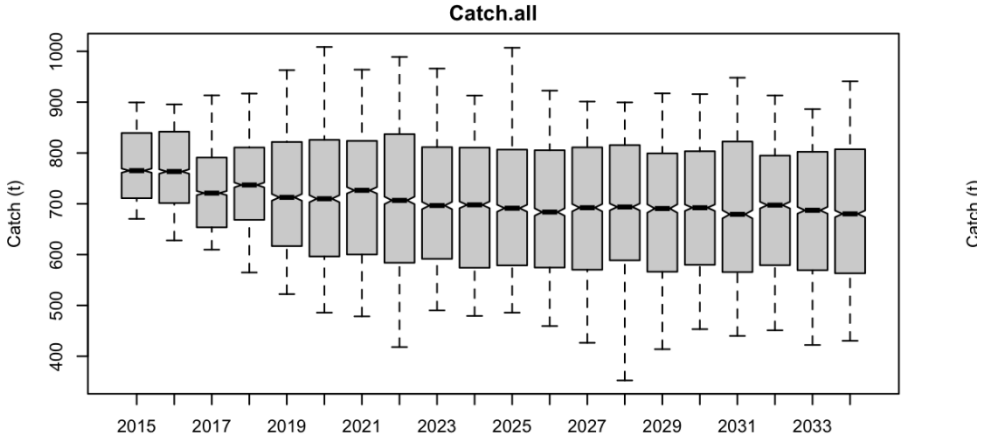

Actual CPUE of TIB
Catch rate
20
30
40
50
60
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033


Actual CPUE of TVH
Catch rate
40
60
80
100
120
140
160
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033

rHCR1

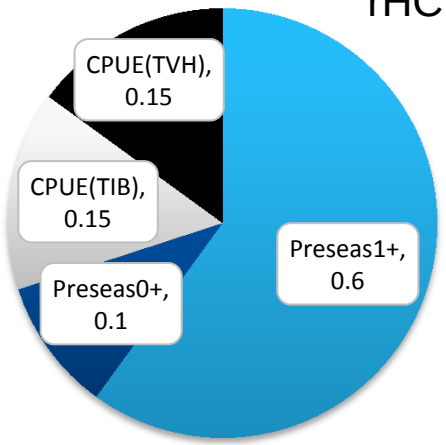


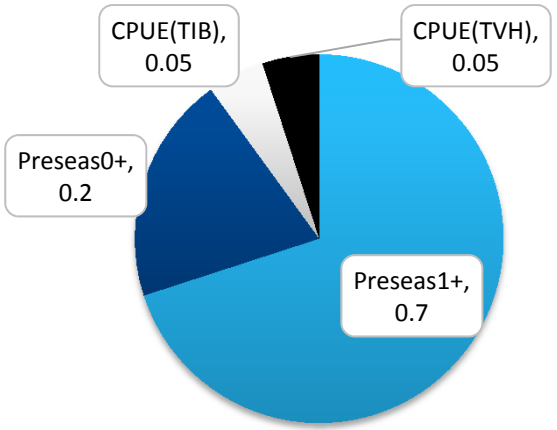
rHCR6r



BALANCED OPTION

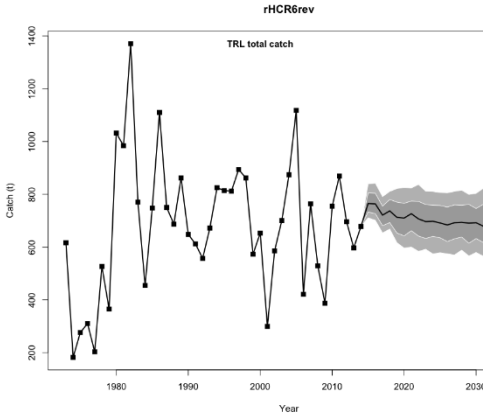
rHCR1



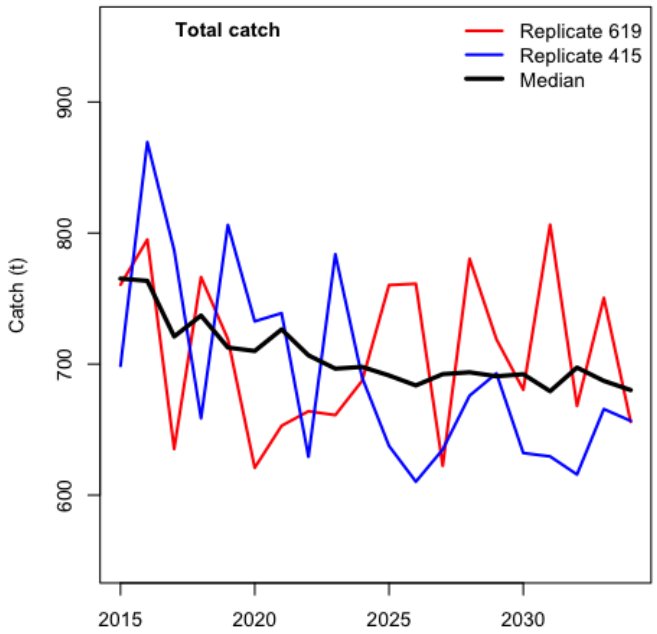


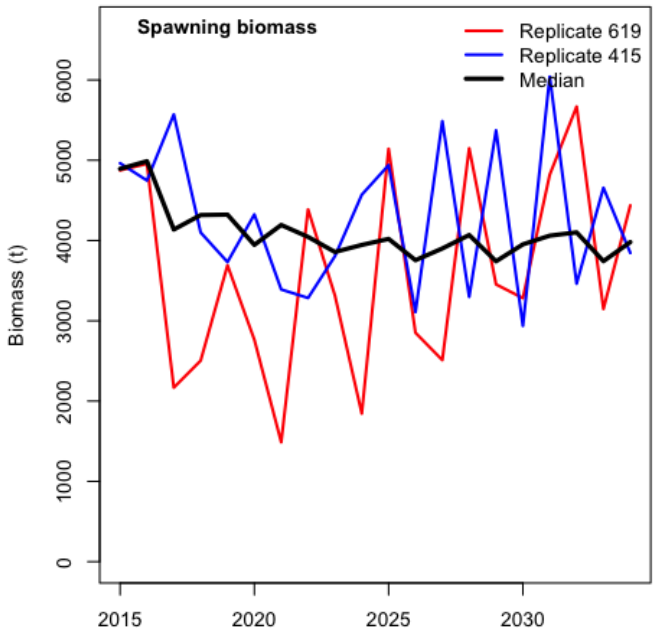
rHCR6

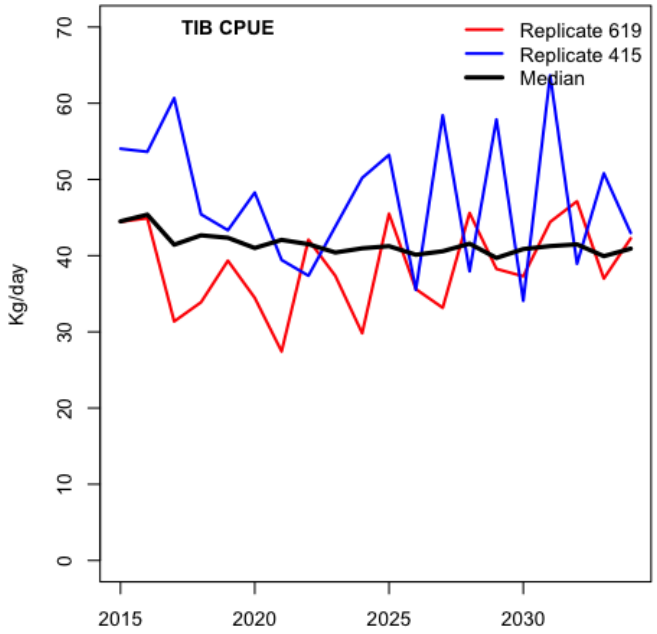
HIGH PRESEASON WT OPTION

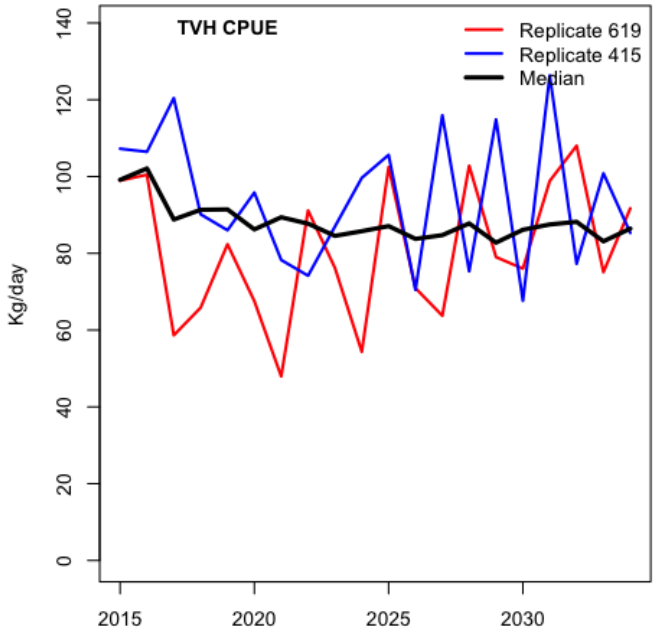

rHCR6rev
TRL total catch
Catch (t)
Year

rHCR6rev


Total catch
Replicate 619
Replicate 415
Median
Catch (t)


Spawning biomass
Replicate 619
Replicate 415
Median
Biomass (t)


TIB CPUE
Replicate 619
Replicate 415
Median
Kg/day


TVH CPUE
Replicate 619
Replicate 415
Median
Kg/day

Outline

- Recap re draft Harvest Strategy agreements
- Empirical (data-based) Harvest Control Rule (HCR) explained
- Example application using past data
- Feedback from TRLRAG
- Feedback from Nokome Bentley
- Alternative HCR candidates and their performance

➢ **Deciding on rules for closure**

➢ **Reviewing data-based trigger and limit reference points**

- Exceptional circumstances clauses
- Sensitivity Analyses
- Discount factors for tiered system (eg more/fewer surveys)

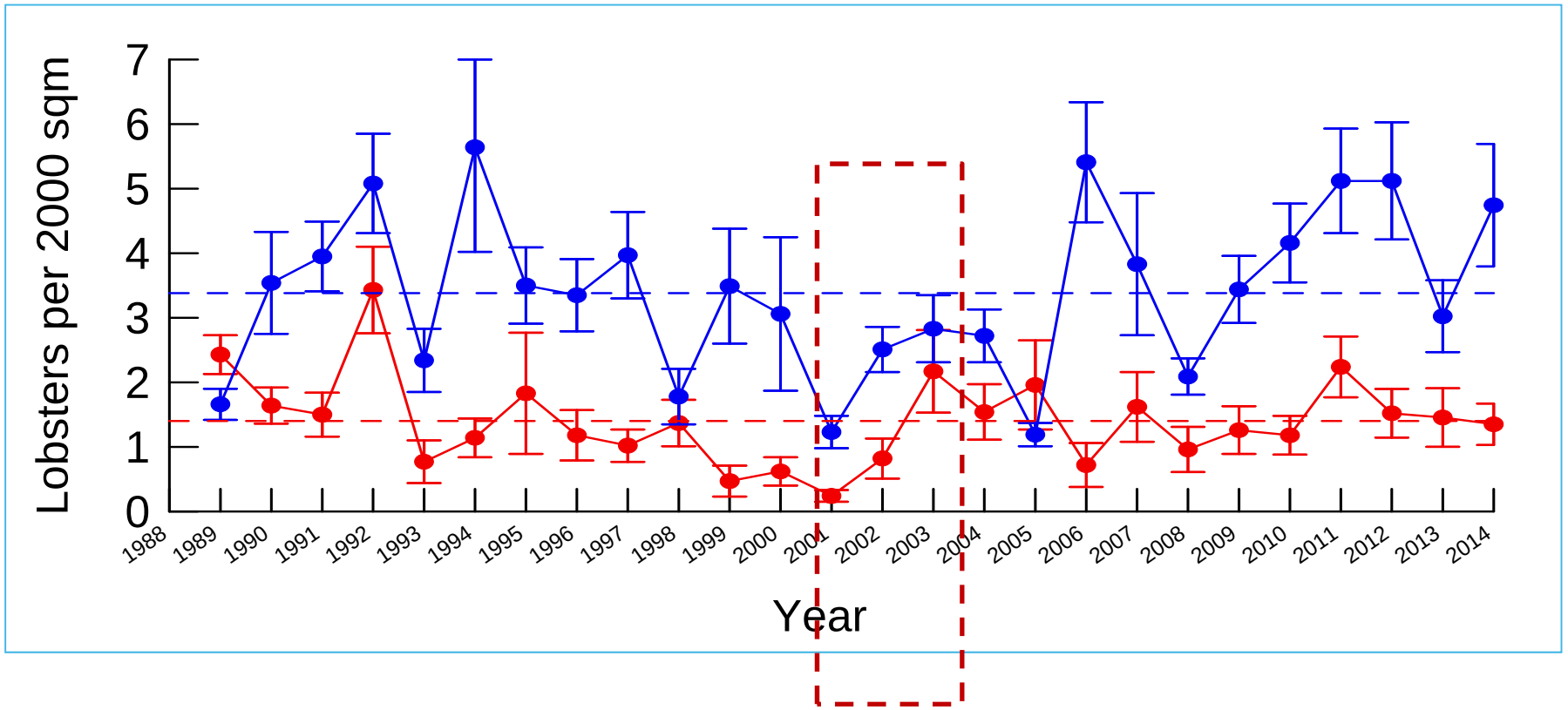
TRL Fishery Closure Rules Scenarios

TRL Fishery Research: TRL Fishery Closure Rules and Scenarios

	Year 1	Year 2	Year 3	Year 4
Stock Assessment	No	No	Yes	
Scenarios				
1	$<B_{lim}$	$<B_{lim}$	$<B_{lim}$	Closed
2	$<B_{lim}$	$<B_{lim}$	✓	?
3	$<B_{lim}$	✓	$<B_{lim}$	Closed
4	✓	$<B_{lim}$	$<B_{lim}$	Closed

Issues
(1) No CPUE available in Year 4 – no 2+ index – no HCR in Year 5 or new rule?
(2) Recruitment (neither 1+ or 0+) is not accounted for – eg. Scenario 2
(3) What agreed rule is applied in Year 5?

TRL Fishery Research: TRL Fishery Closure Rules and Observed Scenarios

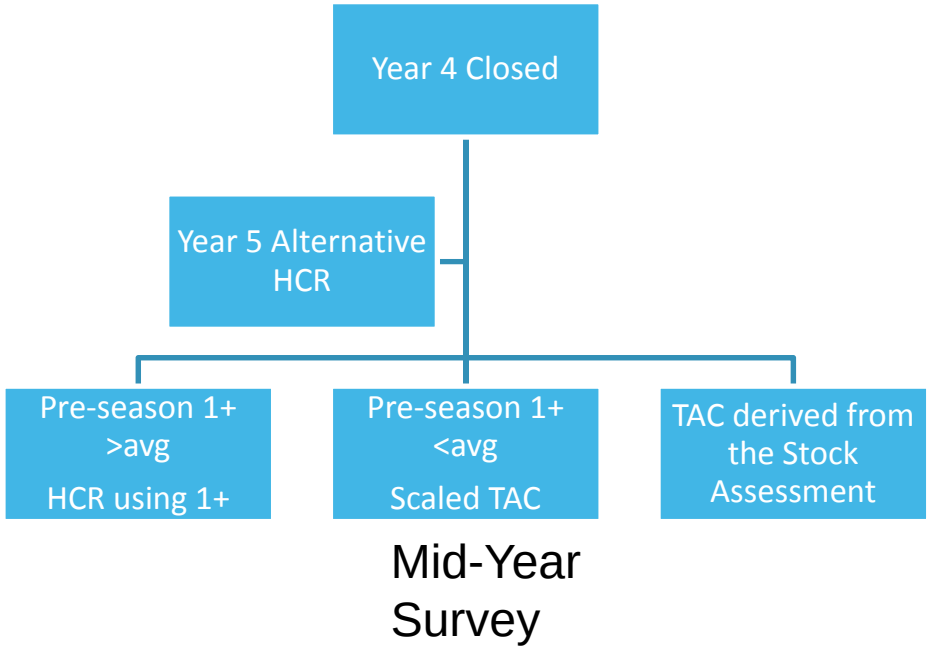


Fishery closed despite increasing stock and recruit trend

TRL Fishery Research: TRL Fishery Closure Rules – possible tiered approach for stock recovery

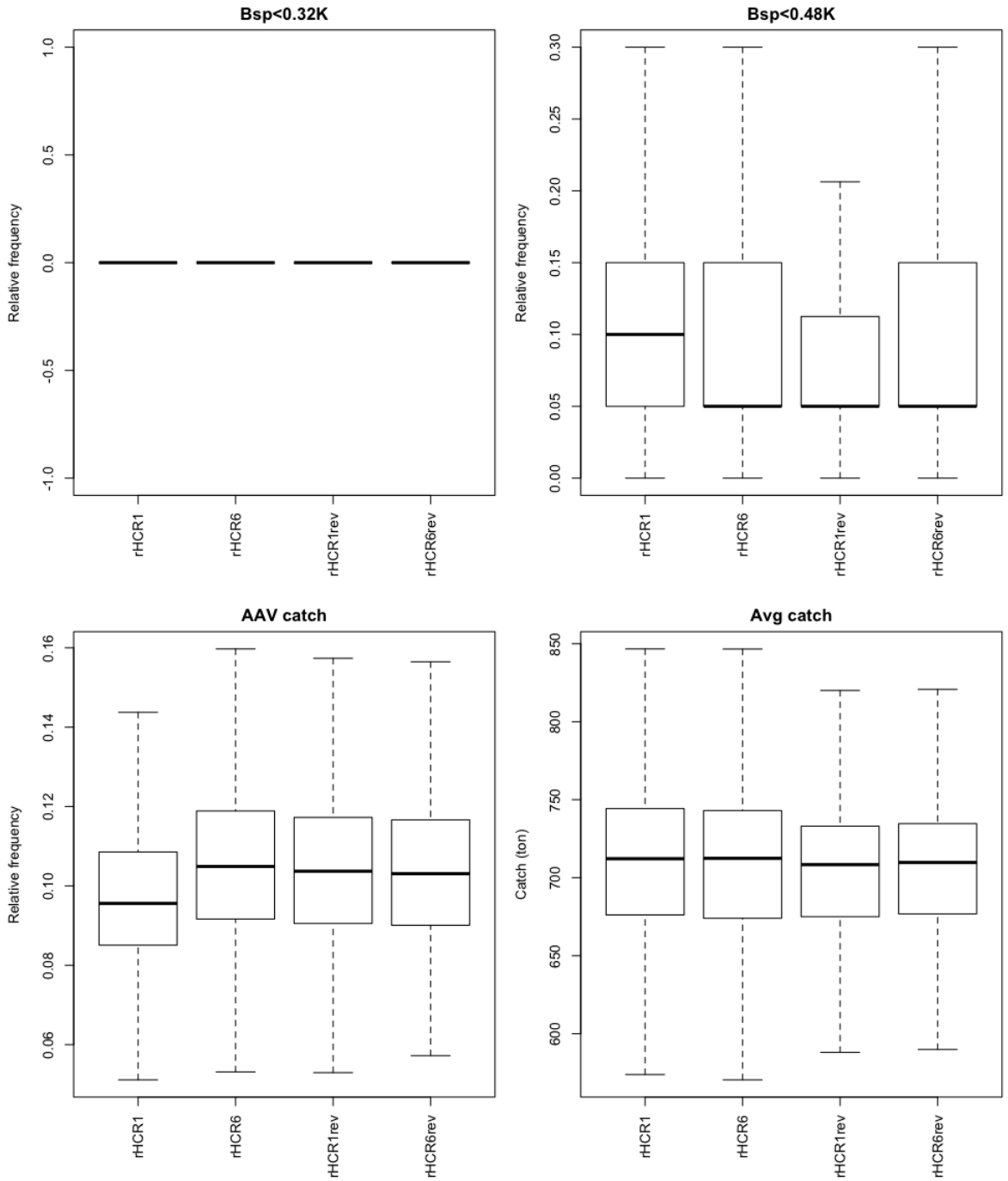
Post-closure HCR alternatives
Tiered Approach

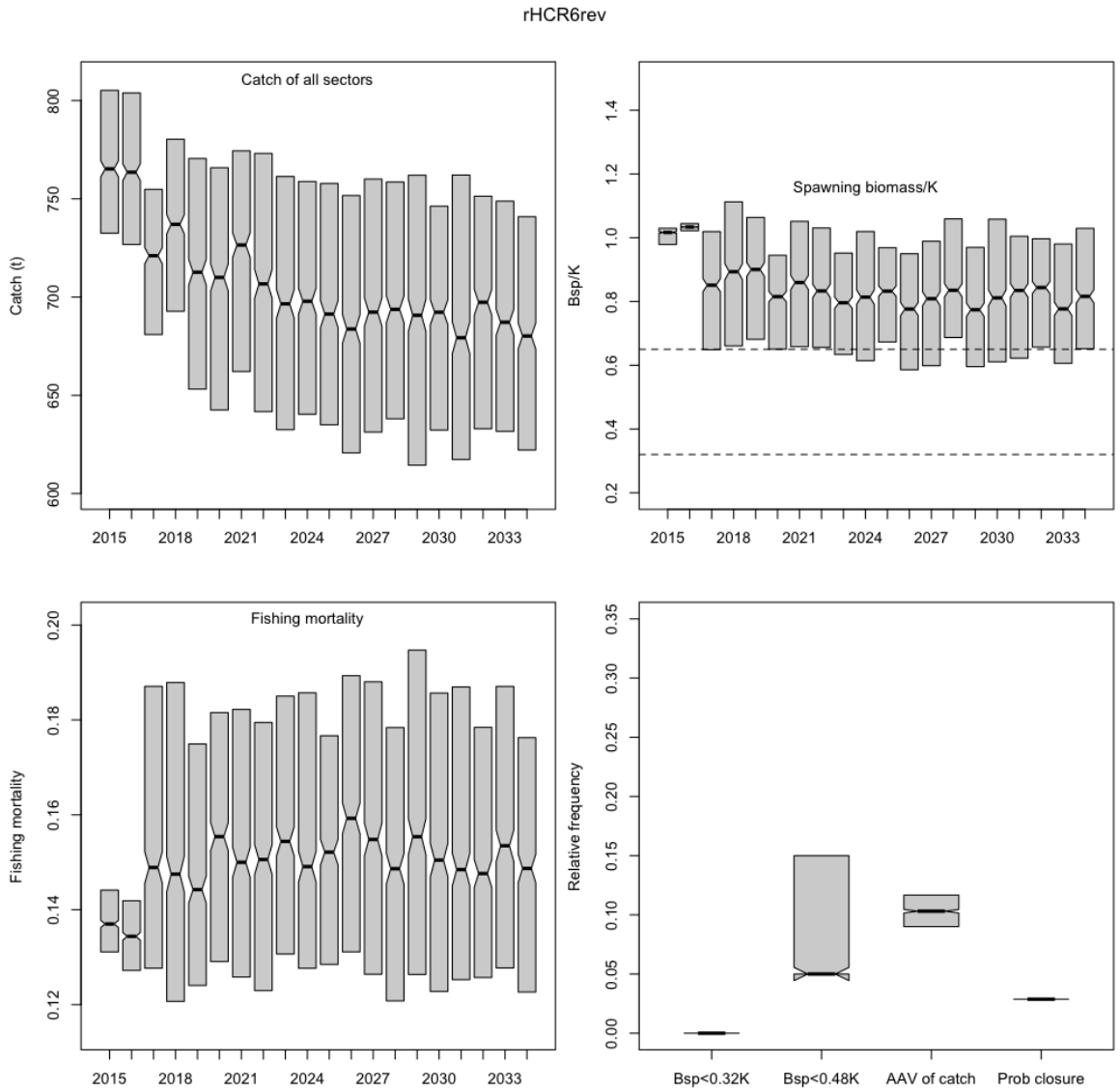
(1) Trigger Fishery Independent Mid-Year Survey in Year 4 (to provide 2+ index)
(2) Triggers more conservative HCR in Year 5
(3) Triggers HCR based on full Stock Assessment – utilising 1+ and 0+ trends



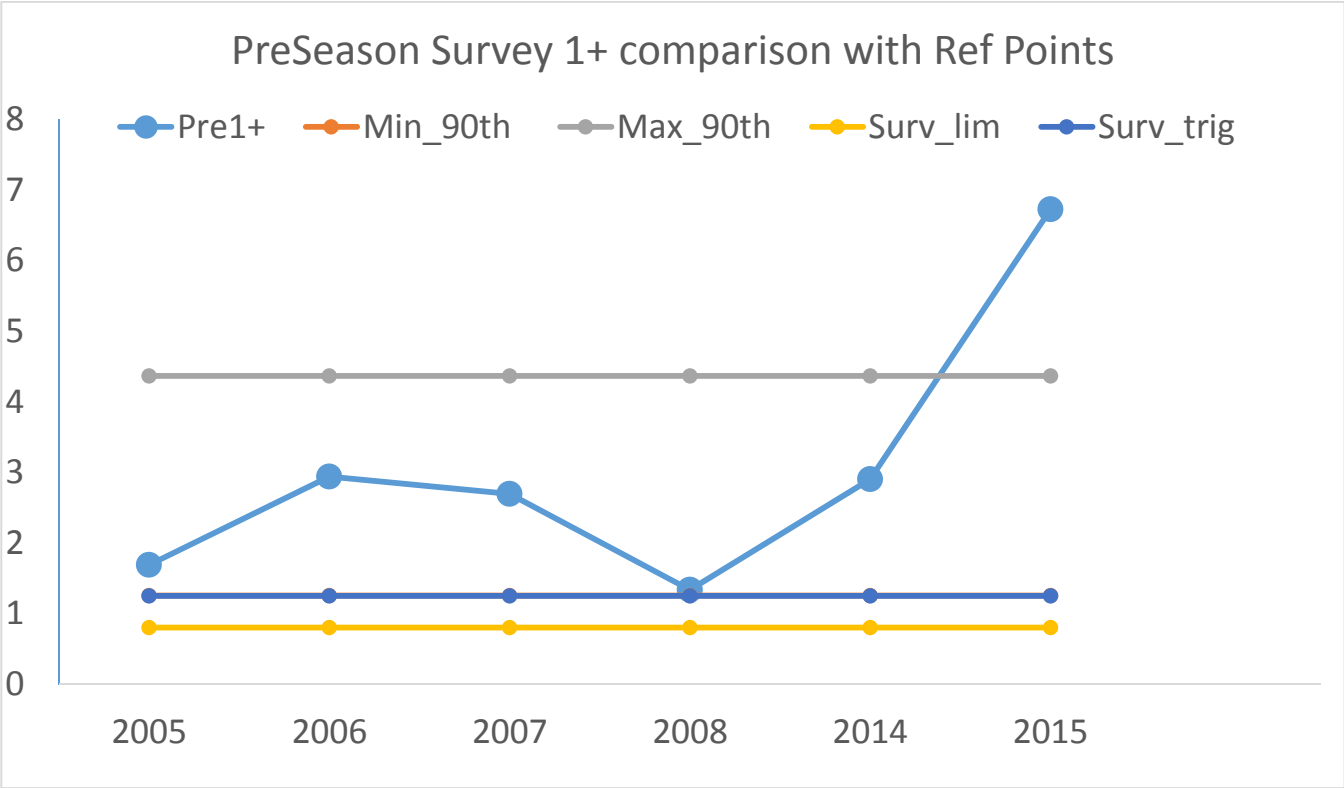
CLOSURE SCENARIOS TESTED

Closure HCR		
cHCR1	All (Pre1, Pre0, CPUE_TVH, CPUE_TIB)	Closures if 2 out of last 3 yrs <Blim; Ln(slopes last 5 yrs); Catch_ave_5yrs; weightings(Pre1;Pre0;CPUE_TVH;CPUE_TIB)=(0.6;0.1;0.15;0.15)
cHCR2	All (Pre1, Pre0, CPUE_TVH, CPUE_TIB)	Closures if last 2 years <Blim; Ln(slopes last 5 yrs); Catch_ave_5yrs; weightings(Pre1;Pre0;CPUE_TVH;CPUE_TIB)=(0.6;0.1;0.15;0.15)
cHCR3	All (Pre1, Pre0, CPUE_TVH, CPUE_TIB)	Closures if 2 out of 3 last yrs <Blim and current Surv<Surv_trig = 1.25; Ln(slopes last 5 yrs); Catch_ave_5yrs; weightings(Pre1;Pre0;CPUE_TVH;CPUE_TIB)=(0.6;0.1;0.15;0.15)

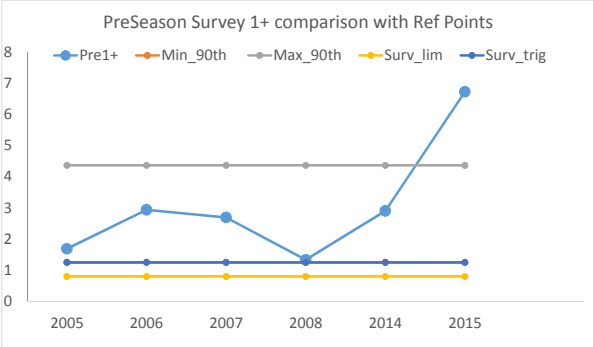

Bsp<0.32K
Relative frequency
1.0
0.5
0.0
-0.5
-1.0
rHCR1
rHCR6
rHCR1rev
rHCR6rev
Bsp<0.48K
Relative frequency
0.30
0.25
0.20
0.15
0.10
0.05
0.00
rHCR1
rHCR6
rHCR1rev
rHCR6rev
AAV catch
Relative frequency
0.16
0.14
0.12
0.10
0.08
0.06
rHCR1
rHCR6
rHCR1rev
rHCR6rev
Avg catch
Catch (ton)
850
800
750
700
650
600
rHCR1
rHCR6
rHCR1rev
rHCR6rev

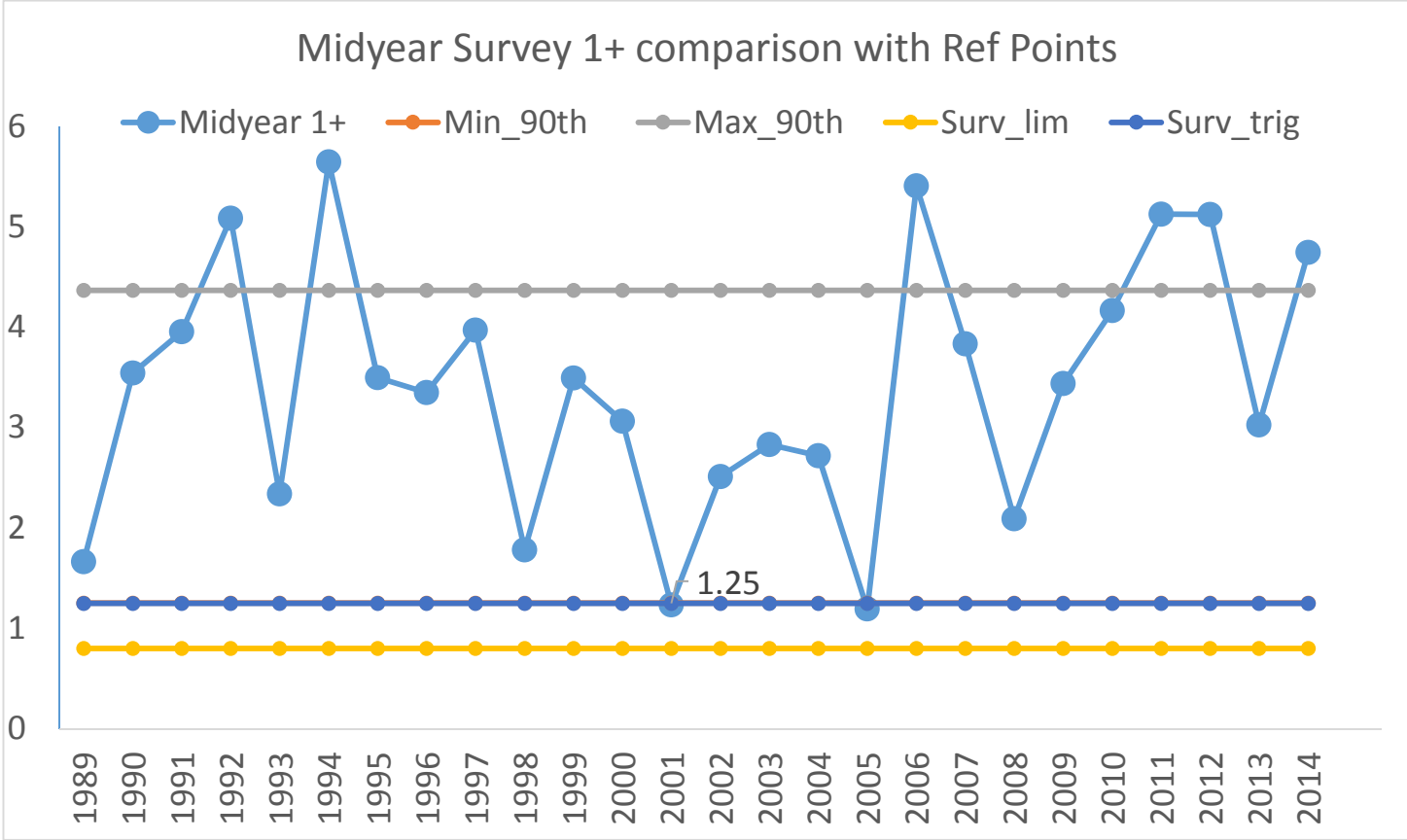

rHCR6rev
Catch of all sectors
Catch (t)
600
650
700
750
800
2015
2018
2021
2024
2027
2030
2033
Spawning biomass/K
Bsp/K
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Fishing mortality
Fishing mortality
0.12
0.14
0.16
0.18
0.20
Relative frequency
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Bsp<0.32K
Bsp<0.48K
AAV of catch
Prob closure

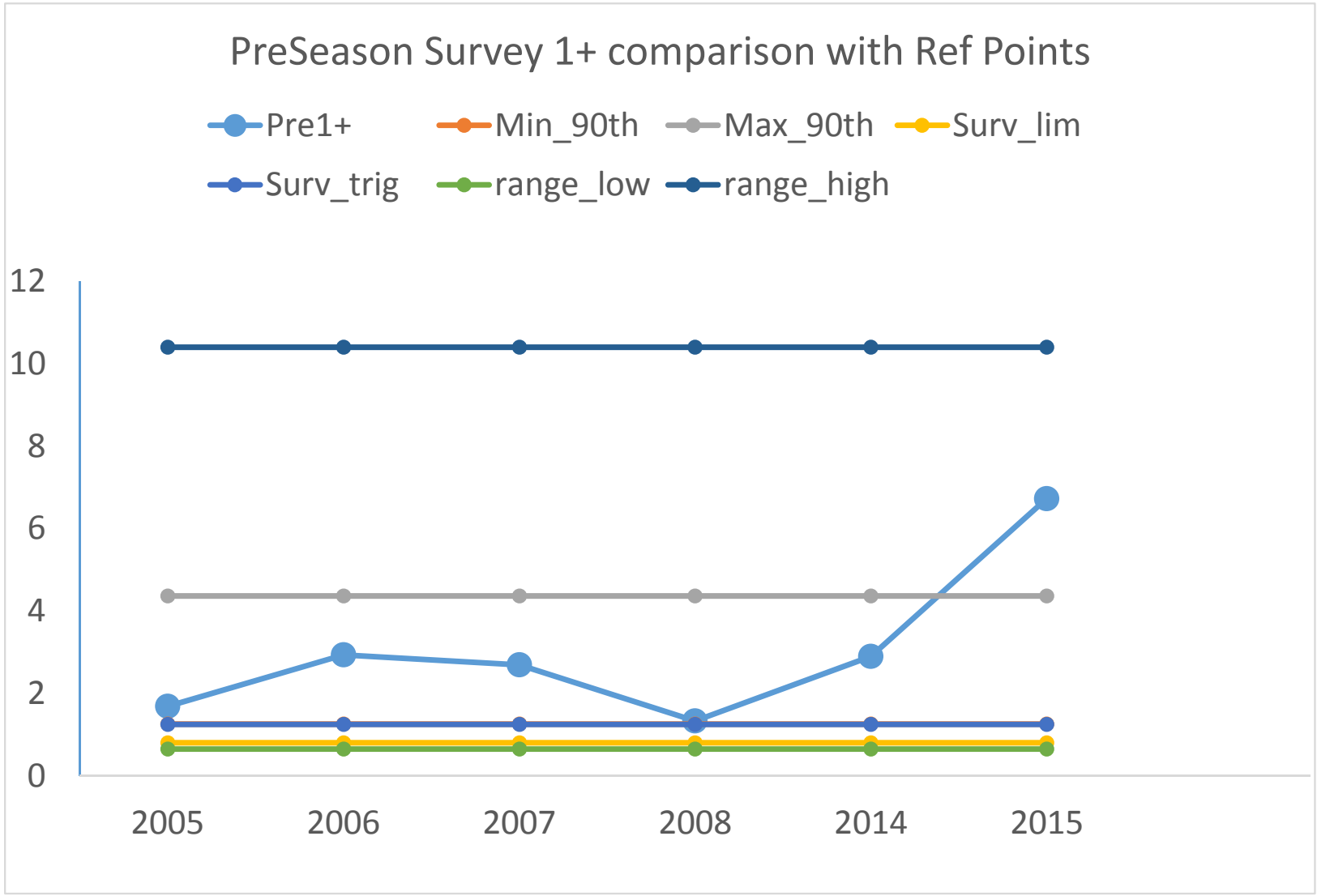
Using trigger and limit reference points based on data



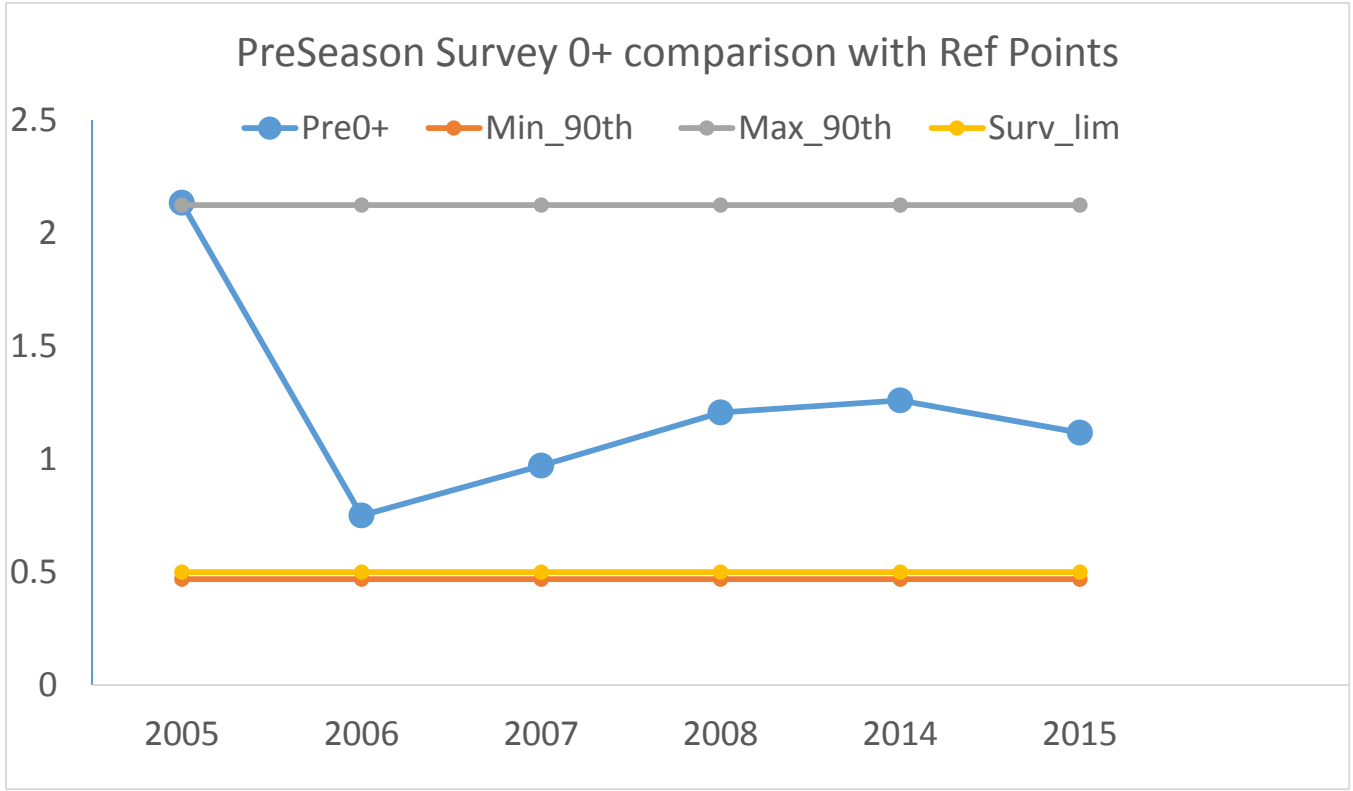
Use 1.25 as trigger? (triggers action such as to do stock assessment or survey)
Use 0.8 as lower limit? (first fishery closure triggered?)


PreSeason Survey 1+ comparison with Ref Points
Pre1+
Min_90th
Max_90th
Surv_lim
Surv_trig
8
7
6
5
4
3
2
1
0
2005
2006
2007
2008
2014
2015


Midyear Survey 1+ comparison with Ref Points
Midyear 1+
Min_90th
Max_90th
Surv_lim
Surv_trig
6
5
4
3
2
1
0
1.25
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014

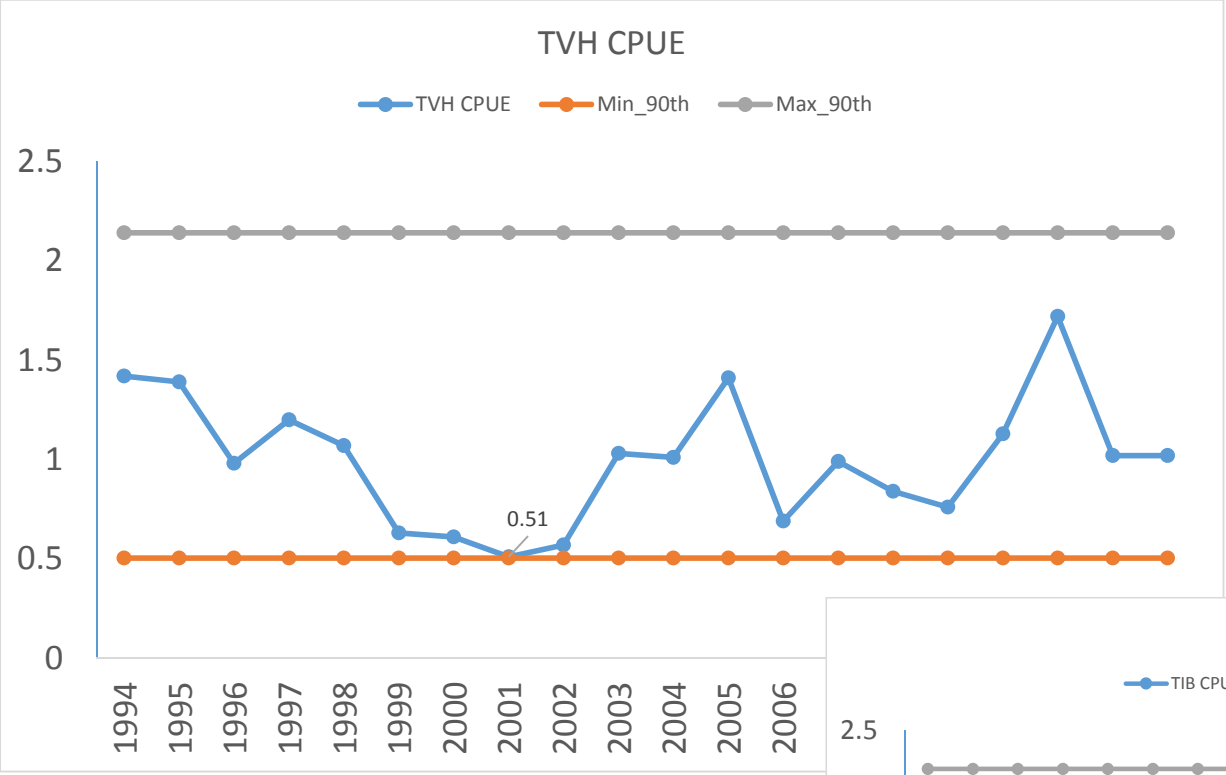

PreSeason Survey 1+ comparison with Ref Points
Pre1+
Min_90th
Max_90th
Surv_lim
Surv_trig
range_low
range_high
12
10
8
6
4
2
0
2005
2006
2007
2008
2014
2015

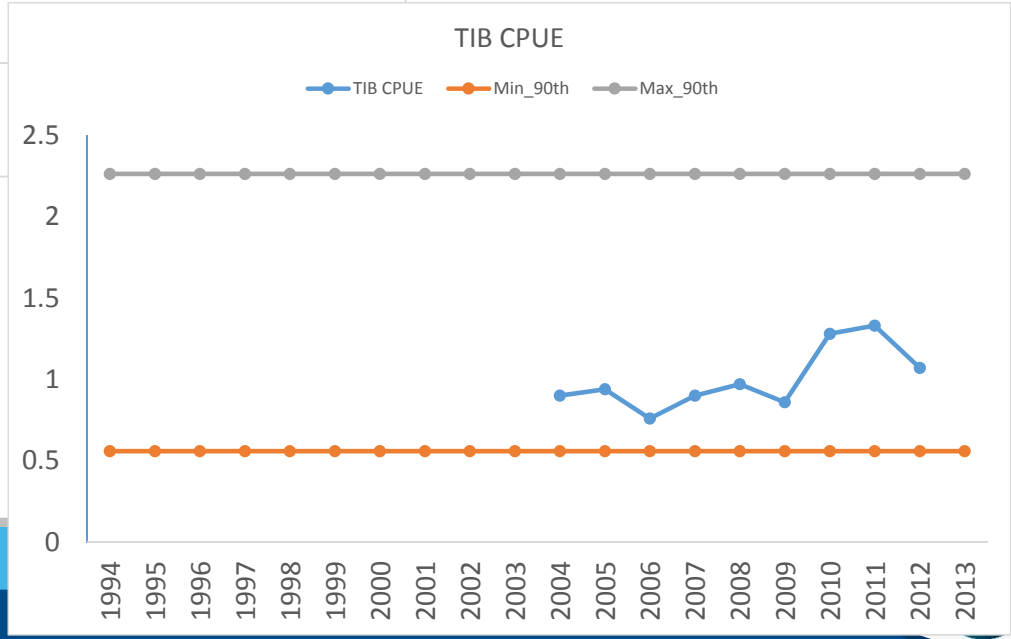
Example limit reference point for Preseas 0+



Use 0.5 as trigger?

CPUE-based trigger reference points





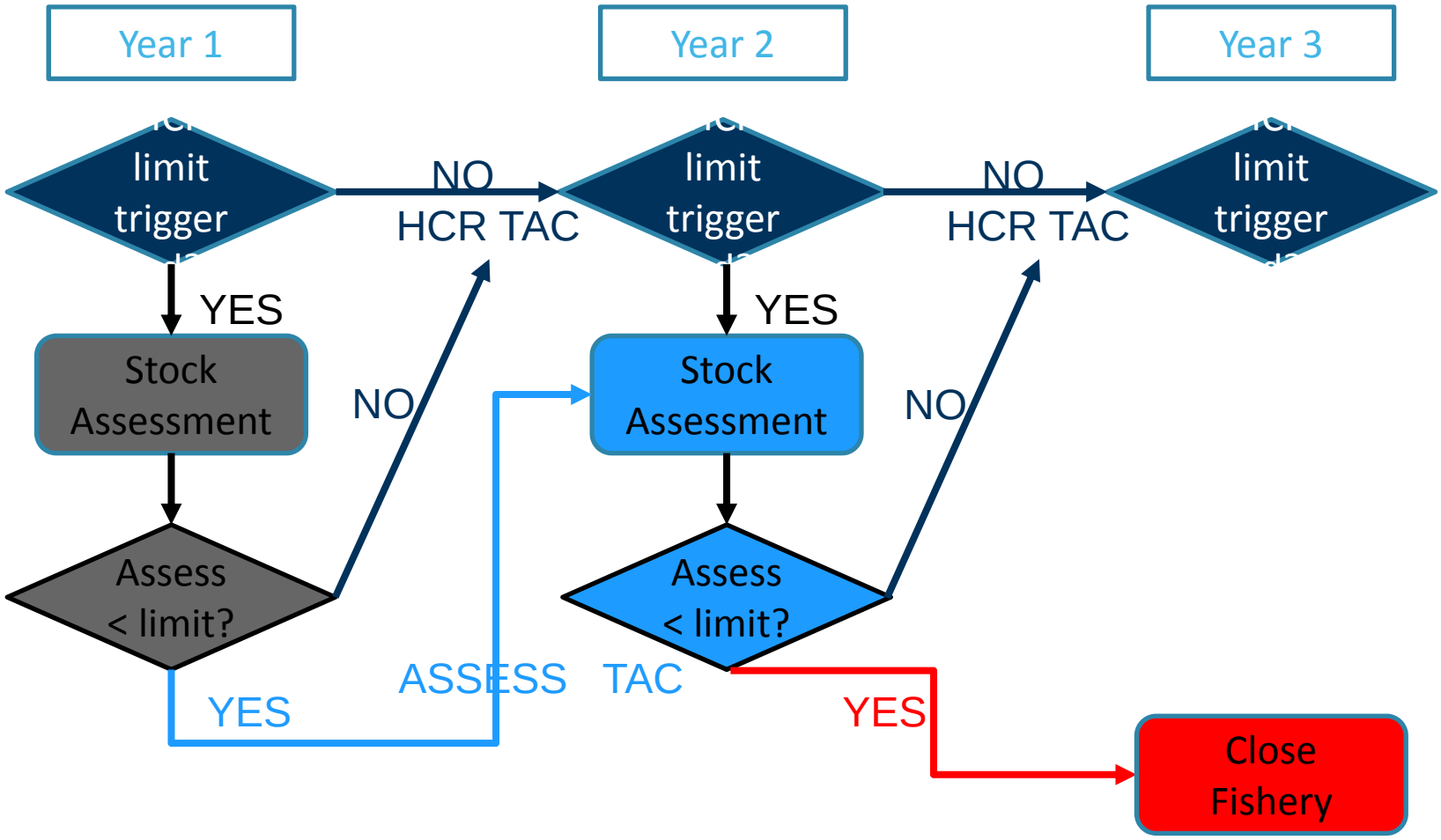
Outline

- Recap re draft Harvest Strategy agreements
- Empirical (data-based) Harvest Control Rule (HCR) explained
- Example application using past data
- Feedback from TRLRAG
- Feedback from Nokome Bentley
- Alternative HCR candidates and their performance

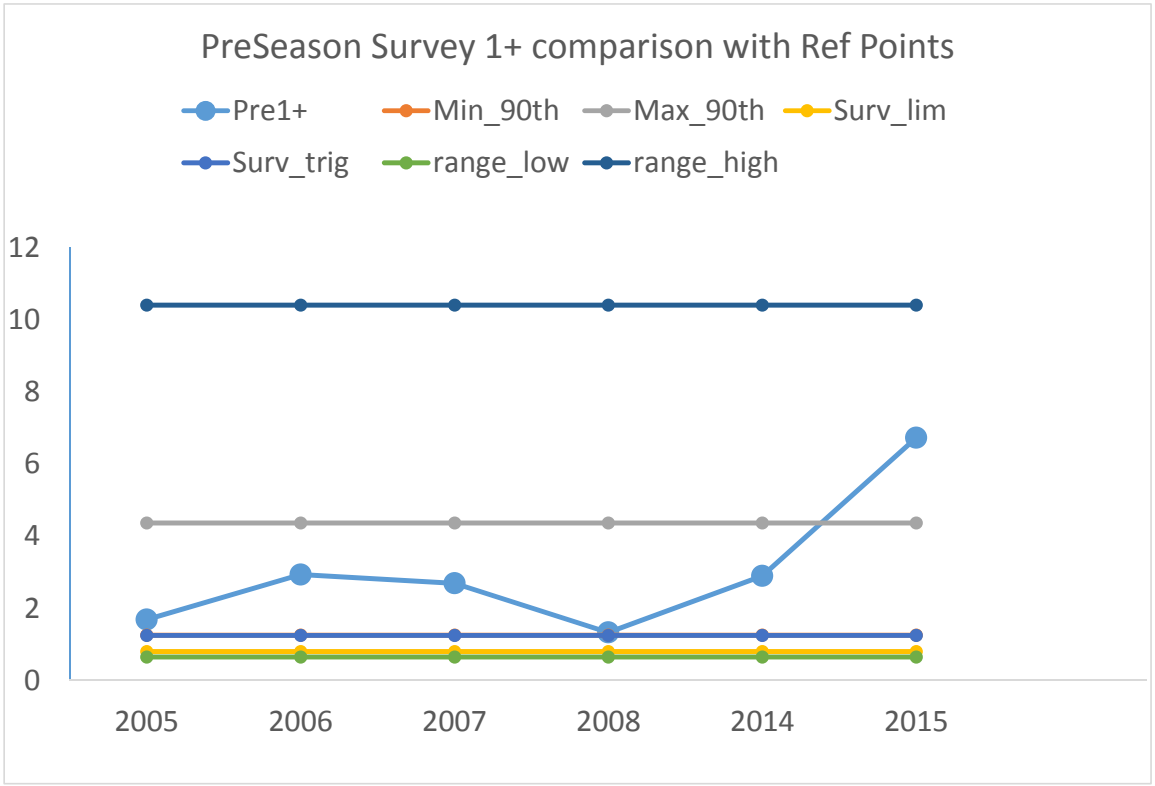
➢**Deciding on rules for closure**

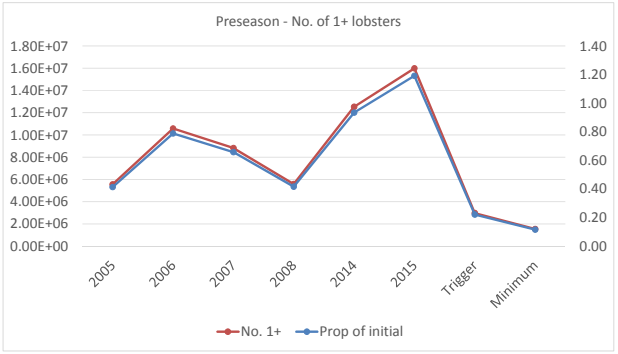
➢**Reviewing data-based trigger and limit reference points**

- Exceptional circumstances clauses
- Sensitivity Analyses
- Discount factors for tiered system (eg more/fewer surveys)


Year 1
Year 2
Year 3
limit trigger
NO
HCR TAC
limit trigger
NO
HCR TAC
limit trigger
YES
YES
Stock Assessment
Stock Assessment
NO
NO
Assess < limit?
Assess < limit?
YES
ASSESS TAC
YES
Close Fishery

Survey & CPUE Trigger Limits for invoking Exceptional Circumstances (i.e. HCR can't be used)





Preseas 1+ index >10.4

Trigger for review = 1.25

Preseas 1+ index < 0.65
Hence if Pre1+ <0.65 exceptional circumstances

Harvest Strategy for TRL: variability and exceptional circumstances

Short-lived species (e.g. TRL) have stocks comprised of only one year class and the stock abundance may vary fourfold on an annual basis depending on the recruitment success in a particular year.

Hence, the TAC will vary significantly on an annual basis reflecting stock abundance.

The harvest strategy may include exceptional circumstances clauses to account for events such as environmental impacts to allow for stocks to recover rapidly.

Outline

- Recap re draft Harvest Strategy agreements
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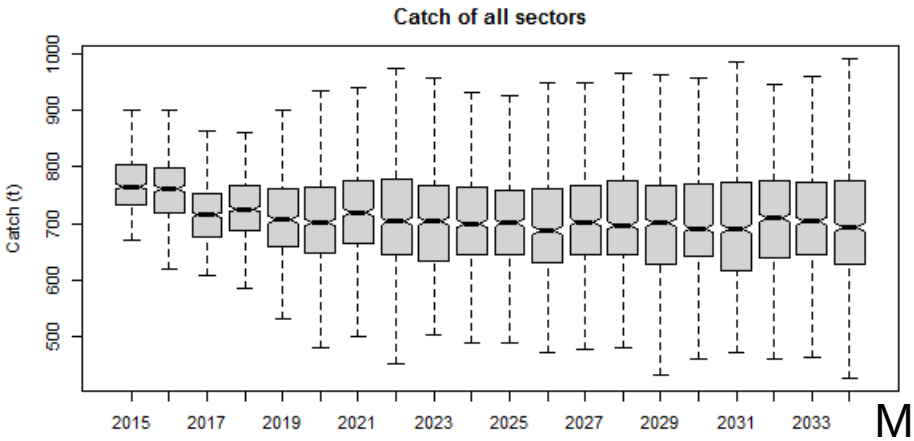
- Feedback from TRLRAG
- Feedback from Nokome Bentley
- Alternative HCR candidates and their performance
- Deciding on rules for closure
- Reviewing data-based trigger and limit reference points
- Exceptional circumstances clauses

➢**Sensitivity Analyses**

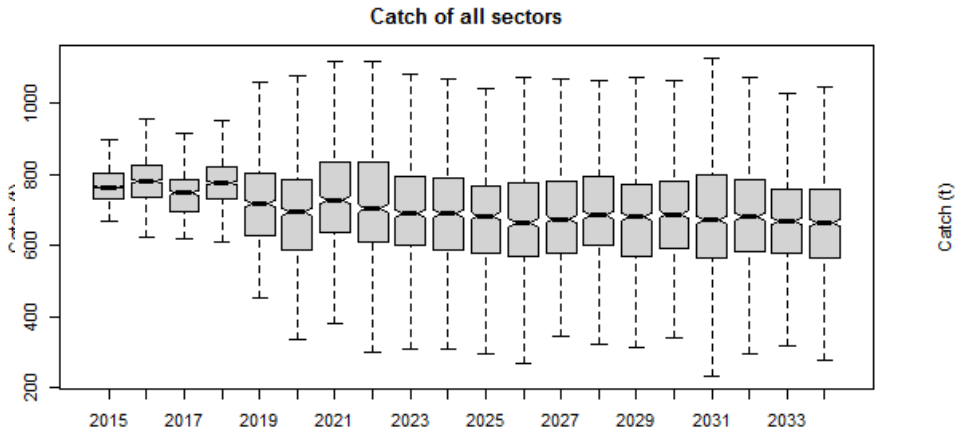
- Discount factors for tiered system (eg more/fewer surveys)

rHCR1



Min 500

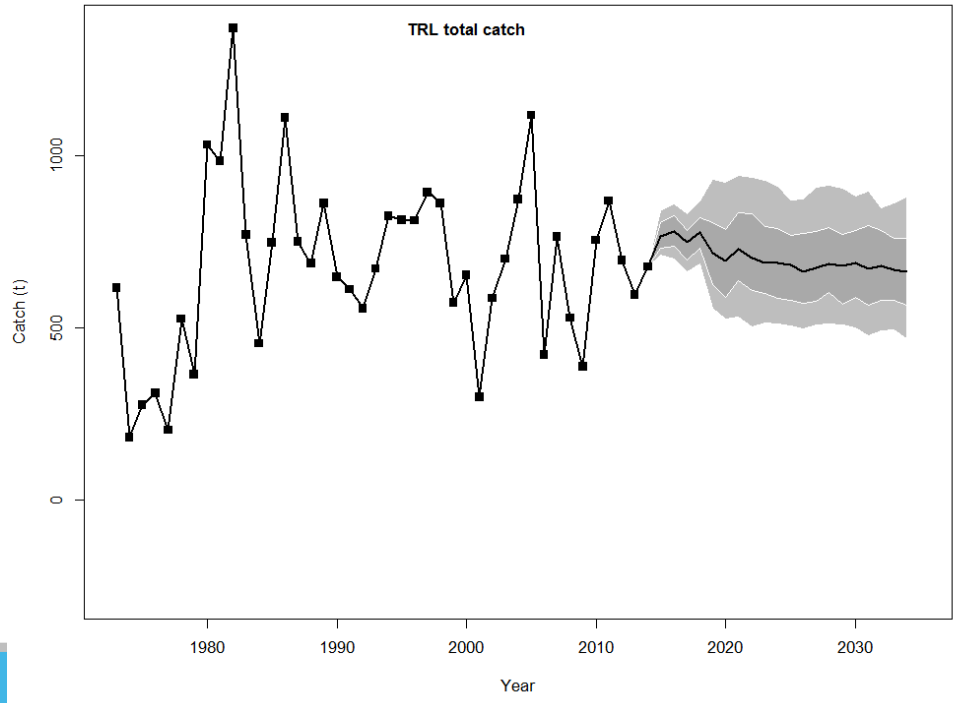
rHCR2

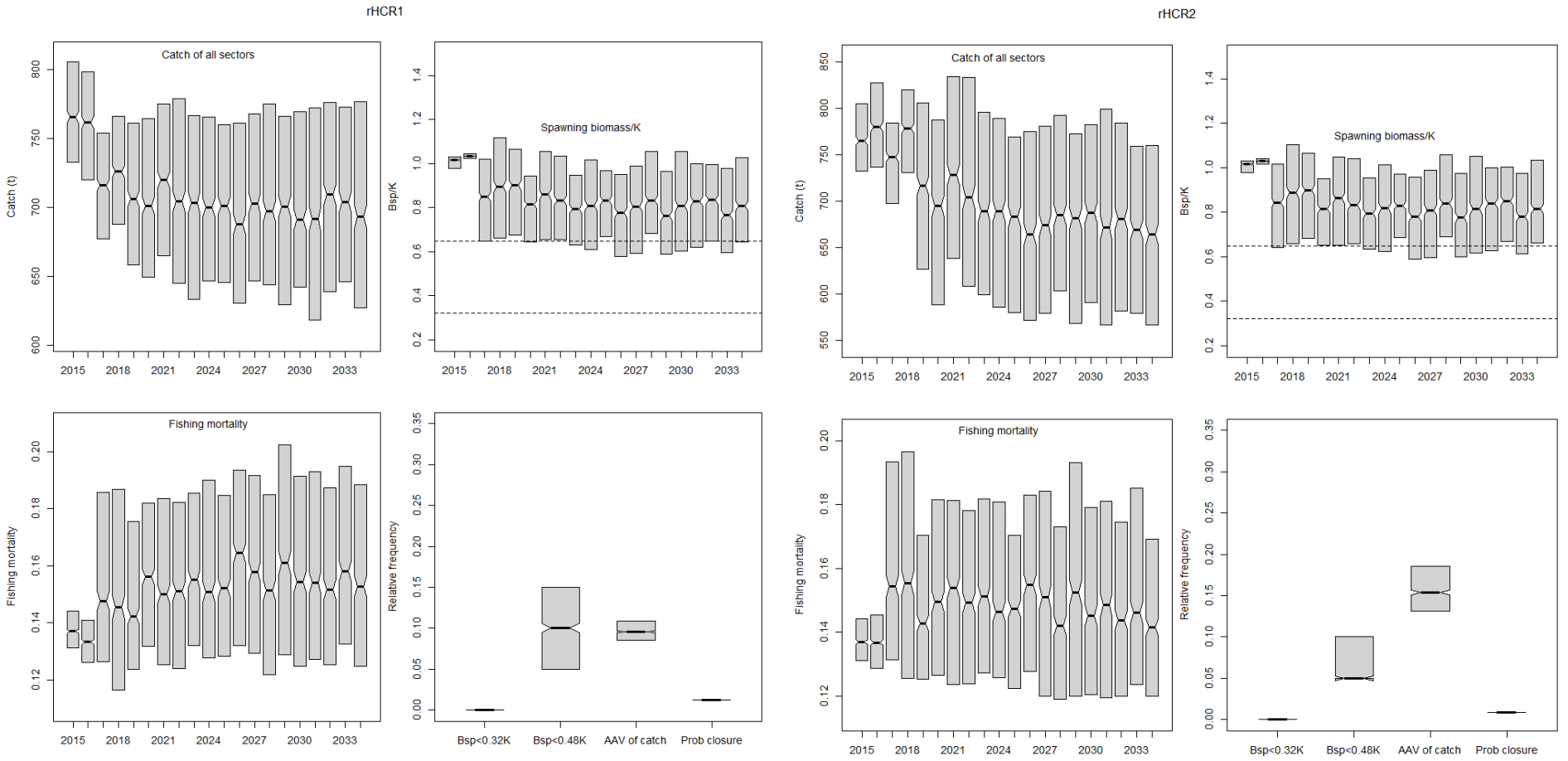


Min 200

rHCR1 (with log) Vs rHCR2 (no log) – more variable catches, both high and low

rHCR2




rHCR1
rHCR2
Catch of all sectors
Spawning biomass/K
Fishing mortality
Catch (t)
Bsp/K
Fishing mortality
Relative frequency
2015
2018
2021
2024
2027
2030
2033
Bsp<0.32K
Bsp<0.48K
AAV of catch
Prob closure

Previous Sensitivities

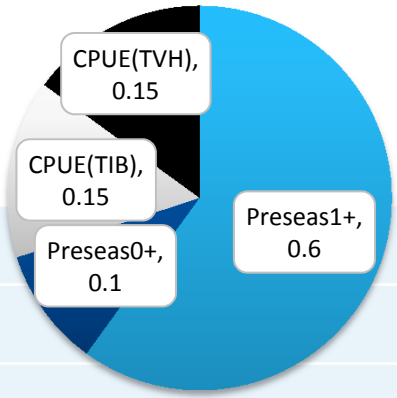
Key sensitivities include :

- Changing the number of years in calculating the slope of the trend in the recent preseason survey data (3yrs. 5yrs, 6yrs);
- increasing the implementation error too much larger values (0.1, 0.2);
- setting the stock recruit steepness parameter to a lower value of h=0.6 (and refitting the model); and
- changing the hyperstability parameters to one for both CPUE series (and refitting the model)

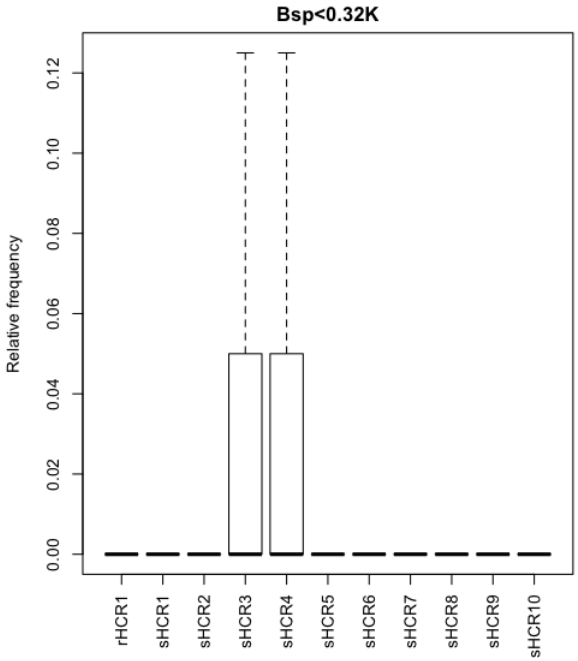
Summary results:

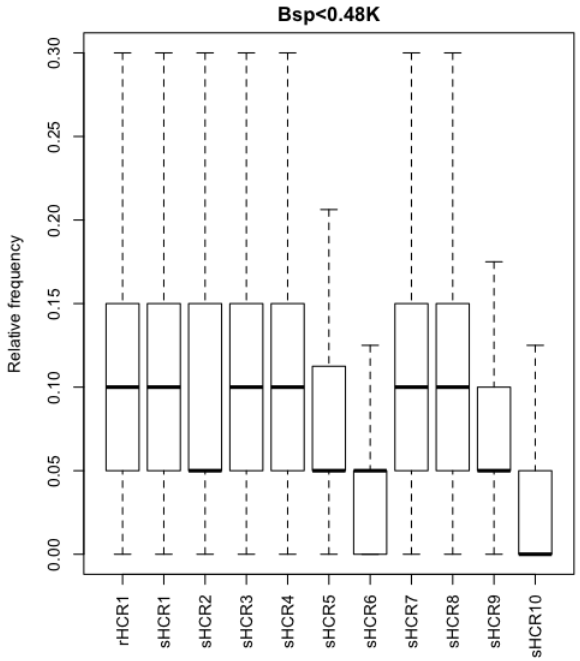
- using fewer preseason survey points in the regression leads to poor outcomes in terms of average catch and AAV.
- If implementation error is large, the performance of the basic HCRs deteriorates in terms of both catch statistics and risk to the resource.
- The risk of depletion of spawning stock biomass is highest under the low steepness scenario.

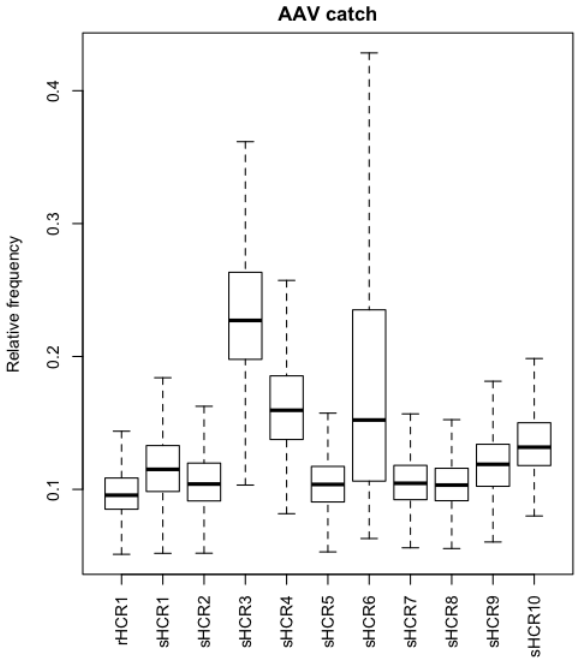
Additional Sensitivities

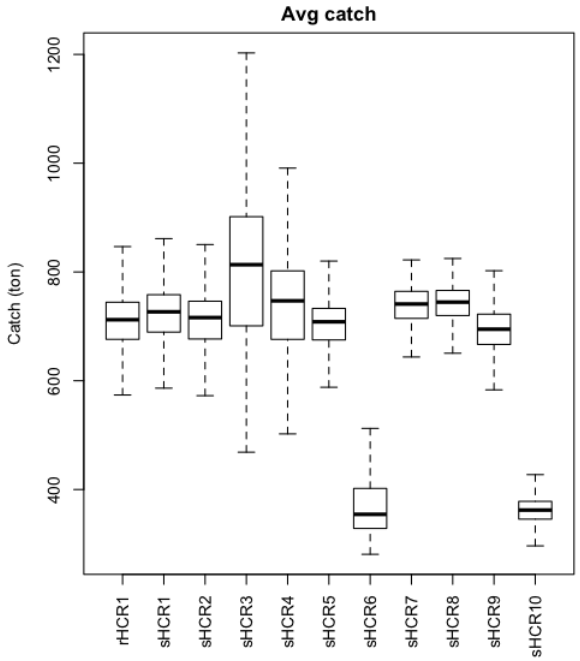


Sensitivities	(rel to rHCR1)
sHCR1	Lagged CPUE
sHCR2	Lower Pre0+ variance
sHCR3	High PNG Catch discrepancy/trawling
sHCR4	Med-High PNG Catch discrepancy
sHCR5	Max Cap = 800
sHCR6	Catchability decreases 1 in 10 yrs
sHCR7	Catchability increases 1 in 10 years
sHCR8	Sustained increase in catchability
sHCR9	High variance Preseason survey
sHCR10	Discount factor re high survey variance

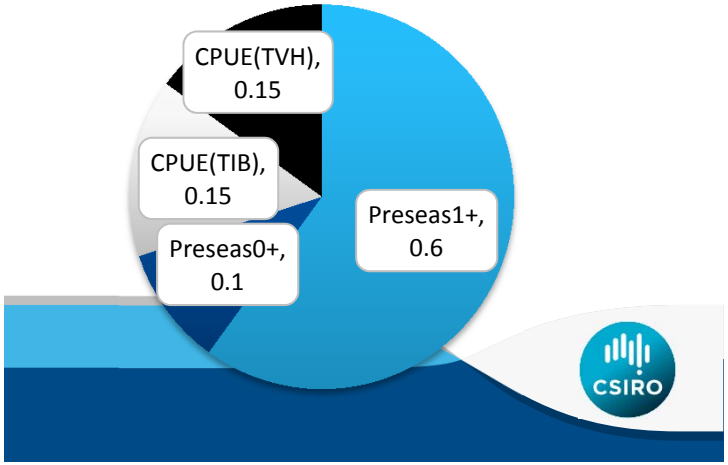


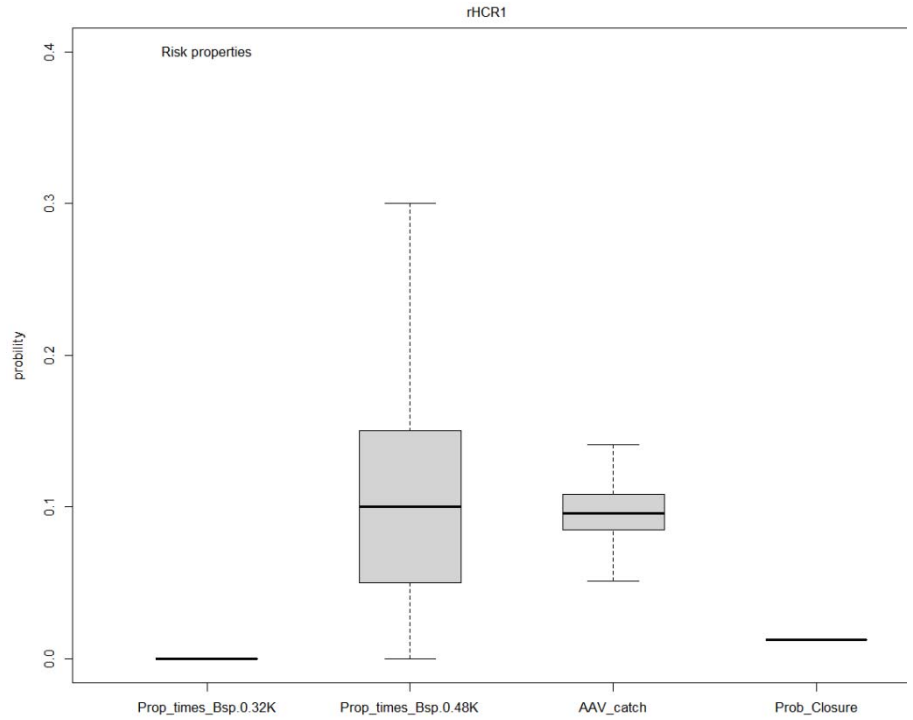


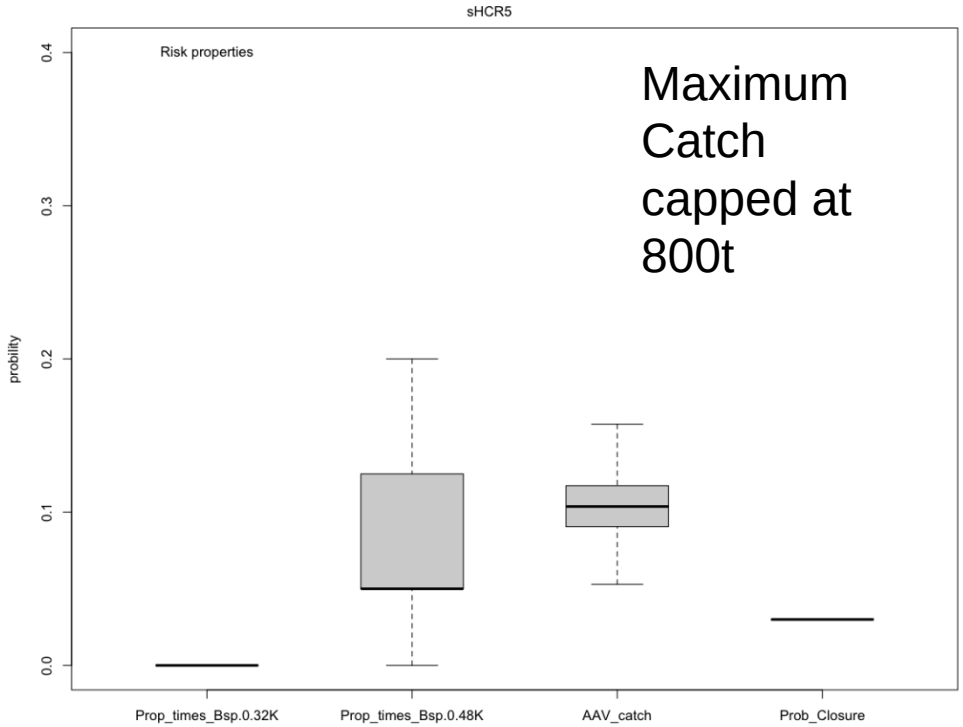




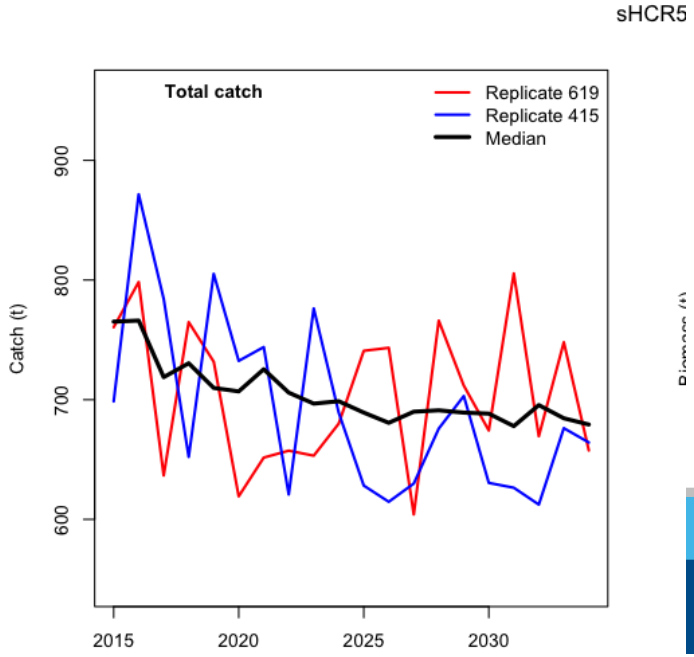
Sensitivities	(rel to rHCR1)
sHCR1	Lagged CPUE
sHCR2	Lower Pre0+ variance
sHCR3	High PNG Catch errors
sHCR4	Med-High PNG Catch errors
sHCR5	Max Cap = 800
sHCR6	Catchability decreases 1 in 10 yrs (underestimate stock size)
sHCR7	Catchability increases 1 in 10 years (overestimate stock size)
sHCR8	Sustained increase in catchability (e.g. technology increase)
sHCR9	High variance Preseason survey
sHCR10	Discount factor re high survey variance

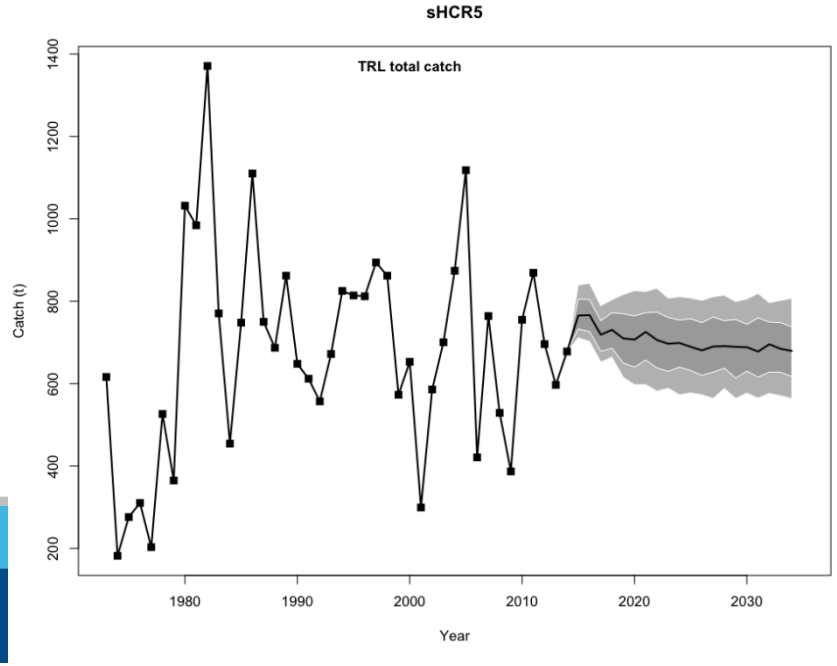


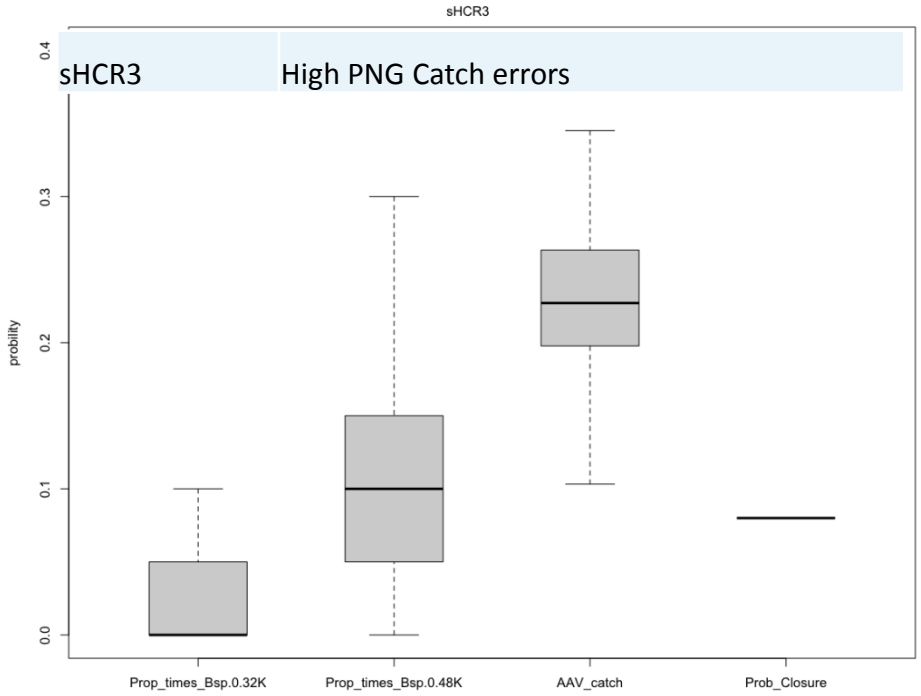




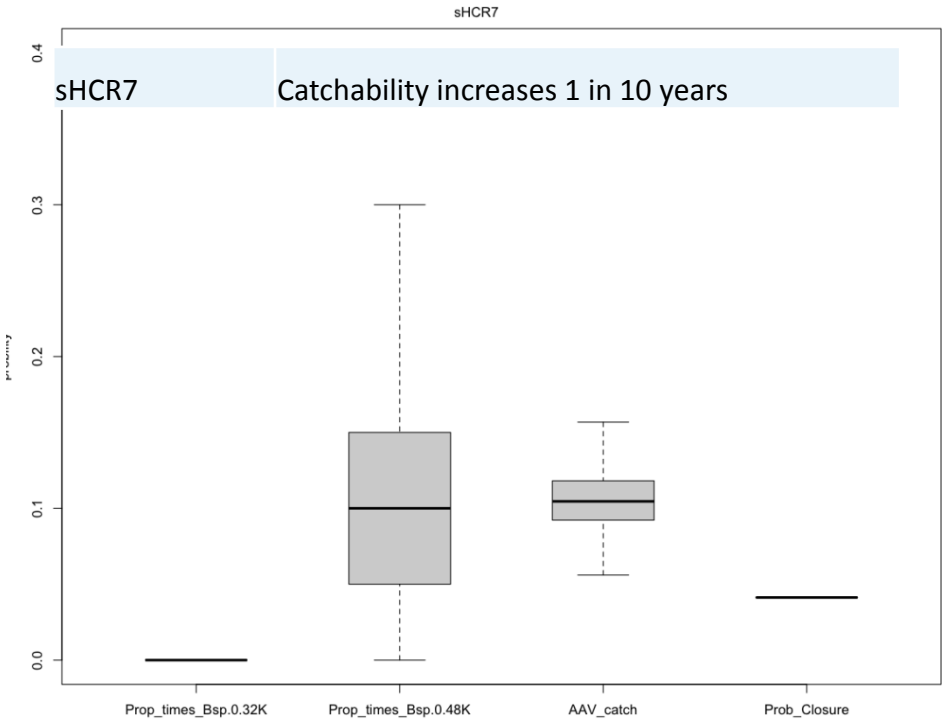
Maximum Catch capped at 800t



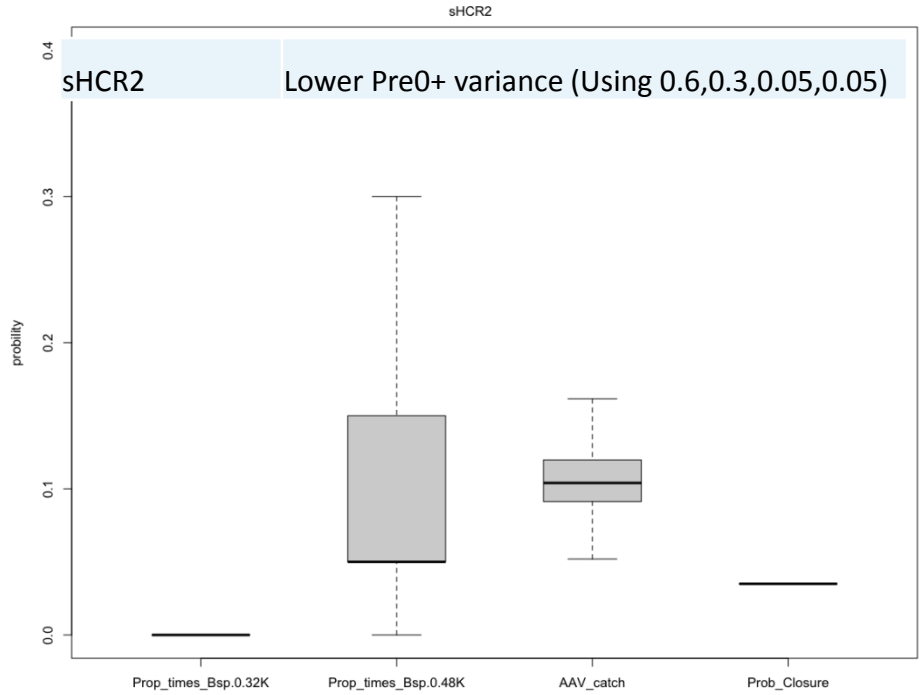




sHCR3 High PNG Catch errors

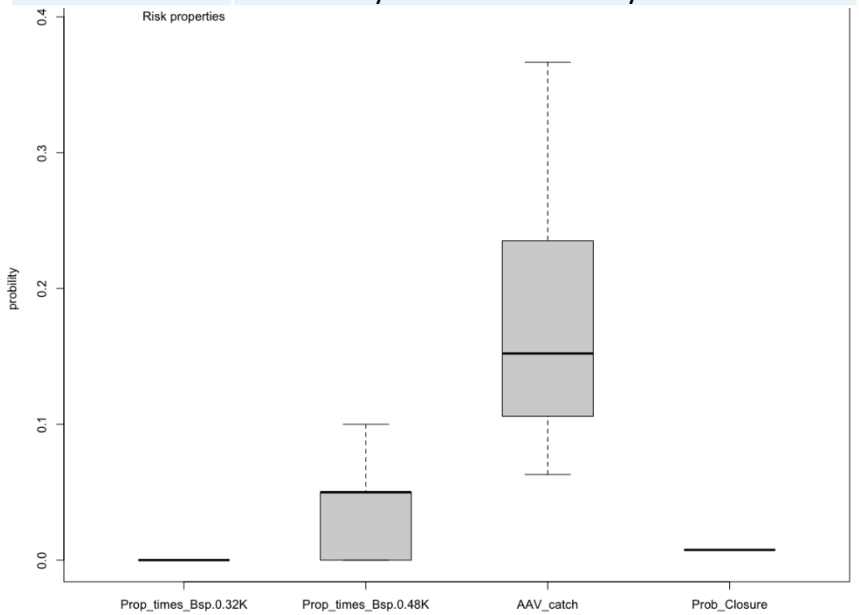


sHCR7 Catchability increases 1 in 10 years

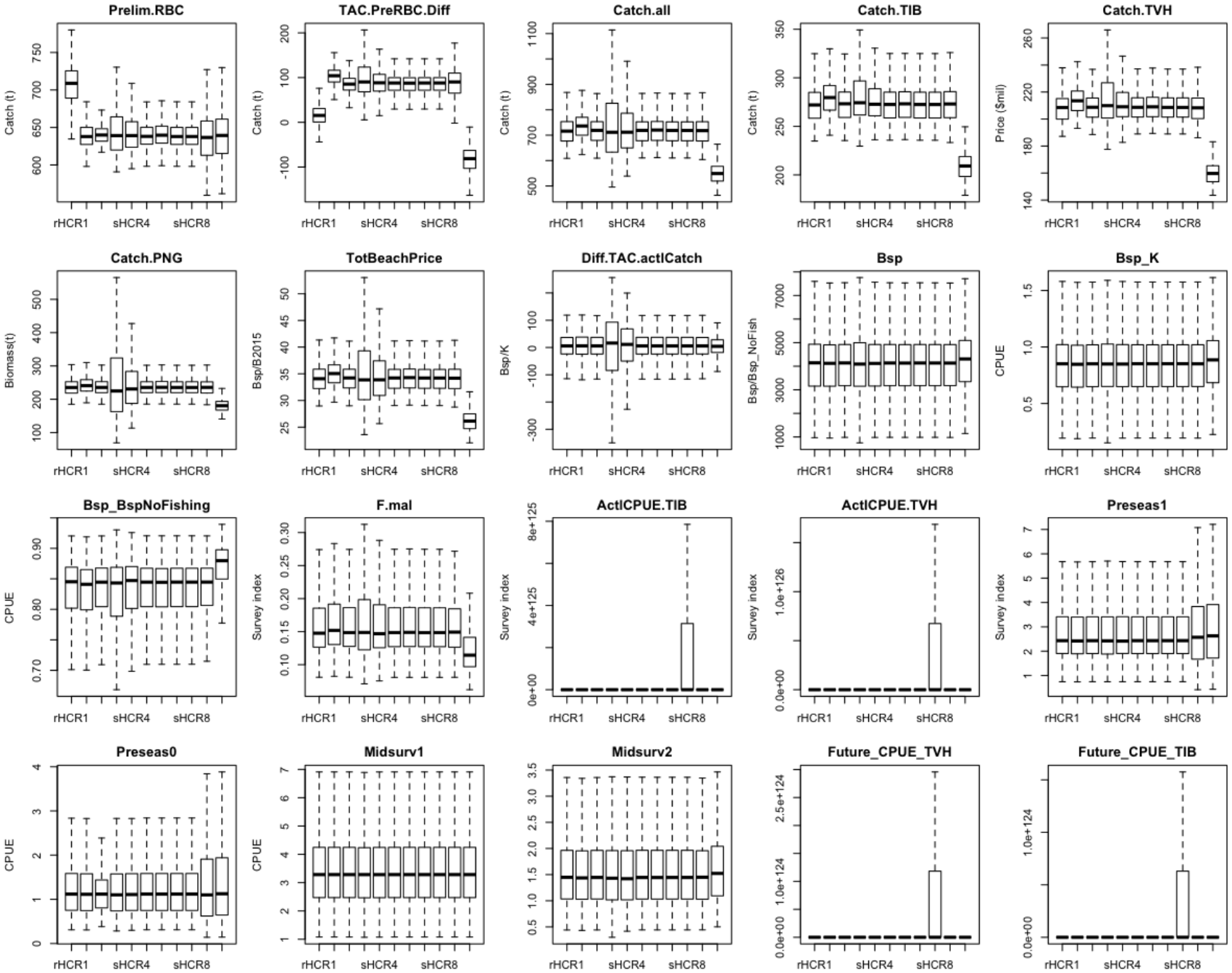


sHCR2 Lower Pre0+ variance (Using 0.6,0.3,0.05,0.05)

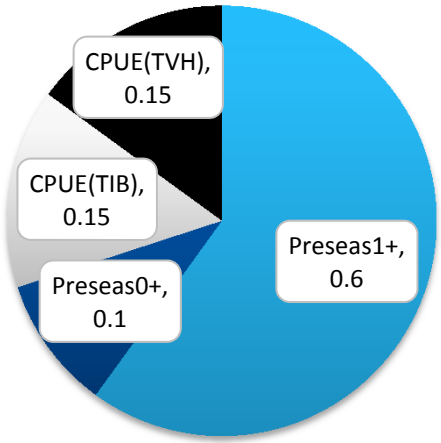
sHCR6 Catchability decreases 1 in 10 yrs



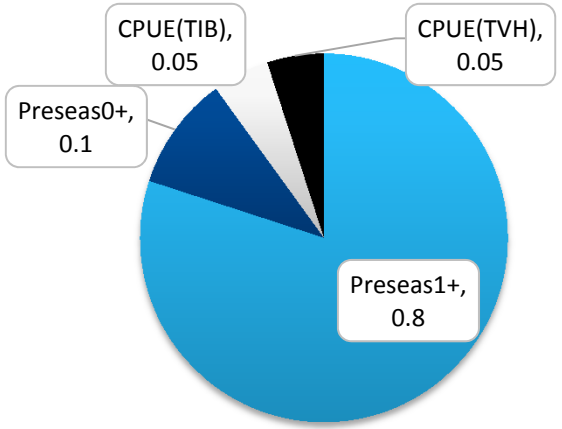
2017


Prelim.RBC
Catch (t)
TAC.PreRBC.Diff
Catch (t)
Catch.all
Catch (t)
Catch.TIB
Catch (t)
Catch.TVH
Price ($mil)
Catch.PNG
Biomass(t)
TotBeachPrice
Bsp/B2015
Diff.TAC.actlCatch
Bsp/K
Bsp
Bsp/Bsp_NoFish
Bsp_K
CPUE
Bsp_BspNoFishing
CPUE
F.mal
Survey index
ActlCPUE.TIB
Survey index
ActlCPUE.TVH
Survey index
Preseas1
Survey index
Preseas0
CPUE
Midsurv1
CPUE
Midsurv2
Future_CPUE_TVH
Future_CPUE_TIB
rHCR1
sHCR4
sHCR8

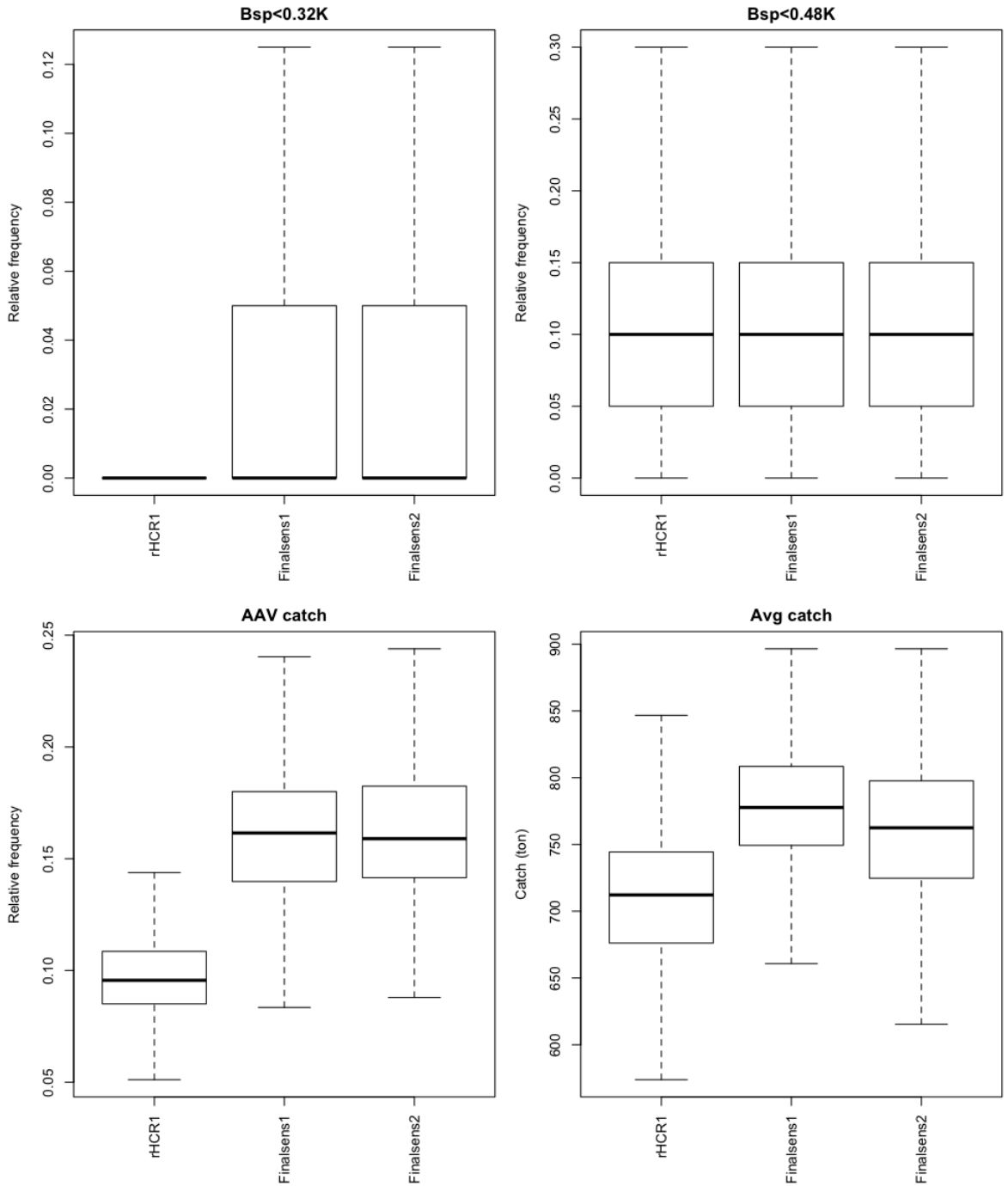
Final Sensitivities – high catch implementation error (PNG); q increase



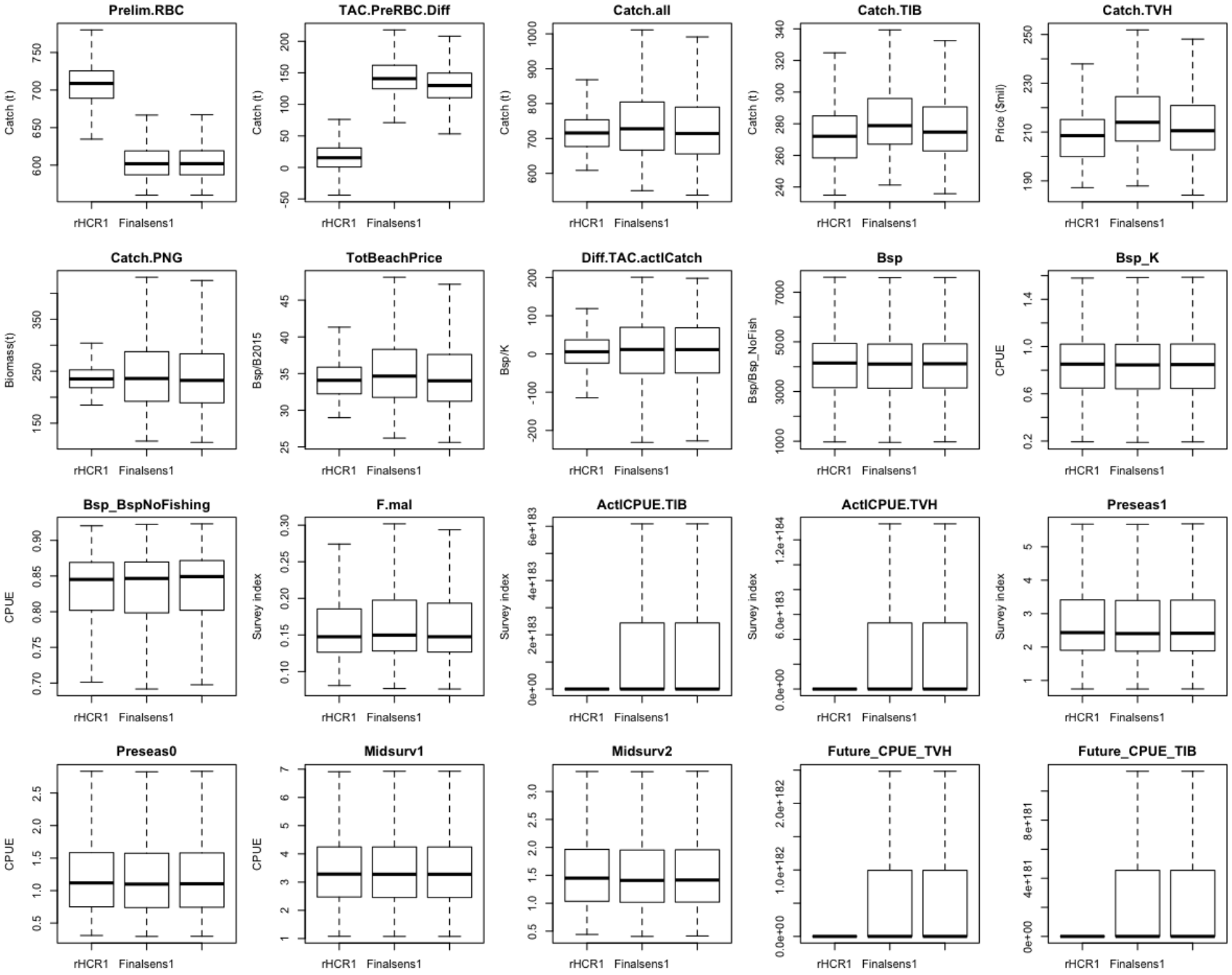
rHCR1

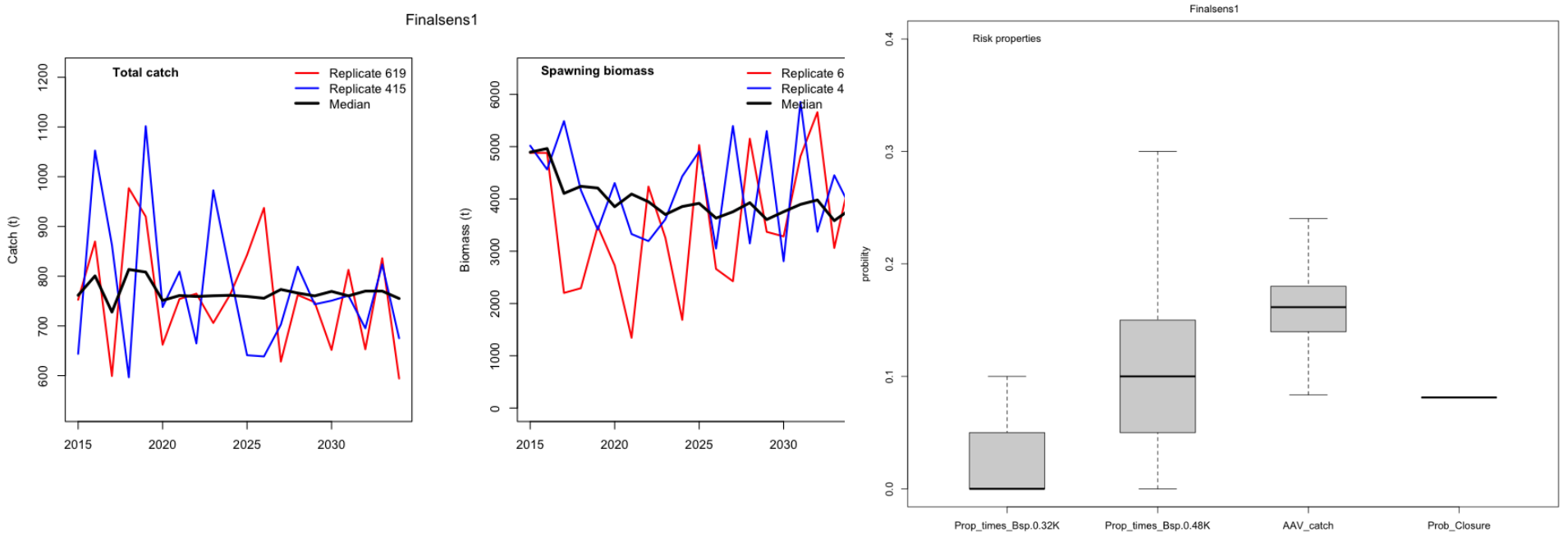


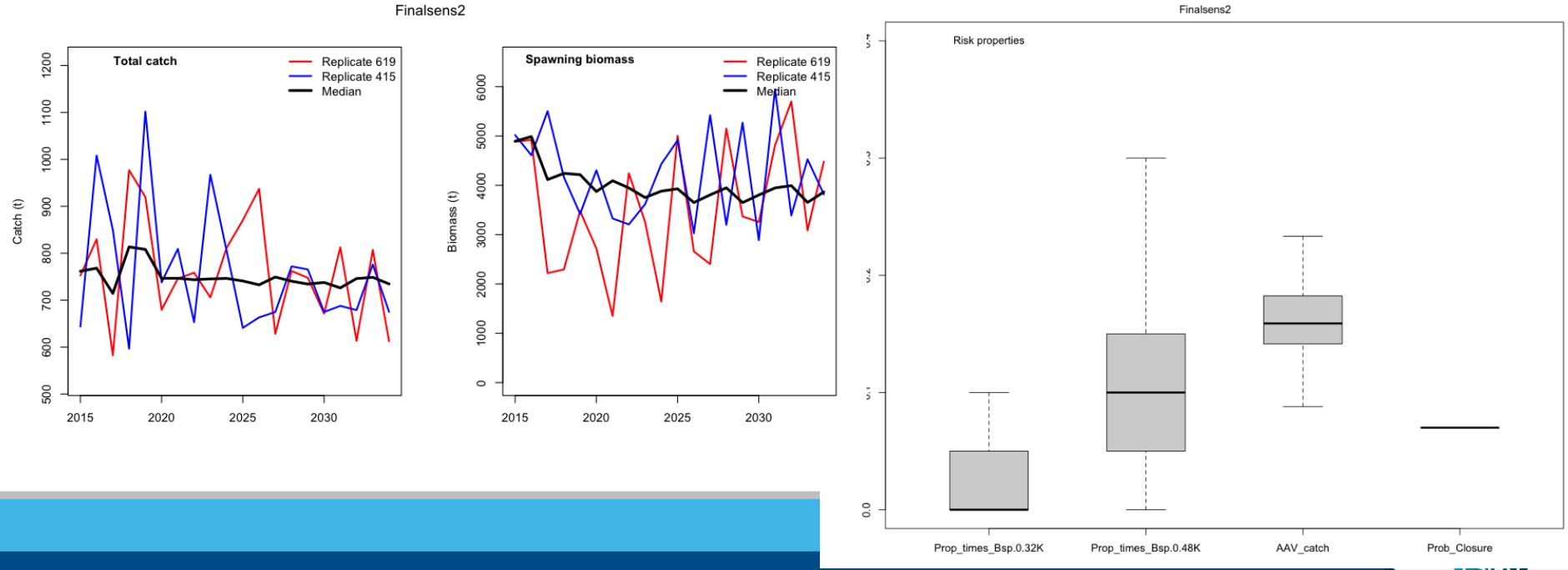
rHCR5


Bsp<0.32K
Relative frequency
0.00
0.02
0.04
0.06
0.08
0.10
0.12
rHCR1
Finalsens1
Finalsens2
Bsp<0.48K
Relative frequency
0.00
0.05
0.10
0.15
0.20
0.25
0.30
rHCR1
Finalsens1
Finalsens2
AAV catch
Relative frequency
0.05
0.10
0.15
0.20
0.25
rHCR1
Finalsens1
Finalsens2
Avg catch
Catch (ton)
600
650
700
750
800
850
900
rHCR1
Finalsens1
Finalsens2

2017


Prelim.RBC
Catch (t)
600 650 700 750
rHCR1 Finalsens1
TAC.PreRBC.Diff
Catch (t)
-50 0 50 100 150 200
rHCR1 Finalsens1
Catch.all
Catch (t)
600 700 800 900 1000
rHCR1 Finalsens1
Catch.TIB
Catch (t)
240 260 280 300 320 340
rHCR1 Finalsens1
Catch.TVH
Price ($mil)
190 210 230 250
rHCR1 Finalsens1
Catch.PNG
Biomass(t)
150 250 350
rHCR1 Finalsens1
TotBeachPrice
Bsp/B2015
25 30 35 40 45
rHCR1 Finalsens1
Diff.TAC.actlCatch
Bsp/K
-200 -100 0 100 200
rHCR1 Finalsens1
Bsp
Bsp/Bsp_NoFish
1000 3000 5000 7000
rHCR1 Finalsens1
Bsp_K
CPUE
0.2 0.6 1.0 1.4
rHCR1 Finalsens1
Bsp_BspNoFishing
CPUE
0.70 0.75 0.80 0.85 0.90
rHCR1 Finalsens1
F.mal
Survey index
0.10 0.15 0.20 0.25 0.30
rHCR1 Finalsens1
ActlCPUE.TIB
Survey index
0e+00 2e+183 4e+183 6e+183
rHCR1 Finalsens1
ActlCPUE.TVH
Survey index
0.0e+00 6.0e+183 1.2e+184
rHCR1 Finalsens1
Preseas1
Survey index
1 2 3 4 5
rHCR1 Finalsens1
Preseas0
CPUE
0.5 1.0 1.5 2.0 2.5
rHCR1 Finalsens1
Midsurv1
CPUE
1 2 3 4 5 6 7
rHCR1 Finalsens1
Midsurv2
0.5 1.0 1.5 2.0 2.5 3.0
rHCR1 Finalsens1
Future_CPUE_TVH
0.0e+00 1.0e+182 2.0e+182
rHCR1 Finalsens1
Future_CPUE_TIB
0e+00 4e+181 8e+181
rHCR1 Finalsens1

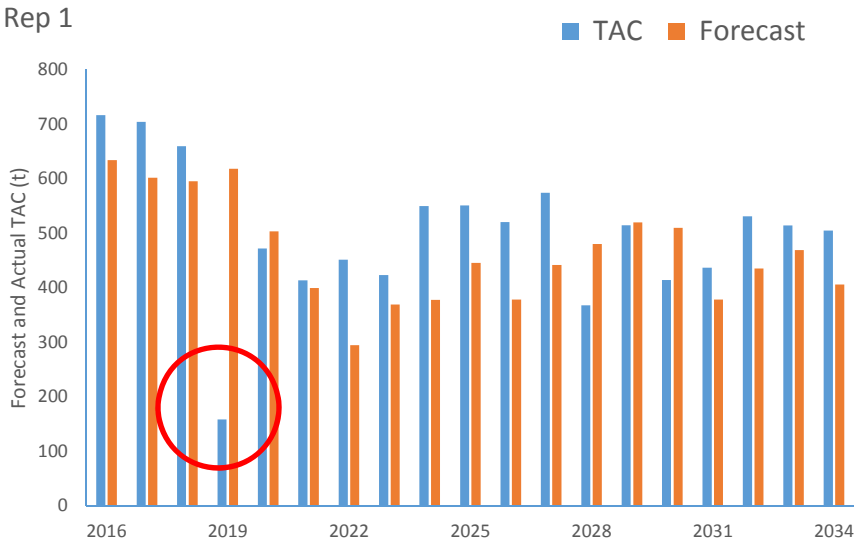

Finalsens1
Total catch
Replicate 619
Replicate 415
Median
Catch (t)
Spawning biomass
Replicate 6
Replicate 4
Median
Biomass (t)
Finalsens1
Risk properties
probility
Prop_times_Bsp.0.32K
Prop_times_Bsp.0.48K
AAV_catch
Prob_Closure

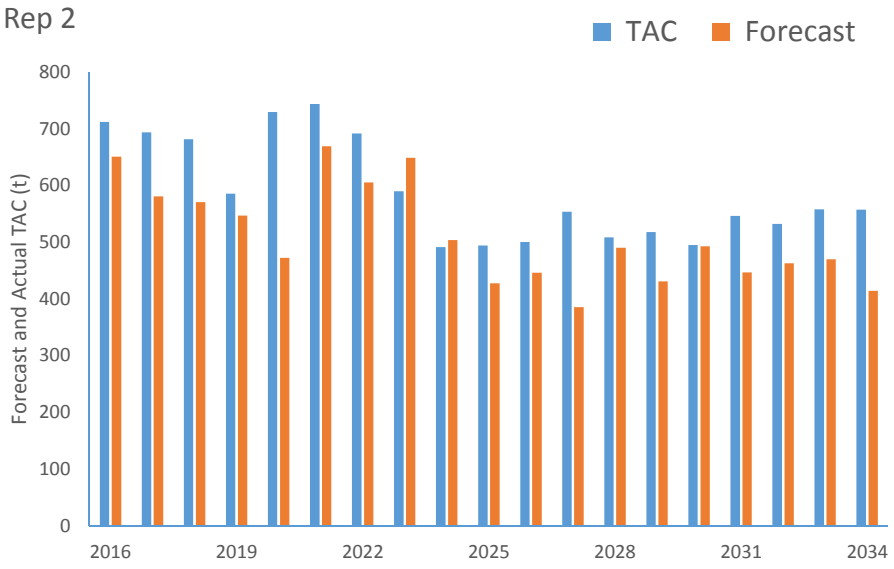

Finalsens2
Total catch
Replicate 619
Replicate 415
Median
Catch (t)
Spawning biomass
Replicate 619
Replicate 415
Median
Biomass (t)
Finalsens2
Risk properties
Prop_times_Bsp.0.32K
Prop_times_Bsp.0.48K
AAV_catch
Prob_Closure

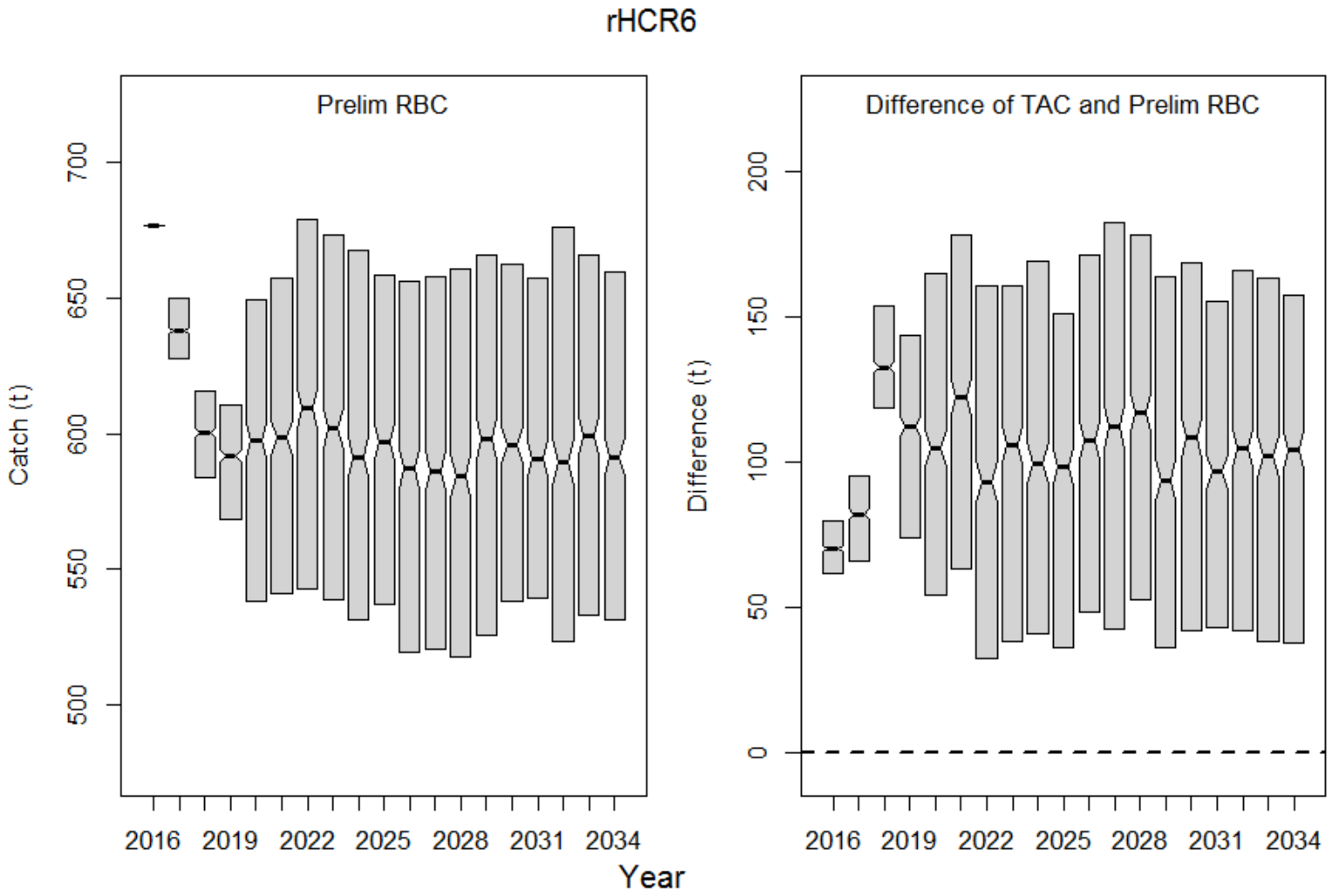
Forecast TAC : Empirical rule based on preseason survey 0+

Forecast(Year) = c * (1+slope0) * Catch_ave

- *c*= tuning parameter (0.85) to adjust so that forecast mostly < actual TAC
- Slope0 = same slope estimate as used in HCR
- Catch_ave = average of previous 5 years' catch







- Can tune so higher probability < final TAC
- Can improve predictive ability by improving precision of survey, particularly 0+ survey sampling (e.g. industry supplemented)

Auto-pilot approach?

- The HCR is an auto-pilot, but the pilot stays on the plane to check for unanticipated events (by conducting regular assessment updates)
- HCR reviews can be brought forward if appreciable changes in scientific perceptions about the resource occur
- Key criteria for such action are:
  - Indications that resource has moved outside the range for which the HCR was tested
  - Evidence to support this must be compelling, so that such action is not taken lightly

Butterworth (2007) Why a Management Procedure Approach

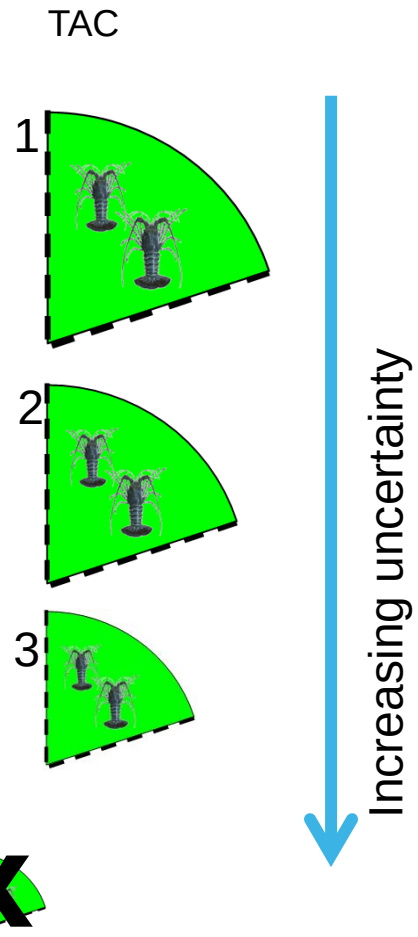
Potential revised harvest strategy

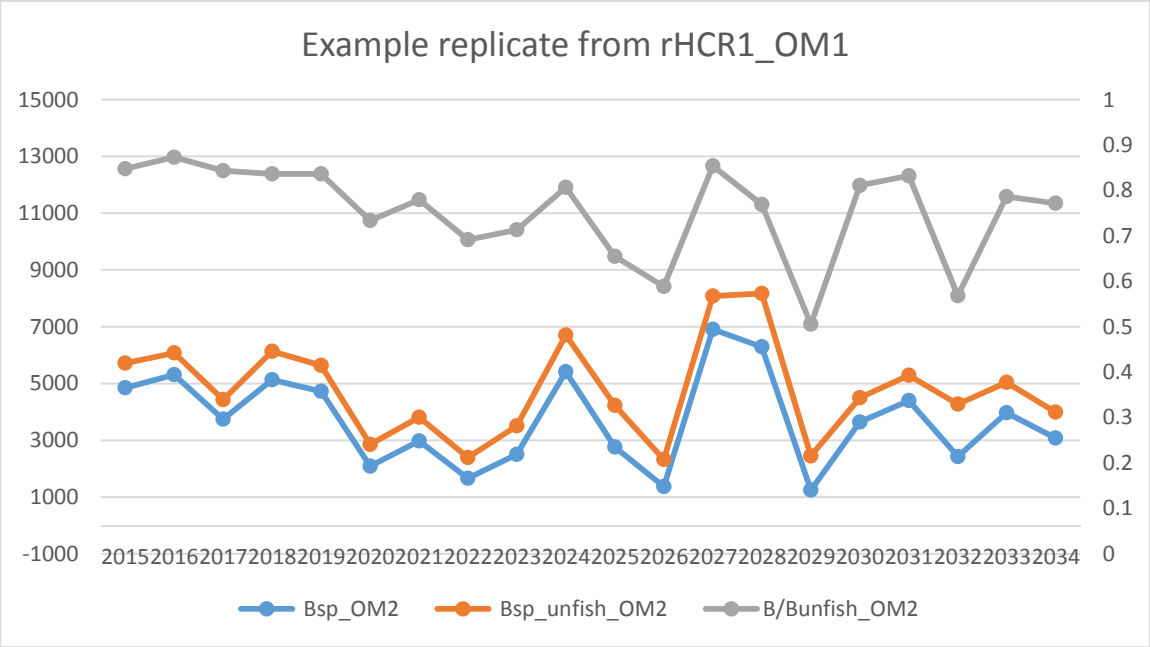
- Annual fishery data analyses (catch, CPUE, size structure)
- Annual survey data analyses (preseason 0+, 1+; any additional survey data)
- Annual implementation of empirical HCR to recommend TAC, also taking into account empirical proxies for resource status (survey reference points) + recommend Forecast TAC
- If exceptional circumstances – trigger action eg surveys, stock assessment, analyse size structure and environmental information
- Every 3 years – full stock assessment to more reliably assess stock status – if deviations from target level, recalibrate HCR

Alternatives for TAC setting

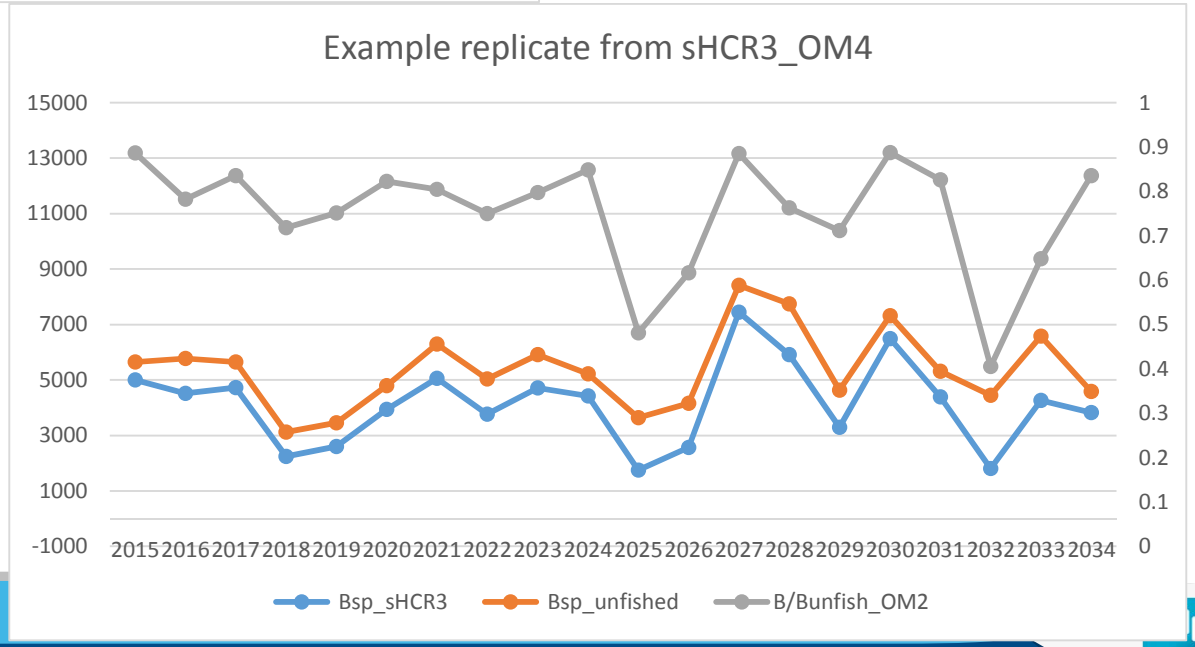
Empirical (data-based) HCR : alternatives depending on data availability and quality:

1. Bonus tier – Midyear and Preseason survey, reliable timely provision of catch data, TIB and TVH CPUE data
2. Top tier - Preseason survey, reliable timely provision of catch data, TIB and TVH CPUE data
3. Middle tier – Preseason survey + catch data
4. Low tier – No surveys, CPUE data
5. Penalty tier – No surveys, no CPUE data




Example replicate from rHCR1_OM1
15000
13000
11000
9000
7000
5000
3000
1000
-1000
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034
Bsp_OM2
Bsp_unfish_OM2
B/Bunfish_OM2

$B_{unfished}$


Example replicate from sHCR3_OM4
15000
13000
11000
9000
7000
5000
3000
1000
-1000
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034
Bsp_sHCR3
Bsp_unfished
B/Bunfish_OM2

Revised Harvest Strategy Reference points (targets and limits)

B_{targ} $=0.8B_{unfished}$

$B_{unfished}$ is assumed to be the model-estimate of spawning biomass at the end of the projection period (2034) under a no-fishing scenario

Btarg has been chosen by TRLRAG as a proxy for BMEY

B_{lim} (0.5Btarg) $=0.32\ B_{unfished}$

If LRP is triggered in 2 successive years, then the fishery is closed

F_{targ} – estimated by model to keep stock around B_{targ} $=0.15$

$B_{threshold}$ /$B_{trigger}$ - Biomass level below which more stringent rules for calculating TAC are applied

$=0.48B_{unfished}$

Thank you

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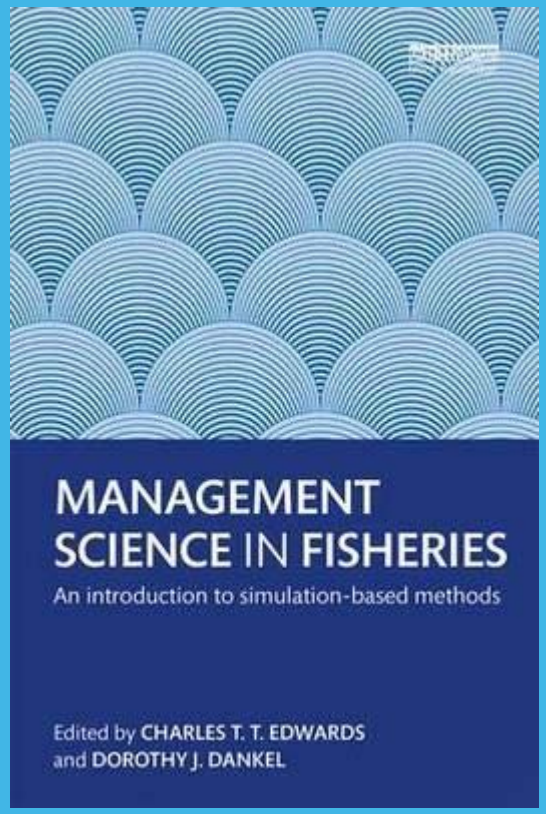

Book on MSE just published!