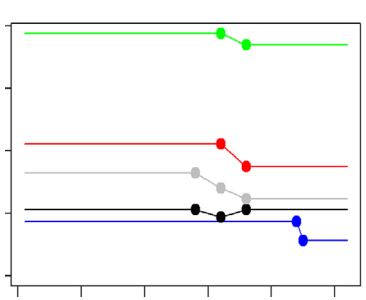
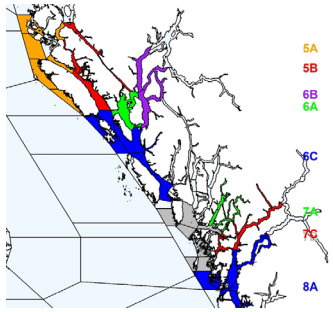
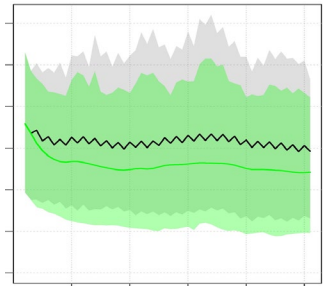
B.C. Sea Cucumber Reference Case Operating Model Development

Updated data, models and example results

6th February 2024







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openMSE

www.openmse.com

PROJECT PAGE:
https://mis-assess.github.io/csrf_hh_io/

CODE:
https://github.com/mis-assess/csrf_hh_data/tree/main/OMs

Aim & Objectives

Aim: Develop a framework for synthesizing data and knowledge into formal operating models for informing management decision making.

Objective 1: Obtain Sea Cucumber data and process these data for conditioning (fitting) population and fishery dynamics models (operating models).

Objective 2: Identify key knowledge and data gaps for refinement of operating models.

Objective 3: Outline key management questions and evaluate these with regard to stated performance objectives.

Contents

1. Data updates

QMA resolution modelling:

Density calculation

Biomass calculation

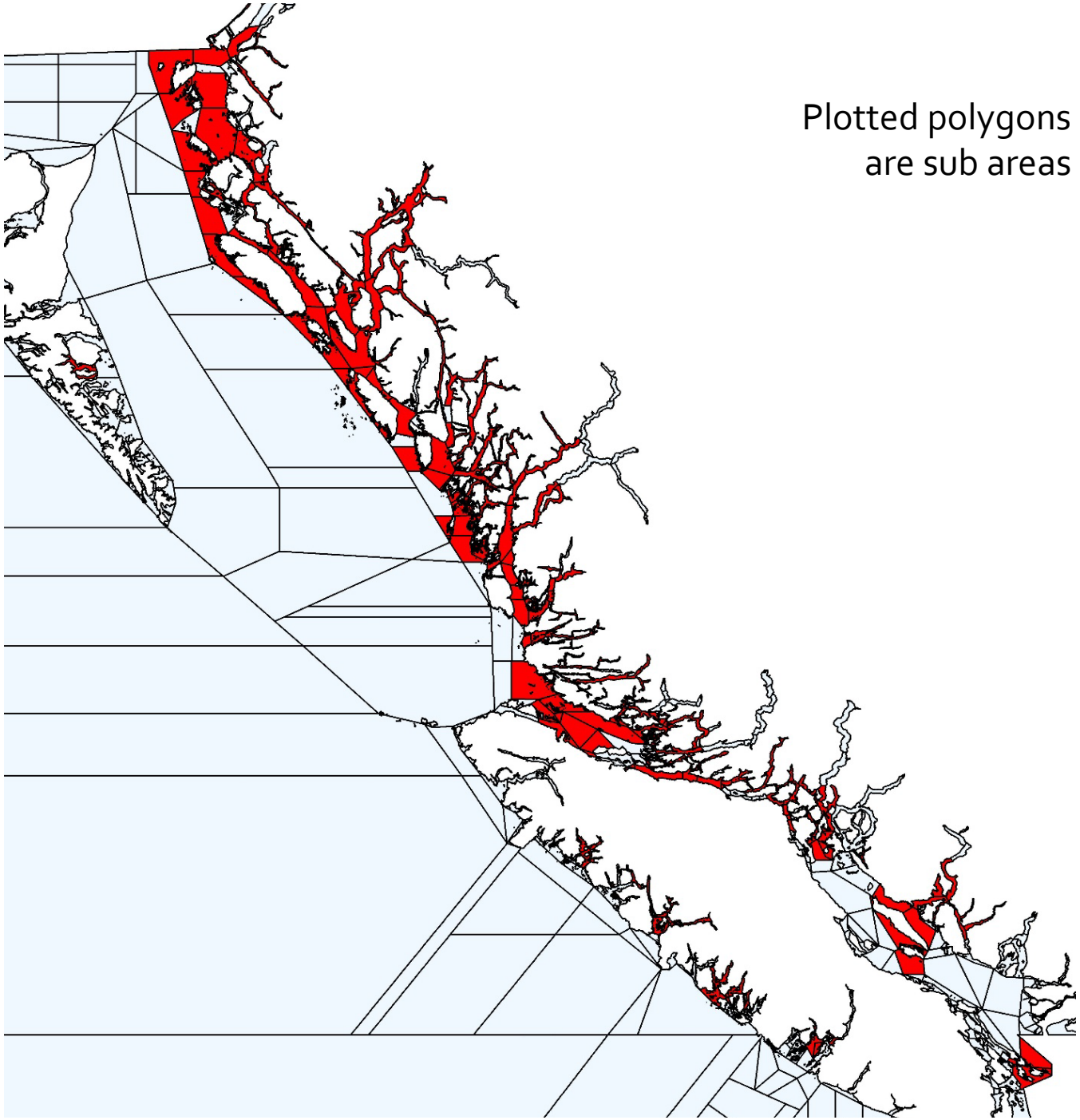
Mean weight calculation

Catch numbers calculation

Giant red sea cucumber, *Apostichopus californicus*

Landings data from 1998 – 2022

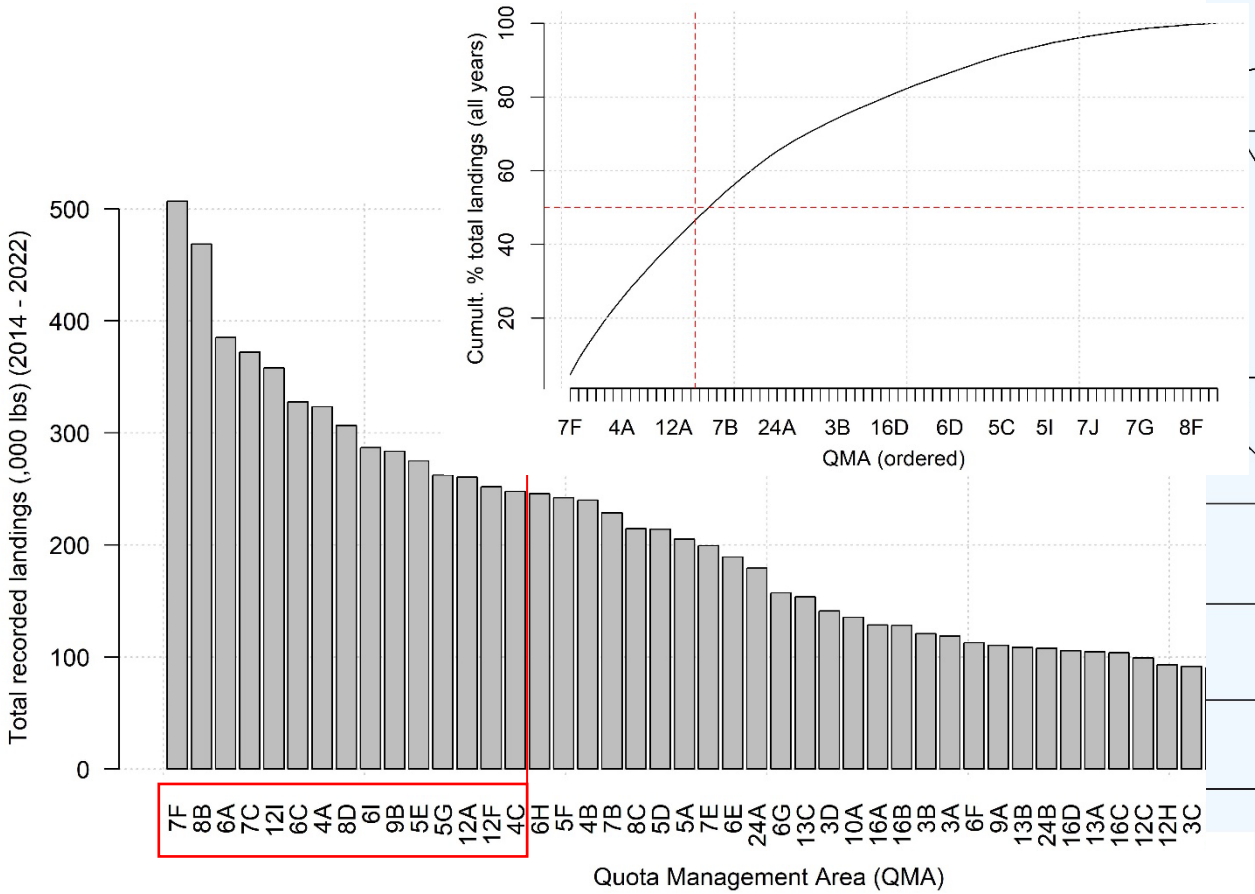
- 49 Management Areas
- 84 Quota Management Areas (QMAs)
- 613 Sub Areas

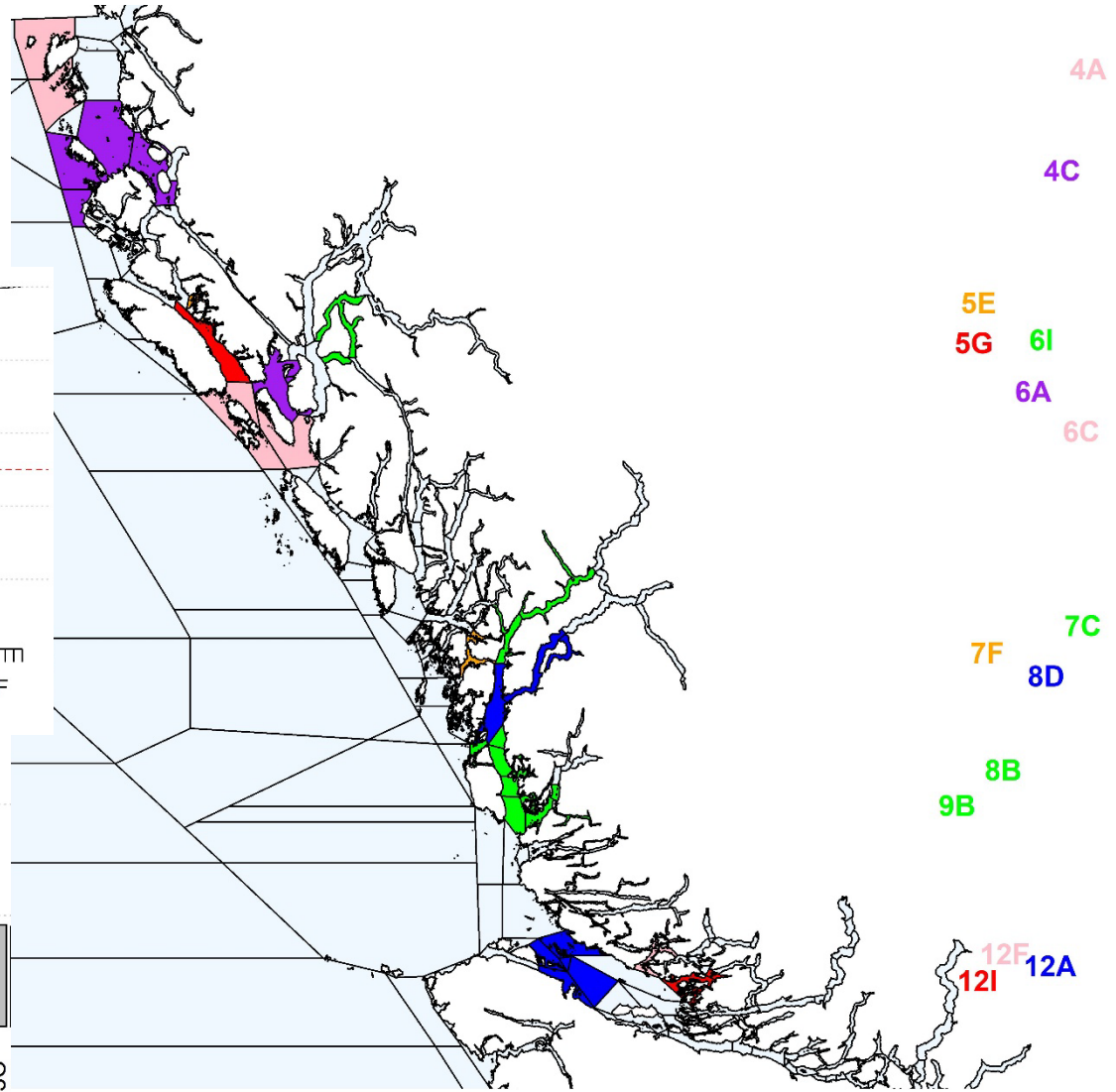


Plotted polygons are sub areas

Note on temporal / spatial definitions

- The spatial unit is Quota Management Area (84 in dataset with landings)
- Landings data are available up to 2022
- 50% of reported landings (2013 onwards) are found in 15 of the QMAs





QMA resolution poses challenges (required data are sparse – at least on the repo)

- Very few QMAs have a density observation in all sub areas (at some point) - viewSeaCukeDensities.csv
- No QMAs have a complete extracted biomass estimate - SeaCucumberReportDataExtractionTable.xlsx
- No QMAs have a mean split weight observation for all sub areas (at some point) - CukeWeightBySubAreaAllData.csv
- Absolute numbers + mean weight (absolute biomass estimates) are needed to set TACs by QMA but are not currently available to my knowledge (the code may be available to do this)

Catch in weight, weight-biology not known and management by numbers

- Catch is reported in kg
- Density data are by numbers
- Somatic growth unknown
- Weight-length unknown
- Weight and length highly variable
- Management essentially numbers-based with empirical mean weight

Extracted biomass data (kg) not available for all sub areas of each QMA

4 QMAs with 3+ years of density estimates (at sub area level):

QMA	MA	SA	Bio
6A	6	5	NA
6A	6	26	NA
6A	6	27	NA
7C	8	5	NA
7C	8	6	NA
7C	8	7	152458
7C	7	30	NA
6C	6	9	NA
6C	6	10	NA
8D	8	4	NA
8D	8	13	90505
8D	8	14	82616

Biomass data (kg) not available for all sub areas of each QMA

10 QMAs of highest historical landings

Type	MA	SA	Biomass
8A	9	1	NA
8A	8	2	NA
8A	9	2	NA
8A	8	3	NA
8A	8	4	NA
8A	9	12	NA
8A	8	13	90505
8A	8	14	82616
8A	8	16	NA
8A	7	26	NA
8A	7	27	NA
8A	7	28	NA
7C	8	5	NA
7C	8	6	NA
7C	8	7	152458
7C	7	17	NA
7C	7	30	NA

Type	MA	SA	Biomass
7B	7	2	NA
7B	7	3	NA
7B	7	12	128869
7B	7	18	141531
7B	7	19	0
7B	7	20	NA
7B	7	21	NA
7B	7	22	8937
7B	7	23	88491
7B	7	24	109781
7B	7	25	313983
7B	7	31	NA
7B	7	32	NA
6C	6	9	NA
6C	6	10	NA
6C	6	11	8283
6C	6	12	84946
6C	6	14	31081
6C	6	15	18896
6C	6	16	72697

Type	MA	SA	Biomass
6A	6	2	NA
6A	6	3	NA
6A	6	5	NA
6A	6	11	NA
6A	6	26	NA
6A	6	27	NA
6A	6	28	NA
6B	6	2	NA
6B	6	3	NA
6B	6	6	NA
6B	6	7	NA
6B	6	8	NA
5B	5	1	NA
5B	5	13	NA
5B	5	14	107836
5B	5	15	NA
5B	5	16	461810
5B	5	17	259400
5B	5	18	NA
5B	5	19	NA
5B	5	23	NA
5B	5	24	NA

Type	MA	SA	Biomass
5A	5	2	NA
5A	4	3	NA
5A	5	4	NA
5A	5	5	NA
5A	5	7	NA
5A	5	11	NA
5A	5	12	NA
5A	5	13	NA
5A	5	20	NA
5A	5	21	NA
5A	5	22	NA
12A	12	9	NA
12A	12	10	NA
12A	12	11	NA
12A	12	13	NA
12A	12	16	NA
7A	7	13	56864
7A	7	14	NA
7A	7	15	NA
7A	7	16	NA

SeaCucumberReportDataExtractionTable.xlsx

A Numbers-based operating model?

- Somatic growth is poorly understood (individuals are difficult to age, measure or weigh)
- Length – weight unknown and naturally variable (time and space, among subareas of a QMA)
- Individuals can lose weight / shrink
- Density surveys are in numbers

- Tactical management by PMA is essentially numbers-based but converted to TAC advice in weight by an empirical estimate of mean weight:

CTAC = ER * PDE * SL * ASW

ER: exploitation rate

PDE: precautionary density estimate

SL: shoreline length

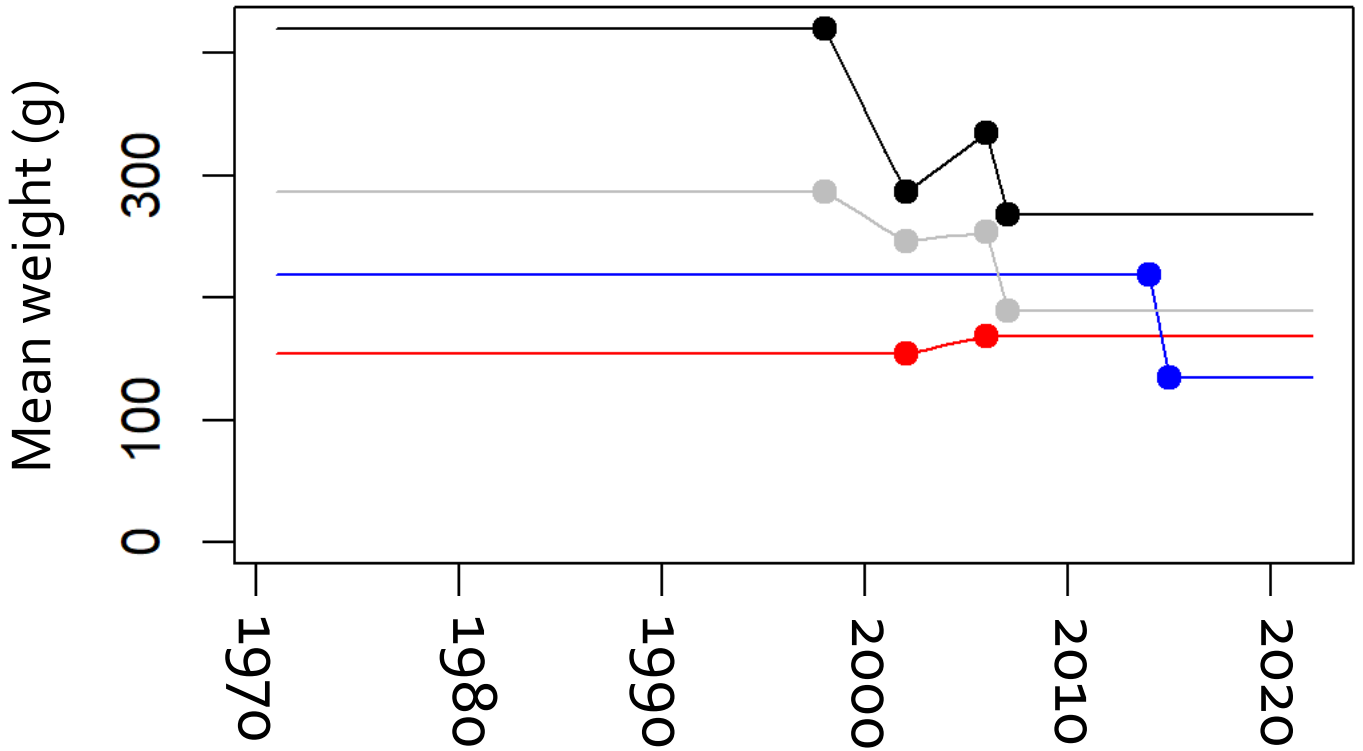
ASW: average split weight

However, catches are reported in weight! Either an OM that tries to simulate weight/size or a numbers based OM conditioned on catch converted to numbers?

Numbers model + catch in numbers
vs
model including length / weight + catch as reported, by weight

I have some mean weight observations but they need to be extrapolated / interpolated to calculate catch in numbers by subarea – but presumably something like this happens to get estimates of sub area biomass for the purposes of TAC calculation?

E.g., the 5 sub areas of QMA 7C have *some* empirical weight data:



Assumptions

Key uncertainties:

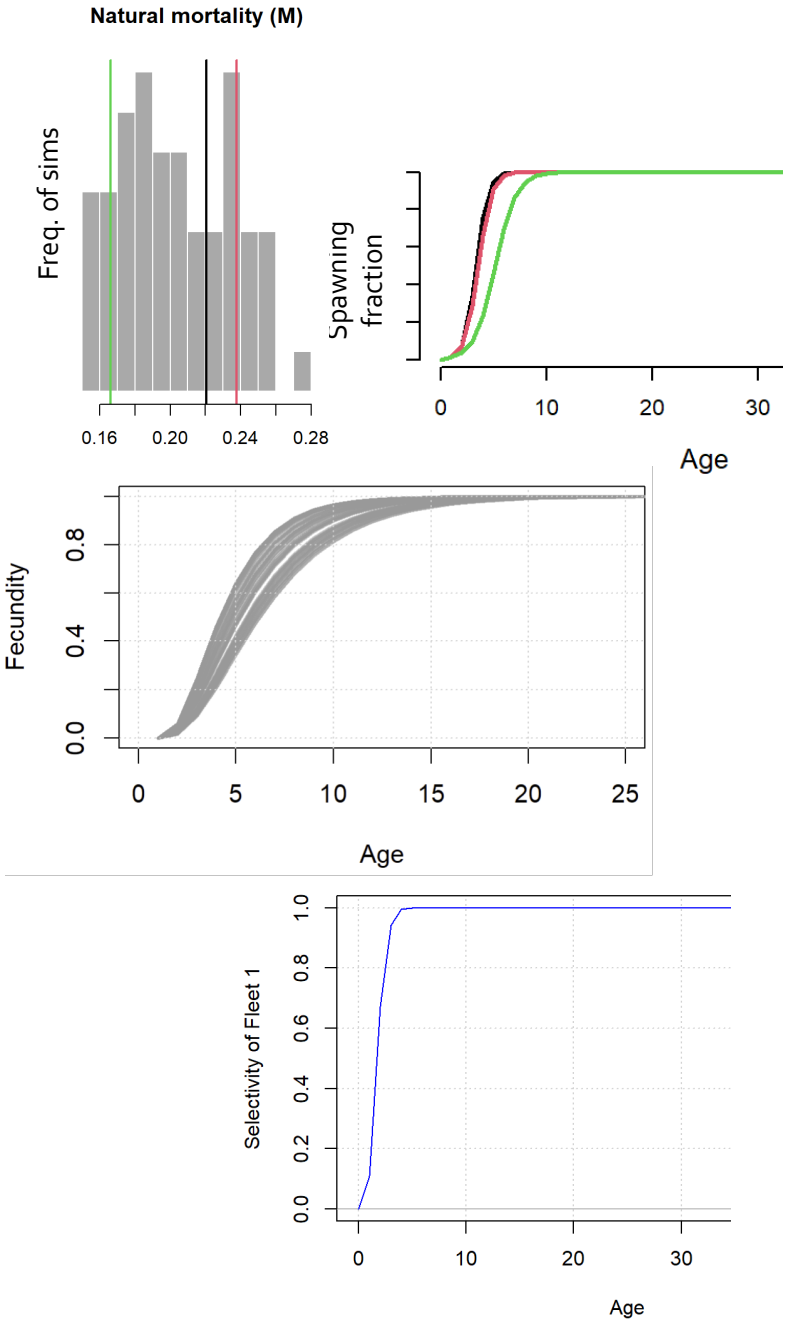
- Natural mortality rate is assumed to be age- and time-invariant and in the range of [0.15, 0.3] roughly equivalent to maximum ages (to 5% cumulative survival) in the range of 10 to 25 years.
- Stock resilience is a core uncertainty. Steepness is assumed to be in the range of [0.5, 0.8] between 50% and 80% unfished recruitment at 20% spawning stock abundance.
- Individual are assumed to be sexually mature between 3 and 8 years
- Fecundity is assumed to be cubic function of relative length calculated from K_{fec} another key source of uncertainty in the model and assumed to be between 0.3 and 0.5 (max length yr^{-1}) (should be correlated with M?) Fec = (1-exp(-Ka))^3

A 'numbers' model:

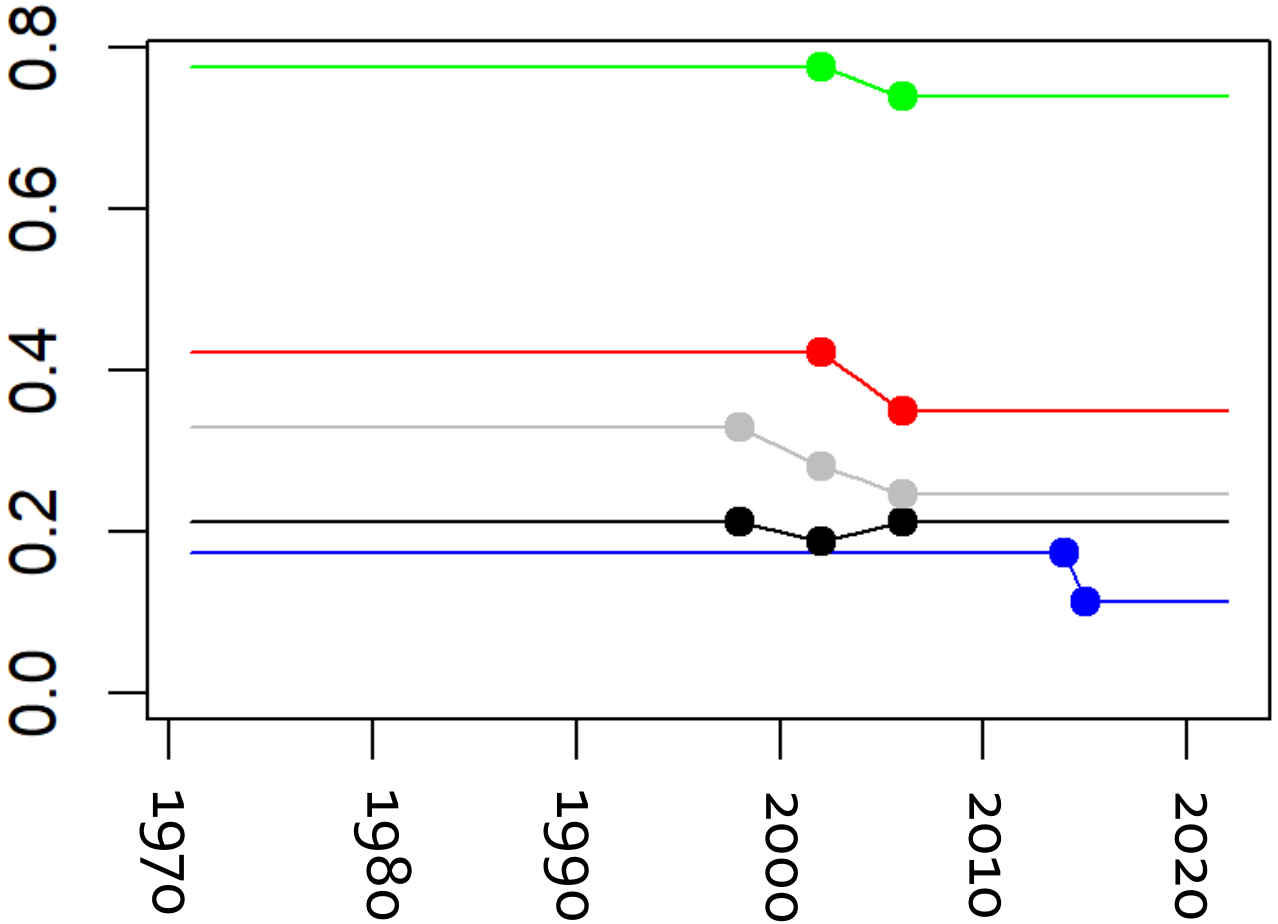
- Asymptotic length is unitless and set = 1 (weight = numbers) (von B. Linf = 1)
- Growth to 'an individual' is rapid and occurs before vulnerability to fishing (von B K = 0.8)
- Length – weight parameters are set to 1. I.e., W = L ≈ 1 for vulnerable individuals

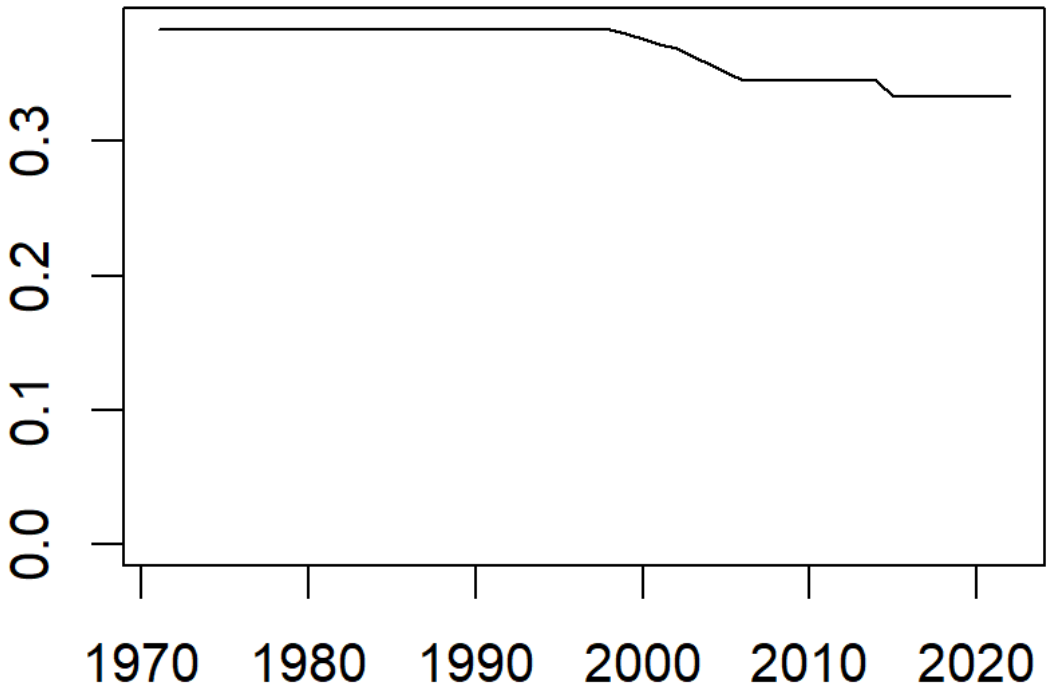
Other assumptions:

- Zero discarding / discard mortality
- Selectivity is asymptotic, 100% at age 4-7
- Fishery catch data were assumed to be taken almost exactly (5% CV)



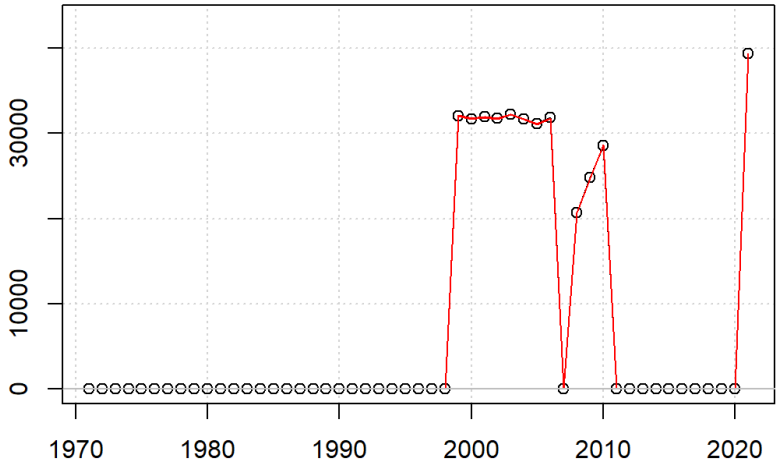
5 sub areas of 7C: density is difficult to scale from subarea to overall QMA:





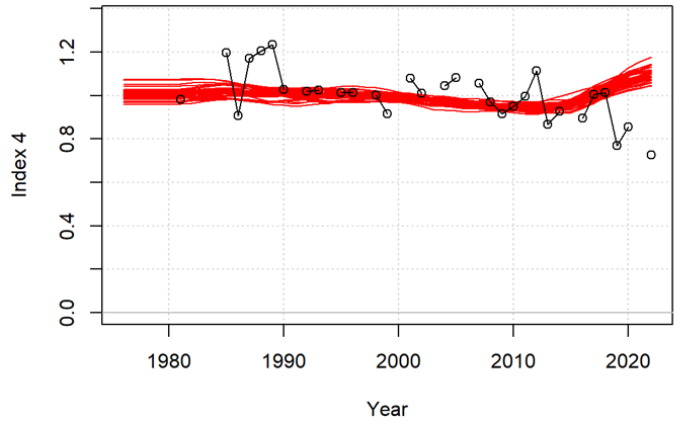
Current conditioning approach

Fishery Catch time series by number (ASW)

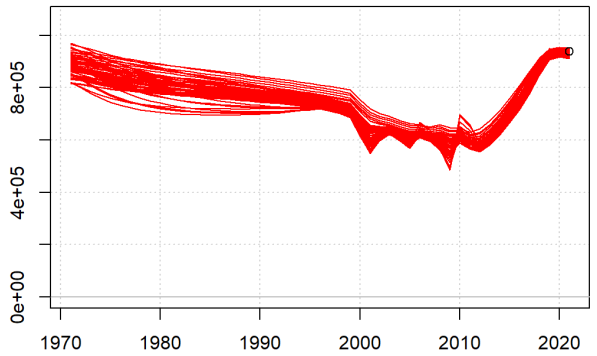


Density survey (#2)

Commercial CPUE (n per hour)



Absolute biomass / numbers survey ?

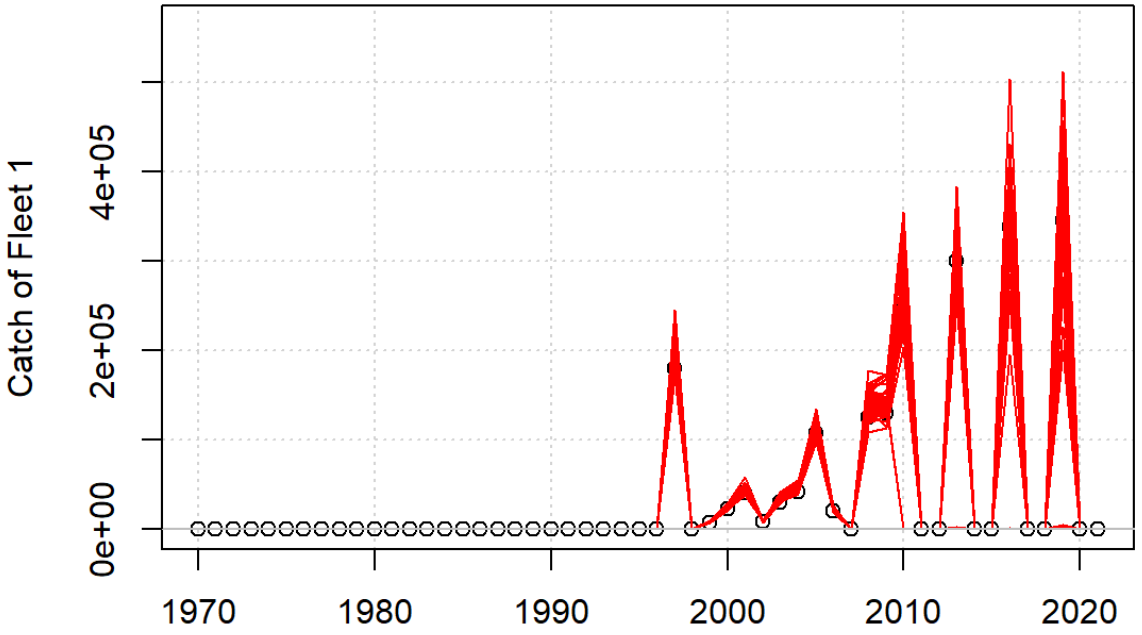


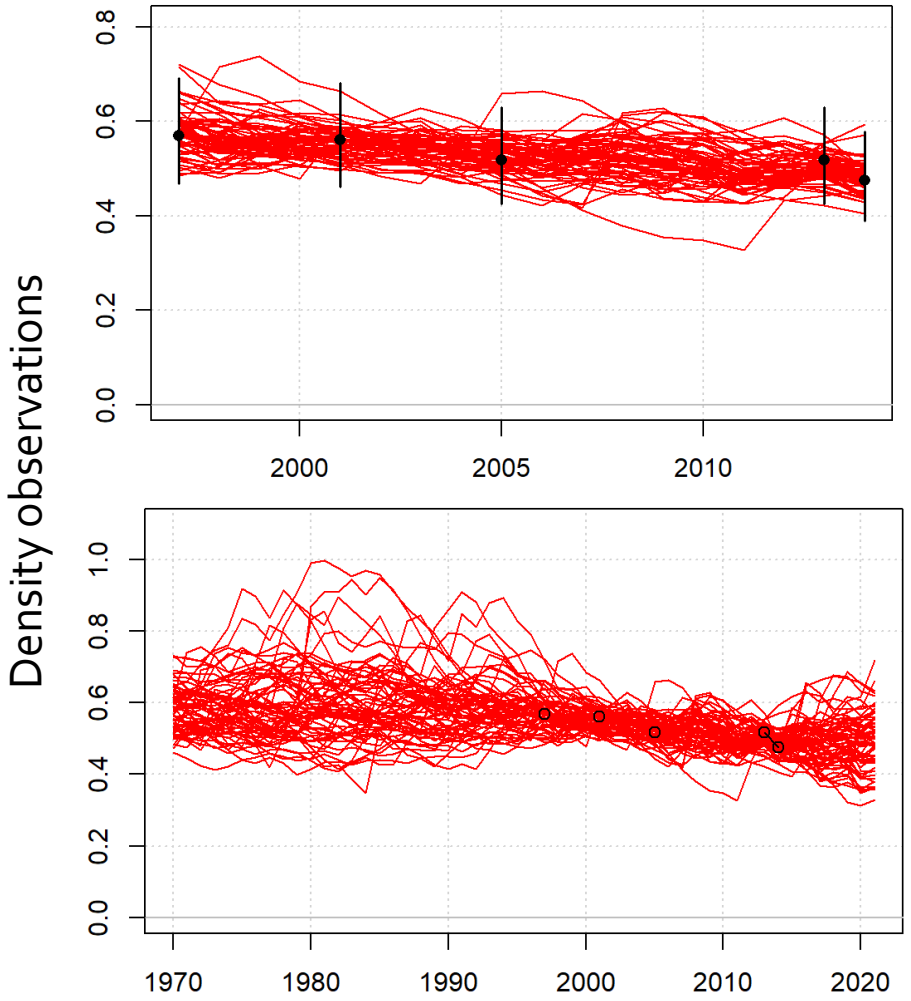
RCM (Rapid Conditioning Model of openMSE)

- Peer-reviewed statistical catch at age / length model
- Fits individual models (multiple red lines in figures above) given sampled parameter values for population and fishery dynamics such as M, steepness etc)
- Creates an openMSE operating model for calculating reference points, evaluating harvest control rules, harvest strategies, data collection protocols etc.

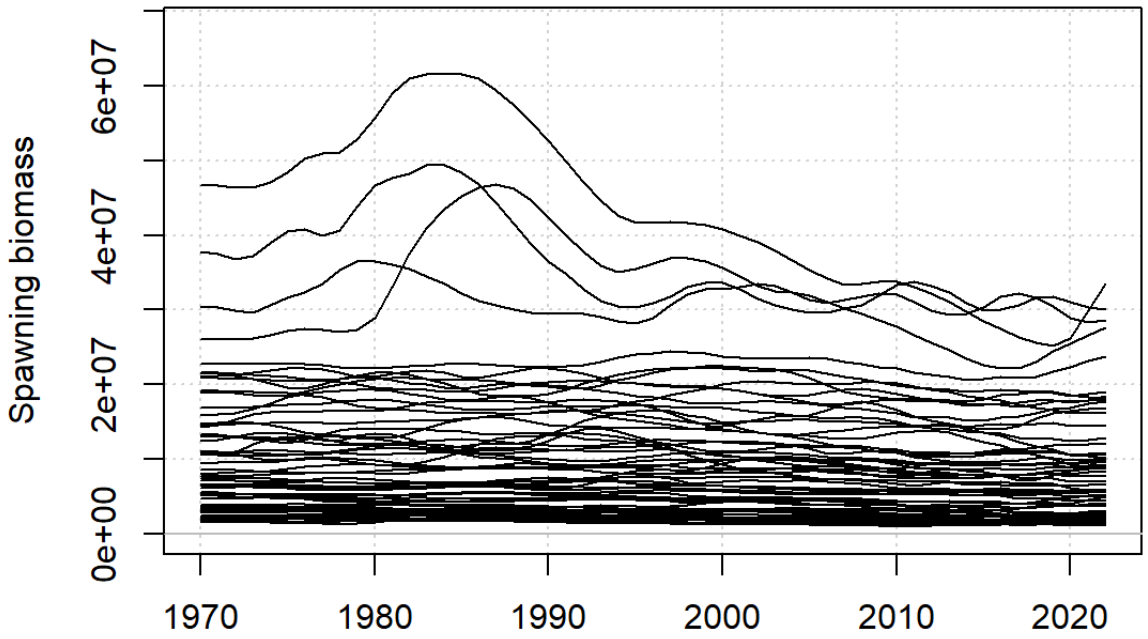
Example RCM fit to QMA 7C data

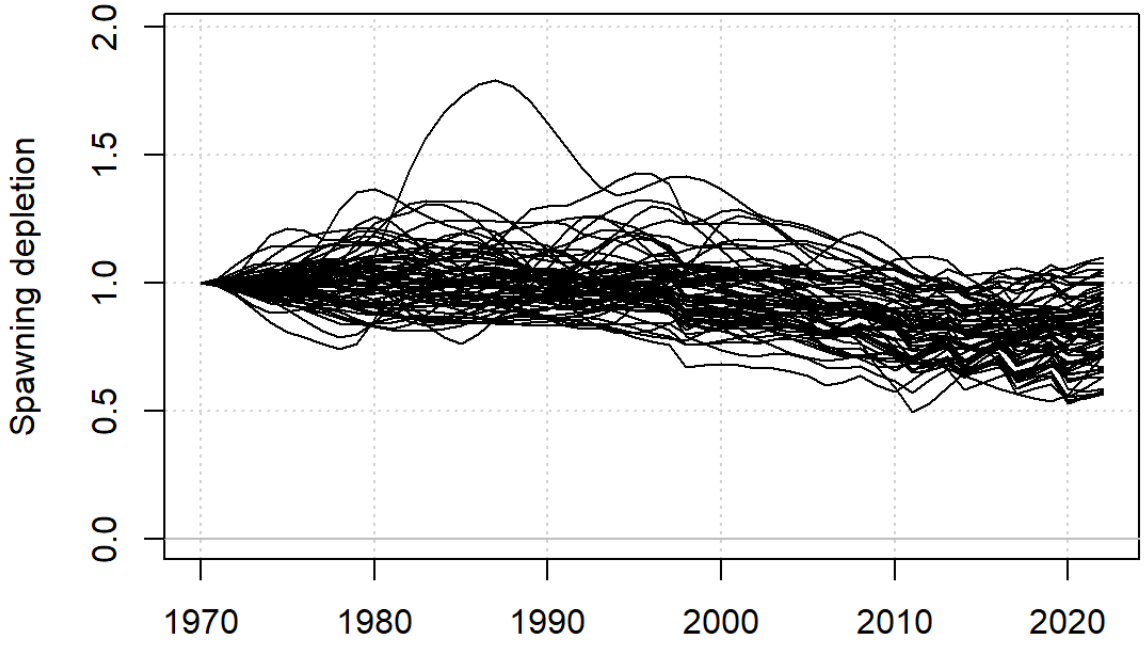
Model is attempting to reconcile observed catches with density observations – locating scale and depletion





Since we added very little info about absolute scale the model only has precision in estimates of stock depletion and sustainable harvest rates





Quantities (unrelated to scale) imply current management rules / reference levels are highly precautionary

QMA	SSB / SSBMSY			Harvest rate at MSY			SSB 2022 / SSBMSY			SSB2022 / SSB0
	Mean	2.50%	97.50%	Mean	2.50%	97.50%	Mean	2.50%	97.50%	Mean
6A	0.262	0.197	0.325	0.37	0.208	0.649	3.053	1.632	6.549	0.768
7C	0.265	0.212	0.33	0.36	0.167	0.634	2.703	1.309	4.363	0.807
8D	0.265	0.198	0.324	0.363	0.189	0.653	4.644	2.537	7.625	0.893

From IFMP:

- LRP at 50% Bo based on data and models from Phase 1 fishery
- 4.2 and 6.7 % (newly reopened) harvest rates
- Triennial harvest rate of 10% used on some QMAs

More on data inputs?

Priority 1:

- The R code / data access for calculating current absolute biomass / numbers
- ASW by sub area in extracted table
- Send list of surveyed subareas to DFO managers to select 10 – 20 sub areas that represent a range of ecological / biological conditions and management approaches

Priority 2:

- Commercial CPUE

IFMP notes on management regime

'Adaptive Rotational Fishing Strategy (ARFS)'

~ 8 week annual opening (maximum effort?)

3-year rotational closure (some annual according to FMP – 'seem to work better', 'Not all QMAs are equally productive')

Limited entry of 85 licenses (still?) - Area licensing (WCVI, ECVI, CC, North Coast)

Coast-wide TAC of 1.36 million pounds - Individual quota 1/85.

QMA TAC by precautionary density estimate and mean split weight (Hand et al 2009: range of 3.5 and 10.3% for an annual style fishery).

2.5 c/m-sh as a minimum density threshold reference level (exposed) 0 c/m-sh (very exposed).

Recreational take is unknown assumed to be low.

First Nations fishing is unknown (but low – 2% FSC set aside?)

Sea Cucumber stock enhancement?

LRP at 50% Bo based on data and models from Phase 1 fishery

4.2 and 6.7 % (newly reopened) harvest rates (data available?)

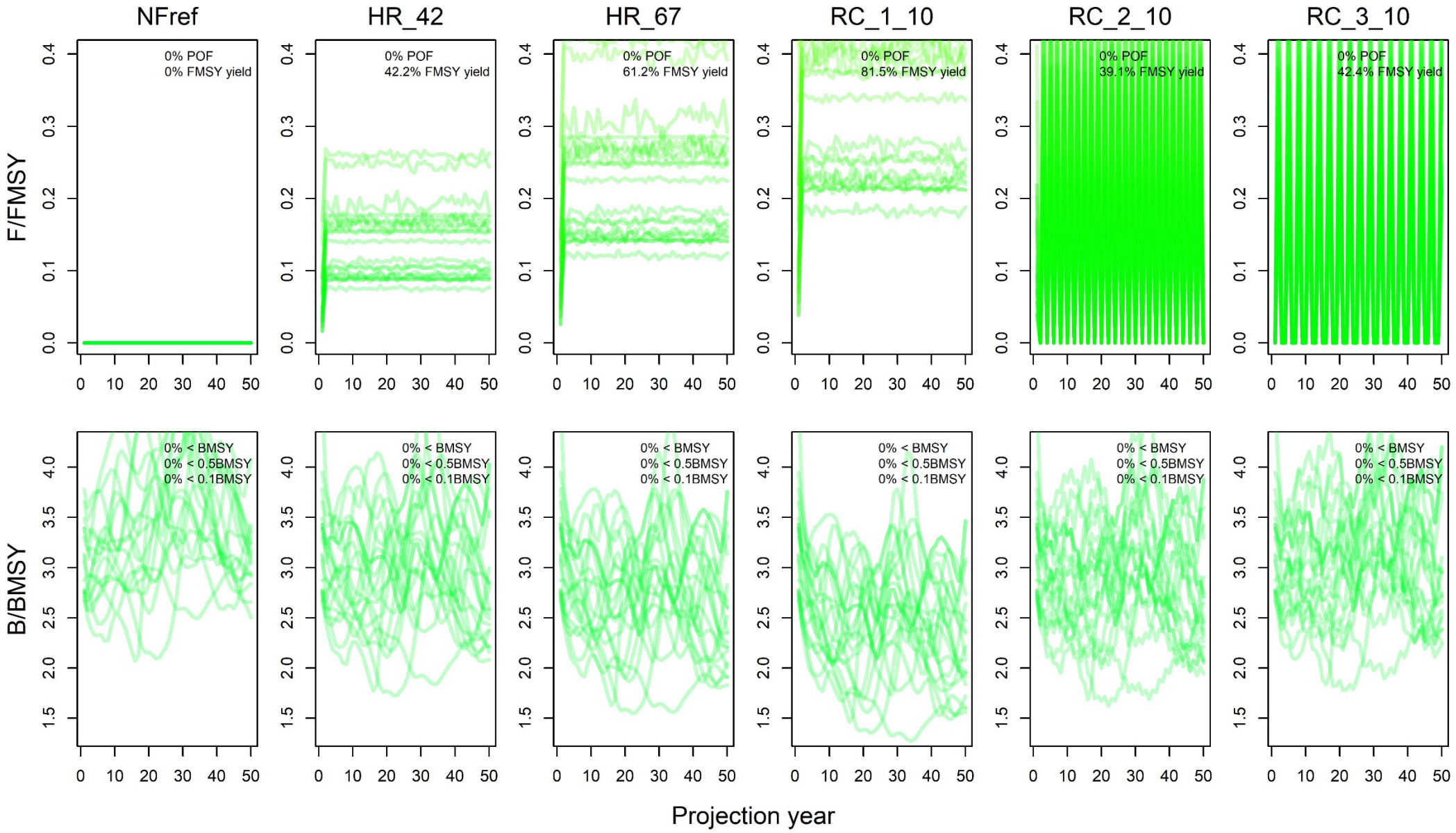
Triennial harvest rate of 10.3% used on some QMAs (data available)

Some management projections

No fishing

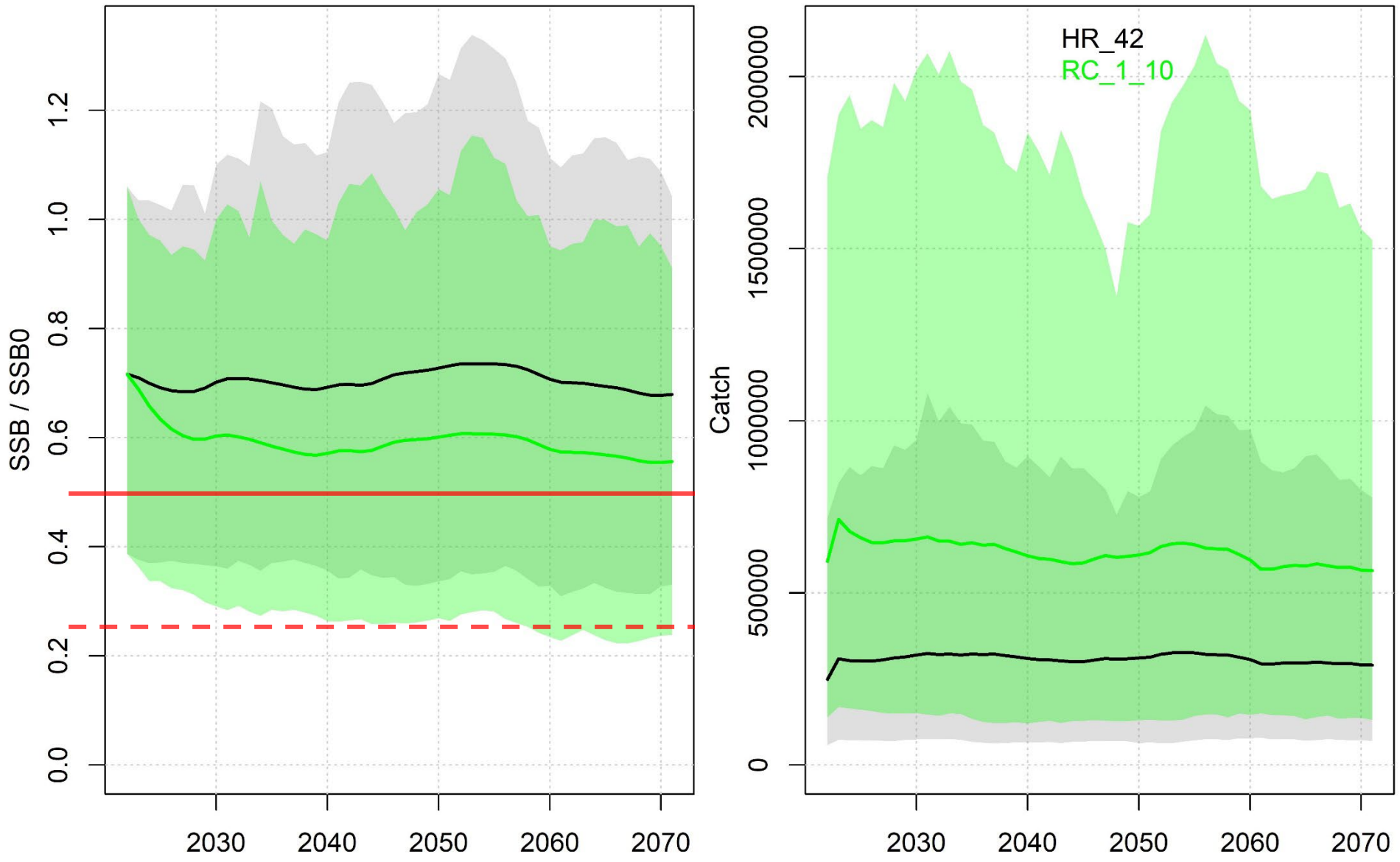
4.2 and 6.7 % annual harvest rate

Rotational closure 1 (none), 2, 3 years at 10% harvest rate



Now with depletion and 90% interval

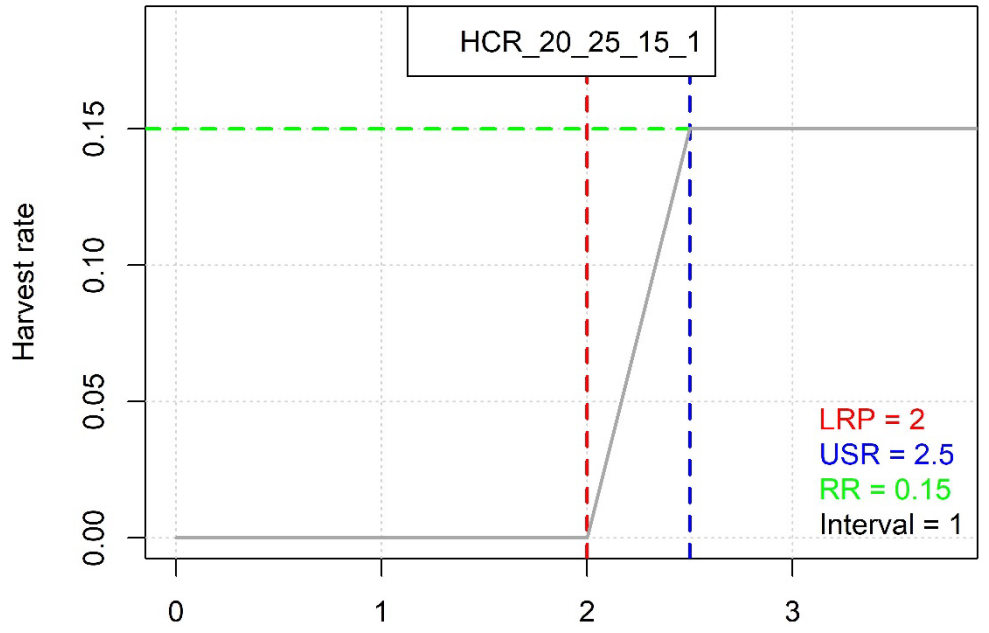
4.2% vs 10% harvest rate

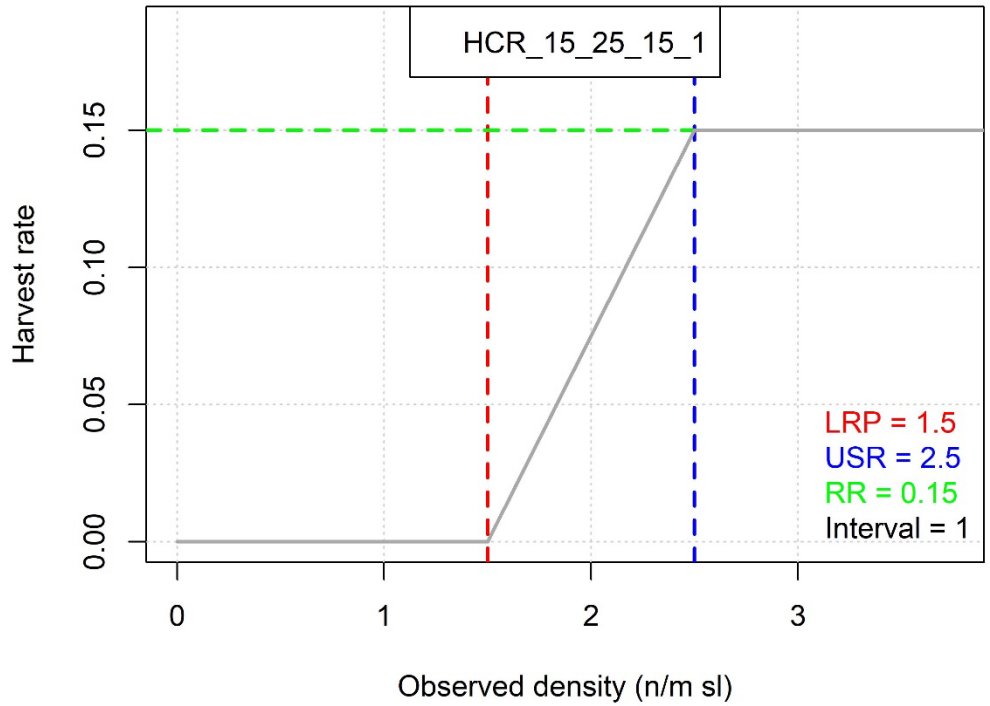


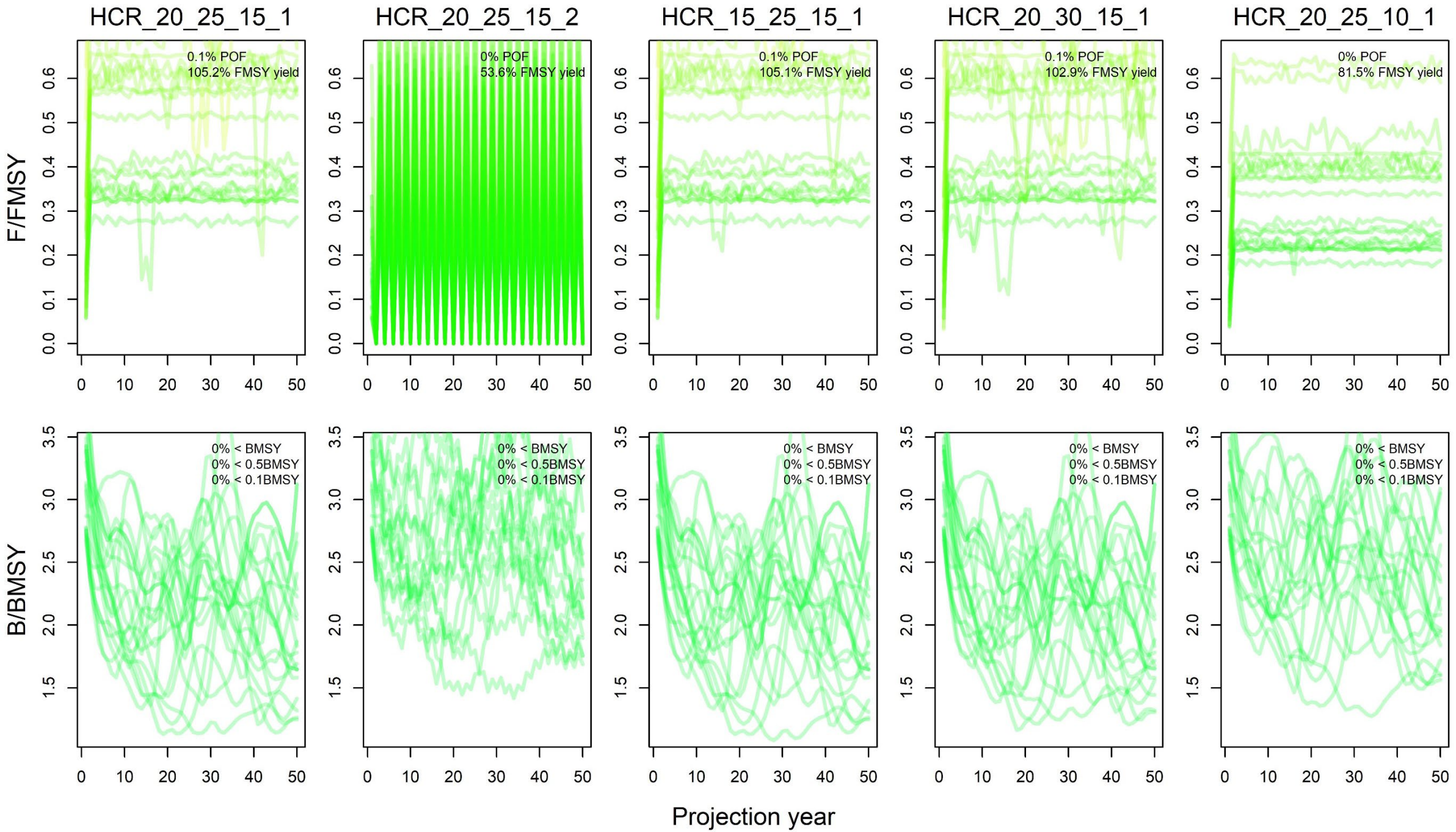
MPs that use density as control points

Tested 5 versions:

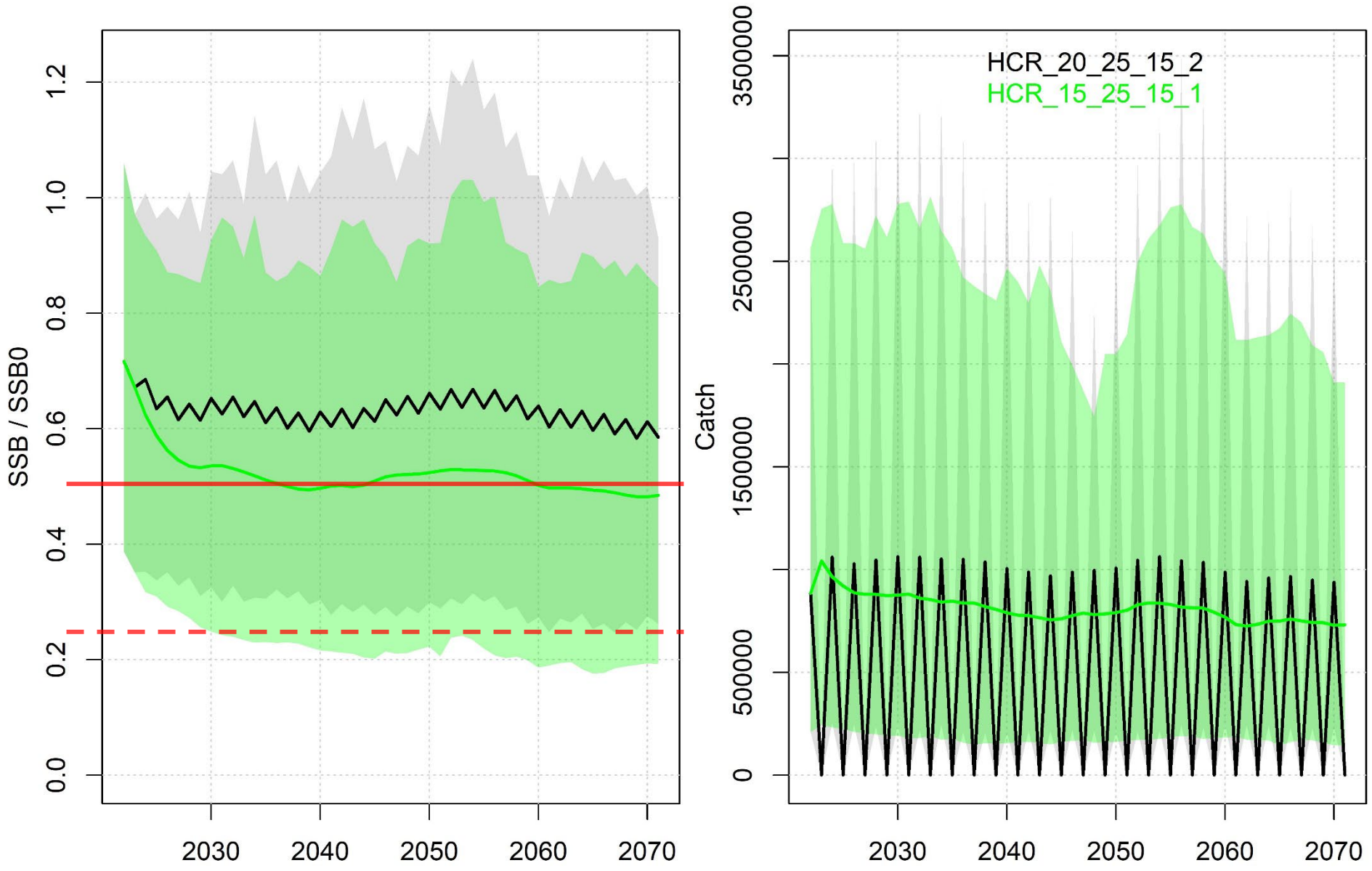
HCR_20_25_15_1
HCR_20_25_15_2
HCR_15_25_15_1
HCR_20_30_15_1
HCR_20_25_10_1






HCR_20_25_15_1
HCR_20_25_15_2
HCR_15_25_15_1
HCR_20_30_15_1
HCR_20_25_10_1
F/FMSY
B/BMSY
0.1% POF
105.2% FMSY yield
0% POF
53.6% FMSY yield
0.1% POF
105.1% FMSY yield
0.1% POF
102.9% FMSY yield
0% POF
81.5% FMSY yield
0% < BMSY
0% < 0.5BMSY
0% < 0.1BMSY
Projection year

Now with depletion and 90% interval



4. Next steps

Data finalization

Areas for operating model refinement (M, h, fecundity, maturity)

Management questions

Robustness

Performance metrics

Data Finalization: items that would be helpful

- Absolute biomass / numbers or (code for those) that are used in QMA TAC calculation (priority)
- Shoreline length per QMA – allows for density c/m-sl control points on HCRs
- Commercial CPUE c/hour
- Better catch in numbers – my average weight calculation is suspect!

Management measures

- TACs based on Fixed harvest rate
- Rotational closures
- Access (license freeze)?
- Age / size limit?
- Tying existing management measures to QMA

Metrics?

- 50% Bo as an LRP
- Density relative to target / limits (e.g. 2.5 c/m-sl)?
- Yield
- Yield stability

Robustness tests

- IFMP on sea otters, illegal harvest:

  'A study done in southeast Alaska showed that the long-term presence of Sea Otters resulted in an up to 100% decline in Sea Cucumber densities (Larson et al. 2013).'

  'Illegal harvest activity has increased over the last few years. The increase in the value of Sea Cucumbers has made them a target for illegal harvesters'.

- Maturity / Fecundity (on / off) (density dependent)
- Sigma R (recruitment variability)
- Steepness
- Selectivity (density dependent)
- Subarea – QMA dynamics
- Natural mortality (level/max age(50), variability, trend)
- Economic model (on / off)
- Imposed spatial closures (30-30)
- Unreported catches (communities fisheries with other reporting system)
-

Areas for operating model refinement

- Weight based OM?
- M, h, Kfec, rec devs (another trawl through the literature?)
- Fecundity ogive (1-exp(-Ka))^3
- Evaluation of coast-wide abundance?
- Developing operating models at varying spatial scales?

More on analyses, management questions?

One or more problem statements or questions:

- What density per subarea is indicative of overfishing?
- How precautionary are current management approaches?
- What is the conservation benefit of no-take subareas?
- Is the 2.5 c/m-sl reopening threshold important to conservation?
- Which areas are currently most at risk?
- What is the relative performance of fontrol points based on unfished density (by subarea) rather than a nominal density (e.g. x c/m-sl)?
- what is the relative performance of alterative control points?
- subarea control points – how well do these achieve overall (summed) LRP performance across multiple areas?
- 15cm 'pencil' effect (is there something more relevant to fishers)
- What small scale impacts are potentially masked by coastwide FSP reporting?

Performance metrics

- Yield
- Conservation (LRP), SSB0, BMSY, density
- Stability in yield
- Economic viability (e.g., catch rate over minimum threshold)
- Accessibility (access to high density areas)
- Harvest rate

More on next steps

Notes on next steps

Thanks!

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Mackenzie Mazur