2023-25 FISS design evaluation

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PURPOSE

To present the proposed designs for the IPHC's Fishery-Independent Setline Survey (FISS) for the 2023-25 period, and an evaluation of those designs, for review by the Scientific Review Board.

BACKGROUND

The IPHC's Fishery-Independent Setline Survey (FISS) provides data used to compute indices of Pacific halibut density for use in monitoring stock trends, estimating stock distribution, and as an important input in the stock assessment. Stock distribution estimates are based on the annual mean weight per unit effort (WPUE) for each IPHC Regulatory Area, computed as the average of WPUE of all Pacific halibut and for O32 (greater than or equal to 32" or 81.3cm in length) Pacific halibut estimated at each station in an area. Mean numbers per unit effort (NPUE) is used to index the trend in Pacific halibut density for use in the stock assessment models.

FISS history 1993-2019

The IPHC has undertaken FISS activity since the 1960s. However, methods were not standardized to a degree (e.g., the bait and gear used) that allows for simple combined analyses until 1993. From 1993 to 1997, the annual design was a modification of a design developed and implemented in the 1960s, and involved fishing triangular clusters of stations, with clusters located on a grid (IPHC 2012). Coverage was limited in most years and was generally restricted to IPHC Regulatory Areas 2B through 3B. The modern FISS design, based on a grid with 10 nmi (18.5 km) spacing, was introduced in 1998, and over the subsequent two years was expanded to include annual coverage in parts of all IPHC Regulatory Areas within the depth ranges of 20-275 fathoms (37-503 m) in the Gulf of Alaska and Aleutian Islands, and 75-275 fathoms (137-503 m) in the Bering Sea (IPHC 2012). Annually-fished stations were added around islands in the Bering Sea in 2006, and in the same year, a less dense grid of paired stations was fished in shallower waters of the southeastern Bering Sea, providing data for a calibration with data from the annual National Marine Fishery Service (NMFS) bottom trawl survey (Webster et al. 2020).

Through examination of commercial logbook data and information from other sources, it became clear by 2010 that the historical FISS design had gaps in coverage of Pacific halibut habitat that had the potential to lead to bias in estimates derived from its data. These gaps included deep and shallow waters outside the FISS depth range (0-20 fathoms and 275-400 fathoms), and unsurveyed stations on the 10 nmi grid within the 20-275 fathom depth range within each IPHC Regulatory Area. This led the IPHC Secretariat to propose expanding the FISS to provide coverage of the unsurveyed habitat with United States and Canadian waters. In 2011 a pilot expansion was undertaken in IPHC Regulatory Area 2A, with stations on the 10 nmi grid added to deep (275-400 fathoms) and shallow (10-20 fathoms) waters, the Salish Sea, and other, smaller gaps in coverage. (The 10 fathom limit in shallow waters was due to logistical difficulties in standardized fishing of longline gear in shallower waters.) A second expansion in IPHC Regulatory Area 2A was completed in 2013, with a pilot California survey between latitudes of 40-42°N.

The full expansion program began in 2014 and continued through 2019, resulting in the sampling of the entire FISS design of 1890 stations in the shortest time logistically possible. The FISS expansion program allowed us to build a consistent and complete picture of Pacific halibut density throughout its range in Convention waters. Sampling the full FISS design has reduced bias as noted above, and, in conjunction with space-time modelling of survey data (see below), has improved precision and fully quantified the uncertainty associated with estimates based on partial annual sampling of the species range. It has also provided us with a complete set of observations over the full FISS design (Figure 1) from which an optimal subset of stations can be selected when devising annual FISS designs. This station selection process began in 2019 for the 2020 FISS and continues with the current review of design proposals for 2023-25. Note that in the Bering Sea, the full FISS design does not provide complete spatial coverage, and FISS data are augmented with calibrated data from National Marine Fisheries Service (NMFS) and Alaska Department of Fish and Game (ADFG) trawl surveys (stations can vary by year – 2019 designs are shown in Figure 1). Both supplementary surveys have been conducted approximately annually in recent years.

Space-time modelling

In 2016, a space-time modelling approach was introduced to estimate time series of weight and numbers-per-unit-effort (WPUE and NPUE), and to estimate the stock distribution of Pacific halibut among IPHC Regulatory Areas. This represented an improvement over the largely empirical approach used previously, as it made use of additional information within the survey data regarding the degree of spatial and temporal of Pacific halibut density, along with information from covariates such as depth (see Webster 2016, 2017). It also allowed a more complete of accounting of uncertainty; for example, prior to the use of space-time modelling, uncertainty due to unsurveyed regions in each year was ignored in the estimation. Prior to the application of the space-time modelling, these unsampled regions were either filled in using independently estimated scalar calibrations (if fished at least once), or catch-rates at unsampled stations were assumed to be equal to the mean for the entire Regulatory Area. The IPHC's Scientific Review Board (SRB) has provided supportive reviews of the space-time modelling approach (e.g., IPHC-2018-SRB013-R), and the methods have been published in a peer-review journal (Webster et al. 2020). Similar geostatistical models are now routinely used to standardise fishery-independent trawl surveys for groundfish on the West Coast of the U.S. and in Alaskan waters (e.g., Thorson et al. 2015 and Thorson 2019). The IPHC space-time models are fitted through the R-INLA package in R.

FISS design objectives

The primary purpose of the annual FISS is to sample Pacific halibut to provide data for the stock assessment (abundance indices, biological data) and estimates of stock distribution for use in the IPHC's management procedure. The priority of the current rationalised FISS is therefore to maintain or enhance data quality (precision and bias) by establishing baseline sampling requirements in terms of station count, station distribution and skates per station. Potential considerations that could add to or modify the design are logistics and cost (secondary design layer), and FISS removals (impact on the stock), data collection assistance for other agencies, and IPHC policies (tertiary design layer). These priorities are outlined in Table 1.

Table 1. Prioritization of FISS objectives and corresponding design layers.

Priority	Objective	Design Layer
Primary	Sample Pacific halibut for stock assessment and stock distribution estimation	Minimum sampling requirements in terms of: • Station distribution • Station count • Skates per station
Secondary	Long term revenue neutrality	Logistics and cost: operational feasibility and cost/revenue neutrality
Tertiary	Minimize removals, and assist others where feasible on a cost-recovery basis.	Removals: minimize impact on the stock while meeting primary priority Assist: assist others to collect data on a cost-recovery basis IPHC policies: ad-hoc decisions of the Commission regarding the FISS design

Design review and finalisation process

Since completion of the FISS expansions, a review process has been developed for annual FISS designs created according to the above objectives:

- The Secretariat presents design proposals based only on primary objectives (Table 1) to the SRB for three subsequent years at the June meeting (recognizing that data from the current summer FISS will not be available for analysis prior to the September SRB meeting);
- These design proposals, revised (if necessary) based on June SRB input, are then reviewed by Commissioners at the September work meeting;
- At their September meeting, the SRB reviews revisions to the design proposals made to account for secondary and tertiary objectives

Following the review process, designs may be further modified to account for any updates based on secondary and tertiary objectives before being finalised during the Interim and Annual meetings and the period prior to implementation:

- Presentation of FISS designs for 'endorsement' by the Commission occurs at the November Interim Meeting;
- Ad hoc modifications to the design for the current year (due to unforeseen issues arising) are possible at the Annual Meeting;
- The endorsed design for current year is then modified (if necessary) to account for any additional tertiary objectives prior to summer implementation (February-April).

Consultation with industry and stakeholders occurs throughout the FISS planning process, at the Research Advisory Board meeting (29 November in 2021) and particularly in finalizing design details as part of the FISS charter bid process, when stations can be added and other adjustments made to provide for improved logistical efficiency. We also note the opportunities for stakeholder input during public meetings (Interim and Annual Meetings).

Note that while the review process examines designs for the next three years, revisions to designs for the second and third years are expected during subsequent review periods as additional data are collected. Having design proposals available for three years instead of the next year only assists the IPHC with medium-term planning of the FISS, and allows reviewers (SRB, IPHC Commissioners) and stakeholders to see more clearly the planning process for sampling the entire FISS footprint over multiple years. Extending the proposed designs beyond three years was not considered worthwhile, as we expect further evaluation undertaken following collection of data during the one to three-year period to influence design choices for subsequent years.

PROPOSED DESIGNS FOR 2023-25

The designs proposed for 2023-25 (Figures 2 to 4) 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.

A review of commercial catch data shows moderate catch rates in recent years in southeast IPHC Regulatory 4A. With these stations last sampled in 2019, sampling in 2025 will provide an updated understanding of Pacific halibut density in this subarea and inform future decisions on sampling frequency in IPHC Regulatory Area 4A. Note that several stations on the IPHC Regulatory Area 4A shelf edge overlap the NMFS bottom trawl survey (in purple in Figure 2, and are not proposed for FISS sampling in the foreseeable future.

In the most recent surveys of IPHC Regulatory Area 4B, the eastern subarea had by far the highest catch rates and is the priority for frequent sampling. The western and central subareas were approved for sampling in 2022, but only the central subarea is to be sampled due to a lack of charter vessel bids for the western subarea. Thus, the western subarea has been added to the 2023 proposal to reduce the risk of bias.

Following this three-year period, the only remaining waters unsampled since FISS rationalization began in 2020 will be:

- Zero-to-low density waters in IPHC Regulatory Area 2A comprising deep (>275 ftm) and shallow (<20 ftm) stations and northern California south of 40°N (sampled comprehensively in 2017), and low-density waters of the Salish Sea (previously sampled in 2018).
- Near-zero density waters in the Salish Sea in IPHC Regulatory Area 2B (sampled in 2018 only).

We anticipate proposing these stations for sampling in 2026-28, 9-10 years after previous FISS sampling, so that the entire 1890-station FISS grid will have been fished from 2020-28.

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. Ongoing oceanographic (e.g., sea ice and bottom temperatures) and ecosystem (e.g., prey species abundance and distribution) changes in this Regulatory Area highlight the potential for changes in the biology and abundance of Pacific halibut in the Bering Sea. Despite prioritizing comprehensive sampling of this Regulatory Area in 2020-22, in each year logistical challenges have precluded achieving the full design. Therefore, it is retained throughout the current three-year plan, to be re-evaluated when and if sampling is successful.

While the proposed designs continue to rely on randomised subsampling of stations within the core IPHC Regulatory Areas (2B, 2C, 3A and 3B) and logistically efficient subarea designs elsewhere, other designs have been considered and remain as options (Webster 2021, Appendix A).

FISS DESIGN EVALUATION

Precision targets

In order to maintain the quality of the estimates used for the assessment, and for estimating stock distribution, the IPHC Secretariat has set a target range of less than 15% for the coefficient of variation (CV) of mean O32 and all sizes WPUE for all IPHC Regulatory Areas. We also established precision targets of IPHC Biological Regions and a coastwide target (IPHC-2020-AM096-07), but achievement of the Regulatory Area targets is expected to ensure that targets for the larger units will also be met.

Reducing the potential for bias

In IPHC Regulatory Areas in which stations are not subsampled randomly (IPHC Regulatory Areas 2A, 4A and 4B), sampling a subset of the full data frame in any area or region brings with it the potential for bias. This is due to trends in the unsurveyed portion of a management unit (Regulatory Area or Biological Region) potentially differing from those in the surveyed portion. Therefore, we also examine how frequently part of an area or region (subarea) should be surveyed in order to reduce the likelihood of appreciable bias. For this, we use a threshold of a 10% absolute change in biomass percentage: based on historical trends (1993-2021): how quickly can a subarea's percent of the biomass of a Regulatory Area change by at least 10%

(e.g., from 15 to 25% of the area's biomass)? By sampling each subarea frequently enough to reduce the chance of its percentage changing by more than 10% between successive surveys of the subarea, we minimize the potential for appreciable bias in the Regulatory Area's index.

We examined the effect of subsampling the FISS stations for a management unit on precision as follows:

- Where a randomised design is not used, identify logistically efficient subareas within each management unit and select priorities for future sampling.
- Generate simulated data for all FISS stations based on the output from the most recent space-time modelling.
- Fit space-time models to the observed data series augmented with 1 to 3 additional years of simulated data, where the design over those three years reflects the sampling priorities identified above.
- Project precision estimates and quantify bias potential for comparison against threshold.

Table 2 shows projected CVs following completion of the proposed 2022-25 FISS designs. With these designs, we are projected to maintain CVs within the target range. Estimates from the terminal year are most informative for management decisions, but they also typically have the largest CVs (all else being equal; these are then reduced in subsequent years as observations are available in both adjacent years, due to the temporal correlation). The final column in Table 2 shows the CV projections immediately following the 2023 FISS, which are also within the target range.

Table 2. Projected CVs (%) for 2022-25 for O32 WPUE estimated after completion of the proposed 2023-25 FISS designs, and (final column) after completion of the proposed 2023 FISS design only.

Reg. Area	2022	2023	2024	2025	2023 (Estimated in 2023)
2A	13	12	13	15	14
4A	10	9	10	10	12
4B	12	9	10	12	9

For maintaining low bias, we 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. 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. For example, if a subarea's % of its Regulatory Area's biomass changed by no more than 8% over 1-2 years but by up to 12% over three years, we should sample it at least every three years based on the 10% criterion discussed above. These criteria are updated as new data are collected and thus they respond to updates in our understanding of the rates of change occurring in each subarea.

Based on estimates from the historical times series (1993-2021) of O32 WPUE, the proposed designs for 2023-25 would be expected to maintain low bias by ensuring that it is unlikely that biomass proportions for all subareas change by more than 10% since they were previously sampled (Table 3). We note that the lack of sampling in the western subarea of IPHC Regulatory 4B in 2022 means that maximum change from the historical time series for this subarea was 13%, exceeding the 10% threshold. Sampling this historically-variable subarea in 2023 again reduces values to within 10%.

Table 3. Maximum expected changes (%) in biomass proportion since previous sampling of subareas that are unsampled in a given year, based on the estimated 1993-2021 time series.

Reg. Area	2022	2023	2024	2025
2A	9	9	9	9
4A	10	7	6	8
4B	13	5	8	10

Post-sampling evaluation for 2021

The evaluation of precision of proposed designs above is based on using simulated sample data generated under the fitted space-time model as data for future years. If observed data are more (or less) variable than those generated under the model, actual estimates of precision may differ from those projected from models making use of the generated data. Table 4 compares the estimates of the CV for mean O32 WPUE for the approved 2021 design based on using simulated data for 2021 and estimated from fitting the models including observed 2021 data. Only the three areas using subarea designs are included, as these are the only areas for which the design options under consideration have a strong influence on precision.

Table 4. Comparison of projected (in 2020) and estimated CVs (%) for O32 WPUE for 2021 by IPHC Regulatory Area.

Regulatory Area	2021 projected CV (%)	2021 estimated CV (%)
2A	15	18
4A	11	15
4B	14	18

Projected CVs in all three areas were lower than those estimated once the observed 2021 data were incorporated into the modelling, although the reasons differ among areas. The 2021 FISS in IPHC Regulatory Areas 4A and 4B did not complete all planned stations due to logistical issues, with 10 out of 59 stations unfished in the former area and 36 out of 73 unfished in the latter. In both areas, the unfished stations covered some of the most productive habitat in recent years. The difference between projected and estimated CVs in IPHC Regulatory Area 2A appears due to an increase in the underlying variability of Pacific halibut density, which is the main factor leading us to recommend increasing the number of targeted stations in this area in

2023 relative to the provisional 2023 proposal made in 2021 (Webster 2021). (Projected CVs were not calculated for other IPHC Regulatory Areas as they are not at present used to evaluate design proposals. Estimated CVs for O32 WPUE for the core IPHC Regulatory Areas of 2B, 2C, 3A and 3B ranged from 4-8% in 2021, with a CV of 10% in IPHC Regulatory 4CDE. With high numbers of proposed stations in each area, CVs will remain well within the target range under proposed designs.)

CONSIDERATION OF COST

Ideally, the FISS design would be based only on scientific needs. However, some Regulatory Areas are consistently more expensive to sample than others, so for these the efficient subarea designs were developed. The purpose of factoring in cost was to provide a statistically efficient and logistically feasible design for consideration by the Commission. During the Interim and Annual Meetings and subsequent discussions, cost, logistics and tertiary considerations (Table 1) are also factored in developing the final design for implementation in the current year. It is anticipated that under most circumstances, cost considerations can be addressed by adding stations to the minimum design proposed in this report. In particular, the FISS is funded by sales of captured fish and is intended to have long-term revenue neutrality, meaning that any design must also be evaluated in terms of the following factors:

- Expected catch of Pacific halibut
- Expected Pacific halibut sale price
- Charter vessel costs, including relative costs per skate and per station
- Bait costs
- IPHC Secretariat administrative costs

Balancing these factors may result in modifications to the design such as increasing sampling effort in high-density regions and decreasing effort in low density regions. At present, with stocks near historic lows and extremely low prices for fish sales, the current funding model may require that some low-density habitat be omitted from the design entirely (as occurred in 2020). This will have implications for data quality, particularly if such reductions in effort relative to proposed designs continue over multiple years. Note that this did not occur in the 2021 and 2022 designs, as it was sufficient to include additional stations in core IPHC Regulatory Areas to generate a revenue-neutral coastwide design.

SRB REQUESTS

At SRB018 (IPHC-2021-SRB018-R), the SRB made the following requests:

SRB018–Req.1 (para. 13) The SRB **REQUESTED** plots by survey area of WPUE vs. depth from both FISS and commercial fisheries to help understand if there is part of the Pacific halibut stock in deeper waters not covered by the FISS.

SRB018–Req.2 (para. 14) The SRB **REQUESTED** that the IPHC Secretariat conduct a preliminary comparison, to be presented at SRB020, between male, female, and sex-aggregated analysis of the FISS data using the spatial-temporal model.

We examined data from commercial sets in our database from the last ten years (2012-21) for the May-September period in which the FISS is undertaken. Very few sets (36) are recorded with mean depths greater than the 732 m (400 ftm) depth limit of the FISS. Several are within IPHC Regulatory Areas 2C and 3A, at locations that are encompassed by the existing FISS grid (i.e., there is no gap in FISS coverage due to locally deep waters). The largest cluster of sets (15) occurs in western IPHC Regulatory Area 4A. We note that the proportion of commercial catch recorded in waters deeper than 732 m is 0% or near 0% in all areas and years except for IPHC Regulatory Area 4A in 2013 (1.3% of catch in that year).

Figure 5 plots mean commercial CPUE for 2012-21 by 50 fathom depth bins and area. Points based on data from fewer than three vessels are omitted for reasons of confidentiality. Sets with depth over 732 m (400 fathoms) are aggregated into a 400+ fathom bin, plotted at 425 fathoms on the figure.

Mean all sizes WPUE from observed FISS data for 2012-21 is shown in Figure 6. Again, means are computed for 50-fathom depth bins. In all areas except IPHC Regulatory Area 2C, WPUE drops to zero at or shallower than the final depth bin. The IPHC Regulatory Area 2C mean for the 350-400 fathom bin is based on just two observations, both from the same station off southeast Baranov Island, with no potential unsampled stations on the FISS 10 nmi grid in deeper water nearby.

The commercial data show some evidence for Pacific halibut presence in deeper waters than those covered by the FISS in IPHC Regulatory Areas 2C, 3A and 4A. As noted above, mapping of these commercial sets shows that in IPHC Regulatory Areas 2C and 3A these waters are encompassed by existing FISS stations: in the case of IPHC Regulatory Area 3A, almost all sets are in a localized area of deeper waters in Prince William Sound surrounded by FISS stations, while a couple of others are on the Gulf of Alaska shelf edge, also close to existing FISS stations. It is only the IPHC Regulatory Area 4A data that suggest the possibility of habitat missed by the FISS, with the potential for adding up to two deeper stations off the north coast of Umnak Island. (Note that to preserve confidentiality of commercial data, plots of individual set locations are not included here.) However, we note the following:

- Commercial fishers may be targeting known but isolated locations of Pacific halibut in patchy habitat that may easily be missed by an expanded 10 nmi FISS grid
- They may also be targeting the easiest to access locations – any consideration of a further FISS expansion should include sampling waters deeper than 732 m throughout an expanded grid to avoid the potential for bias
- At least some of the commercial sets cross the 732 m contour, and it is possible the catch was taken at depths shallower than 732 m
- The number of additional stations in deeper waters is likely to be extremely small, as these depths comprise a very narrow band on the shelf edge, and thus the impact on overall mean WPUE is likely to be minimal
- The magnitude of any gain in coverage and potential reduction in bias will need to be balanced by the high cost and logistical difficulty of fishing in deeper waters in IPHC Regulatory Area 4A

Regarding the second request, we note there are some limitations with the sex information from the FISS. For fish under the commercial size limit of 81.3 cm (32”), only a subsample is selected for biological sampling, and for larger areas, the sampled fish represent only a very small proportion of all under 81.3 cm fish. We therefore limit our analysis to O32 fish, which results in less information on the male population, which due to their much slower growth are more greatly represented among the U32 fish. Furthermore, sex information is missing from about 5% of the O32 Pacific halibut overall, including over 100 sets with no sex data in the early years of the time series (1993-96). In the years 2003-04, there are very high rates of fish with unknown sex, up to almost 40% depending on area compared to <2% in a typical year.

In our preliminary analysis, we modelled data from IPHC Regulatory Area 3A. With the caveats above in mind, Figure 7 compares trends in O32 WPUE by sex with the overall trend previous estimated, for IPHC Regulatory Area 3A, as estimated through three separate spatio-temporal models. Trends in both sexes are similar, noting the gaps in sex-specific information identified above. However, examination of maps of the Gaussian spatial random field (the spatially correlated model residuals), show differences in the distributions of female and male fish. Figure 8 shows that while female O32 fish are distributed across the Regulatory Area, males are more highly concentrated in the west. Maps for other years will be made available as part of the accompanying presentation.

RECOMMENDATIONS

That the SRB:

1) **NOTE** paper IPHC-2022-SRB020-05 that provides background on and a discussion of the IPHC fishery-independent setline survey design proposals for the 2023-25 period;
2) **ENDORSE** the 2023 FISS design as presented in Figure 2, and
3) Provisionally **ENDORSE** the 2024-25 designs (Figures 3 and 4), recognizing that these will be reviewed again at subsequent SRB meetings.

References

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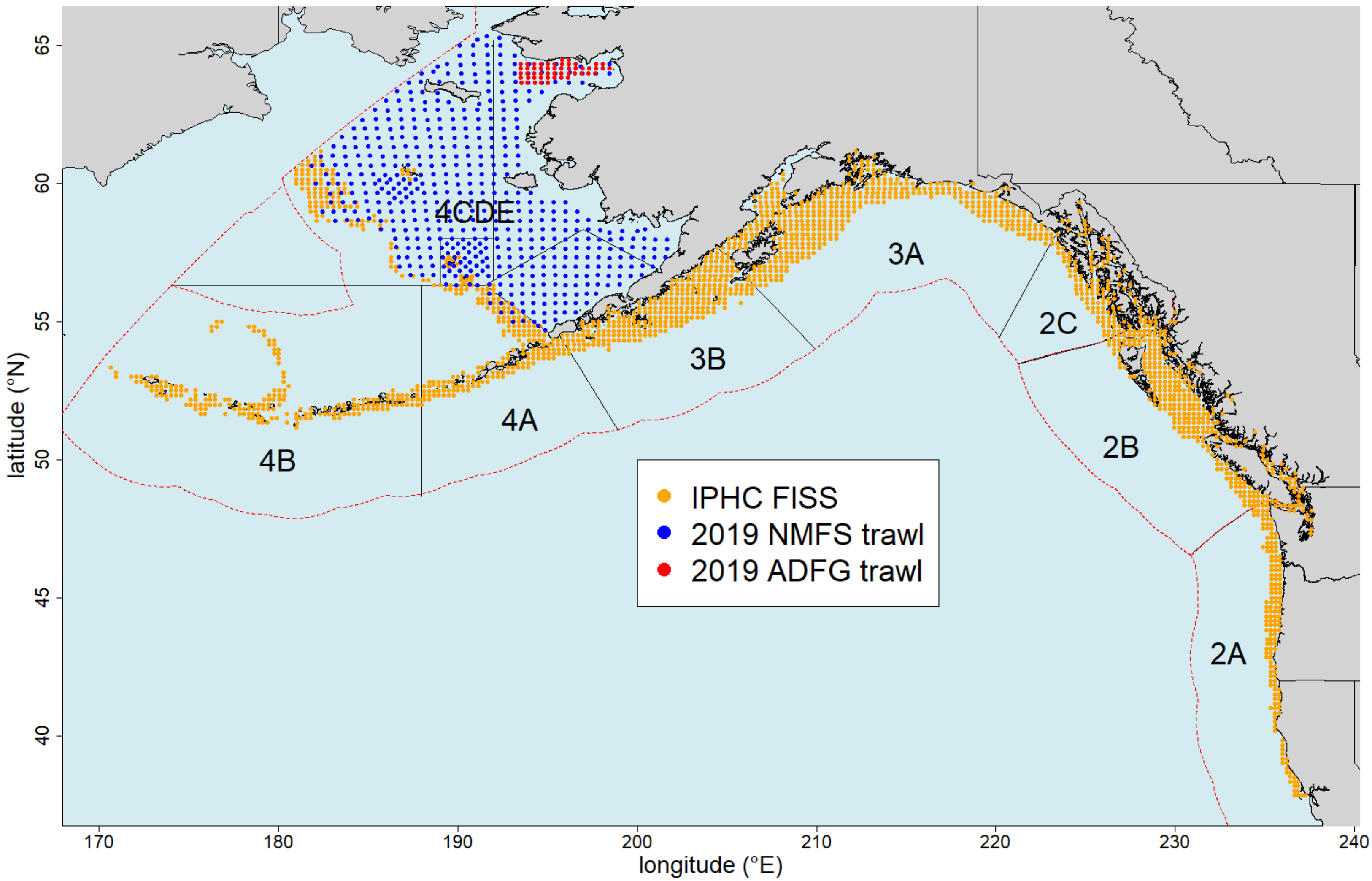

Figure 1. Map of the full 1890 station FISS design, with orange circles representing stations available for inclusion in annual sampling designs, and other colours representing trawl stations from 2019 NMFS and ADFG surveys used to provide complementary data for Bering Sea modelling.

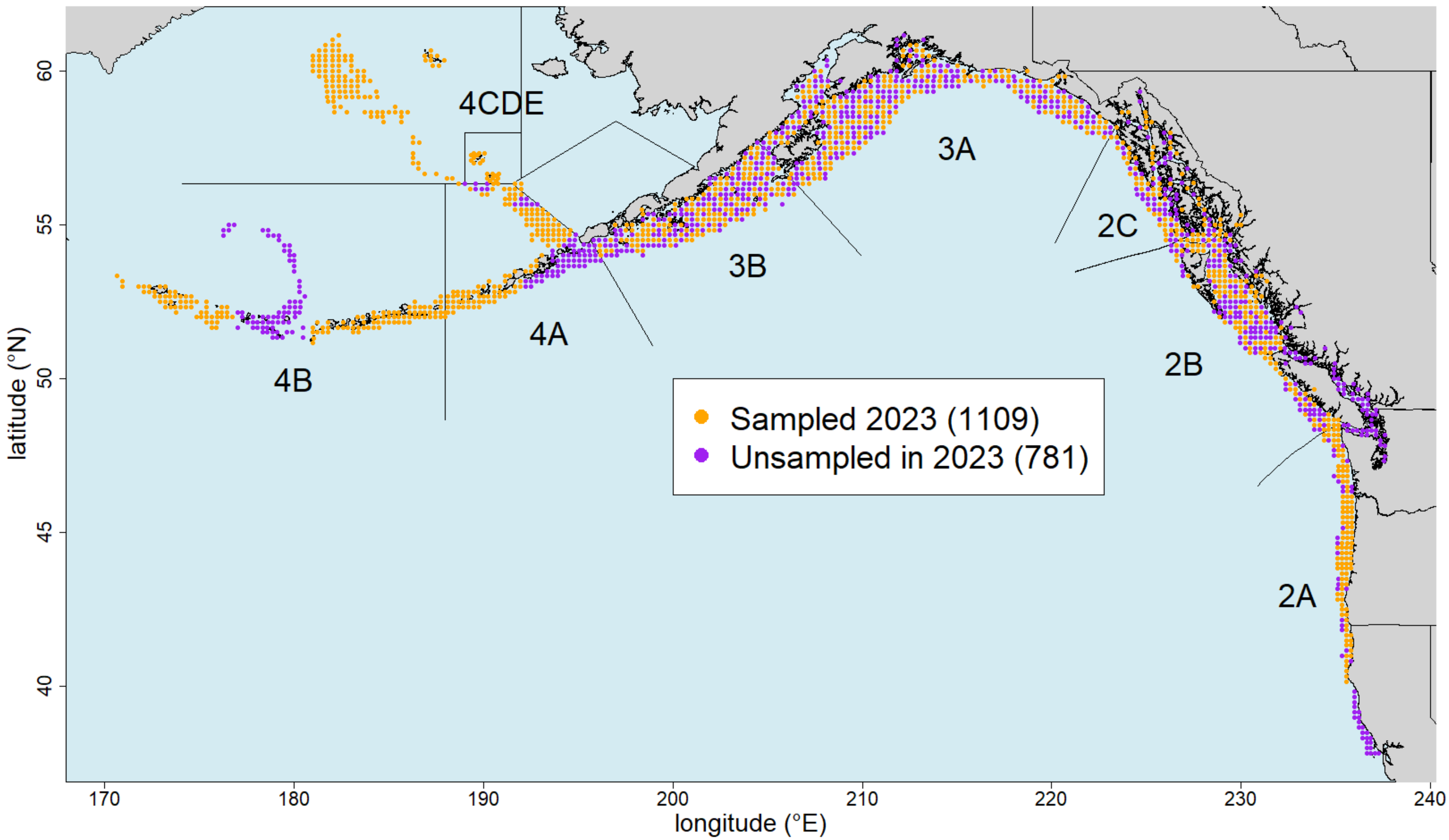

Figure 2. Proposed minimum FISS design in 2023 (orange circles) based on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

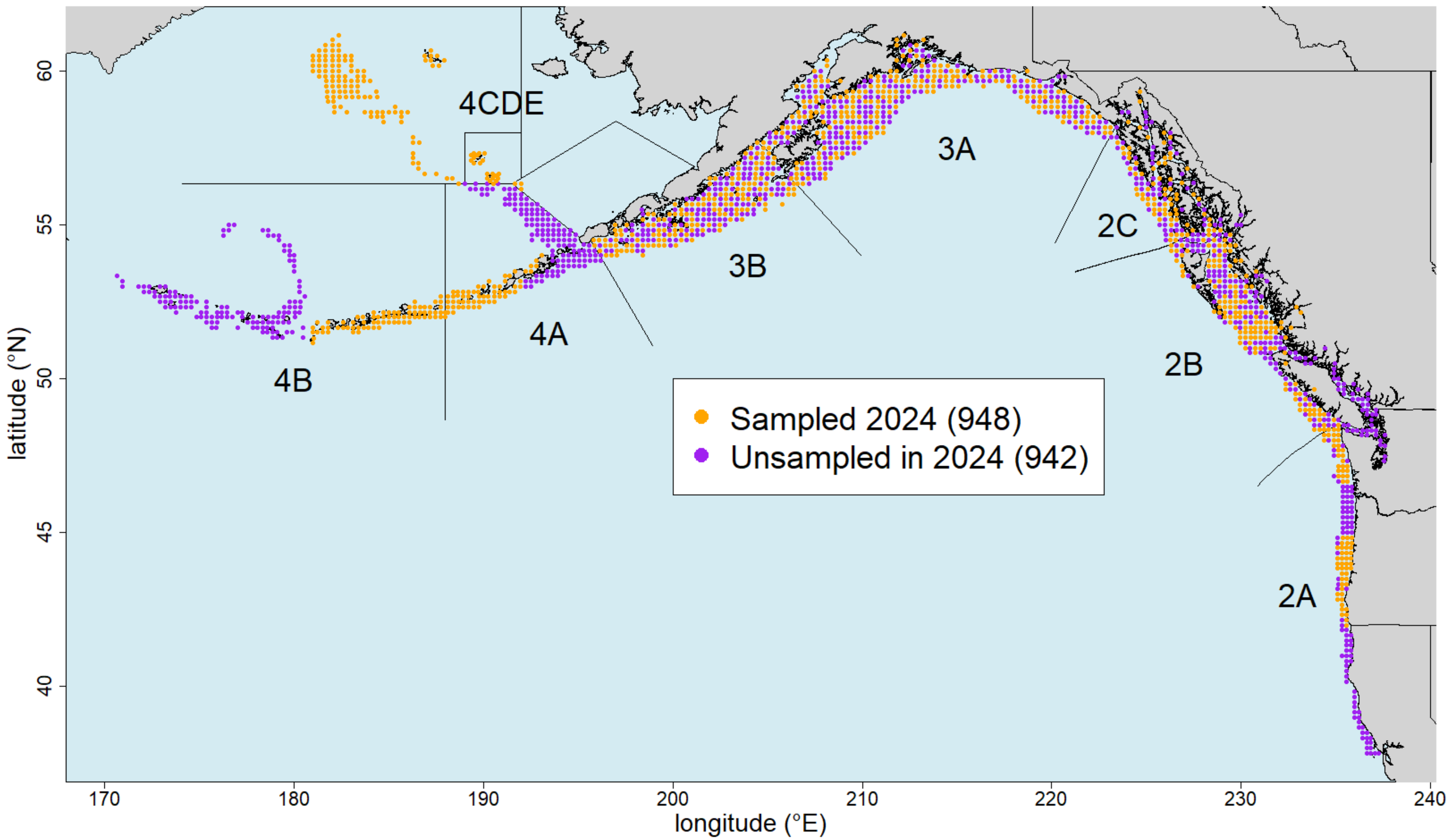

Figure 3. Proposed minimum FISS design in 2024 (orange circles) based on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

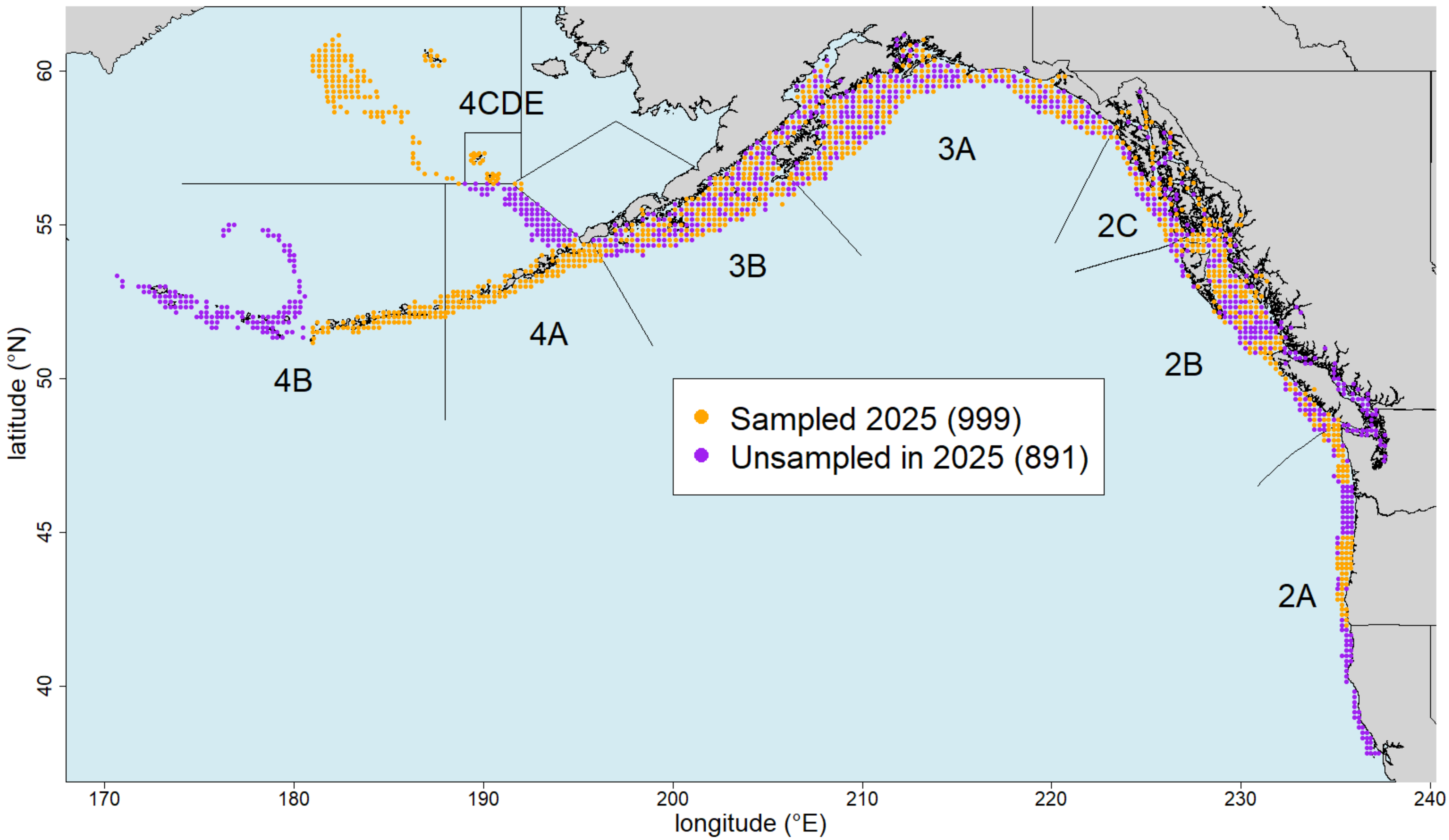

Figure 4. Proposed minimum FISS design in 2025 (orange circles) based on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

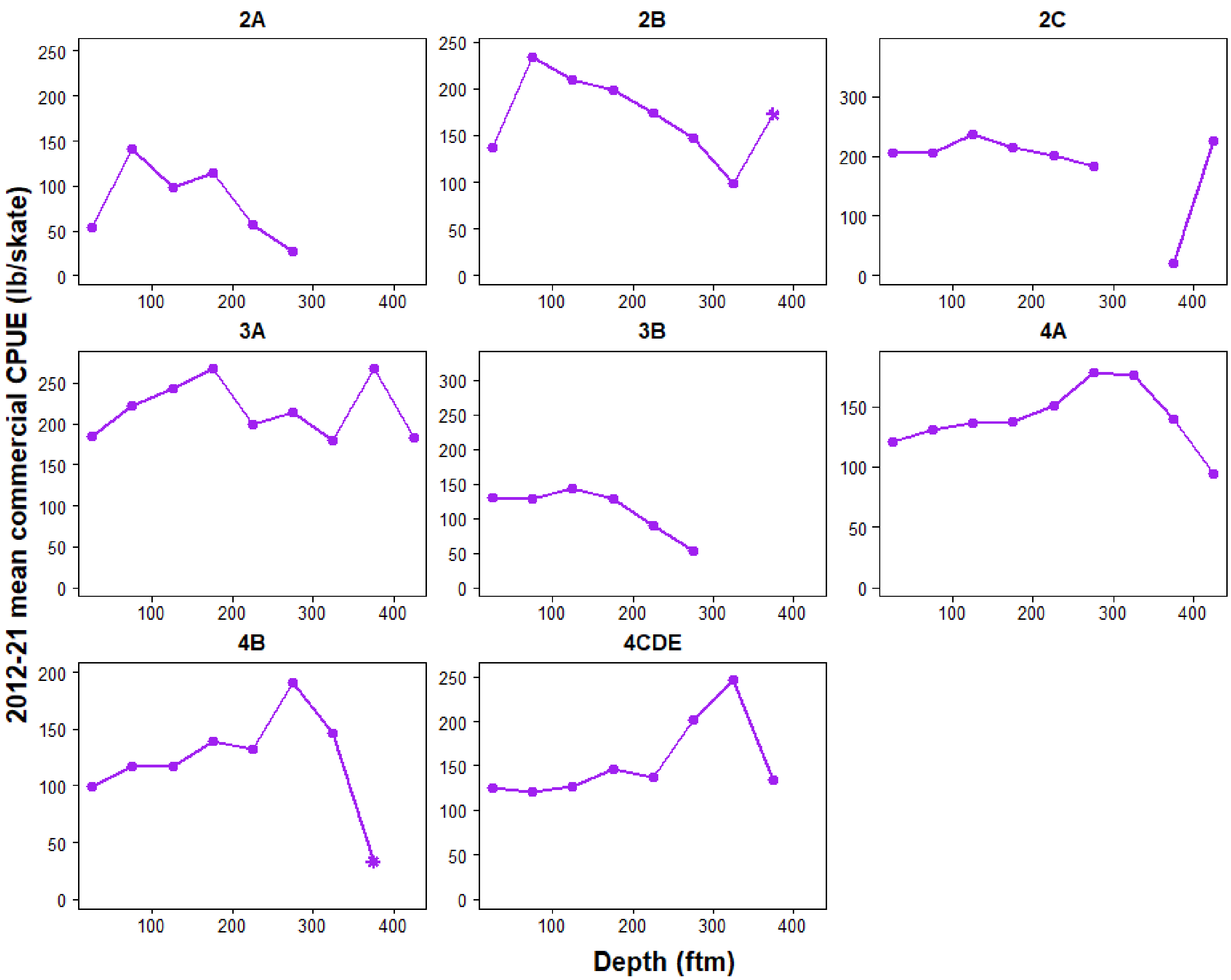

Figure 5. Mean commercial CPUE by IPHC Regulatory Area for 2012-21 calculated from logbook data binned into 50 fathom depth bins. Means based on fewer than five sets are indicated with star symbols, while those based on data from fewer than three vessels are omitted.

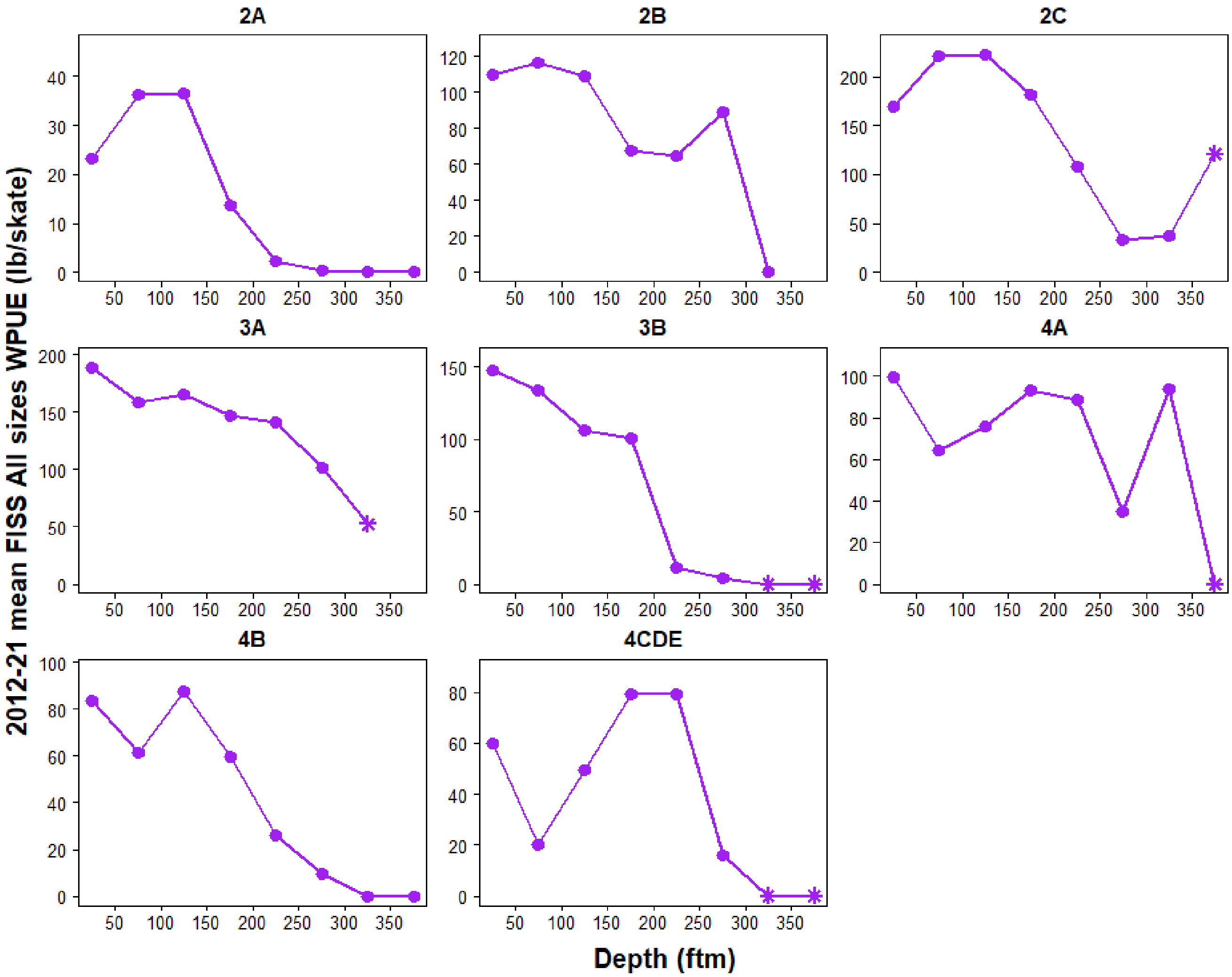

Figure 6. Mean FISS all sizes WPUE by IPHC Regulatory Area for 2012-21 calculated from observed data binned into 50 fathom depth bins. Means based on fewer than five sets are indicated with star symbols.

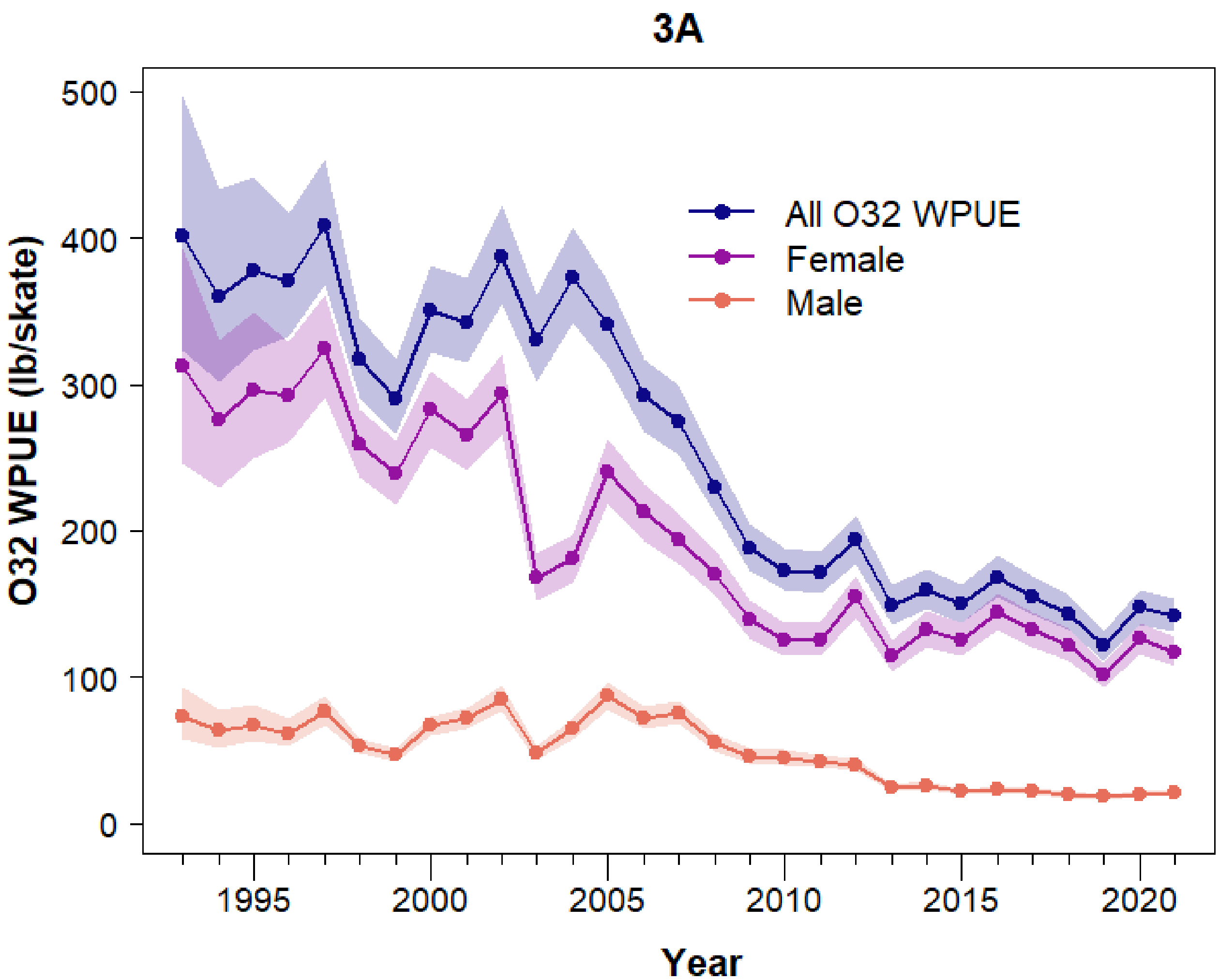

Figure 7. Posterior means (points) and 95% posterior credible intervals (shaded regions) for O32 WPUE for IPHC Regulatory 3A from 1993-2021, for all fish (blue) and those with known sex (purple = females, orange = males).

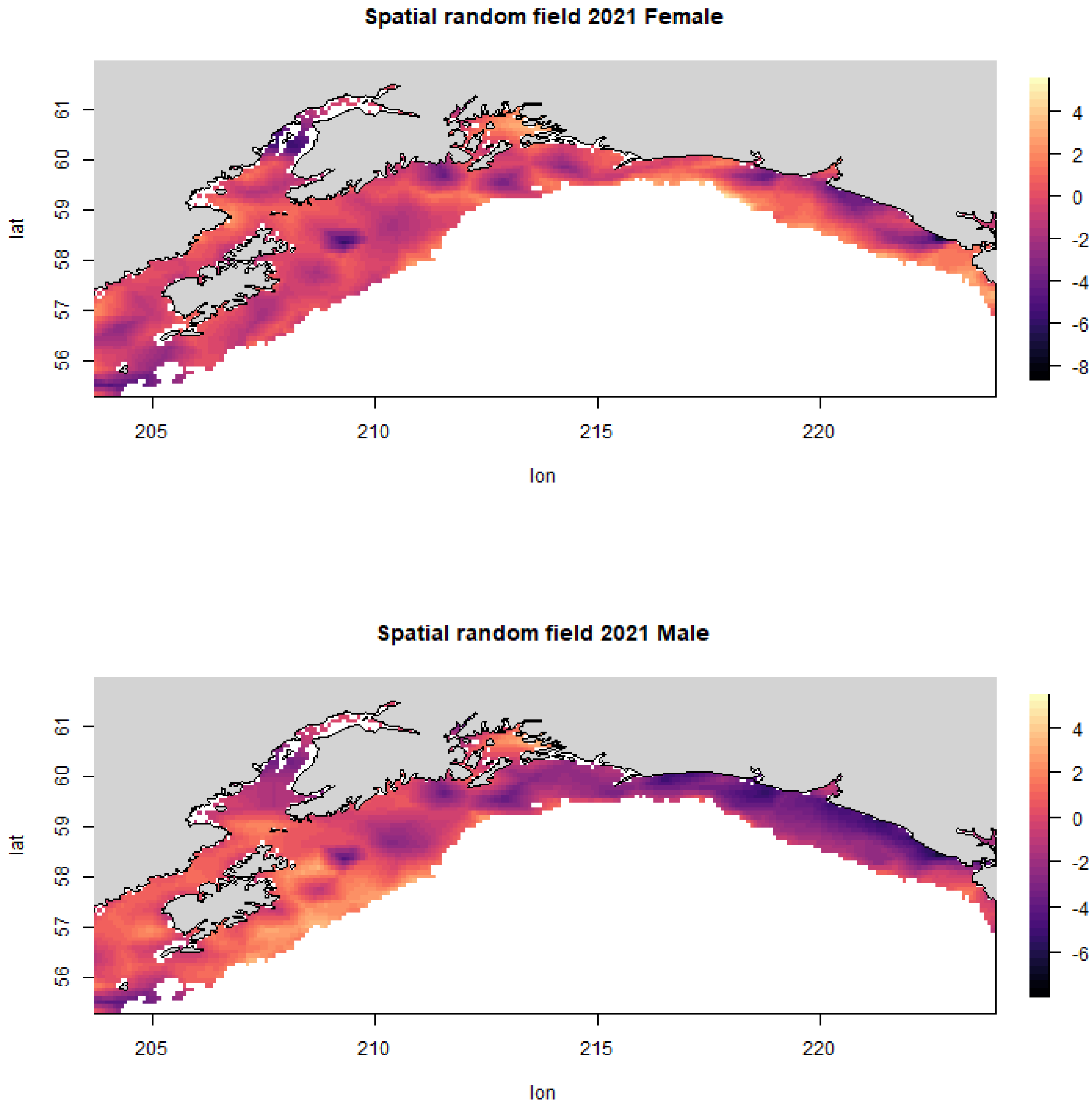

Figure 8. Posterior values of the spatial random field from space-time modelling of female (top panel) and male (bottom panel) Pacific halibut for IPHC Regulatory Area 3A in 2021. Units are log(lb/skate).