2023-25 FISS design evaluation

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Part 1: 2023-25 FISS design evaluation

PURPOSE

To review the 2023-25 FISS designs presented at SRB020 and endorsed by the Scientific Review Board (SRB) at that meeting.

BACKGROUND

At SRB020, Secretariat staff presented proposed FISS designs for 2023-25 together with an evaluation of those designs (Webster 2022). Based on the evaluation, it is expected that the proposed designs would lead to estimated indices of density that would meet bias and precision criteria. In their report (IPHC-2022-SRB020-R, paragraph 12) the SRB stated:

> *The SRB **ENDORSED** the final 2023 FISS design as presented in Fig. 2, and provisionally **ENDORSED** the 2024-25 designs (Figs. 3 and 4), recognizing that these will be reviewed again at subsequent SRB meetings.*

PROPOSED DESIGNS FOR 2023-25

The designs proposed for 2023-25 (Figures 1,1 to 1.3) use efficient subarea sampling in IPHC Regulatory Areas 2A, 4A and 4B, and incorporate a randomized subsampling of FISS stations in IPHC Regulatory Areas 2B, 2C, 3A and 3B (except for the near-zero catch rate inside waters around Vancouver Island), with a sampling rate chosen to keep the sample size close to 1000 stations in an average year, a logistically feasible footprint for the annual FISS. In 2021, designs for 2023-24 were also approved subject to later revision (IPHC-2022-AM098-R). The designs developed in 2021 have largely been carried over into the current 2023-24 proposal, with exceptions noted below.

- IPHC Regulatory Area 2A: Sample the highest-density waters of IPHC Regulatory 2A in northern Washington and central/southern Oregon each year of the 2023-25 period, and in 2023 only, add the moderate density waters of southern Washington/northern Oregon and northern California **(revision from previous 2023 design proposal)**.
- IPHC Regulatory Area 4A: Sample the higher-density western subarea of IPHC Regulatory Area 4A in all three years, the medium-density northern shelf edge subarea in 2023 only, and the historically lower-density southeastern subarea in 2025 only.
- IPHC Regulatory Area 4B: Sample the high-density eastern subarea in all three years, and the western subarea in 2023 only **(revision from previous 2023 design proposal)**.

Stations in the moderate-density waters of IPHC Regulatory 2A proposed for 2023 sampling have not been sampled since 2017 (California) or 2019 (WA/OR). This is a revision from previous proposals, which did not include these stations prior to 2025 (Webster 2021). Evaluation of potential designs in IPHC Regulatory Area 2A showed that unless these waters were sampled in 2023, we project that precision targets would not be met, with an expected 2023 coefficient of variation for mean O32 WPUE of 20% (target range is <15%). We have also received anecdotal reports of increasing recreational catch rates in northern California, providing additional motivation for bringing forward sampling in those waters.

The design proposals again include full sampling of the standard FISS grid in IPHC Regulatory Area 4CDE. The Pacific halibut distribution in this area continues to be of particular interest, as it is a highly dynamic region with an apparently northward-shifting distribution of Pacific halibut, and increasing uncertainty regarding connectivity with populations adjacent to and within Russian waters.

RECOMMENDATION

That the Scientific Review Board:

1) **NOTE** paper IPHC-2022-SRB021-06, which reviewed the 2023-25 FISS designs presented at SRB020 and endorsed by the SRB at that meeting;
2) **RECOMMEND** that the Commission note the SRB endorsement of the proposed 2023 design (Figure 1.1) and provisional endorsement of the proposed 2024-25 designs (Figures 1.2 and 1.3).

References

IPHC 2022. Report of the 20th Session of the IPHC Scientific Review Board (SRB) IPHC-2022-SRB20-R. 19 p.

IPHC 2022. Report of the 98th Session of the IPHC Annual Meeting (AM098) IPHC-2022-AM098-R. 60 p.

Webster, R. A. 2021. 2022-24 FISS design evaluation. IPHC-2021-SRB020-05 Rev_1.

Webster, R. A. 2022. 2023-25 FISS design evaluation. IPHC-2022-SRB020-05.

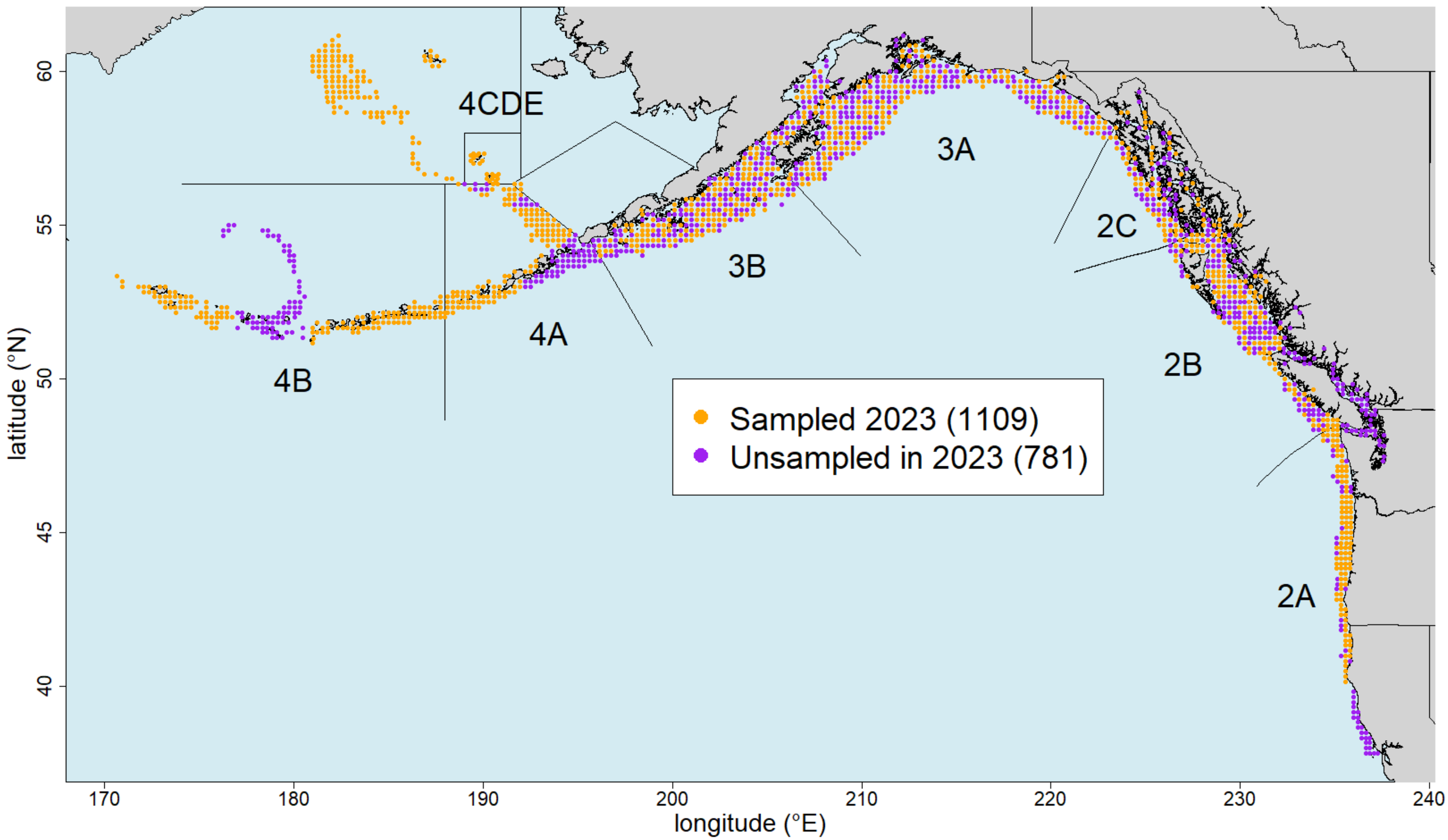

Figure 1.1. Proposed minimum FISS design in 2023 (orange circles) based on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

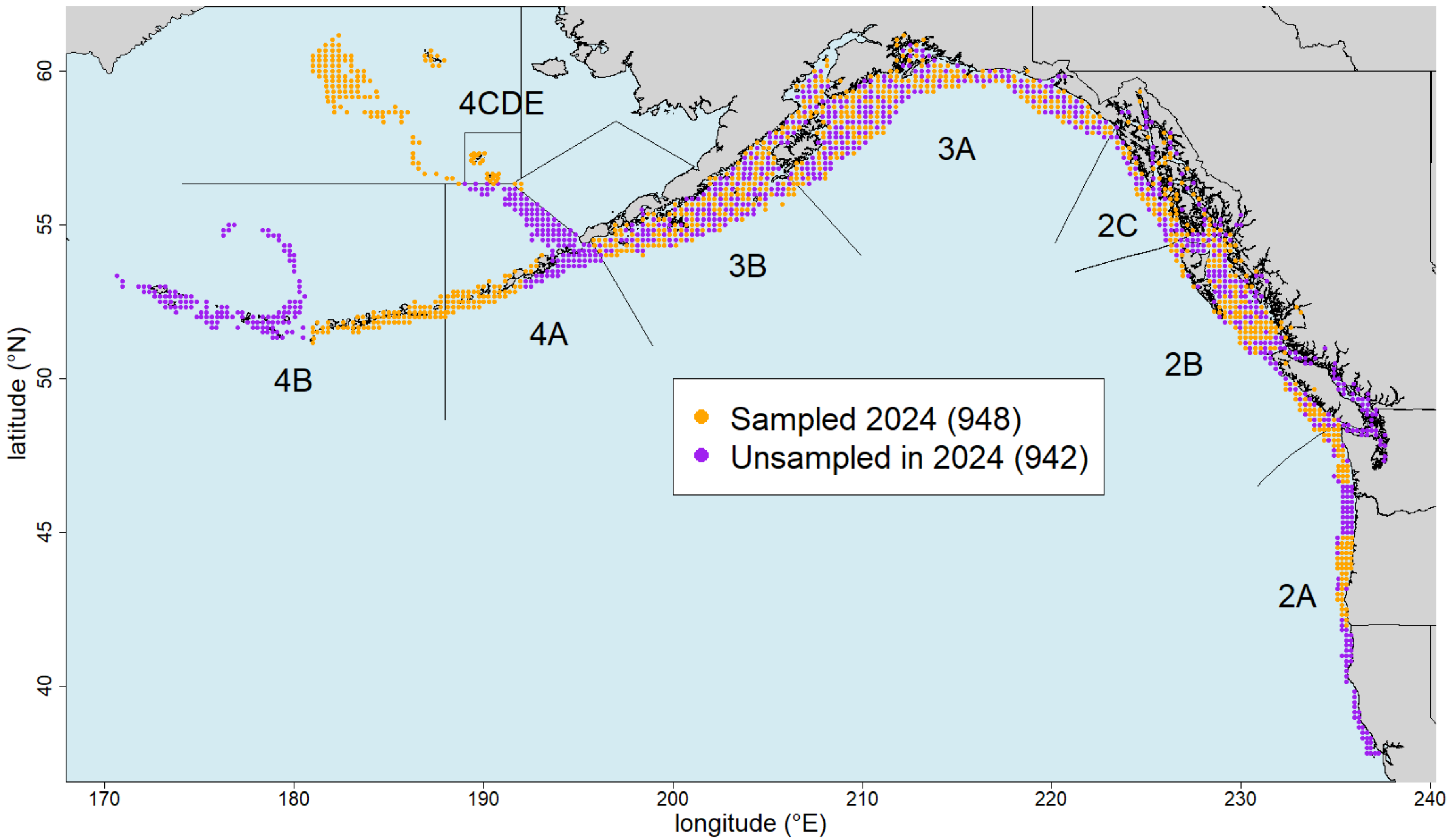

Figure 1.2. Proposed minimum FISS design in 2024 (orange circles) based on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

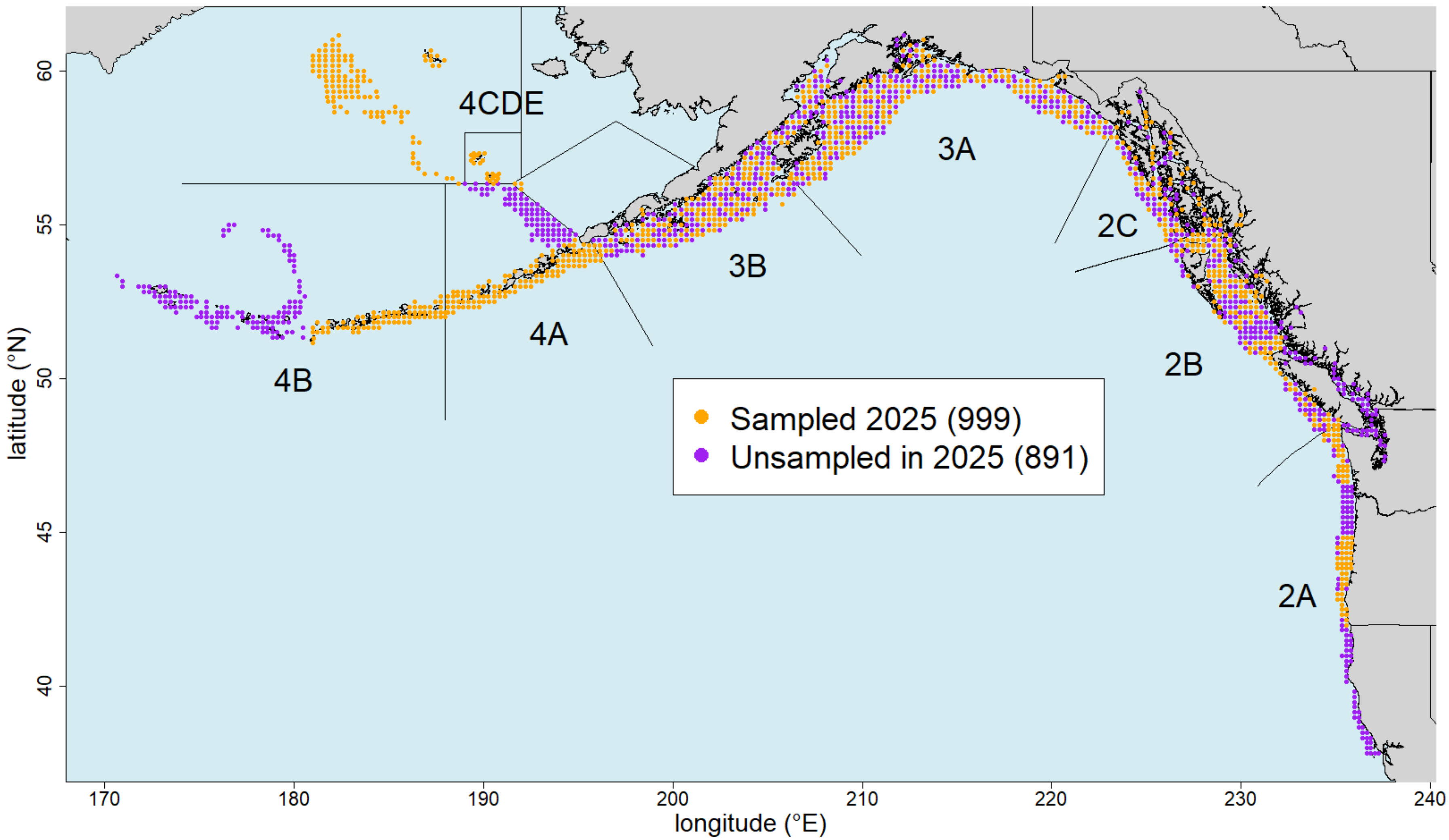

Figure 1.3. Proposed minimum FISS design in 2025 (orange circles) based on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

Part 2: Modelling updates

PURPOSE

To present an update to the space-time model for IPHC Regulatory 4CDE, and a proposal for revising the evaluation of bias potential in future FISS design proposals.

BACKGROUND/INTRODUCTION

The IPHC uses calibrated data from NMFS annual Bering Sea trawl survey along with our own Fishery Independent Setline Survey (FISS) data to provide comprehensive survey coverage of the Bering Sea. The trawl data are calibrated by length distribution and scaled to IPHC index units of lb/skate outside of the space-time models (Webster et al. 2021). While integrating the calibration into the space-time modelling is not possible within the R-INLA framework currently used, the scaling factors can be estimated within the models using a gear (trawl vs setline) coefficient. We propose using this approach going forward for space-time modelling of Bering Sea survey data for Pacific halibut.

As part of the annual evaluation process of proposed FISS designs, we consider the potential for bias in estimates of weight per unit effort (WPUE) caused by omitting part of an IPHC Regulatory Area from the design. Given that cost constraints mean that not all IPHC FISS stations can be fished each year, the potential for bias will always exist, but the intention is to limit the magnitude of the bias through our design choices.

For maintaining low potential for bias in estimates generated from FISS data, since 2020 we have looked at estimates of historical changes in the proportion of biomass in each subarea, and used that to guide the sampling frequency in future designs (Webster 2022). Thus, subareas that have historically had rapid changes in biomass proportion need to be sampled most frequently, and those that are relatively stable can be sampled less frequently. This approach has the disadvantage of giving all years in the time series equal weight – it does not consider how far into the past such rapid changes occurred.

Here we consider a new approach based on the posterior predictive distribution of trends in subarea WPUE. These distributions can give us the posterior probability that a subarea's biomass proportion has changed by more than a specified amount (we use 10% to ensure low bias) within a period of years. By focusing on values for more recent years rather than the entire time series, we can get a better sense of how likely unobserved changes of this magnitude are to occur under proposed FISS designs for the next three years.

BERING SEA MODEL UPDATE

The IPHC trawl to FISS length calibration is described in Webster et al. (2021). Once the trawl data are calibrated to have a length distribution that closely matches that of the FISS based on data from the years the two surveys overlapped (2006 and 2015), the resulting trawl density indices are scaled to have the same units (lb/skate) as the FISS WPUE index (or halibut/skate for numbers per unit effort, NPUE). A single scale factor is estimated from the combined 2006 and 2015 data, and this is applied to all calibrated trawl station-level catch rate data from the entire time series. As this is done outside of the space-time model, any variance associated with estimating this scalar is not propagated into the space-time model estimates.

The IPHC space-time model separates the WPUE process into zero and non-zero components (Webster et al. 2021), linked by a common spatially correlated error process. This means that we can include a gear covariate in each component of the model, thereby estimating separate coefficients for each model component. When implementing the models, we actually included three covariates in each component to ensure the gear coefficient estimates were only being made for data within the 2006 and 2015 gear calibration years. Table 2.1 describes the parameters added to zero (z) and non-zero (nz) model components.

Table 2.1. Parameters added to the space-time model for IPHC Regulatory Area 4CDE to account for gear and calibration experiment effects.

Variable	Description	Zero parameter	Non-zero parameter
Gear type	1=trawl, 0=FISS	g_z	g_{nz}
Calibration stations (overlapping trawl and FISS 2006, 2015 stations)	1=calibration, 0 otherwise	c_z	c_{nz}
Interaction (trawl stations within the calibration study)	1=trawl calibration, 0 otherwise	gc_z	gc_{nz}

Trawl stations within the calibration study have coefficients g_z+gc_z and $g_{nz}+gc_{nz}$, the sum of the overall gear difference and the calibration study-specific gear effect. The equivalent of the scale factors calculated previously are the exponential of these sums, given we are working on logit and log scales for the two model components, zeros and non-zeros respectively. While the second variable is not directly used in the estimation of gear differences, it was included to ensure the model accounted for variability due to differences between calibration stations in 2006 and 2015 and all other stations in the model.

Table 2.2 gives the parameter estimate for O32 WPUE. The estimate of the zero scale factor (8.1 =exp(−{−3.095+0.999})) is interpreted as the ratio of the odds of observing a setline non-zero value to the odds of a trawl non-zero, meaning that the odds that WPUE is not zero is about 8 times greater with setline than trawl gear. The estimated scalar of 16.8 = exp(−{−3.315+0.494}) for non-zero WPUE means that on average the setline index is about 17 times greater than the trawl index when fish are captured. Both measures imply that the calibrated trawl index needs to be scaled up to be equivalent to the setline O32 WPUE index, consistent with the original external estimate of about 37 (i.e., calibrated trawl index values were multiplied by 37 to yield O32 WPUE-equivalent values).

Table 2.2. Parameter estimates for gear difference coefficients from a space-time model for FISS and unscaled calibrated trawl data in IPHC Regulatory Area 4CDE.

Parameter	Posterior mean (SD)	Parameter	Posterior mean (SD)
g_z	−3.095 (0.130)	g_{nz}	−3.315 (0.050)
gc_z	0.999 (0.265)	gc_{nz}	0.494 (0.117)

This partition of the gear scaling into zero and non-zero model components has important implications for the overall index. Within the model, the scaling is applied by undertaking prediction at stations assuming FISS gear only. Figure 2.1 compares the 2021 output for IPHC Regulatory Area 4CDE with external scaling to the output from the above model with gear differences estimated internally. Except for 2006 and 2015 (calibration study years) and the years of highest density (1996-2001), the revised WPUE index is consistently greater than the original model estimate. The original external scalar is applied equally to all trawl stations, but the calibrated trawl stations have much higher proportions of zeros than setline stations. When scaled, these zeros remain zero. This is not the case with the revised model, as the scaling is essentially applied to the probability of being zero (or non-zero), and so the estimate for a station with zero observed trawl index can still increase when standardized for gear type. Thus, this revised approach not only scales non-zero indices, but also accounts for differences in the probability of zero catch between the two gear types. Failure to do this previously appears to have led to negative bias in the index unless there were direct FISS observations together with the trawl data (2006, 2015) or when densities were high and thus there were relatively few zero-observations on the trawl survey (1996-2001).

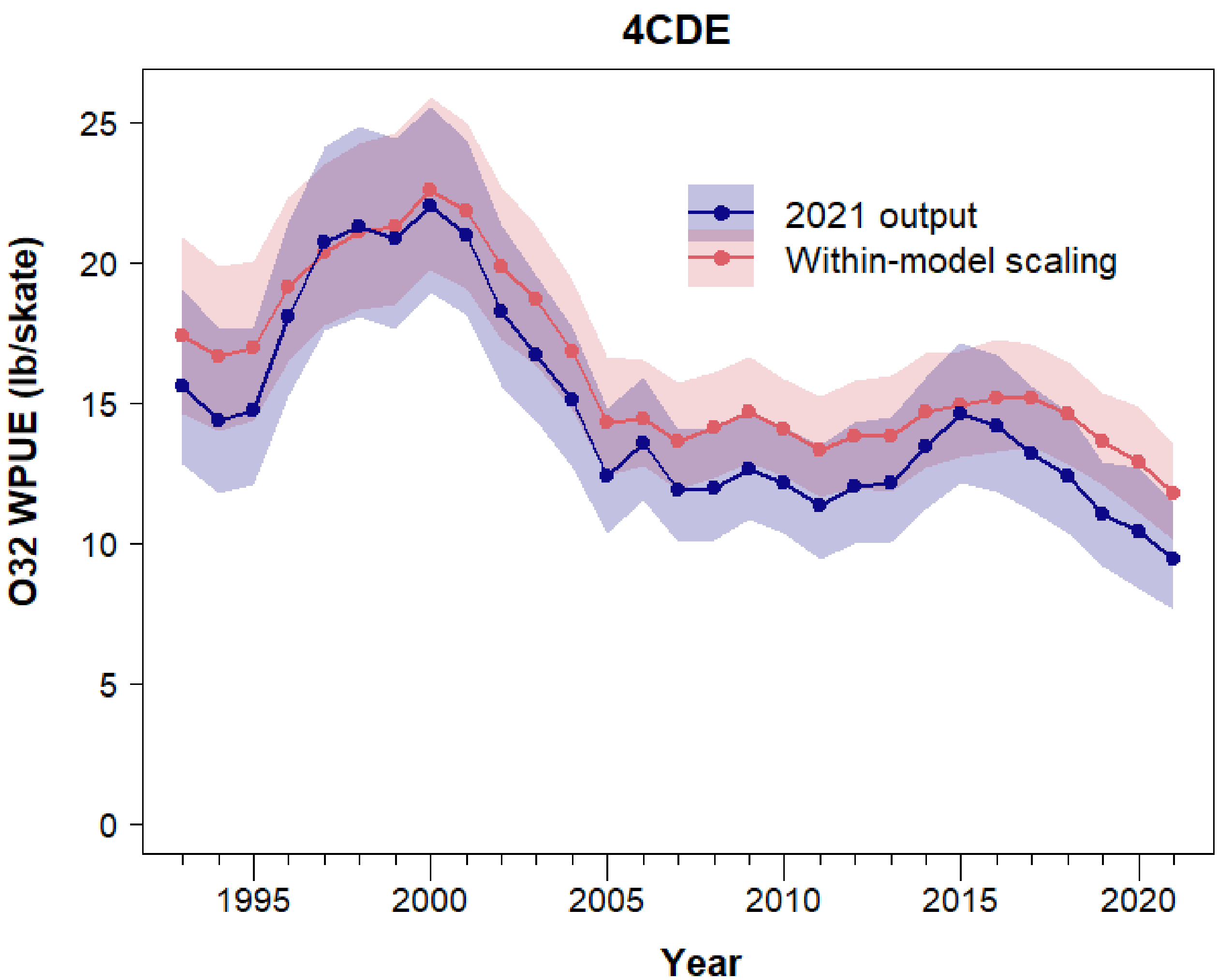

Figure 2.1 Estimated time series from space-time models fitted to IPHC Regulatory Area 4CDE data with gear scaling external to the model (2021 output) and within the model (Within-model scaling).

BIAS EVALUATION METHODOLOGY

At present, design proposals for IPHC Regulatory Areas with subarea sampling (2A, 4A and 4B) are evaluated for bias potential due to unsampled subareas by examining the estimated historical time series: proposals are made that ensure that over the number of unsampled years, the % change in a subarea's proportion of the Regulatory Area biomass did not exceed 10% over the same number of years in the historical time series. For example, if a subarea's time series shows less than 10% change over 3 years throughout the time series, but >10% for any 4-year historical period, we should sample it at least every three years.

This approach weights all part of the time series equally, and is therefore a conservative criterion when rapid relative change was more likely in the past. It also becomes more conservative as more years are added to the time series, with rare events weighted the same as frequently observed changes.

Here we consider an alternative approach making use of the posterior predictive distributions of station WPUE, something we save as a standard part of model output. For each station and each year of the time series, we have 2000 posterior samples. When averaged across stations, this can give us 2000 time series for each subarea of an IPHC Regulatory Area. Suppose we are interested in how likely a subarea's % of the biomass will change by more than 10% over two years. For each two-year period in the time series, we can estimate this as the proportion of samples for which the change was at least 10%:

$$\hat{P}\left(\left|p_{is}-p_{i-2,s}\right|>0.1\right)=\frac{\sum_{k=1}^{N} I\left(\left|p_{isk}-p_{i-2,sk}\right|>0.1\right)}{N}$$

where p_{isk} is the biomass proportion for subarea s in year i and the kth posterior sample, N=2000, and p_{is} is the true biomass proportion in subarea s in year i. $I()$ here is the indicator function taking the value 1 is the argument is true and 0 otherwise. As our goal is to sample frequently enough so that we do not miss large changes (i.e., >10% biomass proportion) in a subarea, we should also include changes of >10% that occur in less than 2 years (in this example), i.e., in one year. More generally:

$$q_{ij^*}=\hat{P}\left(\left|p_{is}-p_{i-j,s}\right|>0.1,\forall j\leq j^*\right)=\frac{\sum_{k=1}^{N} I\left(\left|p_{isk}-p_{i-j,sk}\right|>0.1,\forall j\leq j^*\right)}{N}$$

where j^* is the number of years since the subarea was last sampled (2 in the example above) and j includes all periods less than or equal to this.

As an example, we will consider the sampling of subarea 1 in IPHC Regulatory Area 4B, which comprises the western portion of the area. This subarea last had sampling in 2019 and was proposed for sampling in 2022 but failed to receive any bids. Previously evaluation based solely on the full historical time series (Webster 2022) implied that we could exceed the 10% change threshold over the three years since 2019 as that is something we estimate to have happened at least once in the past.

Figure 2.2 presents the probabilities (as percentages) of at least a 10% change in biomass proportion over the previous j^*=3 years by subarea. For most of the time series, subarea 1 has had high probabilities of this magnitude of change over a 3-year time span. However, this has not been the case from 2016-2021. For those years, the chance of this type of change is estimated to be no more than 6%, reflecting the fact that this subarea has had low and stable biomass in recent years. This implies that we could leave the subarea unsampled for a longer period without risk of large bias in the overall estimates of WPUE.

Note that these probabilities incorporate uncertainty: if an area has not been sampled, the posterior distribution of WPUE values will have greater variability and the probabilities in Figure 2.2 will be greater. This appears to be what is driving the higher probabilities in subarea 2, the central portion of IPHC Regulatory Area 4B. Much of this subarea has been sampled just once, in 2017, with no new data from the subarea since 2019. With less historical data than subarea 1, and (like subarea 1) no recent data, the chance of a change of at least 10% in biomass proportion is approaching 30%. Fortunately, the 2022 FISS has successfully sampled this subarea, observing almost no change since 2017, and therefore we expect these probabilities to be revised downwards once the new data are incorporated into the model.

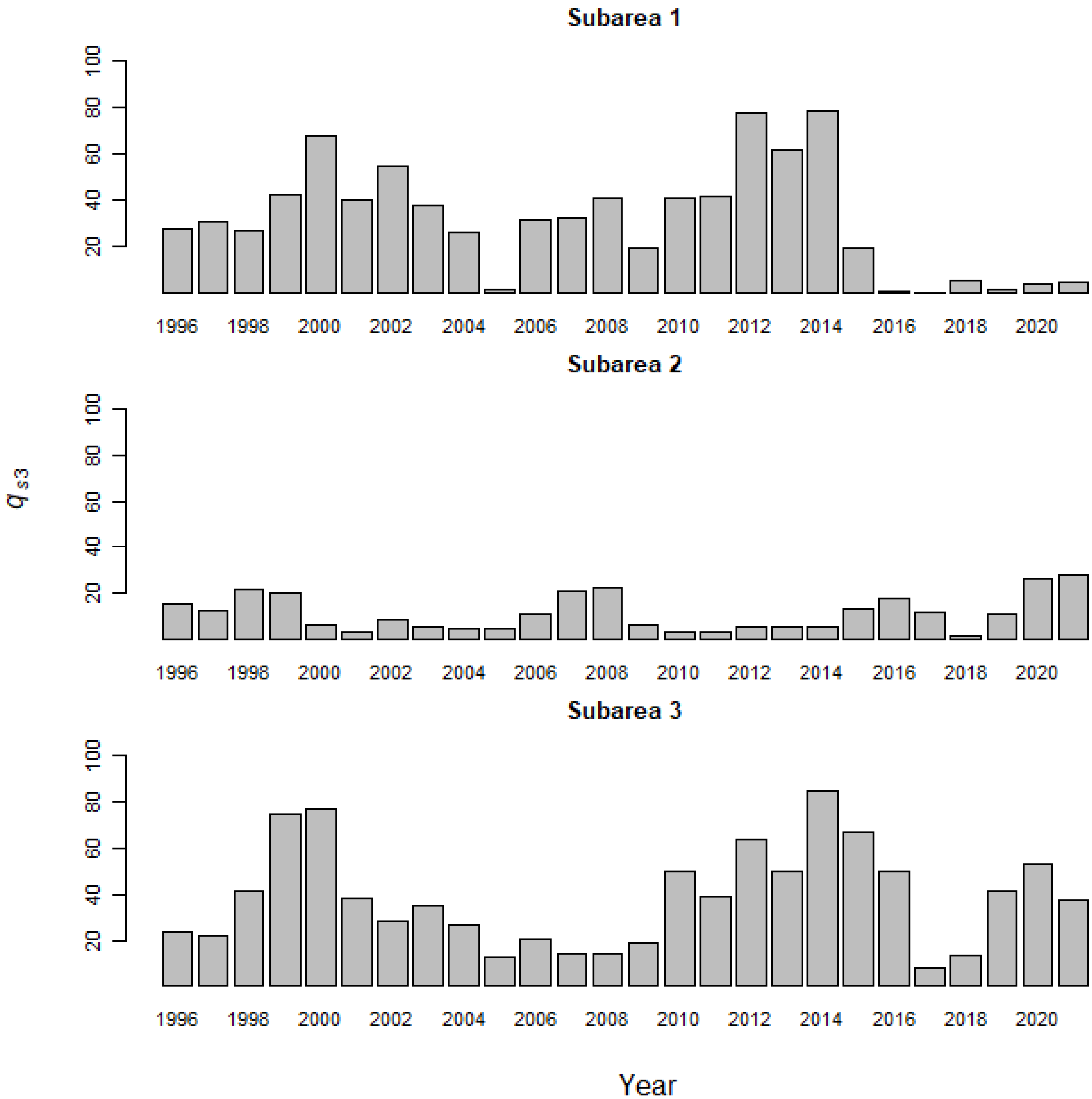

Figure 2.2 Values of q_{s3} (as %) for subareas, *s*, of IPHC Regulatory Area 4B and time interval of j*=3 year, for 1996 to 2021.

Discussion

We consider both the space-time model update and the bias evaluation revision to provide improvements over approaches currently in use. Any input the Scientific Review can provide on these changes will be appreciated by the Secretariat.

RECOMMENDATION

That the Scientific Review Board:

1) **NOTE** paper IPHC-2022-SRB021-06 (part 2) that presents an update to the space-time model for IPHC Regulatory 4CDE, and a proposal for revising the evaluation of bias potential in future FISS design proposals.

References

Webster R. A., Soderlund E, Dykstra C. L., and Stewart I. J. (2020). Monitoring change in a dynamic environment: spatio-temporal modelling of calibrated data from different types of fisheries surveys of Pacific halibut. Can. J. Fish. Aquat. Sci. 77(8): 1421-1432.

Webster, R. A. 2022. 2023-25 FISS design evaluation. IPHC-2022-SRB020-05.