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Maritimes Region

Proceedings of the Regional Peer Review of the Stock Assessment of Snow Crab in Maritimes Region

Meeting dates: March 9–10 and 20, 2023
Location: Bedford Institute of Oceanography and Virtual

Chairperson: Tara McIntyre
Editor: Daphne Themelis

Fisheries and Oceans Canada
Maritimes Region
PO Box 1006, 1 Challenger Drive
Dartmouth, Nova Scotia B2Y 4A2

October 2024

Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

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SUMMARY

A regional peer review of the Stock Assessment of Snow Crab in Maritimes Region was held on March 9–10, 2023 at the Bedford Institute of Oceanography, Dartmouth, NS, and virtually using Microsoft Teams. The meeting reconvened on March 20, 2023 to address questions asked by the reviewers related to the performance of the model. As set out in the Terms of Reference (ToR) the objectives were to report the overall status of the Eastern Nova Scotia and 4X Snow Crab stocks at the end of the 2022 fishing season, their relative abundance and relative exploitation rates during the 2022 season, evaluate the consequences of different harvest levels during the 2023 fisheries on stock abundance, and report on the bycatch of non-target species during the 2022 fishing season.

Participants in this meeting included Fisheries and Oceans Canada (DFO) Science, DFO Resource Management, and representatives from the province of Nova Scotia, Indigenous communities and organizations, fishing industry, non-government organizations, and external experts.

This proceedings document includes a summary of the presentations and is a record of the meeting discussions and conclusions. A Science Advisory Report resulting from this meeting will be published on the Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat's (CSAS) Website once it becomes available.

INTRODUCTION

Snow Crab (*Chionoecetes opilio*, O. Fabricius) is a subarctic species with a distribution from northern Labrador to near the Gulf of Maine. Snow Crab has been a dominant macro-invertebrate in the Scotian Shelf ecosystem since the decline of the groundfish during the late 1980s to early 1990s. They are observed in large numbers in deep, soft-bottom substrates ranging from 60–280 m water depths and at temperatures generally less than 6 ˚C. Scotian Shelf Snow Crab are in the southern-most extreme of its spatial distribution in the Northwest Atlantic.

The Snow Crab fishery on the Scotian Shelf has been in existence since the early 1970s. It occurs annually throughout the year dependent upon the Crab Fishing Area (CFA). In 2005, many CFAs and subareas were merged with the resulting divisions being North-Eastern Nova Scotia (N-ENS; formerly CFAs 20-22), South-Eastern Nova Scotia, S-ENS; formerly CFAs 23, 24), and Northwest Atlantic Fisheries Organization (NAFO) Division 4X.

In support of the fishery, Fisheries and Oceans Canada (DFO) Maritimes Fisheries Management Branch requested that DFO Science Branch assess the status of the resource for the coming fishing season. The last Snow Crab Science Advisory Meeting was completed in February 2020. Since then stock status updates have been conducted to provide Science advice.

The objectives this meeting are:

- Report on overall status of the Eastern Nova Scotia and 4X Snow Crab stocks as of the end of the 2022 season.
- Report on relative abundance after the 2022 season and relative exploitation rates during 2022 fishing season.
- Evaluate the consequences of different harvest levels during the 2023 fisheries on stock abundance and exploitation rate.
- Report on the bycatch of non-target species in the Snow Crab fishery in 2022 and identify any notable changes in the occurrence of these bycatch species relative to previous years.

The meeting was reconvened on March 20, 2023 to discuss the results of applying different assumptions on the performance of the assessment model.

The Terms of Reference for the meeting are shown in Appendix A. Participants in this meeting included Fisheries and Oceans Canada (DFO) Science, DFO Resource Management, and representatives from the province of Nova Scotia, Indigenous communities and organizations, fishing industry, non-government organizations, and external experts (Appendix B). The meeting was held virtually (using MS Teams) and at the Bedford Institute of Oceanography, Dartmouth, NS, from March 9–10, 2023 (see Appendix C for the Agenda). The meeting reconvened on March 20, 2023 to discuss model testing and performance; these metrics are shown in Appendix D.

SNOW CRAB ASSESSMENT

RAPPORTEUR: L. BENNETT

The Chair, T. McIntyre began by introducing herself and the three reviewers, Adam Cook, Brad Hubley, and Andrew Harbicht. Participants were asked to introduce themselves and state their affiliation. The Chair then briefly described the Canadian Science Advisory Secretariat (CSAS) peer review process and the use of the Scientific Advice for Government Effectiveness (SAGE) Principles and Guidelines. The meeting was hosted virtually using Microsoft Teams (MS Teams) as the platform, and tips on the effective use of MS Teams were provided. The Terms of Reference with the specific meeting objectives and the Agenda for the two days were reviewed.

OCEANOGRAPHIC CONDITIONS ON THE SCOTIAN SHELF

Presenter: D. Brickman

Physical environmental conditions occurring in the Gulf of St Lawrence and Scotian Shelf during 2022 were reviewed and presented in the context of the historical time series. The data presented included air temperatures, and ocean surface and bottom temperatures, and sea ice volumes. Warm, salty anomalies originating from the interaction between the Gulf Stream and Labrador current at the tail of the Grand Banks propagate east to west along the shelf break and penetrate onto the shelves via deep channels. During the last decade, these warm salty anomalies have dominated, accounting for a warming trend in bottom temperatures. Air temperatures are trending upwards, sea ice has declined and sea surface temperatures were well above normal. Bottom temperature have been trending upwards since 2005 and 2022 was the warmest on record.

A participant asked for clarification of the term Counterfactual Concept. It was explained that this model predicts conditions based on a fixed pre-industrial CO_2 concentration. Because the climate and counterfactual model simulations are identical except for the climate change forcing, the difference can unequivocally be attributed to climate change.

SCOTIAN SHELF SNOW CRAB FISHERY AND ASSESSMENT

Presenters: B. Cameron and J. Choi

The number of trap hauls declined in all fishing areas in 2022 relative to the previous year. Landings increased in N-ENS and declined in S-ENS and 4X relative to the previous year. The majority of snow crab landed was from inshore fishing. It was clarified that inshore fishing was not caused by a lack of crab offshore, but because of the cost of fuel. It was more economical to make a lot of short trips. Also, the total allowable (TAC) was achieved prior to the offshore zones being opened; the shrimp boxes (areas closed to snow crab fishing to allow access to vessels trawling for shrimp) is on the CFA 23-24 line and was closed at the start of the season.

At-sea observer (ASO) coverage of commercial fishing trips was low. More observed trips were expected in N-ENS where there are mainly day trips, whereas 4X and S-ENS are multiple day trips. The fishery occurs quickly that the ASO target is difficult to meet. There are only a few trained ASO available at the beginning of the season, and the fishery happens too quickly to train more ASO.

It was asked whether observed trips are split between the spring and summer seasons. The assigning of ASO is random. There are few trips with ASO that ‘would see’ soft crab. There is a need for better distribution of coverage because ASO coverage is not representative of the fishery. To use the data for enforcement or scientific advice, coverage must be increased and prioritized. At the current levels, it is only incidental and not useful for providing advice.

A question was asked about the classification of crab carapace condition (CC), specifically the criteria used by ASO to classify CC5 crab (evidence of shell disease). This is a subjective classification by the ASO and processors are not classifying this way.

About 83 stations of the planned 387 survey stations were not completed in 2022 due to mechanical issues with the survey vessel. The stations not completed were located in preferred inshore snow crab habitat. Detailed sampling of snow crabs declined by about half in the N-ENS, and only half of the snow crab caught were commercial size. In the S-ENS, the inshore portion of the survey was missed. It was asked whether older crab are more likely to be present where sampling occurred in 2022. There isn’t enough information to know if the decrease in sampling caused bias because the average distribution of mature snow crab can vary quite a bit annually.

It was asked whether mean temperatures had been calculated for stations that have been consistently sampled in the survey series. These were not, but could be done to ensure the same areas are being compared. It was asked whether any of the stations in 2021 and 2022 were sampled at the same time of the year? This was attempted as much as possible.

Recruitment was assessed using size-frequency histograms of the male snow crab population. Data were used from a subset of stations within 5 km of the stations sampled in 2022. The overall distributions are similar.

The survey data indicate a persistent population in the S-ENS that is fed by recruitment. The female component of the population is doing well in 4X. The spatial distribution of mature females can vary annually.

Sex ratios are biased by the sampling design and gear. Smaller female crab are difficult to capture by the trawl and the survey appears biased toward larger male crab. A map of mature density shows a high number of points with no information; for example, the southern limit of 4X. Comparing 2021 to 2022, there was speculation that females are aging and dying, and a loss of immature females.

Biomass estimates can be provided for 2021 because of a Bayesian approach. The biomass index shows a gradual contraction from 2020–2022. The model predicts across empty space and provides posterior distribution and error estimates. It was asked whether hotspots were checked against logbook data. This could be done, although the timing of the survey and fishery are different. There was a research recommendation to explore what to do with missing years of survey data, that is, how to interpret differences in interpolation.

The reviewers expressed concern with providing advice for 2023 based on an incomplete 2022 survey that did not sample some of the most important areas of commercial biomass and the missing 2020 survey. They were also concerned about the co-variates, as well as biomass, and how the model dealt with missing data. They asked the presenter to provide some cross-validation of the model output to see if it is biased high or low. This could be done by comparing some of the 2021 and 2022 data, even if there is non-stationarity between the two years. This would be a similar test of the CARST model as was done in 2020 when there was no survey.

A reviewer was concerned that the statement that distribution had contracted had not been validated. It was not clear whether the observed contraction might be due to missing survey data and the model making predictions about unobserved spaces. Biomass might not have declined.

It was suggested that other information be used to lend confidence to the model performance, for example, logbook data. It was also suggested to undertake model testing and validation (look at the outputs and robustness of the model to the data and how it deals with missing data). Concern was expressed about the lack of information from ASO and the gaps in survey coverage over the past 3–4 years.

A reviewer expressed concerns about the co-variates as well as biomass. They asked about how the model deals with missing data.

A participant asked whether illegal exploitation can be addressed. This is an action item that Marine Stewardship Council has requested from DFO.

There was insufficient ASO coverage to provide information on the level of non-targeted species catch in the snow crab fishery. This was the fourth objective of the meeting.

The Chair requested that the presenters provide outputs from the model that test how it deals with the missing data. Cross-validation of the model should be undertaken by removing another year or some portion of the data similar to what is missing in 2022 and evaluating the predictions from the model. The presenters were asked to show some outputs of the various covariates and how well they fit to predictions. Look at the model output without the spatial components (predict without random effects) and look at the trend over time.

It was agreed that these analyses would be presented to the group on March 20, 2023.

MARCH 20, 2023: MODEL TESTING

Presenter: J. Choi

An examination of the goodness of fit was presented. The assessment lead looked at various components to see what is the most important variable explaining biomass. Depth was the most important while the spatial component is weak and time is relatively high.

The ability of the model to predict upon itself was tested by examining the posteriors. These were positive showing that it can predict upon itself.

Three scenarios were presented. In Scenario 1, the year 2015 was chosen as an average state. Average density of crab was a little lower, but the variability was higher.

One of the reviewers stated that this gave some confidence in how the model performed. It was asked if mean weight could be modelled separating rather than converting it to biomass. The other two reviewers were also satisfied, noting that the scenario showed the model predictions were more conservative than observed.

For Scenario 2, it was noted by a reviewer that it was reassuring to see how important temperature was in 4X, but they expressed surprise at the importance of depth. The modelled process is driving biomass in all areas in the same way, but the temperature in 4X is driving some of the shifts. The presenter noted that the area has been dominated by pulses of recruitment in the early 2000s. That pulse has been moving through the system, but you can see the resulting effects are different in the areas bound by warm water. In core areas, depth and temperature are confounded.

A reviewer asked why the model predicted a lower aggregate biomass for 2020. There may have been warm water incursions. There are no observations for 2020, but it appears that high density is related to better habitat. The model output is driven by the covariates in 2019 and 2021.

Scenario 3 showed extremely variable predictions when removing local spatial processes. The end result is a very smoothed view of biomass. Temperature and species composition has a great effect on biomass. The overall features of the temporal effect are still apparent. Modelling construct reflects the overall dynamics of the system.

The reviewers were satisfied that the model described the processes driving snow crab biomass. The model appears robust to missing points and not likely to predict biomass outside of what is expected. See Appendix D for the supplementary information presented on March 20, 2023 to address the questions from the reviewers.

APPENDIX A: TERMS OF REFERENCE

Stock Assessment of Snow Crab in Maritimes Region

Regional Science Advisory Process – Maritimes Region

March 9–10, 2023
Dartmouth, NS and MS Teams

Chairperson: Tara McIntyre

Context

Snow Crab (*Chionoecetes opilio*, O. Fabricius) is a subarctic species with a distribution from northern Labrador to near the Gulf of Maine. Snow Crab has been a dominant macro-invertebrate in the Scotian Shelf ecosystem since the decline of the groundfish during the late 1980s to early 1990s. They are observed in large numbers in deep, soft-bottom substrates ranging from 60–280 m water depths and at temperatures generally less than 6 ˚C. Scotian Shelf Snow Crab are in the southern-most extreme of its spatial distribution in the Northwest Atlantic.

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Objectives

The objectives of this science advisory meeting are:

- Report on overall status of the Eastern Nova Scotia and 4X Snow Crab stocks as of the end of the 2022 season.
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- Report on the bycatch of non-target species in the Snow Crab fishery in 2022 and identify any notable changes in the occurrence of these bycatch species relative to previous years.

Expected Publications

- Science Advisory Report

Participation

- DFO Science
- DFO Resource Management
- Indigenous Communities/Organizations
- Fishing Industry
- Provincial representative

- Non-government organizations
- Other invited experts

APPENDIX B: LIST OF PARTICIPANTS

Name	Affiliation
Anderson, Bob	Crab Fishing Area 24/ South-eastern Nova Scotia
Bennett, Lottie	DFO Science - National Capital Region
Boudreau, Ginny	Guysborough Co. Inshore Fishermen's Association
Brickman, David	DFO Science - Maritimes Region
Cameron, Brent	DFO Science - Maritimes Region
Cassista-DaRos, Manon	DFO Science - Maritimes Region
Choi, Jae	DFO Science - Maritimes Region
Clancey, Lewis	Nova Scotia Department Fisheries & Aquaculture
Clarke-Doherty, Leisha	DFO Resource Management - Maritimes Region
Cook, Adam	DFO Science - Maritimes Region
Cormier, Paul	North-eastern Nova Scotia Crab Fishing Area
Couture, John	Oceans North
Crouse, Rick	Pisces Consulting
Denny, Leonard	Eskasoni Fish & Wildlife Commission/Crane Cove Seafoods
d'Entremont, Dennis	Crab Fishing Area 24/ South-eastern Nova Scotia
Doucette, Charles	Potlotek First Nation
Glass, Amy	DFO Science - Maritimes Region
Gould, Bobby	Waycobah Fisheries
Harbicht, Andrew	DFO Science - Gulf Region
Harris, Lei	DFO Science - Maritimes Region
Hayman, Tim	DFO Resource Management - Maritimes Region
Hubley, Brad	DFO Science - Maritimes Region
Kehoe, Andrew	Crab Fishing Area 24/ South-eastern Nova Scotia
Langille, Janet	DFO Resource Management - Maritimes Region
MacDonald, Gordon	Crab Fishing Area 23/ South-eastern Nova Scotia
MacDonald, Raphael	Dalhousie University
MacMullin, Neil	Crab Fishermen's Association
Martin, Tim	Native Council of Nova Scotia
McIntyre, Tara	DFO Science - Maritimes Region
Mombourquette, Greg	Crab Fishing Area 24
Nicholas, Hubert	Membertou First Nation / Fisheries
Paul, Tyson	Unama'ki Institute of Natural Resources
Penny, Lorne	DFO Resource Management - Maritimes Region
Risser, Winifred (Junior)	4X Snow Crab Fishing Area

APPENDIX C: AGENDA

Day 1 – March 9

09:00 – 09:30 Welcome and Introduction (Chair)

09:30 – 10:00 Oceanographic Conditions on the Scotian Shelf (David Brickman)

10:00 – 10:30 2022 Snow Crab Fishery (Brent Cameron)

10:30 – 10:45 **Health Break**

10:45 – 12:00 Scotian Shelf Snow Crab Assessment (Jae Choi)

12:00 – 13:00 **Lunch**

13:00 – 14:00 Examination by Reviewers

14:00 – 14:45 General Discussion

14:45 – 15:00 **Health Break**

15:00 – 16:00 Review of Science Advisory Report

Day 2 – March 10

09:00 – 09:15 Review of Day 1

09:15 – 10:15 Continue Review of Science Advisory Report

10:15 – 10:30 **Health Break**

10:30 – 12:00 Continue Review of Science Advisory Report

Meeting adjourned - to reconvene on March 20, 2023

APPENDIX D: MODEL PERFORMANCE METRICS PRESENTED MARCH 20, 2023

As the following will examine a number of different scenarios, we begin by labeling the default solutions presented at the RAP with the full data set as Scenario 0.

The basic parameter estimates and variance components for numerical abundance are shown in Table S0.1. Depth (z) was most important in terms of variance components. Overall posterior predictive checks suggest reasonable performance (Figs S0.1-S0.3, Tables S0.1-S0.3).

There are a few reasons why cross validation is not used with and instead more traditional (asymptotic) criteria and visual posterior predictive checks are used. First, a single model fit and posterior simulation from joints distributions requires requires 18 hrs and 15-20 GB of storage.

Exhaustive cross validation is operationally not feasible simply from a time perspective. Philosophically, unlike point-focused Maximum-Likelihood or adhoc optimzation-based methods that can very easily get “stuck” in multiple local suboptima, Bayesian methods, in theory, explore the full joint-distribution of the parameter space and provide posterior distributions that expresss this variability. Cross validation (CV) is especially useful with the former due to its point-optimization focus.

With the latter, CV operates at cross-purposes by restricting this parameter space and reducing overall inference on how much the data supports the model and understanding of the distribution by limiting it. This not important if there is an over-abundance of data as in many Machine Learning problems, however, when operating under data-limited situations, this can significantly alter the former of the joint-parameter landscape.

Table S0.1 Parameter estimates for positive valued numerical abundance. Usual goodness of fit criteria are also shown.

Factor	mean	sd	cv
Intercept	1479.56099	376.00185	25.41
SD time	0.31206	0.08658	27.74
SD cyclic	0.56676	0.19510	34.42
SD t	0.16822	0.10708	63.65
SD z	**1.12992**	**0.41555**	**36.78**
SD pca1	0.00000	0.00000	4.68
SD pca2	0.06075	0.04653	76.60
SD space	0.69260	0.02900	4.19
SD space_time	0.53392	0.01916	3.59
Rho for time	0.79639	0.09420	11.83
GroupRho for space_time	0.64295	0.04134	6.43
Phi for space	0.02676	0.03316	123.92
Phi for space_time	0.07568	0.02907	38.42
overdispersion	4.71389	0.34219	7.26
Pearson = 0.89; Spearman= 0.89; dic= 35195; waic= 35164; waic_p_eff=1709; mlk= -7749.65; n=5815			

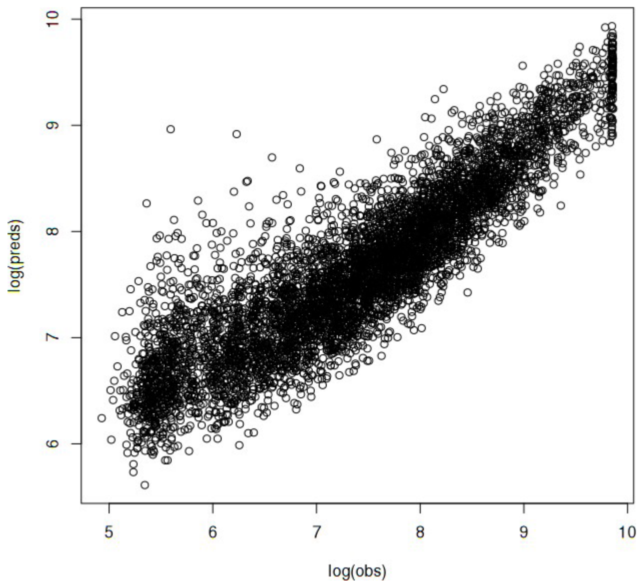

Fig S0.1 Posterior predictive check (numerical abundance).

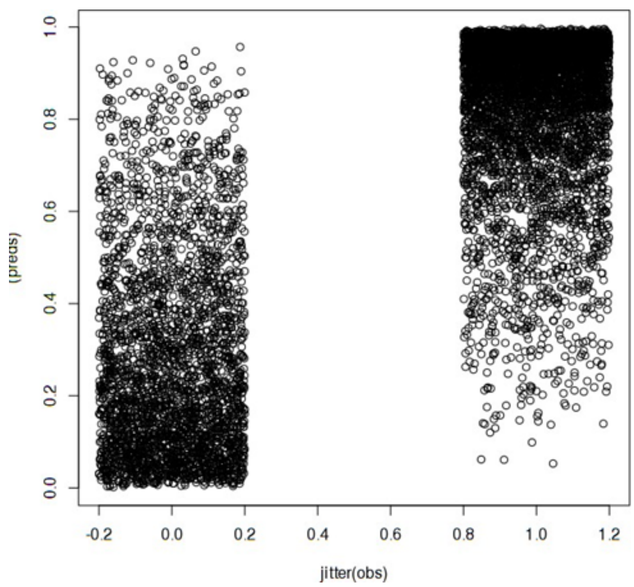

Fig S0.2 Posterior predictive check (probability of positive value). X- axis has been "jittered".

Table S0.2 Parameter estimate for probability of observing a positive value. Usual goodness of fit criteria are also shown.

Factor	mean	sd	cv
Intercept	0.6577	0.06461	9.82
SD time	0.6367	0.07630	11.98
SD cyclic	0.1938	0.06952	35.88
SD t	0.4207	0.12230	29.07
SD z	**4.5975**	**1.11403**	**24.23**
SD pca1	0.2421	0.07850	32.43
SD pca2	0.1653	0.05738	34.71
SD space	1.9881	0.12260	6.17
SD space_time	1.2116	0.10887	8.99
Rho for time	0.6513	0.10862	16.68
GroupRho for space_time	0.8559	0.03568	4.17
Phi for space	0.1084	.006610	61.00
Phi for space_time	0.1144	0.05800	50.69
Pearson = 0.8157; Spearman= 0.766; dic= 6607; waic= 6468; waic_p_eff=796; mlk= -7057; n=8655			

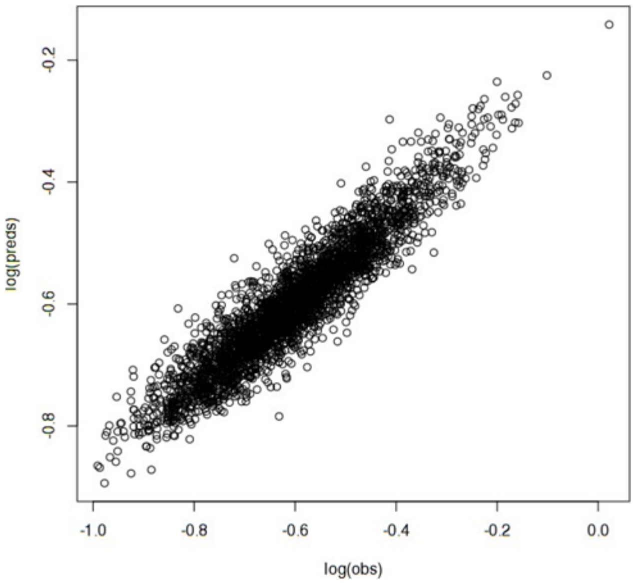

Fig S0.3.Posterior predictive check (mean body mass).

Table S0.3 Parameter estimate for mean body mass. Usual goodness of fit criteria are also shown.

Factor	mean	sd	cv
Intercept	0.54397	0. 19166	35.23
SD the Gaussian observations	0.04453	0.00091	2.04
SD time	**0.19753**	**0.07630**	16.42
SD cyclic	0.00881	0.00102	11.62
SD t	0.00078	0.00029	37.09
SD z	0.16476	0.07517	45.62
SD pca1	0.00413	0.00337	81.72
SD pca2	0.1653	0.05738	20.81
SD space	0.03639	0. 00173	4.76
SD space_time	0.05468	0. 00172	3.14
Rho for time	0.99699	0.00090	0.09
GroupRho for space_time	0.73233	0.01517	2.07
Phi for space	0.51236	0.05272	10.29
Phi for space_time	0.12167	0.01186	9.75
Pearson = 0.936; Spearman= 0.929; dic= 9232; waic= 9269; waic_eff=1141; mlk= 14701; n=3169			

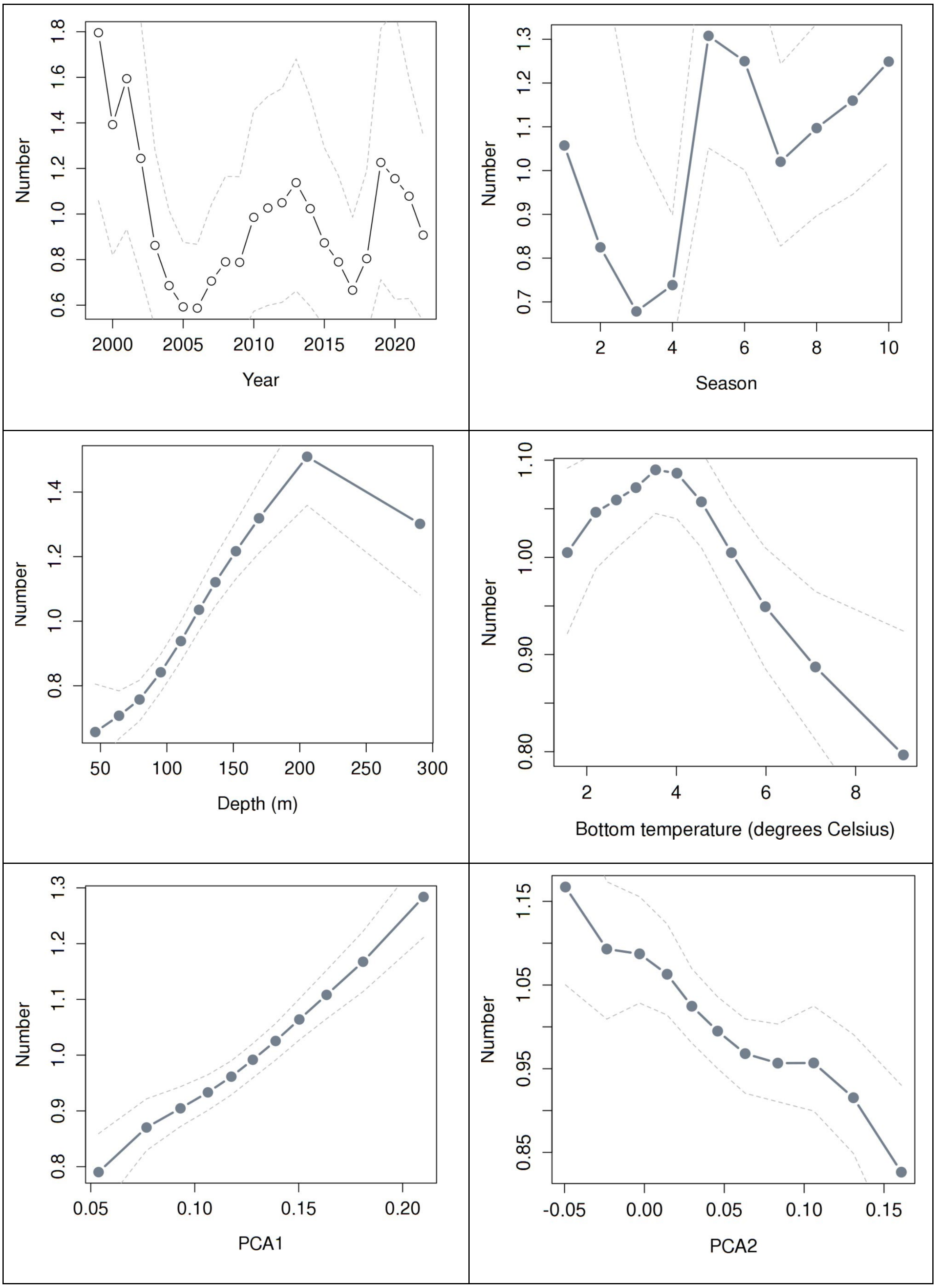

Fig S0.4 Covariate effects for Scenario 0. 95%CI also shown.

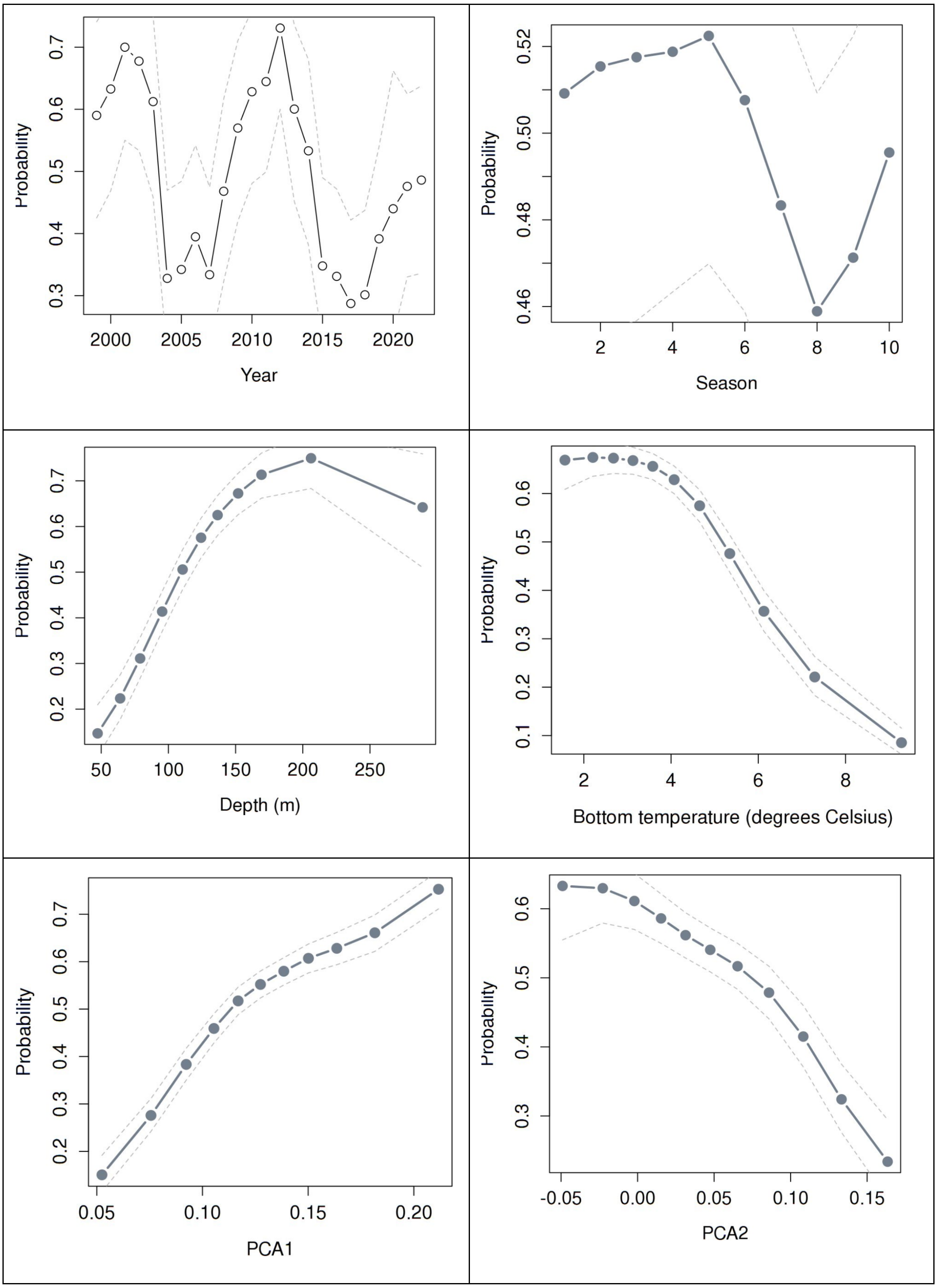

Fig S0.5 Covariate effects for Scenario 0 on Presence-absence. 95%CI also shown.

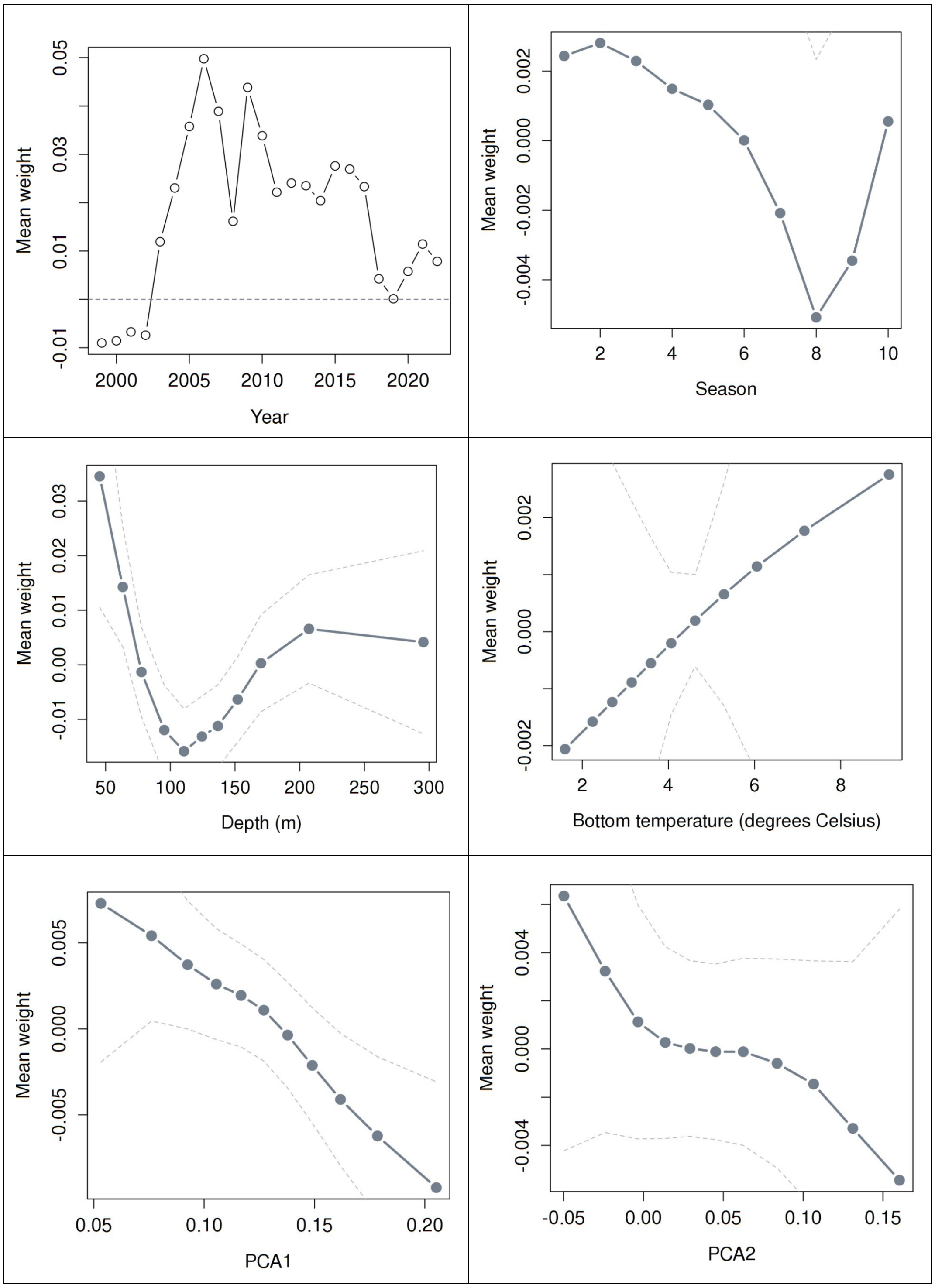

Fig S0.6 Covariate effects for Scenario 0 on mean weight. 95%CI also shown.

Scenario 1: Testing removal of location in 2015

Approach:

The same 83 stations that were not completed in 2022 were removed from the 2015 survey and modelling re-done (herein, Scenario 1). This is a limited form of cross validation, in that it is not done repeatedly and completely randomly. However, as the the reviewer questioned the potential bias of first and second order moments, this was chosen as a simple alternative to exhaustive and time consuming cross validation. We will compare Scenario 1 solutions with the predictions with the full data set (Scenario 0).

The year 2015 was chosen as there was complete sampling in that year and not too distant in time relative to 2022 (reducing time-related divergence in sampling approaches and ecosystem states). A polygon was constructed and used to identify and remove stations (brown in Fig S1.0)

Fig S1.0. Stations in 2015. The full sample will be denoted as Scenario 0. The brown points identify the stations removed that were interior to the polygon of unfinished stations in 2022. The results associated with these locations removed will be called Scenario 1.

For 2015:

Mean mass density in stations dropped = 1159 kg / km^2 (sd=2076; n=83)

Mean mass density in stations kept = 1271 kg / km^2 (sd=2079; n=330)

Overall model performance was similar to Scenario 0. However, the marginal effect of depth varied (e.g, Tables S0.* vs S1.*).

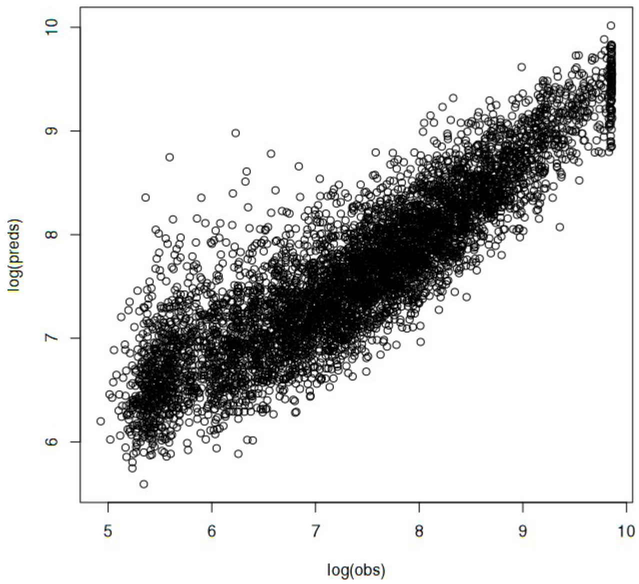

Fig S1.1 Posterior predictive check (numerical abundance).

Table S1.1 Parameter estimate for numerical abundance. Usual goodness of fit criteria are also shown.

Factor	mean	sd	cv
(Intercept)	1521.82087	4.490e+02	2.950e+01
SD time	0.31138	5.727e+00	1.839e+03
SD cyclic	0.31269	3.999e+00	1.279e+03
SD t	0.09509	1.941e+02	2.042e+05
SD z	**0.52346**	**2.195e+00**	**4.192e+02**
SD pca1	0.00011	3.003e+09	2.687e+15
SD pca2	0.11923	7.045e+01	5.909e+04
SD space	0.64693	2.071e-01	3.201e+01
SD space_time	0.53476	2.376e-01	4.443e+01
Rho for time	0.80616	1.030e-01	1.278e+01
GroupRho for space_time	0.71294	3.383e-02	4.750e+00
Phi for space	0.03581	3.767e-02	1.052e+02
Phi for space_time	0.04263	3.414e-02	8.010e+01
Overdispersion	4.24199	2.232e-01	5.260e+00
Pearson= 0.900; Spearman= 0.882; dic= 34798; p.eff= 1972; waic=34886;waic.p.eff=1628; mlk= 7562; n= 5749			

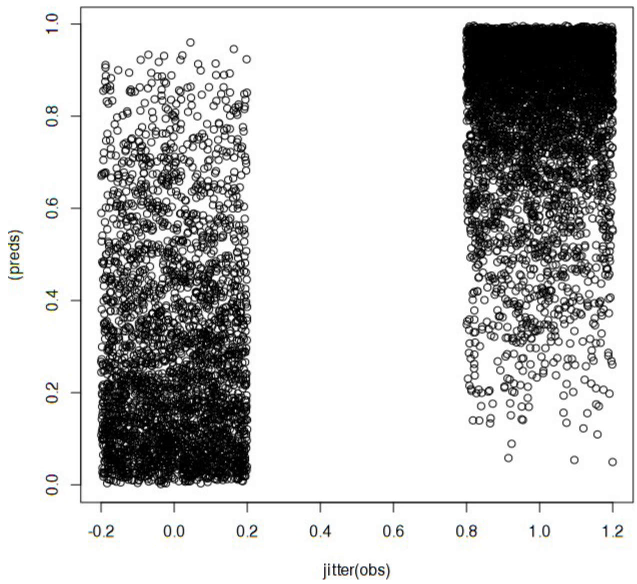

Fig S1.2 Posterior predictive check (probability of positive value). X- axis has been "jittered".

Table S1.2 Parameter estimate for presence-absence. Usual goodness of fit criteria are also shown.

Factor	**mean**	**sd**	**cv**
(Intercept)	0.6574	0.06703	10.20
SD time	0.6471	0.14882	23.00
SD cyclic	0.2667	0.13237	49.63
SD t	0.4839	0.12353	25.53
SD z	**6.1994**	**1.80731**	**29.15**
SD pca1	0.2288	0.09328	40.78
SD pca2	0.1994	0.07865	39.44
SD space	1.9140	0.10831	5.66
SD space_time	1.2692	0.11654	9.18
Rho for time	0.6844	0.12239	17.88
GroupRho for space_time	0.8936	0.02774	3.10
Phi for space	0.1269	0.08246	64.96
Phi for space_time	0.1218	0.06155	50.55
Pearson= 0.812; Spearman= 0.763; dic= 6547; p.eff= 1818; waic=6417;waic.p.eff=768; mlk= 7089; n= 8572			

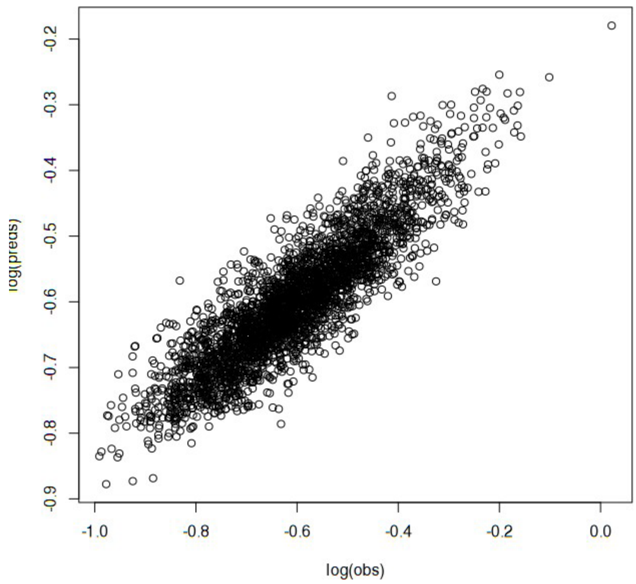

Figure S1.3: Posterior predictive check (mean body mass).

Table S1.3 Parameter estimate for mean body mass. Usual goodness of fit criteria are also shown.

Factor	mean	sd	cv
(Intercept)	0.55592	0.01042	1.87
SD the Gaussian observations	0.05034	0.00092	1.82
SD time	0.02417	0.00929	38.42
SD cyclic	0.00720	0.00443	61.49
SD t	0.01355	0.01510	111.47
SD z	**0.15679**	**0.06884**	**43.90**
SD pca1	0.00276	0.00262	94.98
SD pca2	0.00284	0.00269	94.68
SD space	0.00602	0.00286	47.49
SD space_time	0.06095	0.00136	2.23
Rho for time	0.73720	0.19145	25.97
GroupRho for space_time	0.89449	0.01072	1.20
Phi for space	0.62340	0.32316	51.84
Phi for space_time	0.31638	0.04386	13.86
Pearson= 0.888; Spearman= 0.877; dic= -8829; p.eff= 1118; waic=-8799; waic.p.eff=9178; mlk= 14653; n= 3136			

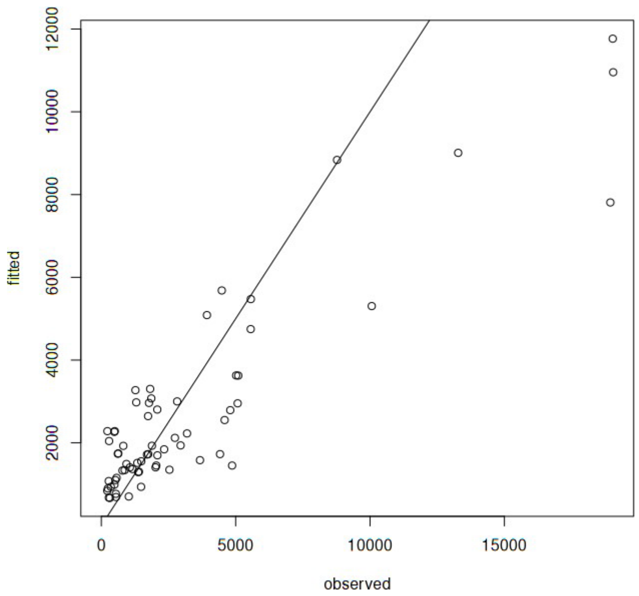

Figure S1.4. Prediction and observations numerical density of the 83 stations removed. Pearson correlation of 0.91 and a Spearman of 0.72.

Predicting numerical density at these locations is similar though there is underestimation of abundance at high densities (Fig S1.4). Prediction of mean size was more variable (Fig S1.5). Prediction of presence-absence (Fig S1.5) was also poor, especially absence of snow crab.

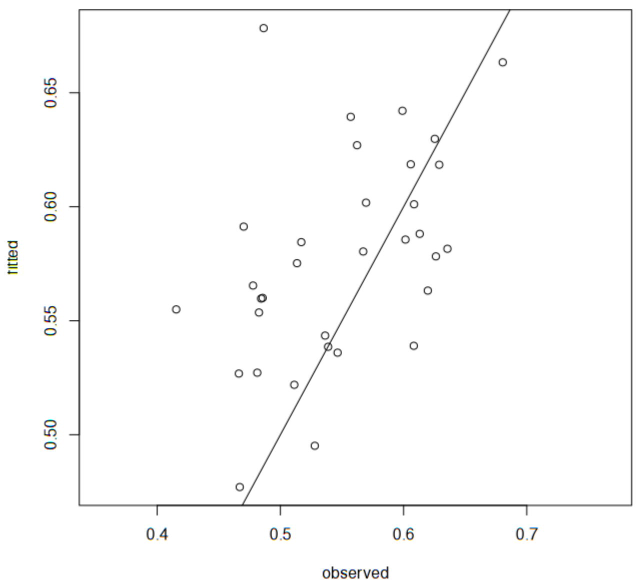

Figure S1.5. Prediction and observations of mean size crab in the 83 stations removed. Pearson correlation of 0.48 and a Spearman of 0.52.

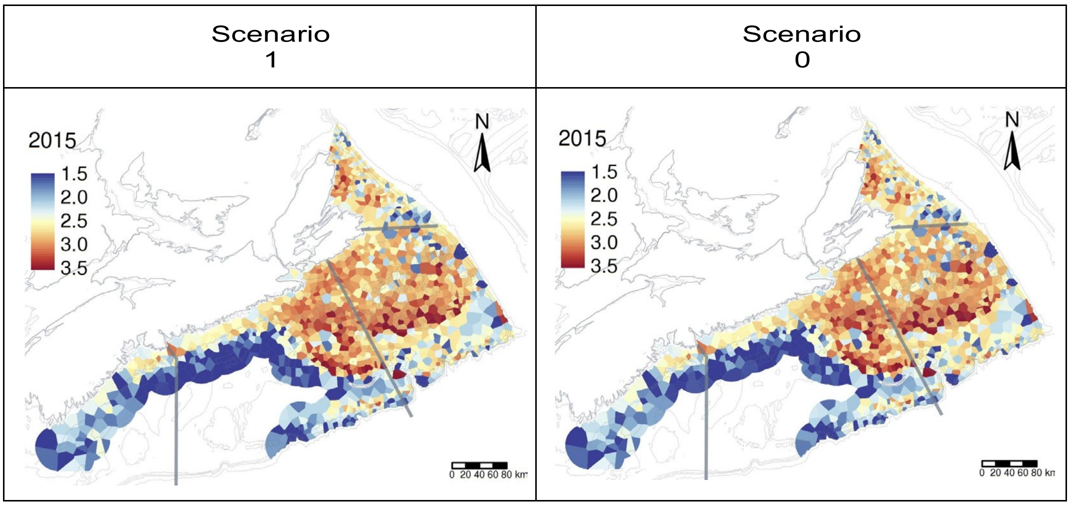

Fig S1.6 Biomass of fishable crab after removal and refit of models (Scenario 1; left), vs with all data (Scenario 0; right).

What is observed in the differences between Scenarios 0 and 1 is that the overall (aggregate) effect of station removal was low (Figs S2.6, S2.7). The overall temporal pattern was minimally affected, though variability did increase (Fig S2.7). Overall estimates of biomass for SENS (Fig S1.8) and for the area of interest (Fig S1.9) suggest low bias.

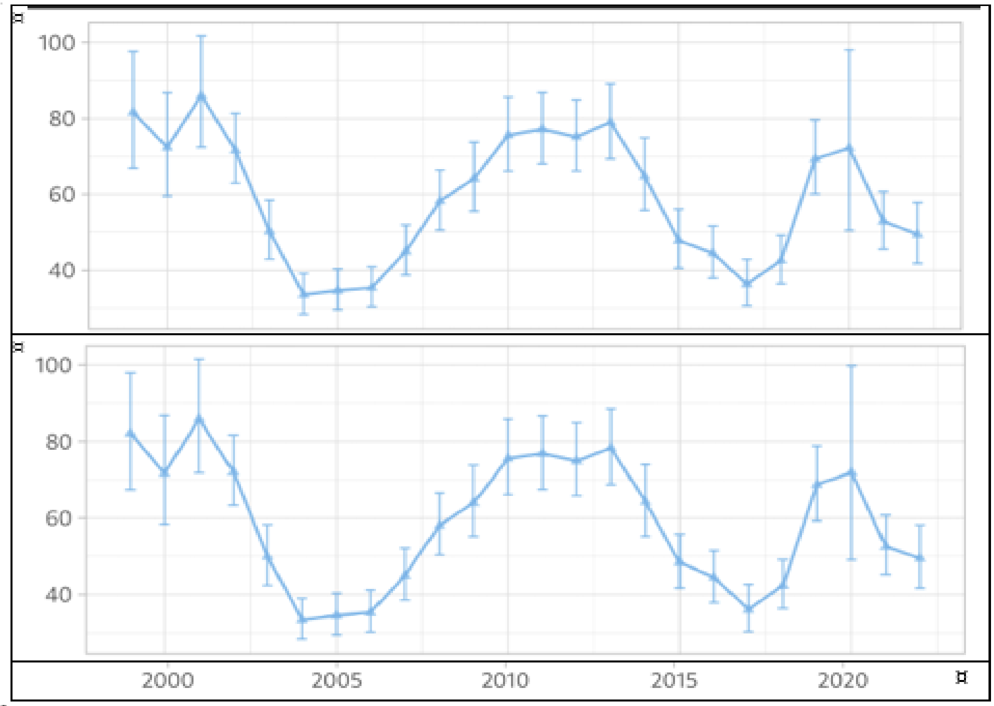

Fig S1.7. Aggregate biomass estimates for SENS by year and 95% CI. Top: Scenario 1; Bottom Scenario 0. A minor bias in abundance and elevated variability is evident for 2015 in Scenario 1.

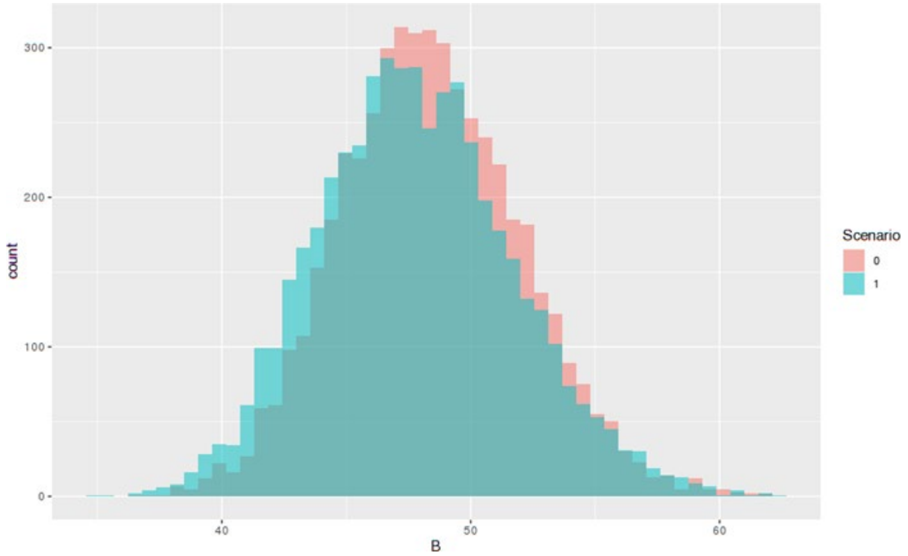

Fig S1.8. Posterior distributions of S-ENS biomass estimates for year 2015 under full data (Scenario 0) and 83 stations removed (Scenario 1). Some bias towards lower values are evident on the lower tail and bias towards larger values in the upper tail. That is, variability is higher in Scenario 1 relative to Scenario 0.

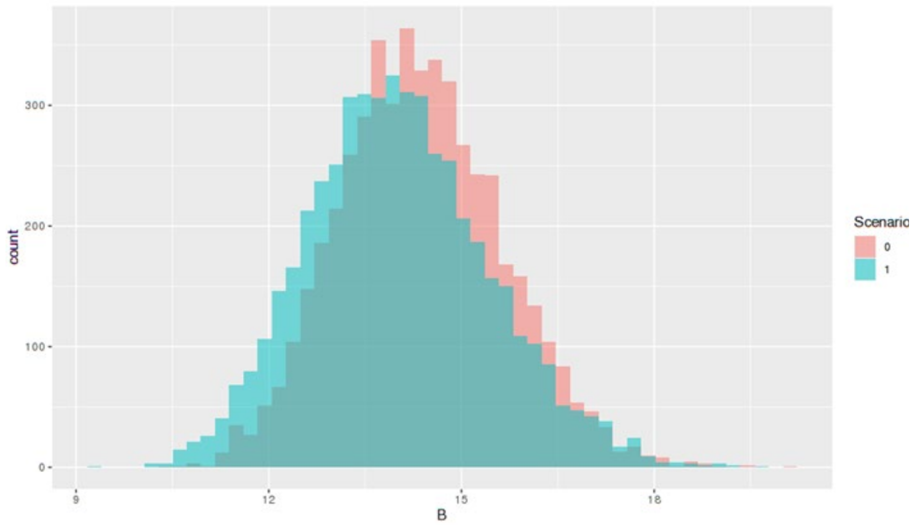

Figure S1.9. Posterior distributions fishable biomass estimates, interior to the 2022 polygon of missing data, inferred for 2015. There is overlap and lower bias in Scenario 1 relative to Scenario 0.

Scenario 2: Removal of species composition and temperature effects

The influence of removal of species composition and temperature effects resulted in similar but slightly poorer model solutions relative to Scenario 0 (Figs S2.1-3; Tables S2.1-3). Depth was still the most informative factor. Area 4X was most affected by this modification; S- and N-ENS are less affected (Fig S2.4). Overall form of the time-series by fishing area is similar (except 4X; Fig S2.5): Scenario 2 results in larger 95% Credible Intervals as well as higher magnitude estimates of abundance, especially along the margins of 4X. He trajectories of the most recent period (2021-2022) suggest stronger declining trends in Scenario 2, relative to a flatter one for Scenario 0 (Fig S2.5).

Table S2.1. Parameter estimate for numerical abundance. Usual goodness of fit criteria are also shown.

Factor	mean	sd	cv
(Intercept)	1510.2529	245.74112	16.27
SD time	0.2991	0.05735	19.18
SD cyclic	0.2934	0.06311	21.51
SD z	**0.7488**	**0.25009**	**33.40**
SD space	0.6926	0.03254	4.70
SD space_time	0.5512	0.01913	3.47
Rho for time	0.6527	0.15077	23.10
GroupRho for space_time	0.6519	0.03680	5.64
Phi for space	0.0318	0.03672	115.47
Phi for space_time	0.0676	0.02665	39.42
overdispersion	4.5084	0.29891	6.63
Pearson= 0.89; Spearman= 0.89; dic= 35234; p.eff= 2173; waic=35238; waic.p.eff=1710; mlk= -7759; n= 5815			

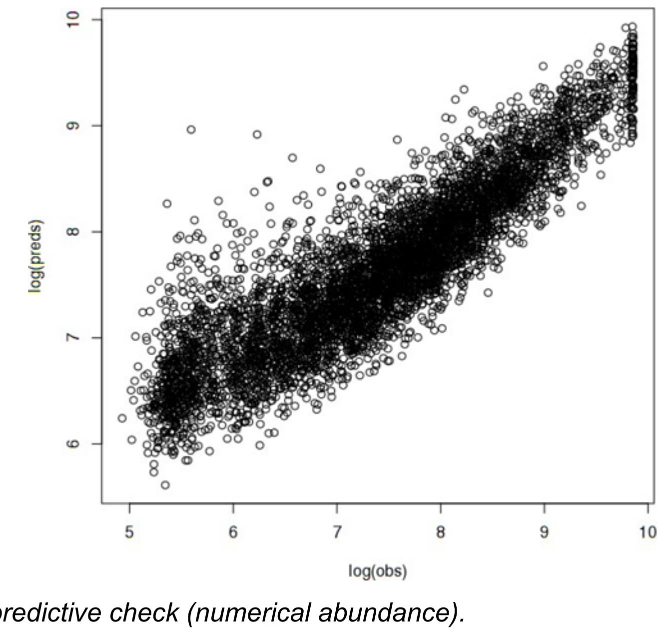

Fig S2.1. Posterior predictive check (numerical abundance).

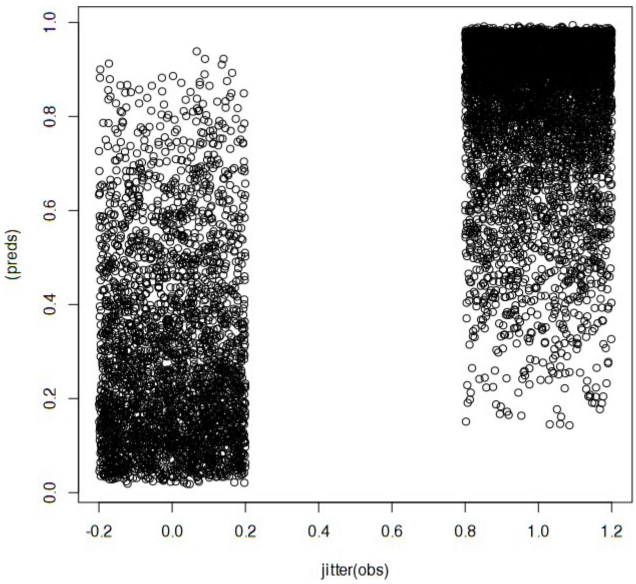

Fig S2.2. Posterior predictive check (probability of positive value). X- axis has been "jittered".

Table S2.2. Parameter estimate for probability of positive value. Usual goodness of fit criteria are also shown.

Factor	mean	sd	cv
(Intercept)	0.67934	0.09869	14.53
SD time	0.78621	0.15497	19.71
SD cyclic	0.27097	0.04652	17.17
SD z	**6.83368**	**2.44591**	**35.79**
SD space	2.70506	0.17003	6.29
SD space_time	1.68504	0.18391	10.91
Rho for time	0.79735	0.08737	10.96
GroupRho for space_time	0.92324	0.02150	2.33
Phi for space	0.01475	0.01112	75.40
Phi for space_time	0.19470	0.06845	35.16
Pearson= 0.824; Spearman= 0.773; dic= 6946; p.eff= 1276; waic= 6755; waic.p.eff=913; mlk= -6855; n= 8655			

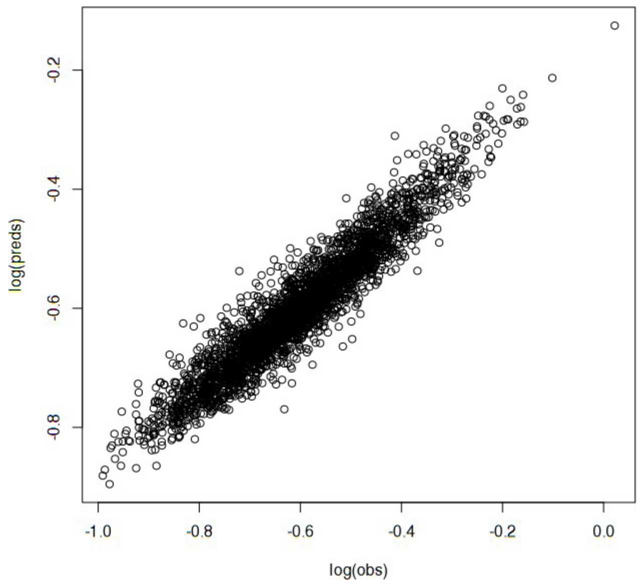

Fig S2.3. Posterior predictive check (mean body mass).

Table S2.3 Parameter estimate for mean body mass. Usual goodness of fit criteria are also shown.

Factor	mean	sd	cv
(Intercept)	0.55584	0.01022	1.84
SD the Gaussian observations	0.04227	0.00200	4.72
SD time	0.02142	0.00724	33.82
SD cyclic	0.00953	0.00509	53.43
SD z	**0.16159**	**0.07411**	**45.86**
SD space	0.04212	0.00338	8.03
SD space_time	0.05094	0.00208	4.09
Rho for time	0.73174	0.17833	24.37
GroupRho for space_time	0.62041	0.04483	7.23
Phi for space	0.39511	0.14363	36.35
Phi for space_time	0.11254	0.04221	37.51
Pearson= 0.951; Spearman= 0.945; dic= -9431; p.eff= 1669; waic=9487; waic.p.eff=1228; mlk= -14755; n= 3169			

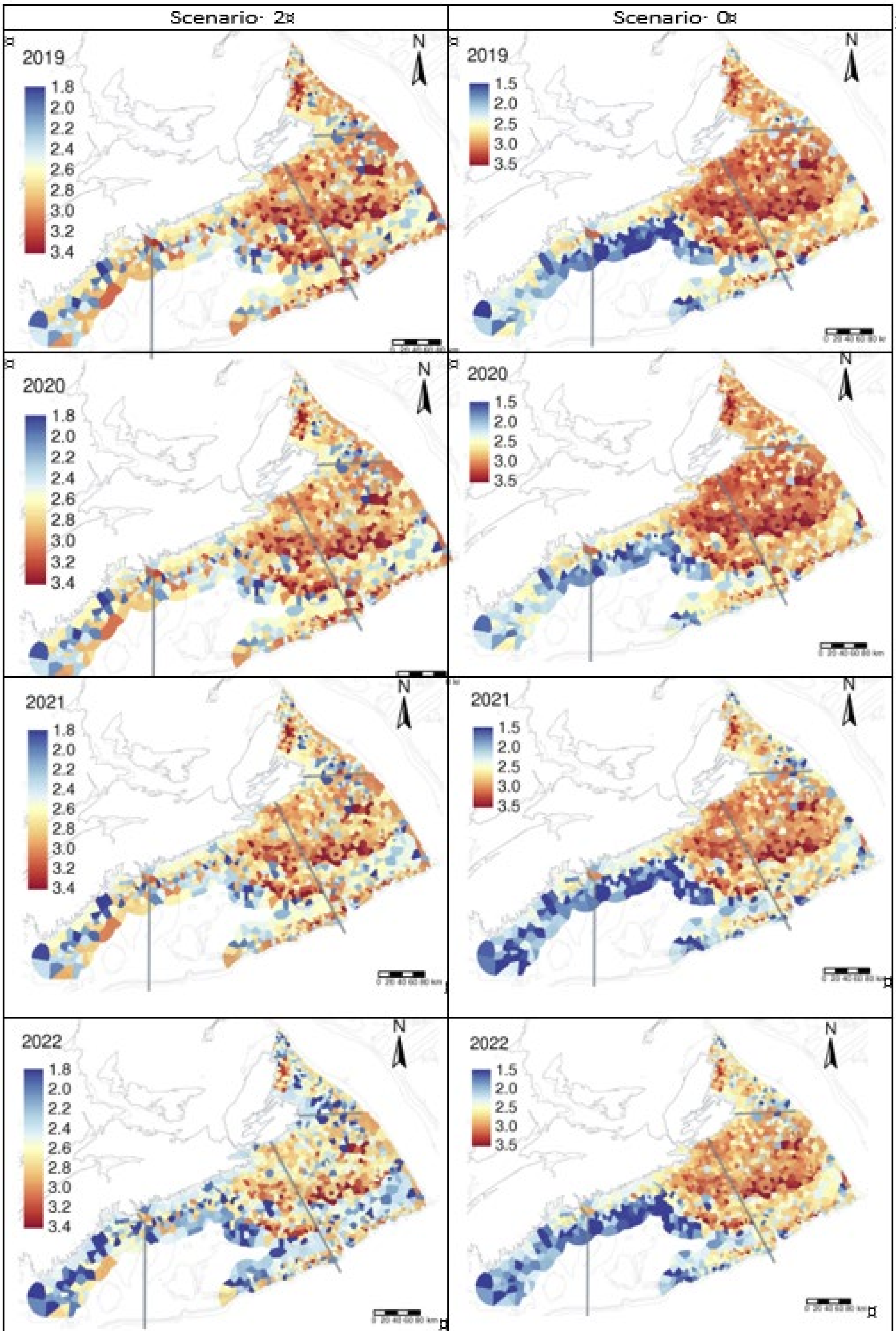

Fig. S2.4: Spatiotemporal distributions of biomass in Scenario 2 (left) and Scenario 0 (right).

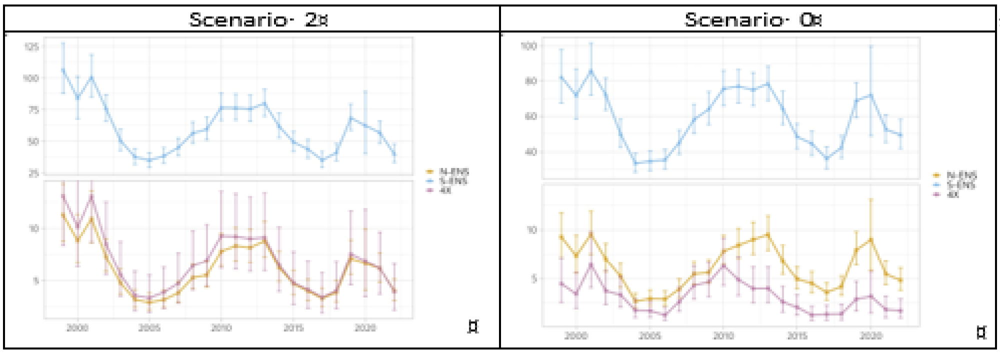

Fig. S2.5: Aggregate time-series comparing Scenario 2 (left) with Scenario 0 (right).

Scenario 3: Removal of spatial and spatiotemporal random effects

Removal of the effects of spatial and spatiotemporal random effects is to remove local space-time processes/structure. This results in more homogenous spatial solutions as they are influenced more by underlying spatiotemporal covariates (temperature, species composition) that tend to operate upon larger spatiotemporal scales (smoother). The overall consequence upon posterior predictive ability was to increase variability (Fig S3.1-4). The overall form of the timeseries by fishing area is similar to Scenario 0 (Fig S3.5). The trajectory from 2021 to 2022 estimates of abundance is flat or increases in Scenario 3, while those of Scenario 0 tend to decline in this time interval. The variability, however, suggests these differences are not strong.

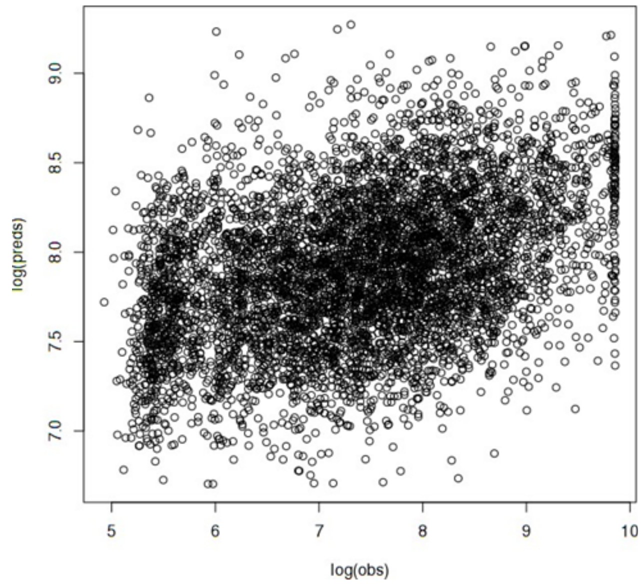

Fig S3.1 Posterior predictive check (numerical abundance).

Table S3.1 Parameter estimate for numerical abundance.

Factor	mean	sd	cv
(Intercept)	2506.65964	500.34049	19.96
SD time	0.31511	0.07556	23.98
SD cyclic	0.80772	0.29778	36.87
SD t	0.25467	0.20874	81.97
SD z	**2.30189**	**0.90322**	**39.24**
SD pca1	0.08193	0.06117	74.66
SD pca2	0.09694	0.07406	76.40
Rho for time	0.65853	0.16445	24.97
nbin 1/overdispersion	1.22352	0.02426	1.98
Pearson= 0.356; Spearman= 0.375; dic= -39191; p.eff= 50; waic=39212; waic.p.eff=68; mlk= -19733; n= 5815			

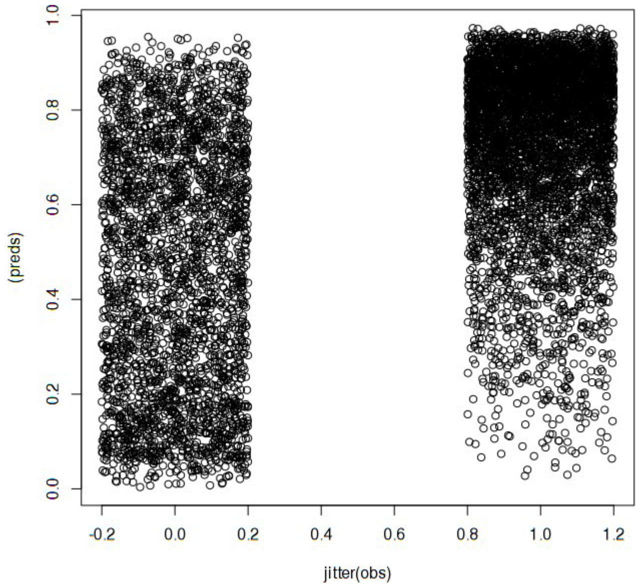

Fig S3.2 Posterior predictive check (probability of positive value). X- axis has been "jittered".

Table S3.2 Parameter estimate for presence-absence mean.

Factor	**mean**	**sd**	**cv**
Intercept	0.5907	0.046	7.79
SD time	0.3909	0.09726	24.88
SD cyclic	0.8539	0.37762	44.22
SD t	0.5783	0.26117	45.16
SD z	**7.5133**	2.88706	38.43
SD pca1	0.2109	0.10243	48.57
SD pca2	0.1578	0.07236	45.85
Rho for time	0.6721	0.14805	22.03
Pearson= 0.520; Spearman= 0.498; dic= -8913; p.eff= 42; waic=8913; waic.p.eff=42; mlk= -4581; n= 8655			

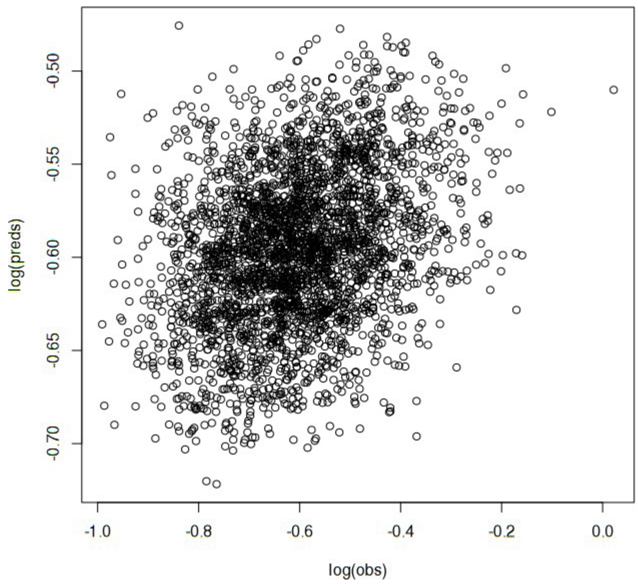

Fig S3.3. Posterior predictive check (mean body mass).

Table S3.3 Parameter estimate for mean body mass.

Factor	mean	sd	cv
(Intercept)	0.55577	0.00780	1.40
SD the Gaussian pbservations	0.07552	0.00007	0.09
SD time	0.01013	0.00141	13.90
SD cyclic	0.00001	0.00000	6.21
SD t	0.00377	0.00034	9.07
SD z	**0.19325**	**0.00684**	**3.54**
SD pca1	0.00122	0.00011	8.95
SD pca2	0.00013	0.00003	26.43
Rho for time	0.80537	0.03147	3.91
Pearson= 0.319; Spearman= 0.306; dic= -7369; p.eff= 27; waic=-73698913; waic.p.eff=27; mlk= 3554; n= 3169			

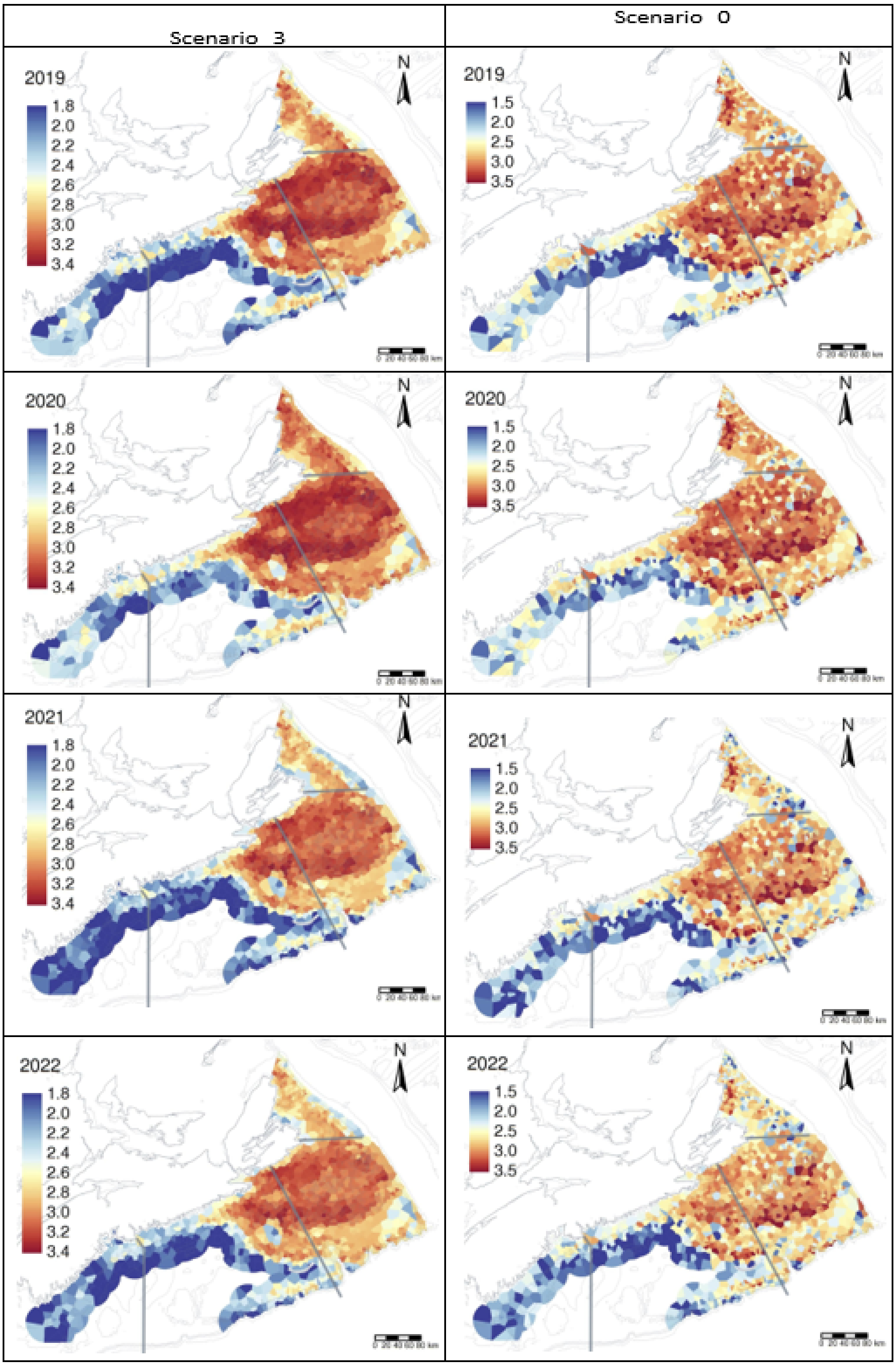

Fig. S3.4: Spatiotemporal distributions of biomass in Scenario 3 (left) and Scenario 0 (right).

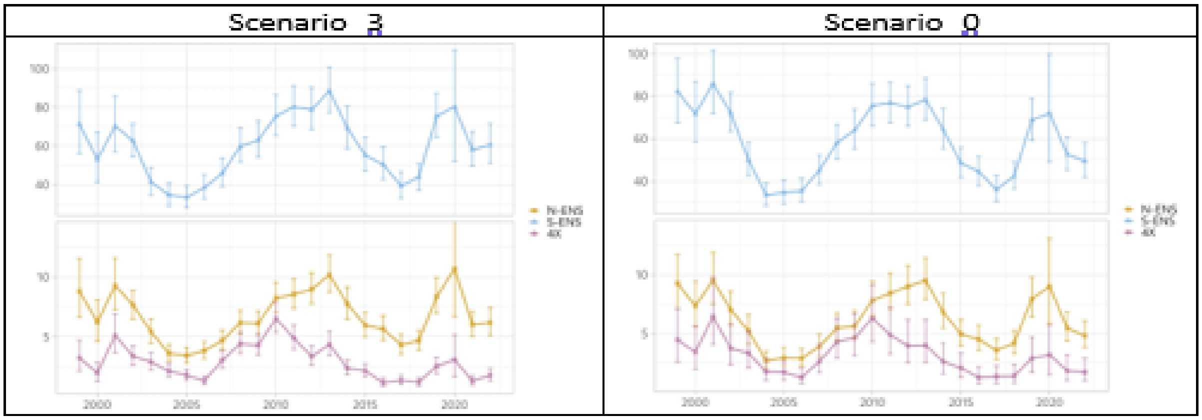

Fig. S3.5: Aggregate timeseries comparing Scenario 3 (left) with Scenario 0 (right).