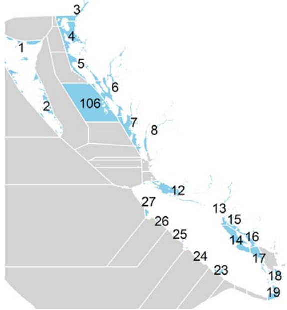
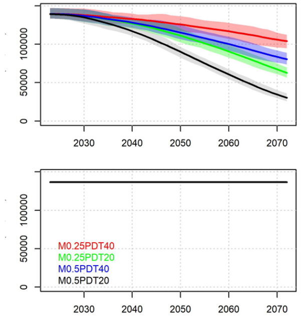
B.C. Geoduck Reference Case Operating Model Development

Updated data, models and example results

17 November 2023





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

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

Contents

1. Data updates

Age- length observations

Length-weight observations

Annual absolute biomass survey by sub-bed

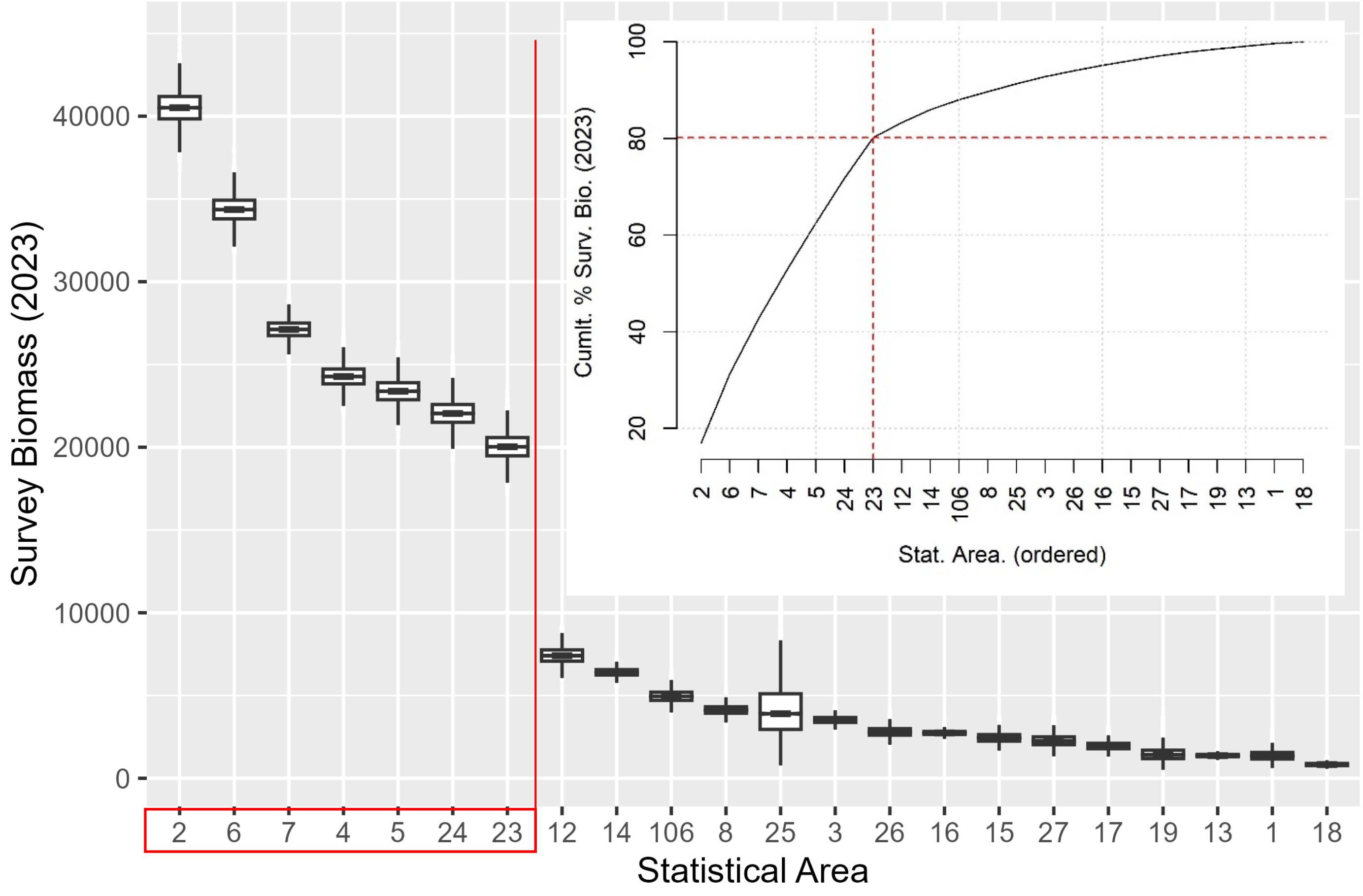
Age-composition survey data by sub-area

Annual catch data by statistical area

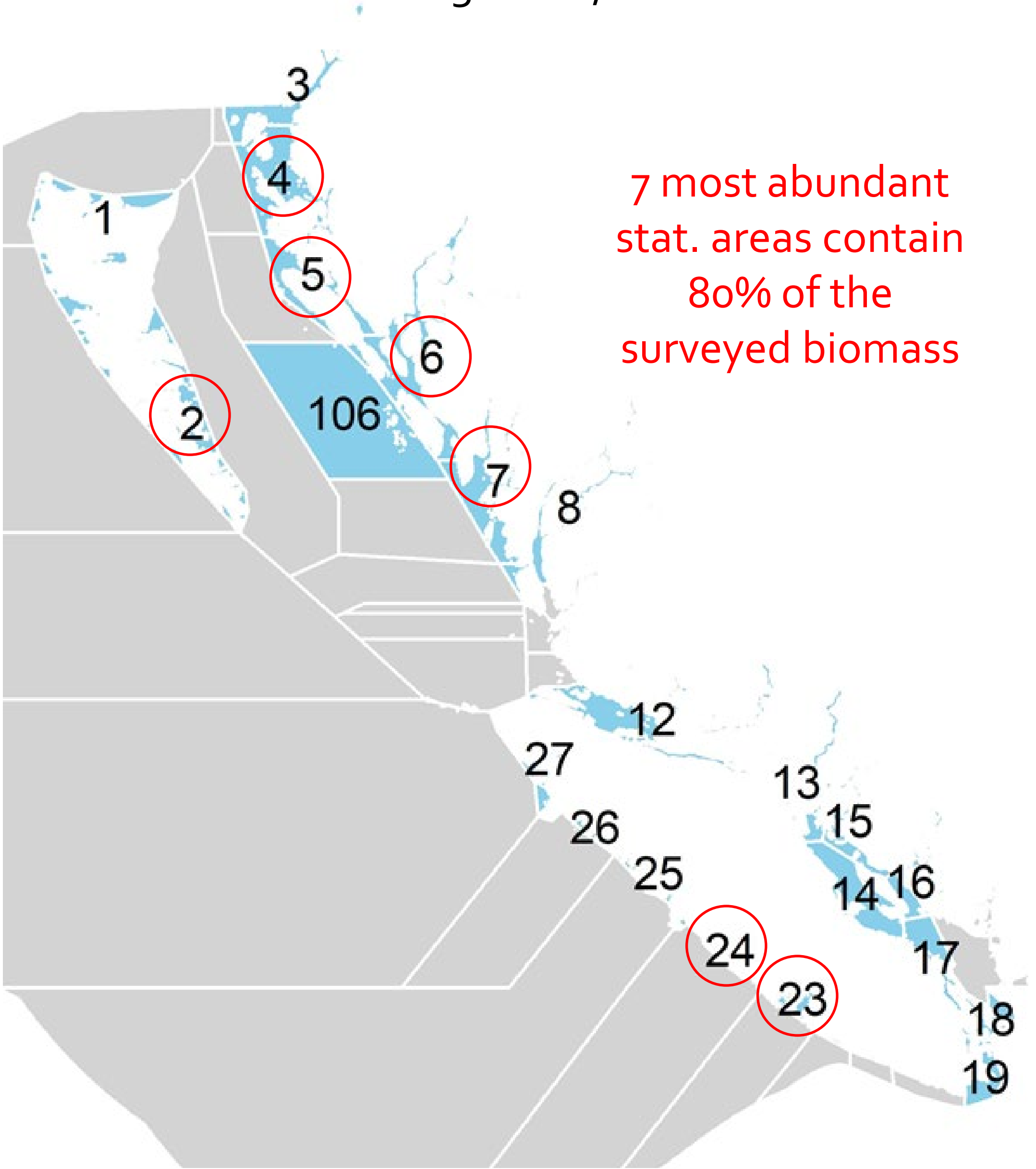
Fishery dependent CPUE data

Note on temporal / spatial definitions

- The spatial unit is Statistical area
- Some data are available up to 2023, but for now the models are fitted to 2022.
- The most abundant areas by survey biomass are: 2, 6, 7, 4, 5, 24, 23

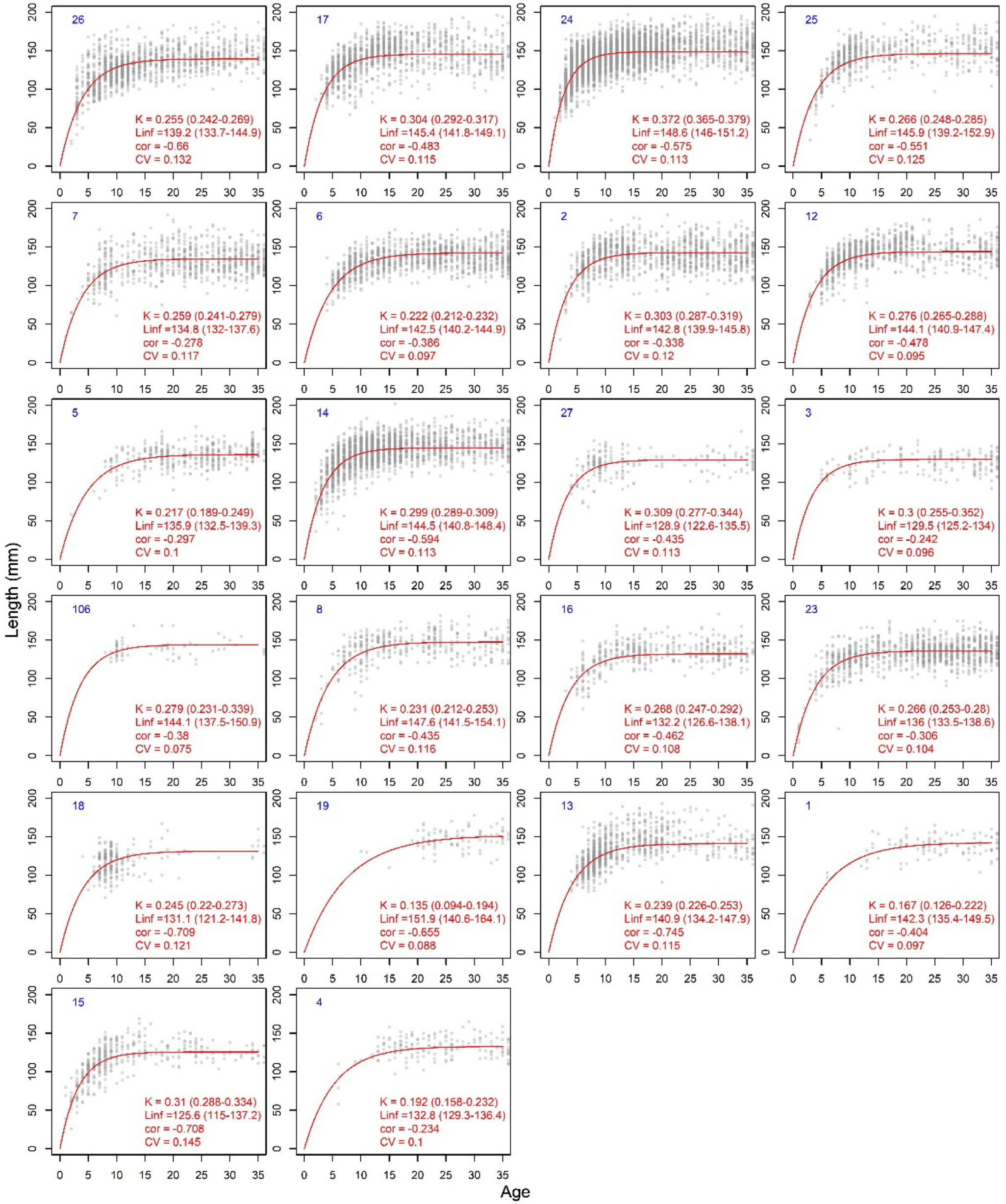


22 stat. areas have age data, not source = RSO

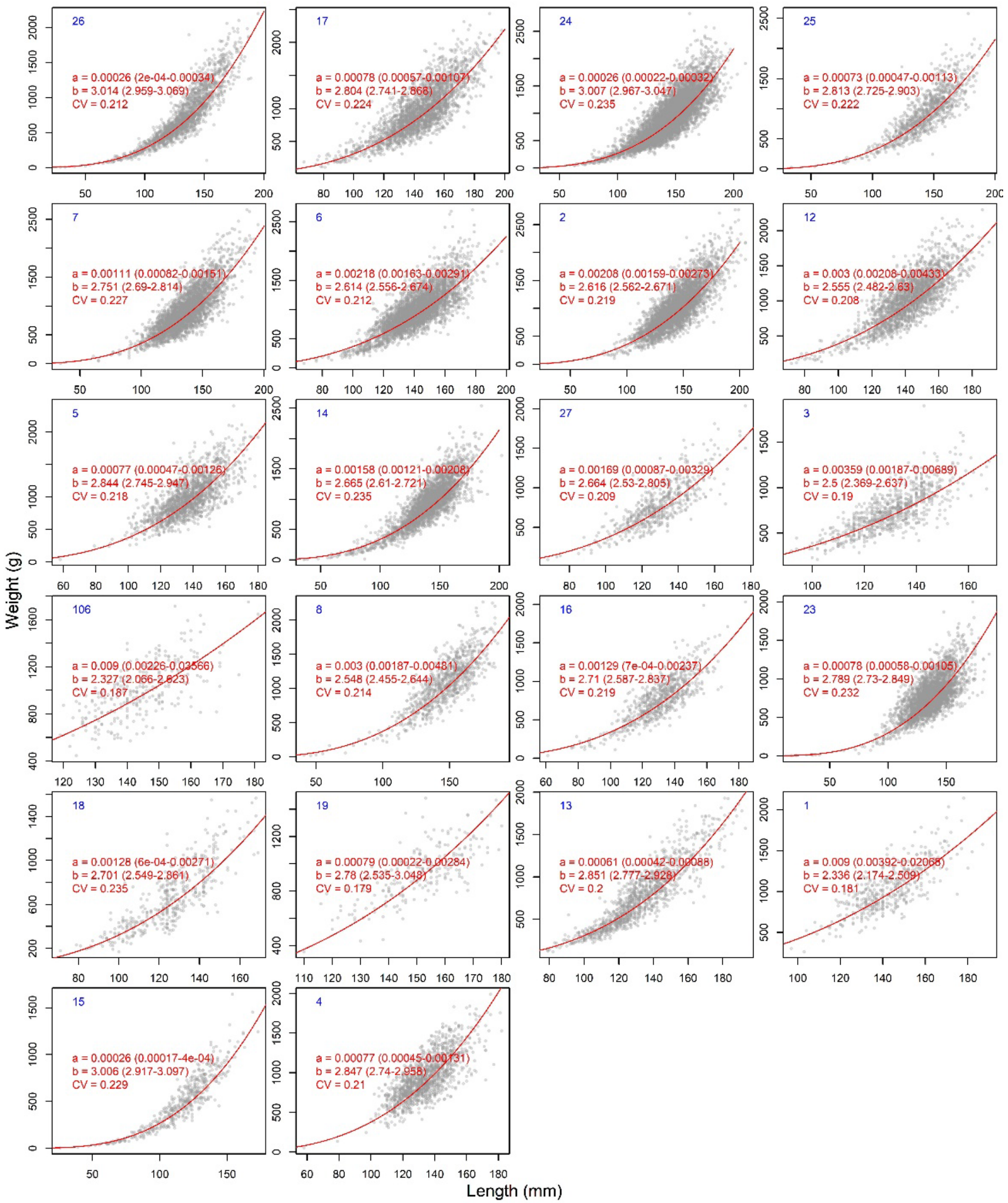


Unchanged from February

Somatic Growth (VB)



Length-Weight



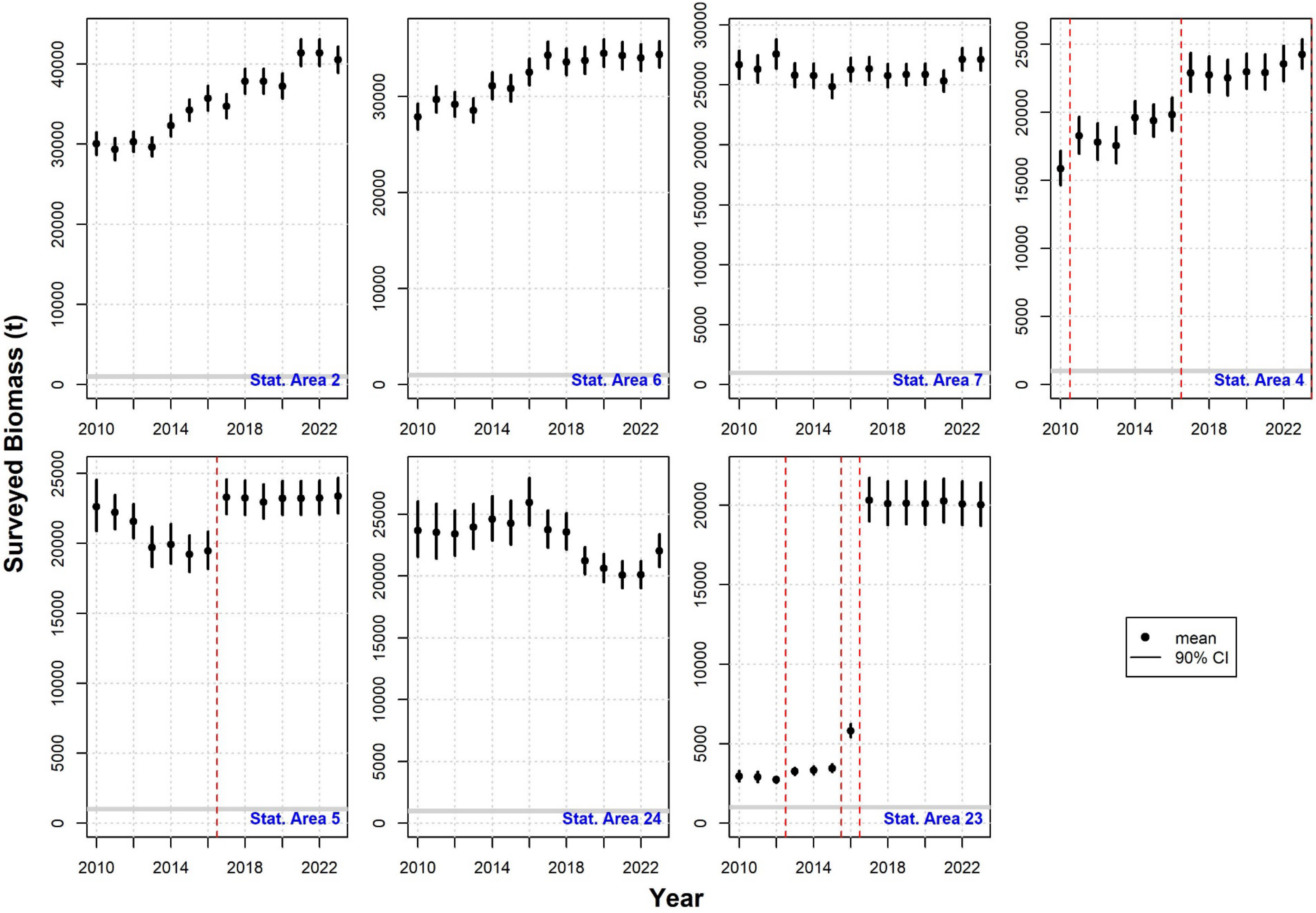
Now have time series of surveyed biomass from 2010 – 2023 including precision

Apparent discontinuities in the biomass survey.

Here, more than 15% changes among years are used to sever the index for the purposes of operating model conditioning.

Only chunks with more than 1 year were included.

The most recent chunk is assumed to be unbiased (q=1).



Calculation of survey biomass precision by Stat. area

1. Median and 75% CIs were provided by sub bed
2. The corresponding lognormal mean and St.Dev. was calculated
3. Total mean by Stat. area was calculated by summing the sub-bed means
4. Total St.Dev. by Stat. area was calculated assuming there were no correlations among the sub bed estimates:

$$\sigma_{Stat.area} = \sqrt{\sum \sigma_{sub}^2}$$

This interpretation provides the most precise estimate of Stat. area biomass. Note that when conditioning models, the data sources are assigned relative weights so the real issue is whether precision is representative over time and among indices rather than correct in absolute terms.

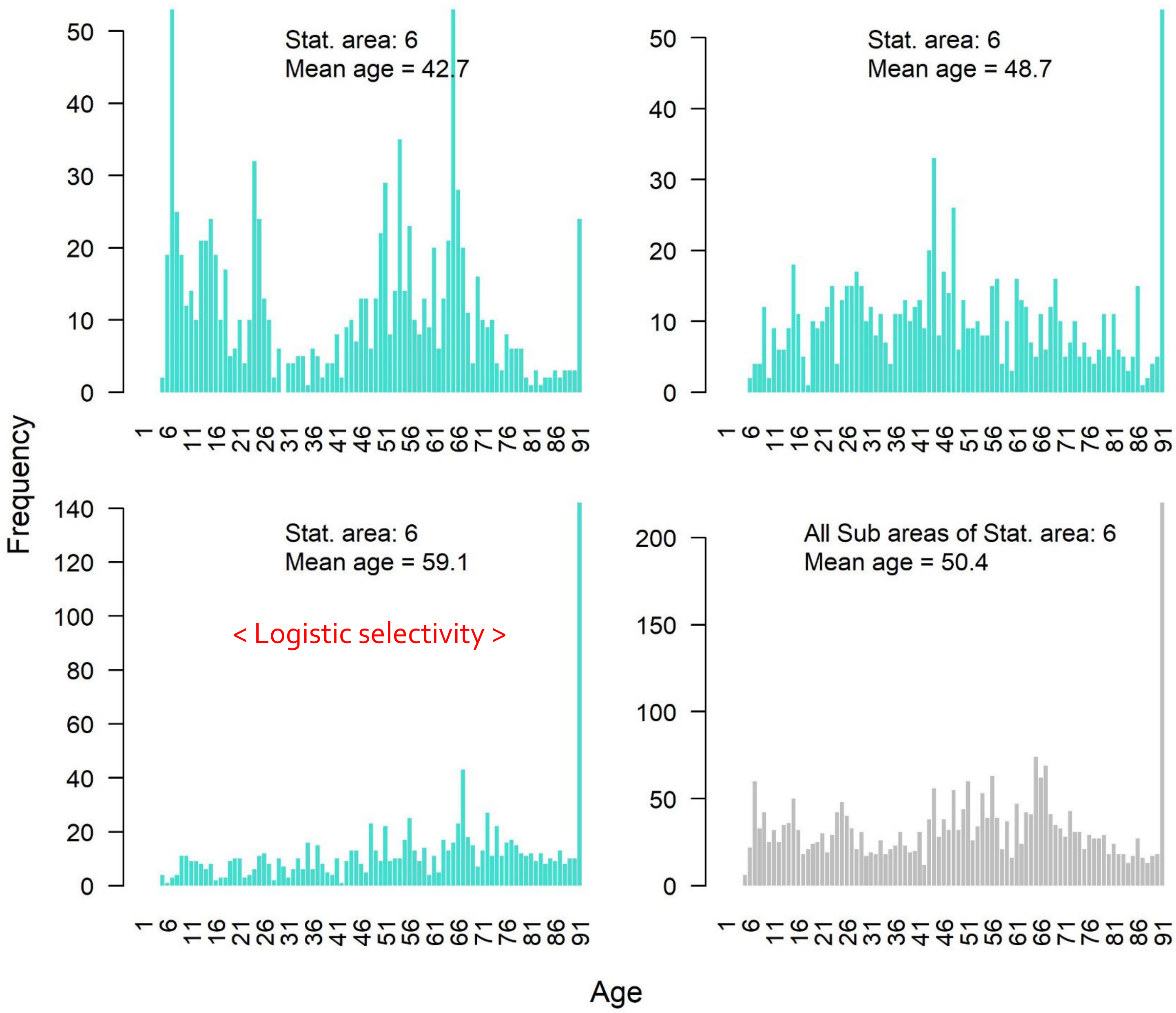
Age composition by sub-area

Age composition data for each statistical area were disaggregated sub-area to account for spatial heterogeneity in age structure.

The ‘oldest’ subarea (that with highest mean age) was assigned a logistic selectivity (flat topped, older individuals are as or more likely to be sampled), all other sub areas were assigned a dome-shaped selectivity.

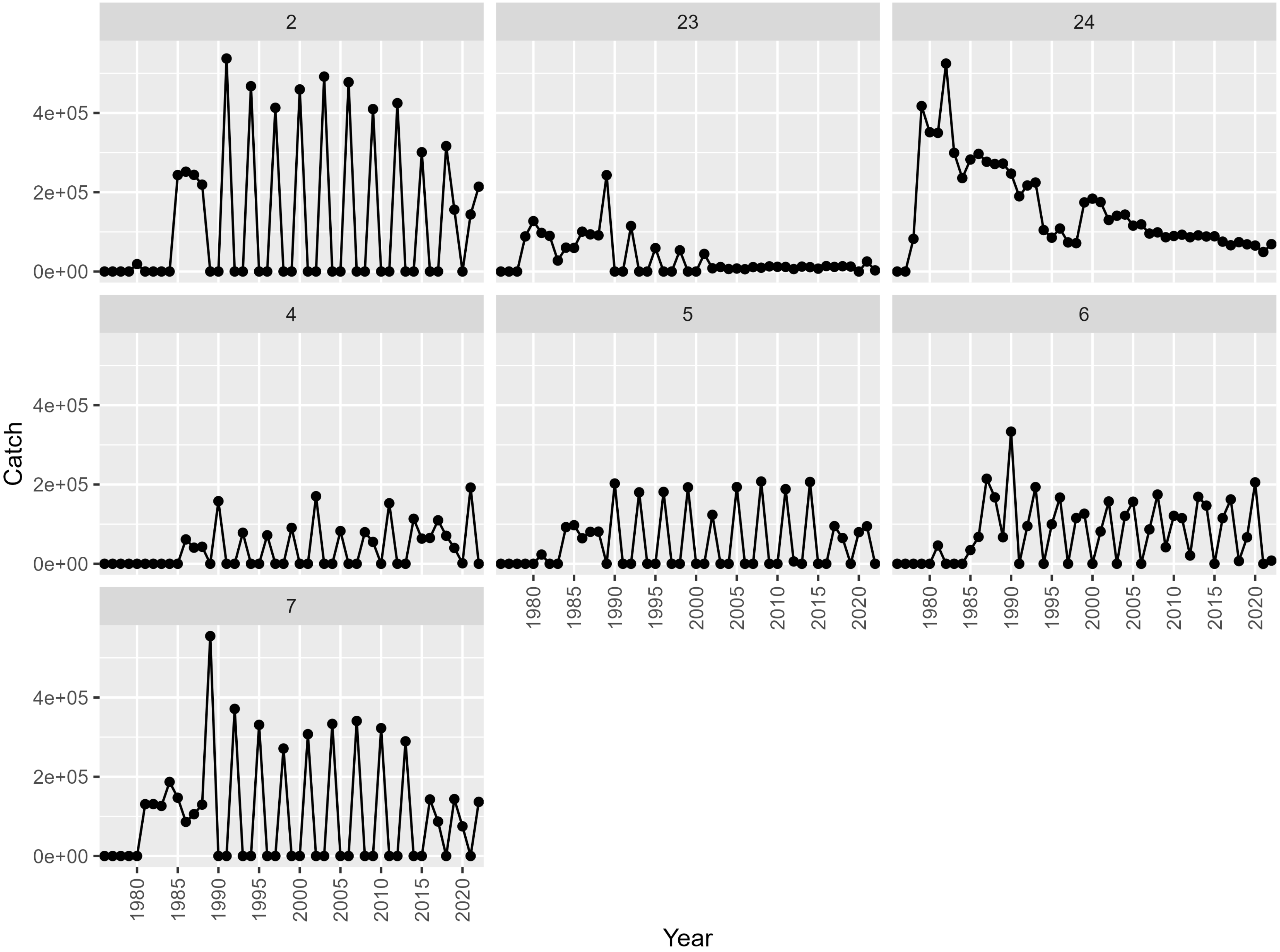
Only those subareas were included that had more than one year of observations (otherwise the model is simply estimating selectivity parameters).

The exception was the oldest subarea with logistic selectivity – this can be estimated with only a single year of data



Annual commercial Catch data from 1976 to 2022

Catches are assumed to be observed precisely (a CV of 5%).

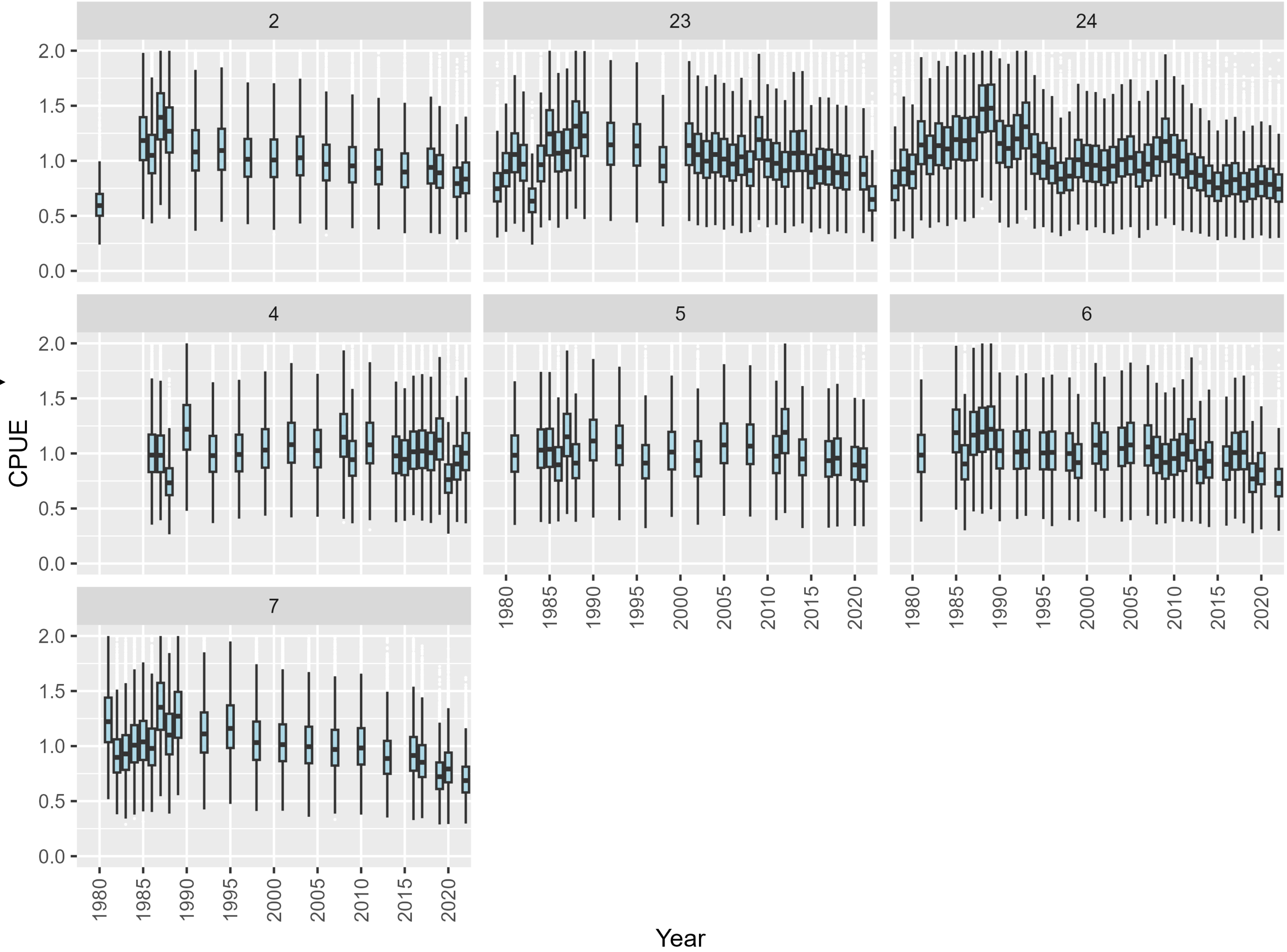


Nominal commercial CPUE from 1981 to 2022.

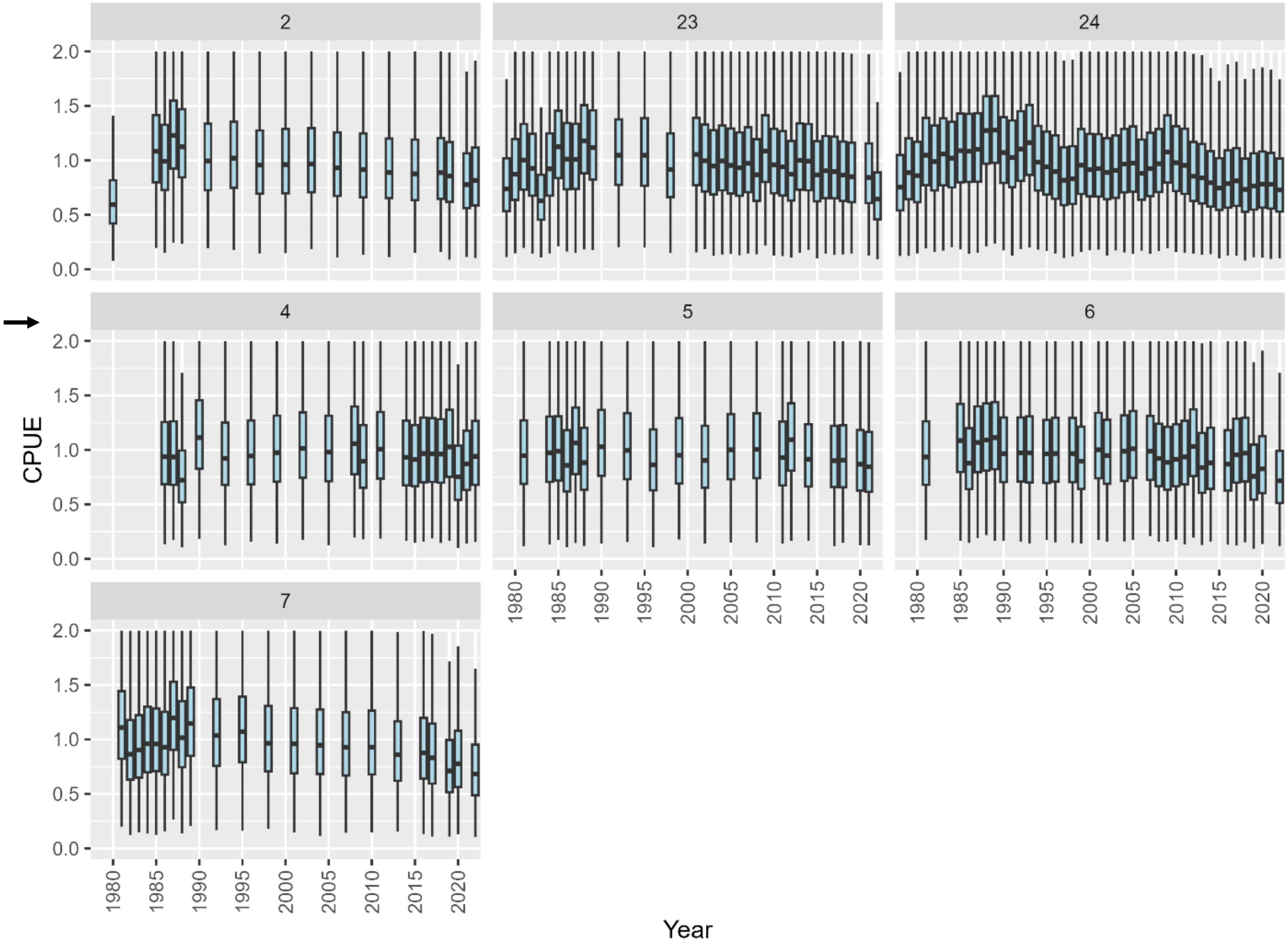
No precision can be calculated.

These plots →

Show the means and a 25% coefficient of variation



Because the current data (means) are suspect, they were included as a placeholder and a very high level of uncertainty was assumed – a CV of 50% so that the data were essentially ignored.



The next step is to calculate standardized indices for these statistical areas that can account for factors affecting catchability.

More on data inputs?

- standardized cpue
- hierarchical somatic growth estimation
- post 1990 cpue
- sensitivity w/wo cpue
- fit to just final survey biomass
- explore fitting to bed – specific biomass surveys (longer time series, a cumulative percentage of overall Stat area biomass)
- sensitivity w/wo bed trend
- Note analyses are focused on biomass available to fishing (unknown abundance deeper than 20m for example)
- Survey biomass includes closed areas (can include contamination closures, pollution, sewage etc)
- Suggested a 2-year lag between data and quota advice
- Some areas are in a 3 year rotation (partly for business planning reasons)

2. Revised Models

Conditioning approach

Model fit

Model estimates

Operating model conditioning approach

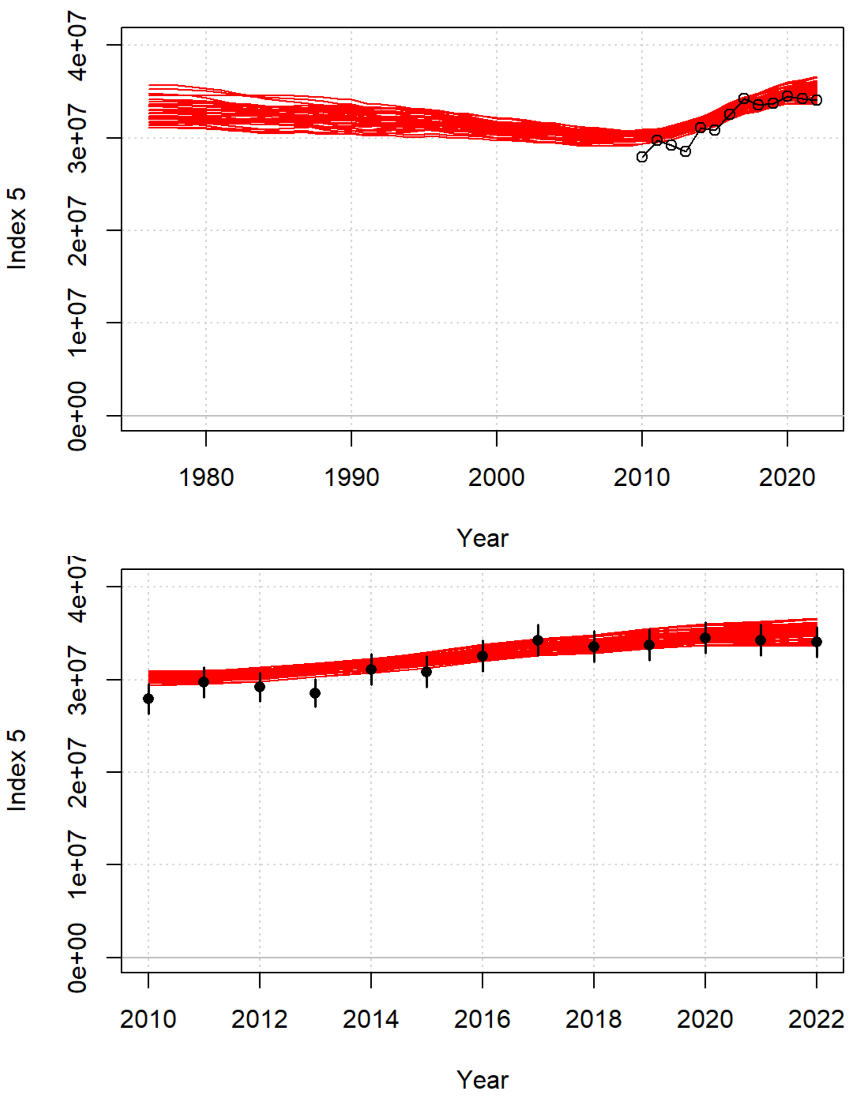
- Statistical catch-at-age using the rapid conditioning model (RCM, of openMSE)
- Somatic growth and weight-length parameters taken from empirical data
- Age- and time-invariant *M* estimated from a lognormal prior (mean = 0.025, cv = 0.3)
- Commercial selectivity was assumed to be fixed: 5% at 100mm and fully selected and asymptotic from 120mm.

New for this round:

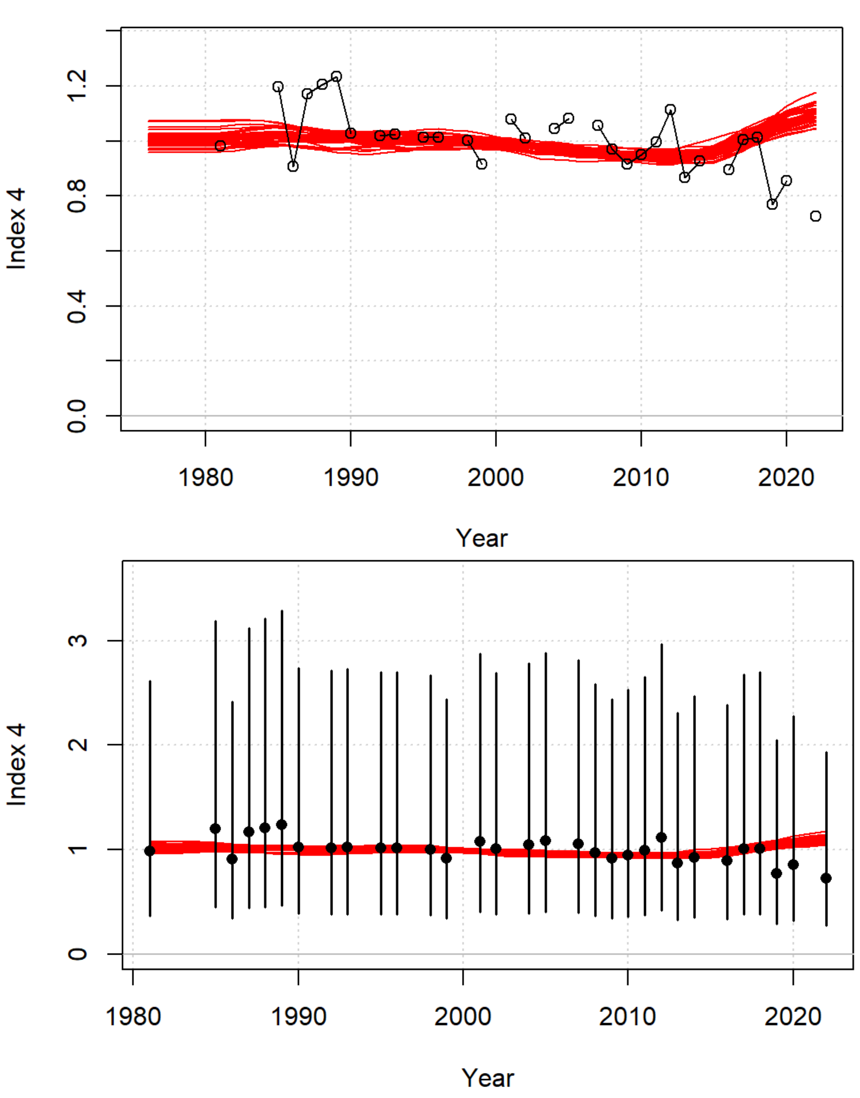
- Parameterized for age selectivity
- One or more sub areas of age composition data. 'Oldest' sub area is assumed to have logistic selectivity, the rest dome-shaped.
- One or more biomass survey 'chunks'. Most recent is assumed to be accurate (q=1), other chunks estimate the constant of proportionality between the survey and biomass.
- A fishery dependent CPUE index (currently a vague, place holder)

Model fit for stat. area 6: indices

Survey biomass

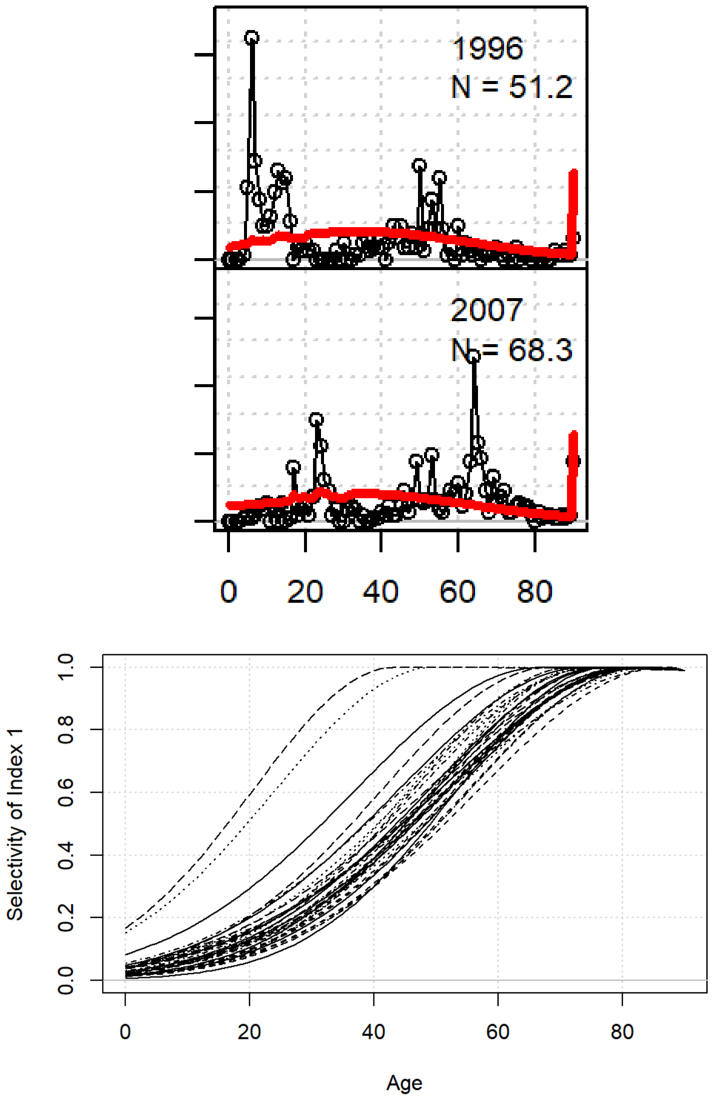


Nominal CPUE

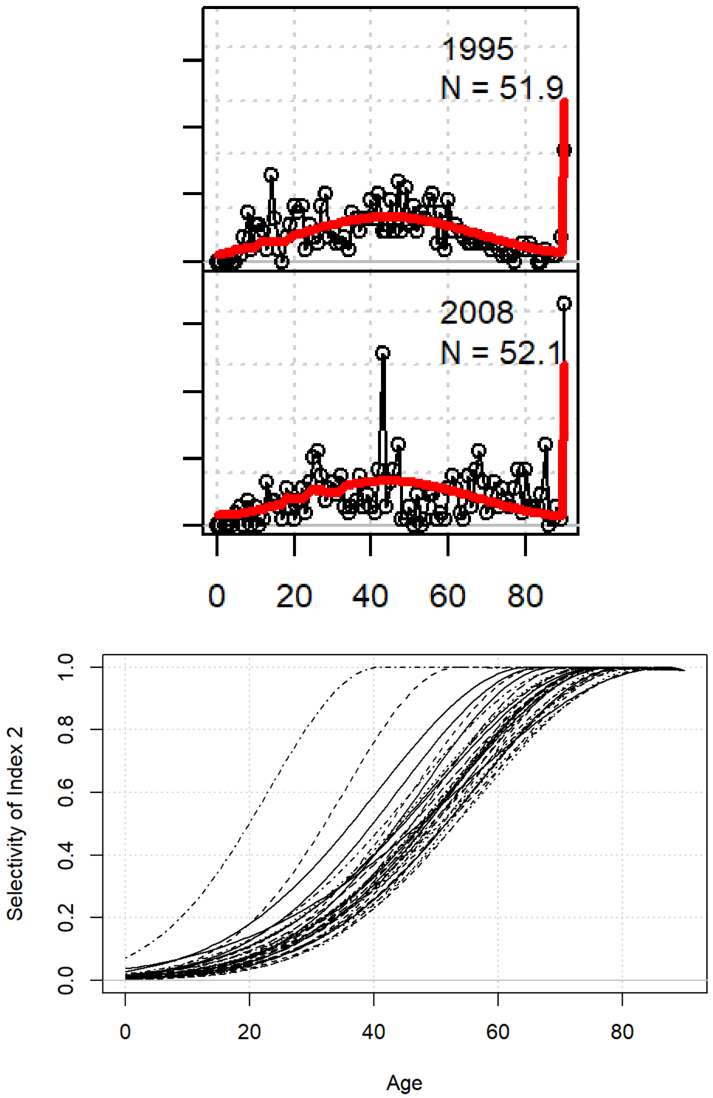


Model fit for Stat. area 6: age composition

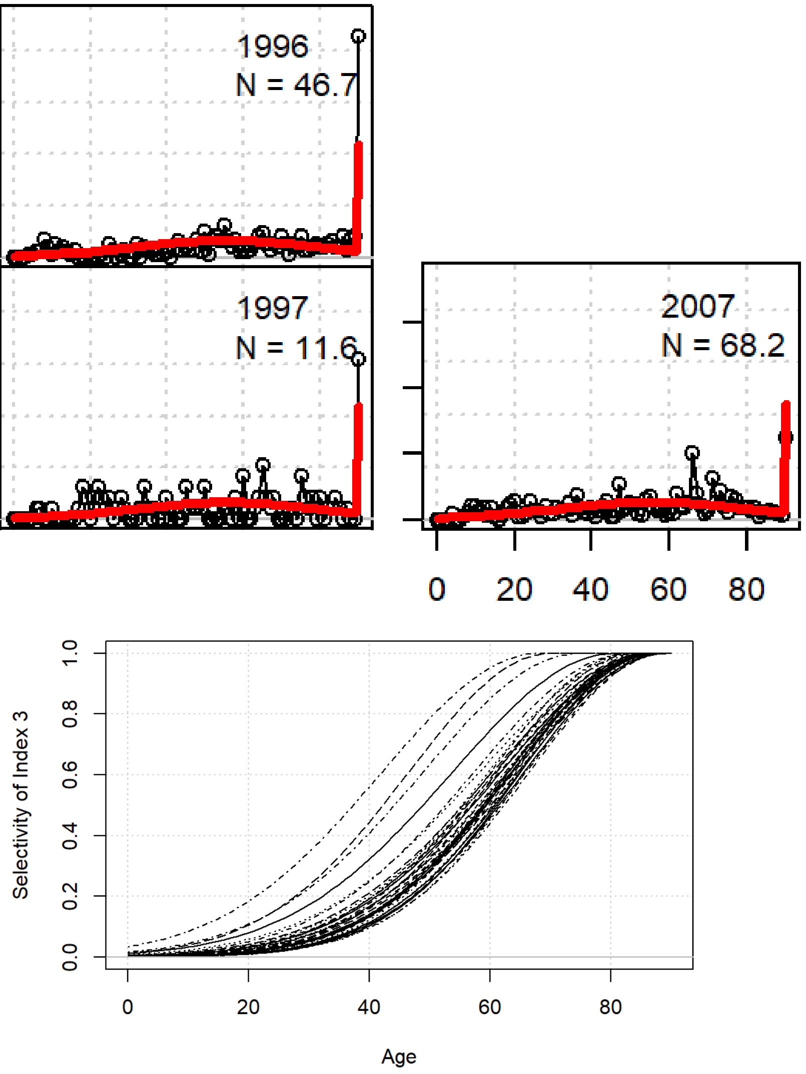
Free to estimate dome



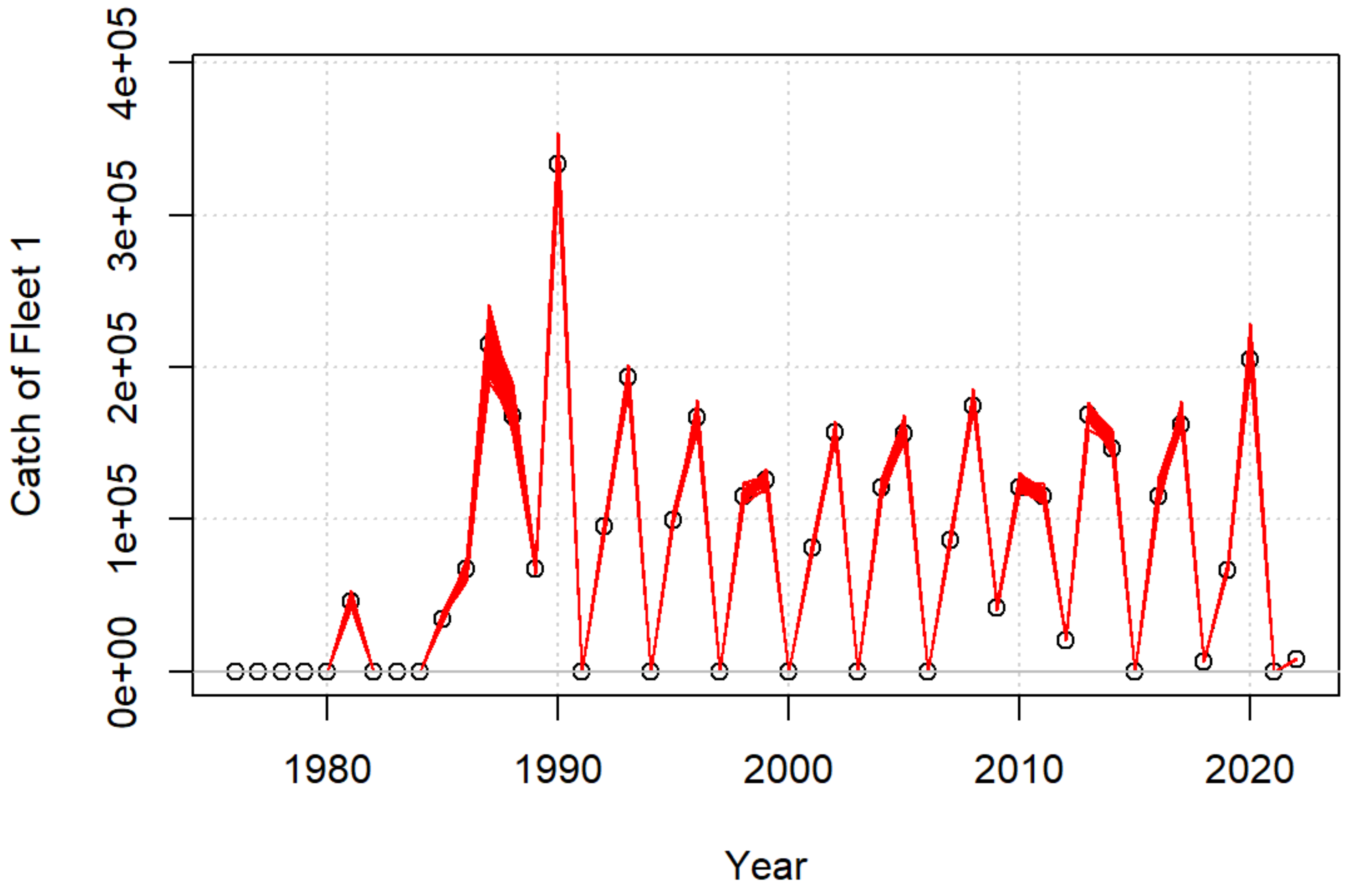
Free to estimate dome



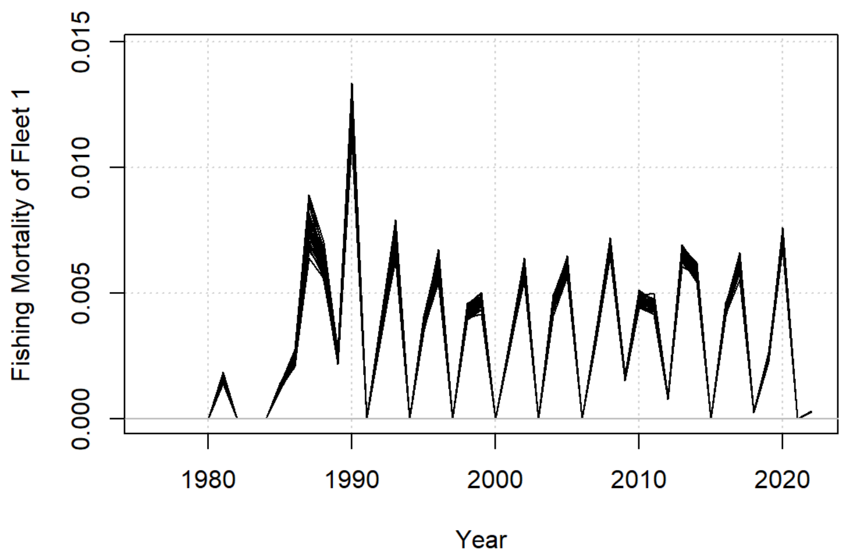
Fixed logistic

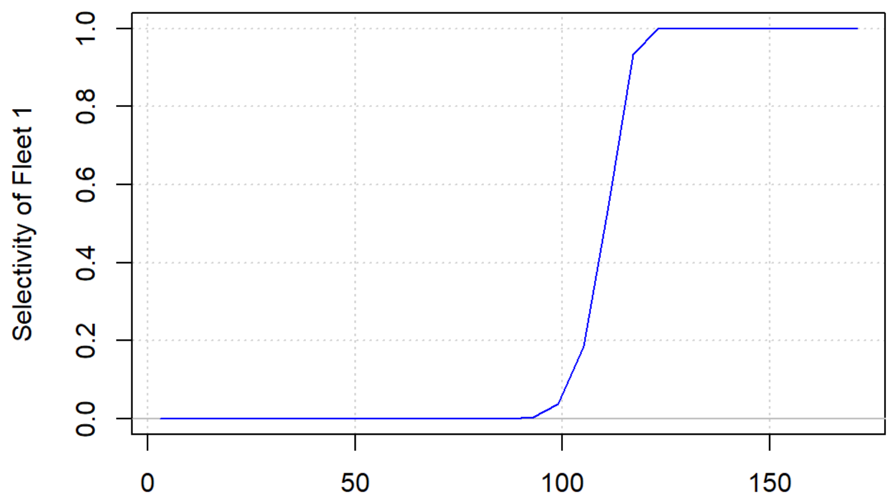


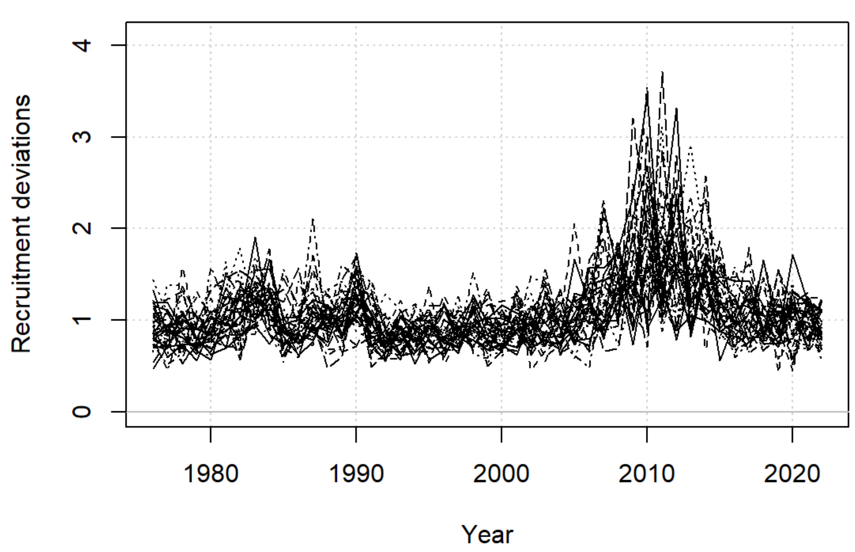
Model fit for Stat Area 6: catches

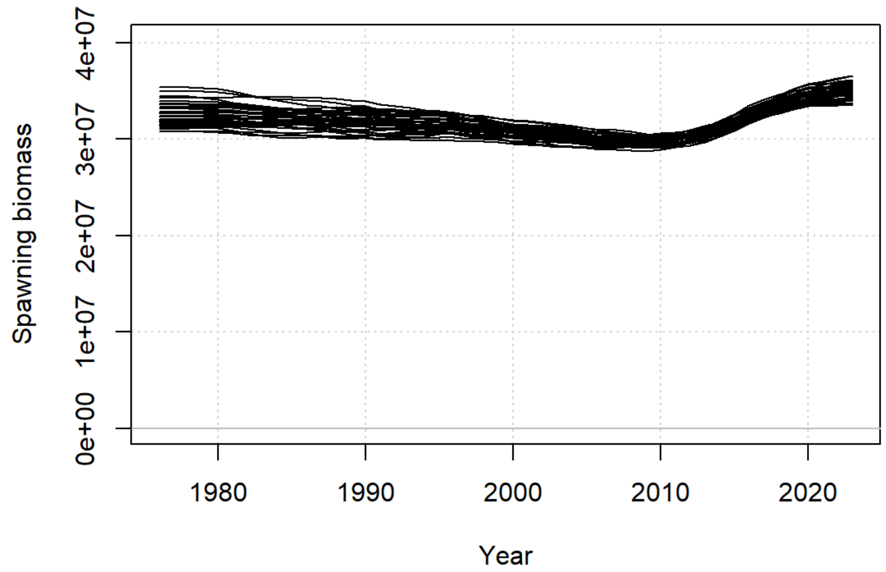


Stat. area 6 model estimates / assumptions









Model estimates

M = natural mortality rate

HR = U = harvest rate (catch / vulnerably biomass)

F = -log(1-U)

D = depletion = SSB2022 / SSBo

B = biomass (all ages)

Bo = unfished biomass

SSBo = unfished spawning biomass

Stat_Area	M_MLE	M025	M975	HR_2022	F_2022	D_2022	B_2022	B0	SSB0
1	0.051	0.011	0.235	0	0	1.01	1465	1447	1433
2	0.052	0.040	0.067	0.0062	0.0064	1.18	40860	34712	34514
3	0.077	0.005	1.276	0	0	1.01	3840	3818	3782
4	0.030	0.013	0.068	0	0	1.00	23910	23800	23578
5	0.046	0.032	0.068	0	0	1.00	24071	23966	23713
6	0.054	0.033	0.089	0.0003	0.0003	1.13	35170	31044	30755
7	0.049	0.042	0.058	0.0063	0.0065	0.99	26949	27295	27055
8	0.042	0.012	0.151	0.0103	0.0107	0.97	4298	4440	4422
12	0.036	0.022	0.058	0.0031	0.0032	0.98	7512	7654	7623
13	0.043	0.031	0.060	0	0	1.20	1260	1053	1042
14	0.078	0.010	0.626	0.0043	0.0044	0.93	6978	7475	7434
15	0.073	0.023	0.233	0	0	1.01	2510	2477	2443
16	0.035	0.001	0.914	0.0014	0.0014	0.87	3049	3512	3497
17	0.081	0.037	0.180	0.0081	0.0088	1.37	1418	1033	1017
18	0.048	0.002	0.978	0.0067	0.0069	0.99	972	983	977
19	0.041	0.006	0.263	0.0003	0.0003	0.91	1844	2032	2023
23	0.048	0.039	0.060	0.0002	0.0002	1.06	21140	19973	19813
24	0.066	0.054	0.081	0.0033	0.0034	1.00	22049	22103	21981
25	0.045	0.033	0.061	0	0	0.86	3328	3860	3843
26	0.056	0.046	0.067	0	0	0.93	3039	3262	3234
27	0.033	0.024	0.044	0	0	0.82	2334	2863	2848
106	0.040	0.001	3.309	0	0	1.02	4808	4730	4720

Estimation issues for low abundance Stat. areas

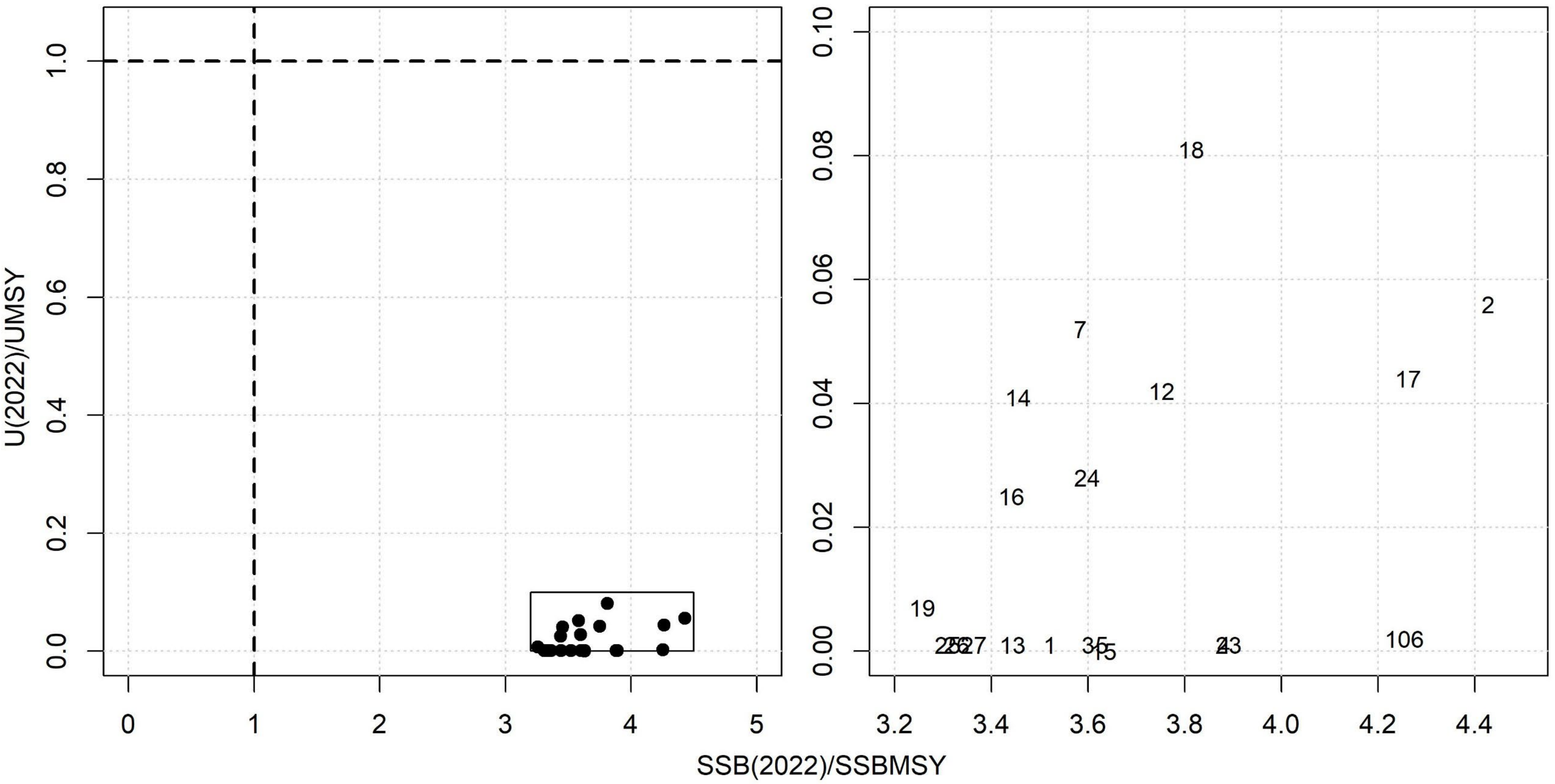
- It would appear that low sample sizes for the ageing data in the less abundant areas can lead to unrealistically high estimates of M in the tails of the distribution.
- The MLE estimates seem plausible however.
- These runs may benefit from either fixing M or setting a much higher precision on the M prior.
- In any case the MLE estimates of the M, and related reference points (e.g. UMSY) are probably interpretable as-is, but the percentiles are not.

Ref. Pts.

Br = SSBMSY / SSBo   UMSY = MSY / VBMSY   Us = U(2022) / UMSY   Bs = SSB(2022) / SSBMSY

Stat.A.	**Br**	Br_025	Br_975	**UMSY**	UMSY_025	UMSY_975	**Us**	Us_025	Us_975	**Bs**	Bs_025	Bs_975
1	**0.27**	0.25	0.3	**0.108**	0.062	0.135	**0.001**	0.001	0.002	**3.521**	3.257	3.792
2	**0.26**	0.24	0.3	**0.106**	0.079	0.123	**0.056**	0.049	0.072	**4.428**	4.083	5.099
3	**0.27**	0.24	0.6	**0.155**	0.096	0.542	**0.001**	0	0.001	**3.601**	2.171	3.961
4	**0.25**	0.22	0.3	**0.076**	0.031	0.141	**0.001**	0.001	0.003	**3.882**	3.601	4.269
5	**0.26**	0.24	0.3	**0.108**	0.069	0.139	**0.001**	0.001	0.001	**3.629**	3.354	3.873
6	**0.26**	0.25	0.3	**0.112**	0.08	0.129	**0.002**	0.002	0.003	**8.993**	3.754	22.689
7	**0.26**	0.25	0.3	**0.113**	0.1	0.129	**0.052**	0.048	0.058	**3.584**	3.414	3.83
8	**0.26**	0.24	0.3	**0.084**	0.051	0.221	**0.148**	0.062	0.199	**5.384**	3.503	15.623
12	**0.25**	0.24	0.3	**0.077**	0.059	0.119	**0.042**	0.029	0.052	**3.752**	3.513	3.965
13	**0.26**	0.25	0.3	**0.093**	0.078	0.131	**0.001**	0.001	0.001	**3.444**	3.221	4.456
14	**0.27**	0.25	0.3	**0.147**	0.094	0.511	**0.041**	0.014	0.05	**3.455**	3.121	4.444
15	**0.26**	0.25	0.3	**0.178**	0.127	0.565	**0**	0	0.001	**3.632**	3.313	3.928
16	**0.24**	0.22	0.3	**0.08**	0.025	0.12	**0.025**	0.012	0.054	**3.441**	3.287	3.634
17	**0.27**	0.25	0.3	**0.151**	0.084	0.223	**0.044**	0.035	0.061	**4.262**	3.427	5.459
18	**0.26**	0.23	0.5	**0.109**	0.053	0.634	**0.081**	0.026	0.11	**3.813**	2.533	4.116
19	**0.26**	0.24	0.3	**0.09**	0.024	0.368	**0.007**	0.002	0.015	**3.257**	3.045	3.47
23	**0.25**	0.25	0.3	**0.109**	0.09	0.13	**0.001**	0.001	0.002	**3.891**	3.596	4.107
24	**0.26**	0.25	0.3	**0.124**	0.105	0.143	**0.028**	0.024	0.033	**3.598**	3.356	3.801
25	**0.26**	0.25	0.3	**0.091**	0.074	0.113	**0.001**	0.001	0.001	**3.31**	3.121	3.499
26	**0.26**	0.26	0.3	**0.118**	0.101	0.134	**0.001**	0.001	0.001	**3.328**	3.116	3.586
27	**0.24**	0.23	0.2	**0.083**	0.059	0.1	**0.001**	0.001	0.002	**3.363**	3.165	3.635
106	**0.25**	0.22	0.4	**0.073**	0.031	0.537	**0.002**	0	0.003	**4.255**	3.947	4.446

Overfishing / underfishing



Reference point results

- All models estimate productive stock size very low with respect to unfished (~25%) due to the unusual growth and maturity of geoduck

- Current estimates of exploitation rate and stock level suggest the stocks are very lightly exploited and close to unfished stock sizes

- MLE UMSY estimates (harvest rate at MSY) are between 8% and 15%.

- The models reflect the most recent reported catches and biomass surveys – most stocks are either not exploited or at the most, have a harvest rate of 1%.

- Analyses of alternative management rules are likely to look similar due to their being modifications from already highly conservative management .

More on model fit and configuration?

- Note about (probably ignorable) highgrading

- MM – what about putting the localized recruitment variability into the simulations based on the model misfit to subareas

- need to align catches to season

- catch curve M trend

3. Example uses

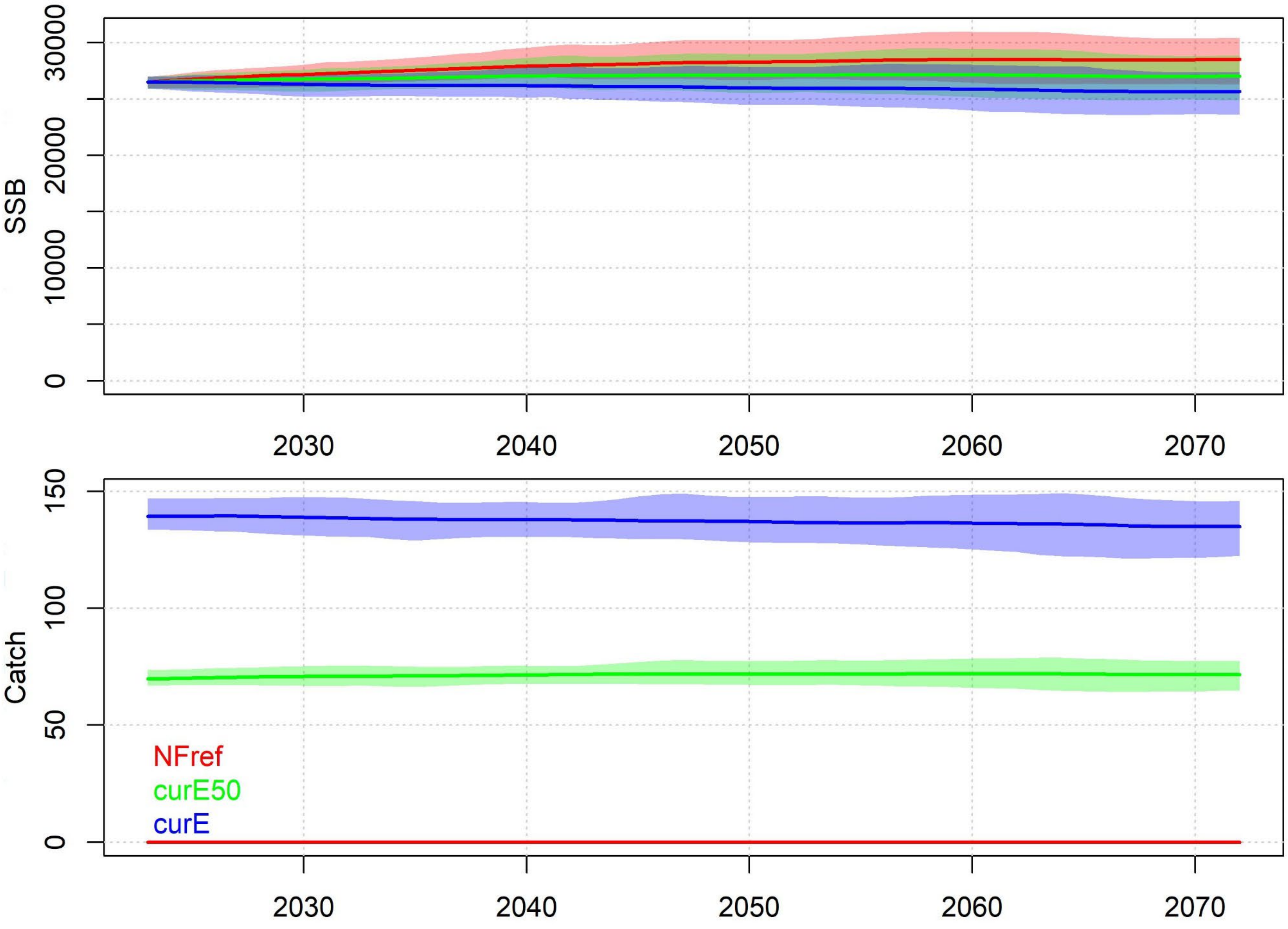
Projection of sea otter predation

Impact of precision in survey

Impact of closures (rebuilding analysis)

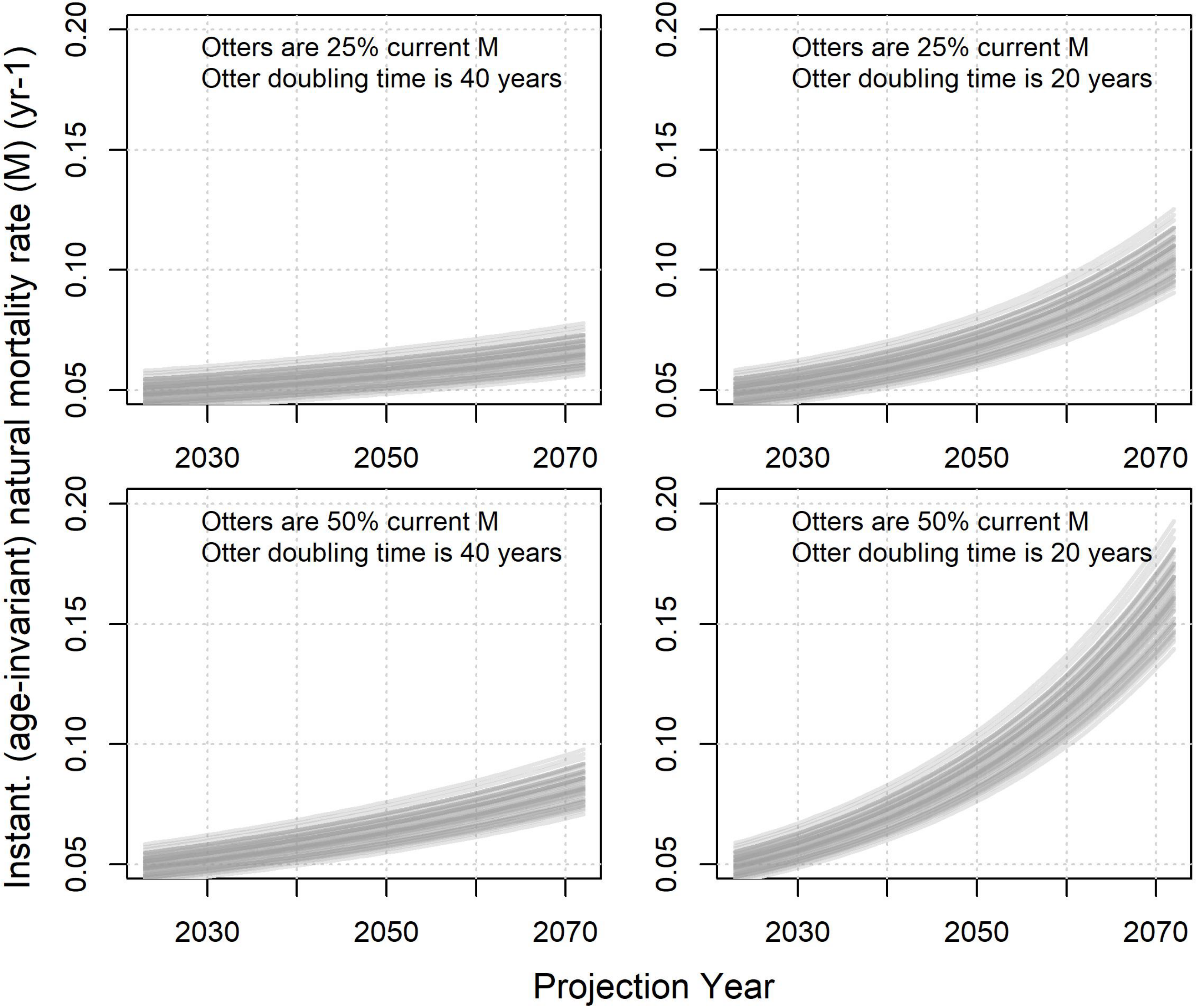
Context

The SA7 stock is sufficiently underfished that projected SSB outcomes are comparable between current exploitation rate and no exploitation.



Projection of Sea Otter predation (SA7)

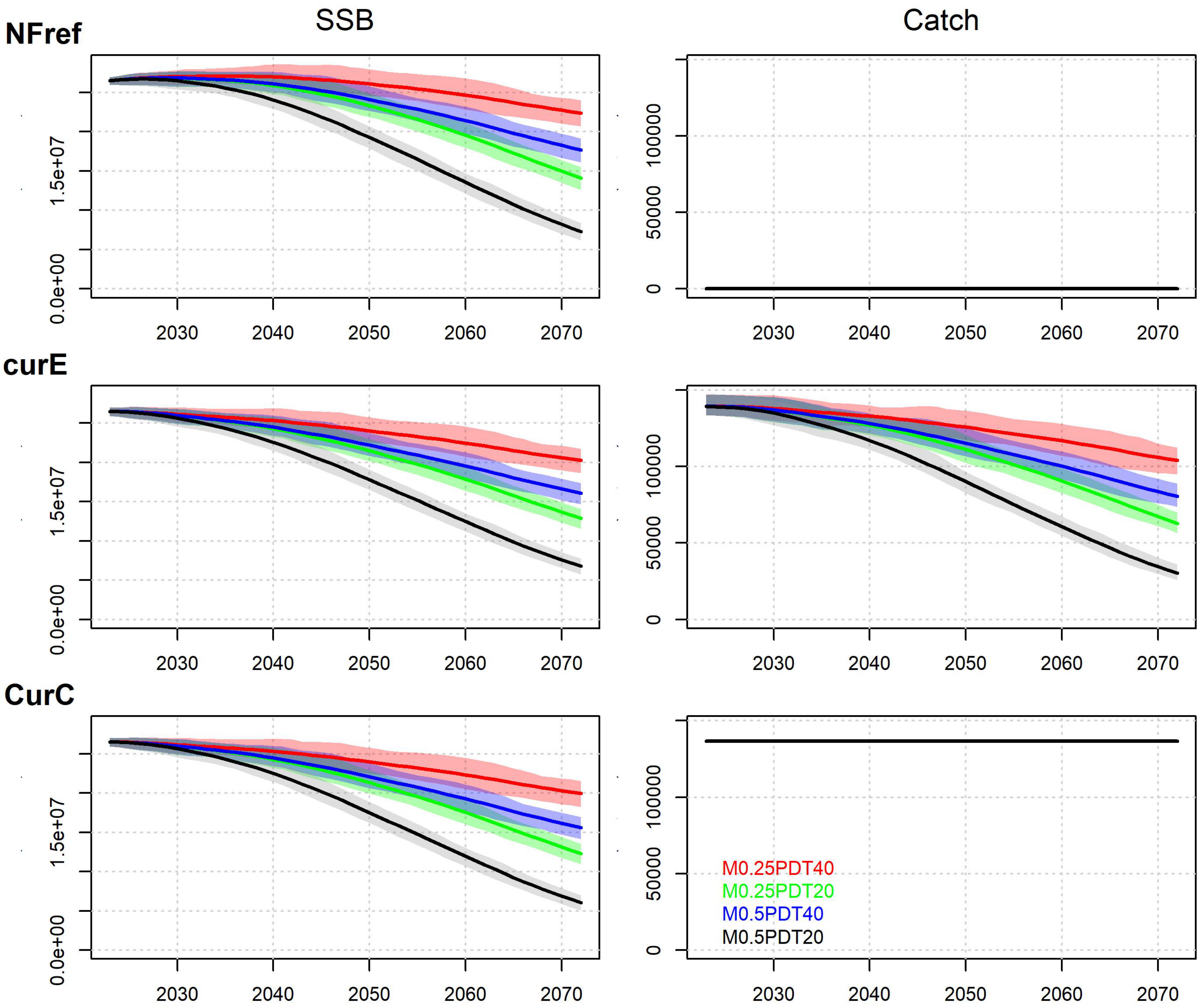
- Simplistic projection approach based on modifying 'natural mortality rate'
- Assign a fraction of current M (that varies among simulations) to sea otters
- Assign a doubling time of the sea otter population
- Obviously could do much more complex M response to biomass density, abundacne of other species, predator – prey functional response etc.



Projection of Sea Otter predation (SA7)

Even if otters were responsible for ¼ of the current natural mortality rate in SA7, and their population doubling time was 40 years, they would still be a larger determinant of absolute biomass than current fishing.

I.e. very little difference between curE (current effort) and NFref (no fishing reference) trajectories relative to the other otter scenarios.



Impact of biomass survey precision

- Current exploitation rate is very low and hence can be expected to have limit impact on biomass outcomes
- Evaluated four index based management procedures that fish at varying multiples of the current Catch / index ratio:

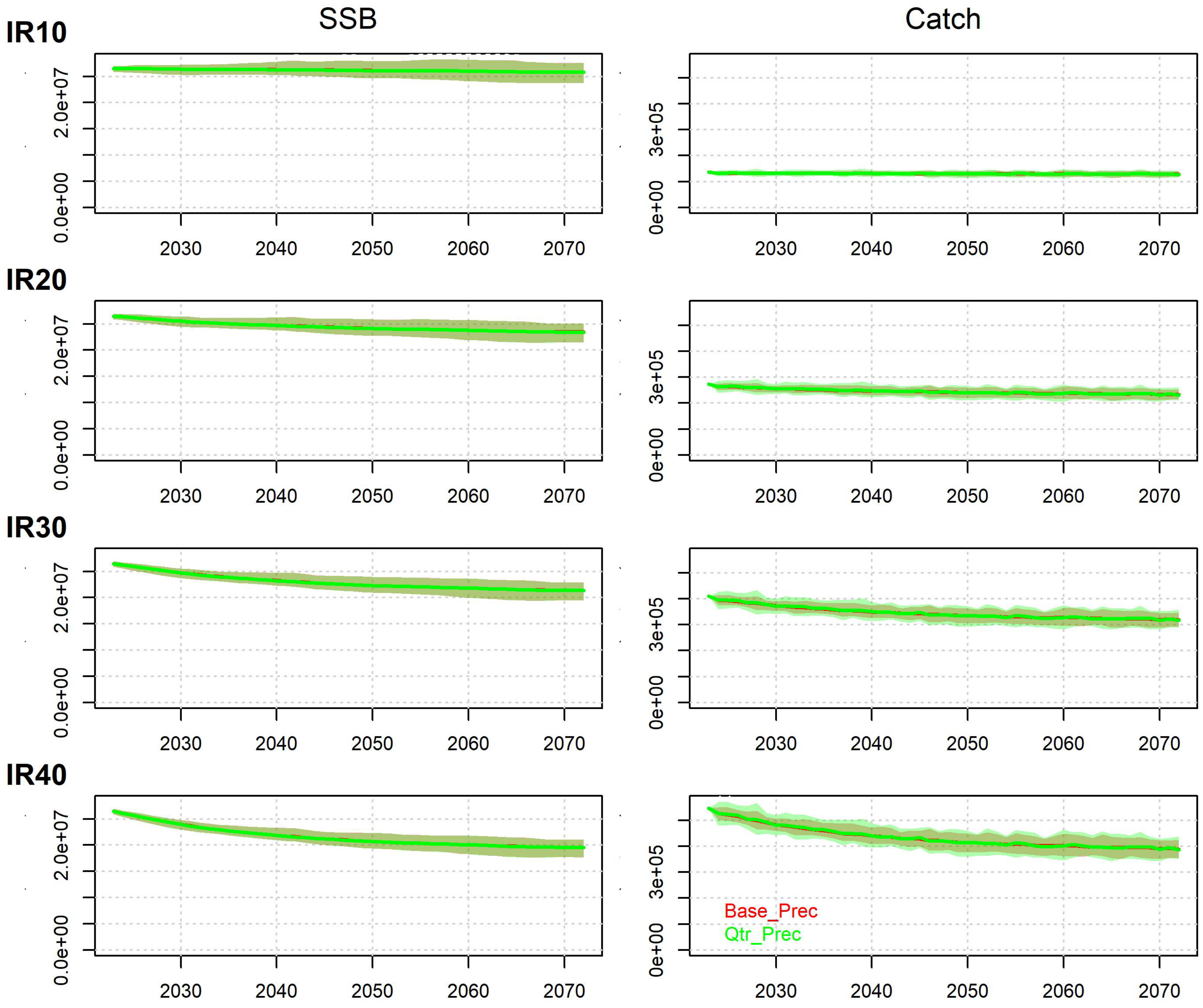
$$TAC_{y+1} = \Delta \cdot I_y \cdot C_{2022}/I_{2022}$$

(IR10, IR20, IR30, IR40 with Δ values of 1, 2, 3 and 4, respectively).

- Ran these for current index precision and one quarter current index precision (approximately ¼ current sampling effort).

Impact of biomass survey precision

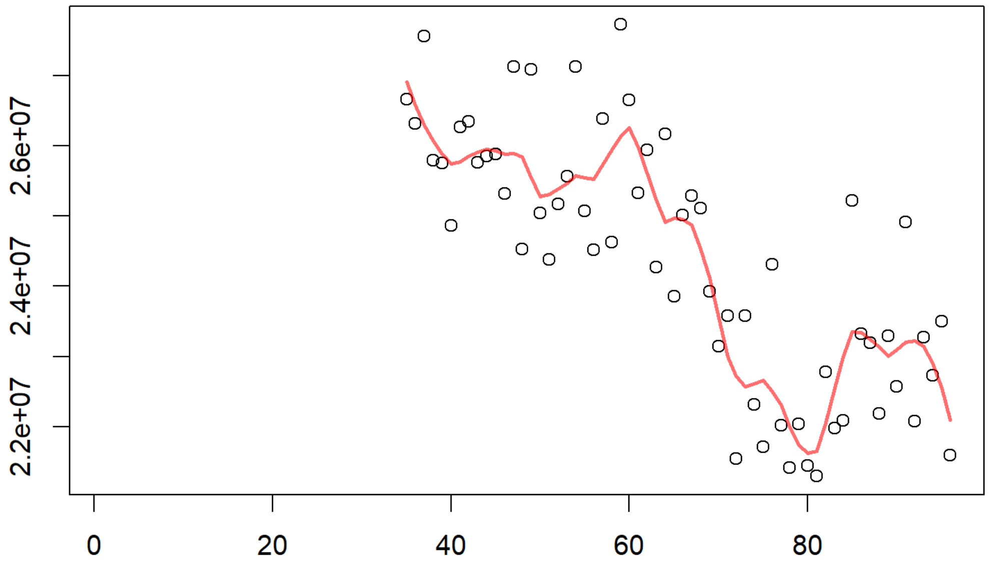
Very little impact on SSB – only impact on variability in catches.



MPs can be designed to better adapt to ‘noisy’ input data

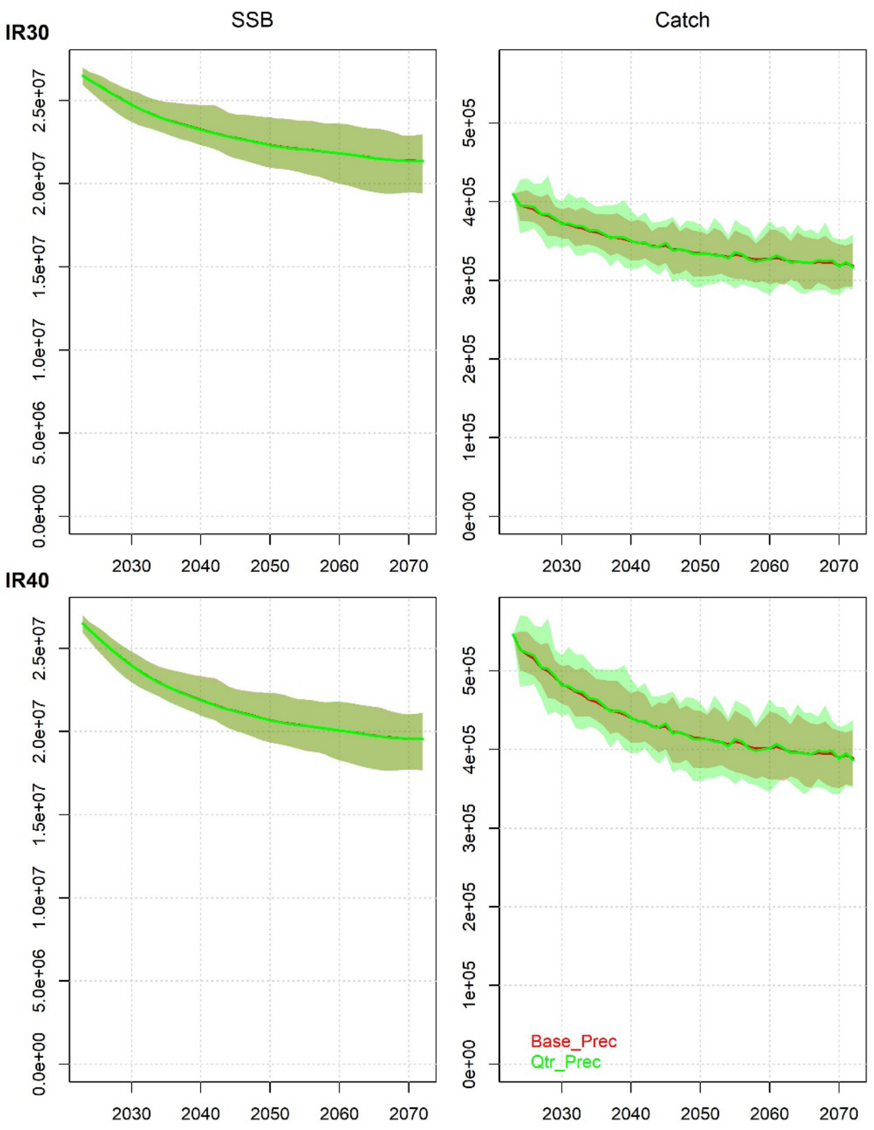
Here we use a polynomial smoother with
$n_{parameters}$ = (number of years of observations) / 5

$$TAC_{y+1} = \Delta \cdot \boldsymbol{s}(I_y) \cdot C_{2022}/I_{2022}$$

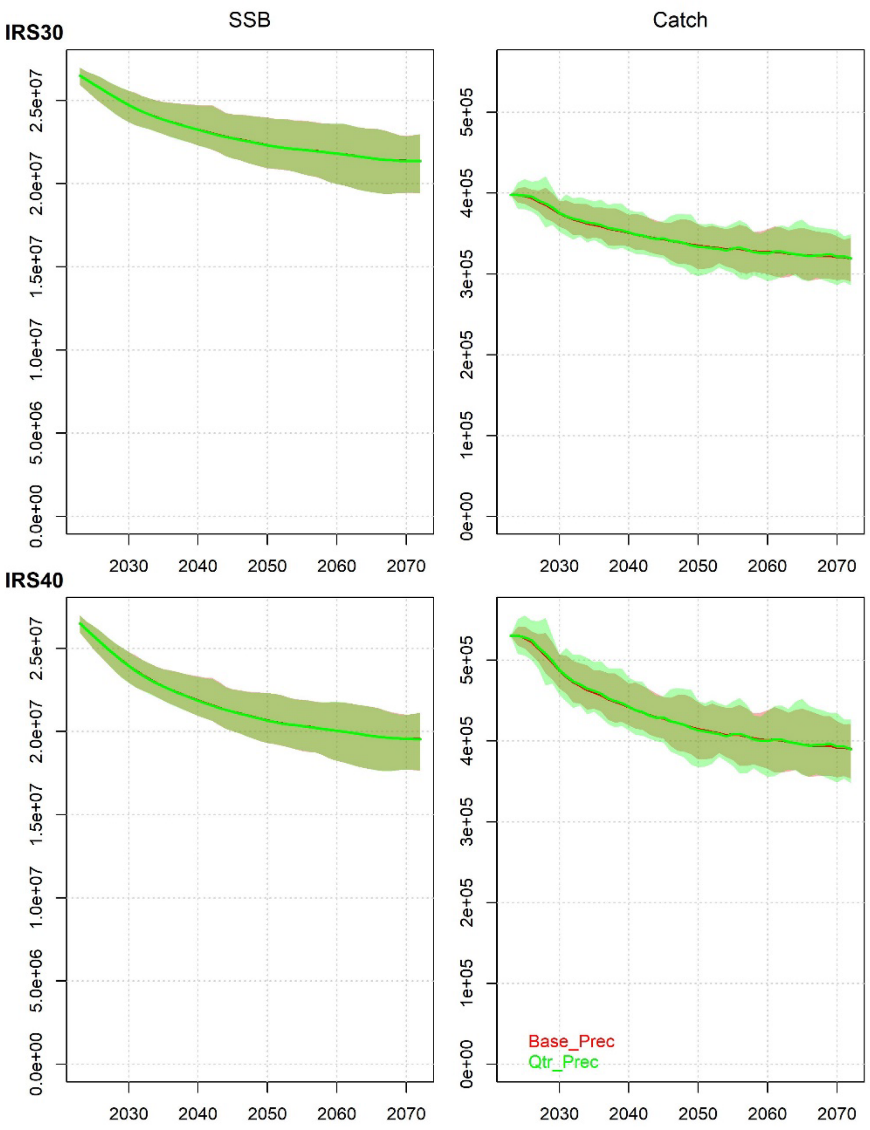


Less variable catches with smoothers

As before – no smoother

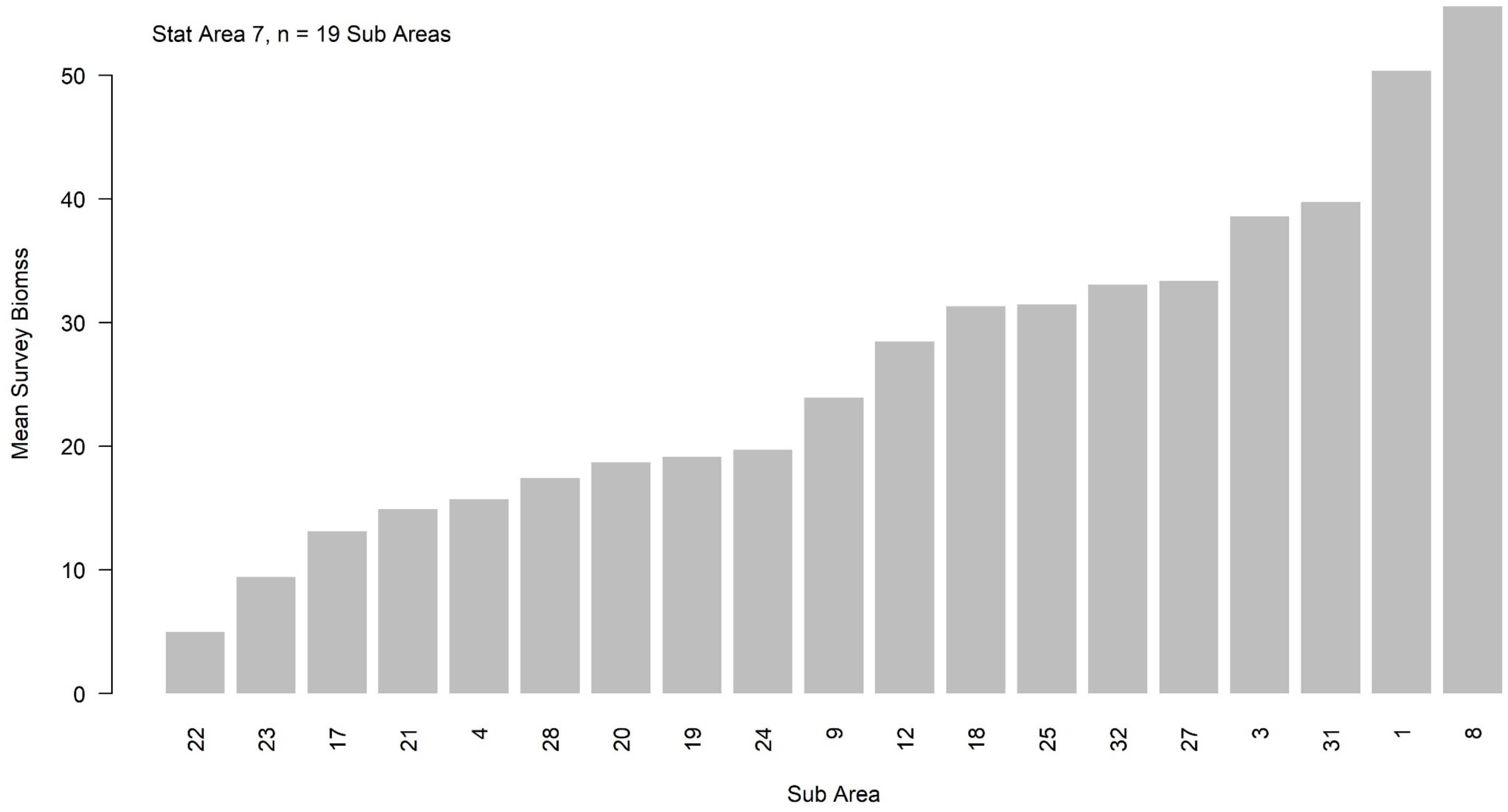


With smoother



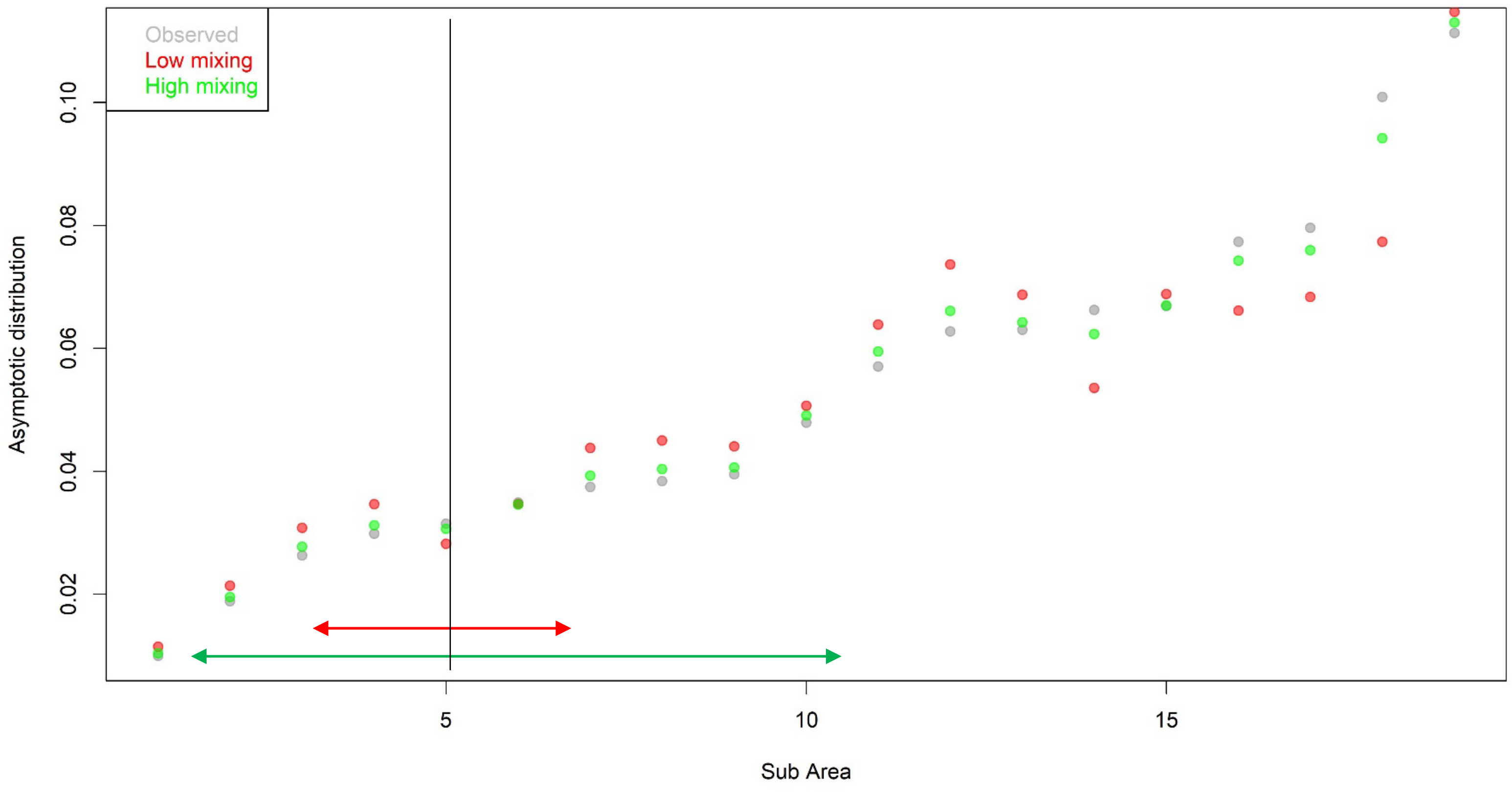
Superimposition of fine-scale spatial heterogeneity

Mean biomass surveyed historically in each Sub Area



Mixing as a function of distance

- For now mixing is calculated assuming distance is represented linearly by Sub Area number (a hack for this demo only). High mixing SD = 5, low mixing SD = 1

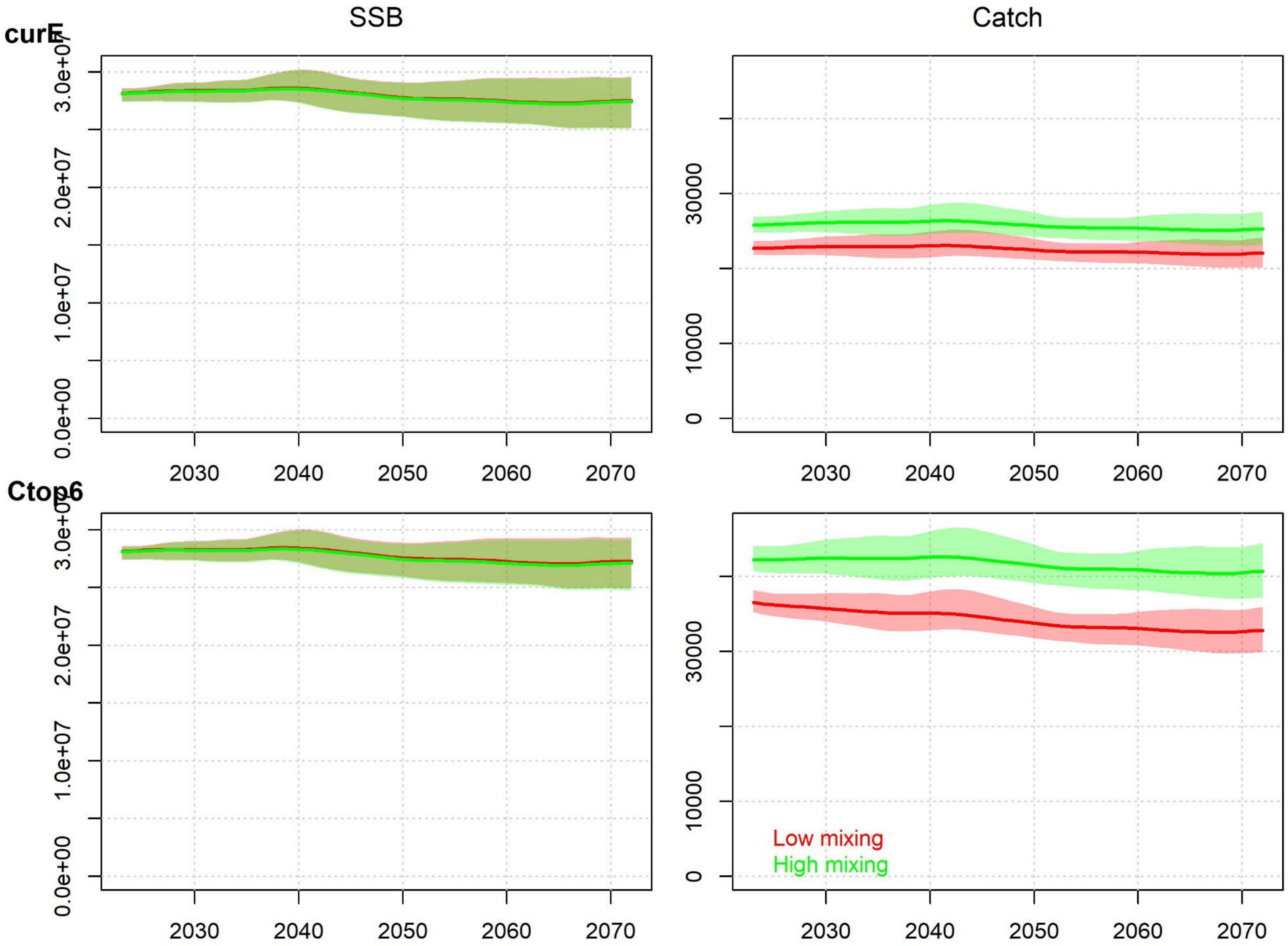


Outcome

Let us assume effort redistribution into open areas....

Very little impact of either mixing or closures on SSB

Closing all but the highest abundance areas (top 6) led to improved



More on example uses

- Mixing extremes (fully mixed, local only)
- Closures / effort redistribution / local scale management procedures
- Freeze catch, with closures for contrast
- #1 MP
- #2 LRP (more biologically based) current LRP is 40% unfished (the default USR)
- LRP in response to changing environmental conditions
- LRP / predators / fishery impacts / serious harm
- Economic viability
- Fishery versus economic sustainability
- Performance metrics relating to stability (MPs)
-

4. Next steps

Data finalization

Areas for operating model refinement

Management questions

Robustness

Performance metrics

Areas for operating model refinement

- Less arbitrary basis for severing survey biomass indices into blocks
- Develop rules for removing inconsistent age-composition data (or use expert judgement)
- Standardized CPUE series by management area
- Hierarchical estimates of asymptotic length (Linf) (Meghan Burton)
- More management options to test (e.g. open closure rules, index rate MPs etc.)
- Evaluation of coast-wide abundance
- Developing operating models at varying spatial scales
- Superimpose spatial structure (subbed heterogenety for example).
- Develop robustness tests!

More on analyses, management questions?

One or more problem statements or questions:

- what is coast wide status / status by Stat. area?
- We need a limit reference point coastwide and by Stat area
- We want to know the potential biological risk from increasing numbers of predators
- Are small-scale spatial closures likely to be effective?

Robustness tests

- Natural mortality rate (climate, predators)
- Unreported catches
- Changes in somatic growth
- Changes in recruitment strength

…

Performance metrics

- Yield
- Conservation (LRP)
- Stability in yield
- Economic viability
- Accessibility (ie in relation to the location of open / closed areas)
- Harvest rate (efficiency)

More on next steps

Notes on next steps

Thanks!

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