# 2022-24 FISS design evaluation

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## PURPOSE

To present proposed designs for the IPHC's Fishery-Independent Setline Survey (FISS) for the 2022-24 period, and an evaluation of those designs, as reviewed and endorsed by the Scientific Review Board in June 2021 (SRB018).

## 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) trawl survey (Webster et al. 2020).

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 within 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 fishing 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 2022-24. 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 are conducted approximately annually.

*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 (Webster et al. 2020). It also allowed a more complete 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 - 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).

*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 a 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:<br>• Station distribution<br>• Station count<br>• 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<br>Assist: assist others to collect data on a cost-recovery basis<br>IPHC policies: ad-hoc decisions of the Commission regarding the FISS design |

*Review process*

Since completion of the FISS expansions, a review process has been developed for annual FISS designs created according 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 objectives;
- 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 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. 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 time period to influence design choices for subsequent years.

**PROPOSED DESIGNS FOR 2022-24**

The designs proposed for 2022-24 (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. This was also used to generate the designs originally proposed for 2020 (but modified as a result of the impact of COVID19 and cost considerations), and for those proposed and approved for 2021. In 2020, designs for 2022-23 were also approved subject to revision. We are proposing one change from that 2022 design, bringing forward by one year (from 2023 to 2022) the sampling of the central and western subareas of IPHC Regulatory Area 4B to reduce the risk of bias in estimates from that area. Thus, we propose that:

- In 2022 the lower-density western and central subareas of IPHC Regulatory Area 4B are sampled, followed by the higher-density eastern subarea in 2023-24
- The higher-density western subarea of IPHC Regulatory Area 4A be sampled in all three years, with the medium-density northern shelf edge subarea added in 2023 only
- The highest-density waters of IPHC Regulatory 2A in northern Washington and central/southern Oregon are proposed for sampling in each year of the 2022-24 period
- The low-density waters of the Salish Sea in IPHC Regulatory Areas 2A and 2B are not proposed for sampling in 2022-24

Following this three-year period, it is expected that all subareas not recently sampled will be included during the subsequent 3-5 years. These include the southeastern subarea of IPHC Regulatory 4A, and lower-density waters of IPHC Regulatory 2A (see below).

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, with an apparently northward-shifting distribution of Pacific halibut, and increasing uncertainty regarding connectivity with populations adjacent to and within Russian waters. Distribution and density shifts of other demersal species and crab stocks, as well as sustained environmental change, continue to indicate the need for increased monitoring in this IPHC Regulatory Area.

We note that at SRB018, the SRB endorsed the final 2022 FISS design as presented in Figure 2, and provisionally endorsed the 2023-24 designs (Figs. 3 and 4) (IPHC-2021-SRB018-R).

**FISS DESIGN EVALUATION**

*Precision targets*

In order to maintain the quality of the NPUE estimates used for the assessment and of the WPUE estimates used to estimate 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 in the 2022-24 proposals), 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 Region) potentially differing from those in the surveyed portion. To reduce the potential for bias, we also looked at how frequently part of an area or region ("subarea") should be surveyed in order to reduce the likelihood of appreciable bias. For this, we proposed a threshold of a 10% absolute change in biomass percentage: 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 2022-24 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). The final column in Table 2 shows the CV projections immediately following the 2022 FISS, which are also within the target range.

The projected CV for 2024 for IPHC Regulatory Area 2A is close to exceeding the target, and in future revisions of the 2024 design, we may wish to consider adding stations from southern Washington/northern Oregon, and northern California to the design ("subarea 2" for this Regulatory Area). While historical data show this subarea to be highly stable over time in terms of its biomass proportion, by 2024 it will have been five years since any part of it was last sampled, and with no other lower-density subareas planned for sampling that year in IPHC Regulatory Areas 4A and 4B, this may be a logistically feasible year for fishing those stations. Should estimated CVs increase more rapidly than projected, future designs would be revised accordingly.

**Table 2.** Projected CVs (%) for 2021-24 for O32 WPUE estimated after completion of the proposed 2022-24 FISS designs, and (final column) after completion of the proposed 2022 FISS design only.

| Reg. Area | 2021 | 2022 | 2023 | 2024 | **2022** (Estimated in 2022) |
|---|---|---|---|---|---|
| **2A** | 13 | 13 | 14 | 15 | 14 |
| **4A** | 10 | 9 | 9 | 10 | 10 |
| **4B** | 10 | 12 | 10 | 12 | 14 |

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 (in absolute terms) but by up to 12% over three years, we should sample it at least every three years based on the 10% criterion discussed above.

Based on estimates from the historical times series (1993-2020) of O32 WPUE, the proposed designs for 2022-24 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).

**Table 3**. Maximum expected absolute changes (%) in biomass proportion since previous sampling of subareas that are unsampled in a given year, based on estimated the 1993-2020 time series.

| Reg. Area | 2021 | 2022 | 2023 | 2024 |
|---|---|---|---|---|
| **2A** | 8 | 9 | 9 | 9 |
| **4A** | 8 | 10 | 6 | 6 |
| **4B** | 10 | 9 | 8 | 10 |

### 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. After initial scientific designs, focused solely on primary objectives have been established, secondary and tertiary considerations (Table 1) are factored in to produce 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 (2020 was an exceptional case). 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 design, as the price increases observed in 2021 made it sufficient to include additional stations in core IPHC Regulatory Areas to generate a revenue-neutral coastwide design.

*Optimised designs for 2022*

IPHC Secretariat proposed two potential modifications of the proposed scientific minimum design (Figure 2) for 2022 that optimize the design to help achieve the secondary objective of long-term revenue neutrality. Optimized Design 1 (Figure 5) adds stations to the core IPHC Regulatory Areas (2B, 2C, 3A and 3B) to meet the secondary objective. Optimized Design 2 (Figure 6) adds fewer stations than those added in Optimized Design 1 and removes the northern stations from IPHC Regulatory Area 4CDE in order to meet the secondary objective. Both optimized designs meet the precision and bias criteria of the evaluation conducted above, as reducing the northern Bering Sea design for a single year is not expected to have a meaningful impact on either precision or bias in that area.

At SRB019, the optimized designs were noted by the SRB (IPHC-2021-SRB019-R), which also drew attention to the potential importance of increased sampling in the Bering Sea:

> SRB019–Rec.02 (para. 14):
>
> *NOTING the presentation of three alternative 2022 sampling designs (Figs. 1, 2, and 3) that optimize the SRB018-endorsed proposed 2022 design for cost, thereby meeting the goals of long-term revenue neutrality (Secondary Objective), without compromising the scientific goals of the FISS (Primary Objective), the SRB RECOMMENDED that the Secretariat prioritize 2022 sampling designs that include IPHC Regulatory Area 4CDE despite the relatively low contribution of this area to overall biomass and variance. This region is an important area to monitor for future range shifts and biological samples collected here are likely to be important for understanding the biology of Pacific halibut at their leading range edge.*

Based on the SRB's comments and the factors suggesting elevated priority for 4CDE identified by the Secretariat above, optimized design 1 (all stations in IPHC Regulatory Area 4CDE) is recommended by the Secretariat. Optimized design 2 is reserved as an alternative if bid availability and or other considerations arise.

## RECOMMENDATIONS

That the Commission:

1) **NOTE** paper IPHC-2021-IM097-09 that presents the FISS design proposals for 2022-24 together with an evaluation of the proposed designs;
2) **ENDORSE** optimized design 1 for the 2022 FISS, with full sampling in IPHC Regulatory Area 4CDE (Figure 5), and optimized design 2, reduced sampling in IPHC Regulatory Area 4CDE (Figure 6), as an alternative if necessary.
3) Provisionally **ENDORSE** the proposed designs for 2023-24, as provisionally endorsed by the Scientific Review Board at SRB018, recognizing that the 2023-24 designs are expected to be modified in subsequent years.

## REFERENCES

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IPHC 2020. Report of the 96th Session of the IPHC Annual Meeting (AM096) IPHC-2020-AM096-R. 51 p.

IPHC 2021. Report of the 18th Session of the IPHC Scientific Review Board (SRB) IPHC-2021-SRB018-R. 21 p.

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Thorson, J. T., Shelton, A. O., Ward, E. J., and Skaug, H. J. 2015. Geostatistical delta-generalized linear mixed models improve precision for estimated abundance indices for West Coast groundfishes. ICES Journal of Marine Science 72(5): 1297-1310. doi:10.1093/icesjms/fsu243.

Thorson, J. T. 2019. Guidance for decisions using the Vector Autoregressive Spatio-Temporal (VAST) package in stock, ecosystem, habitat and climate assessments. Fisheries Research 210: 143-161. doi:10.1016/j.fishres.2018.10.013.

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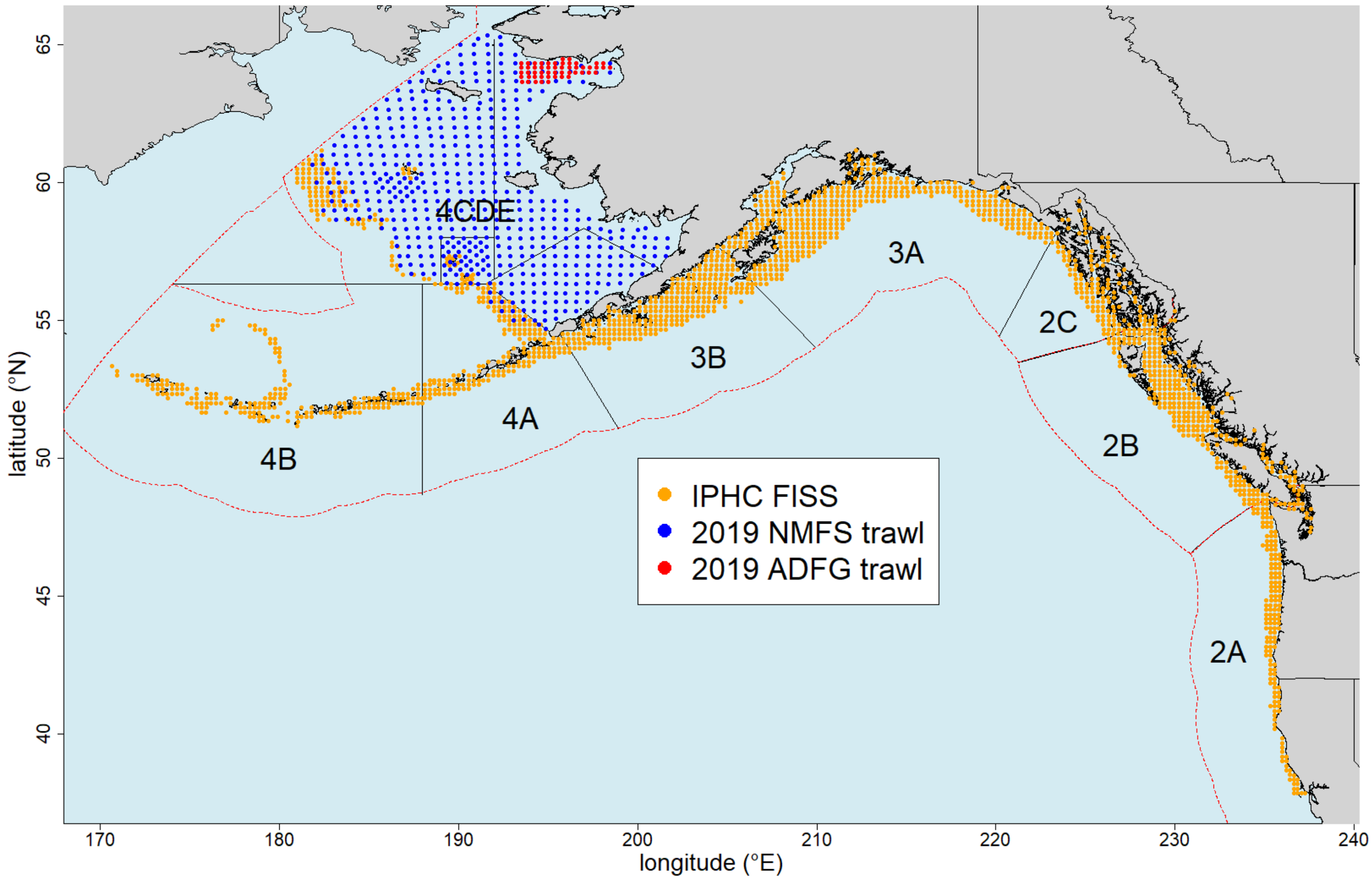
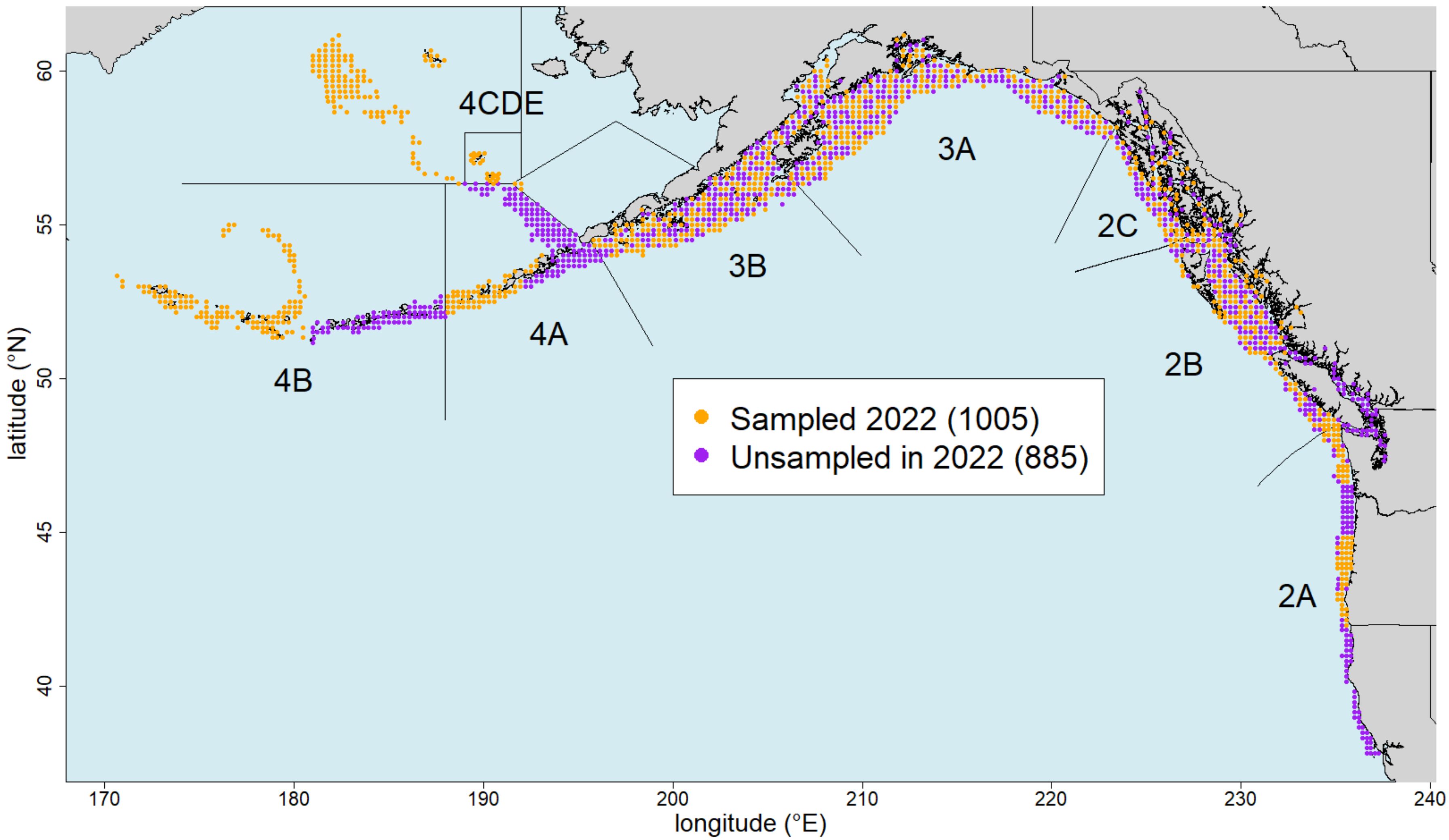
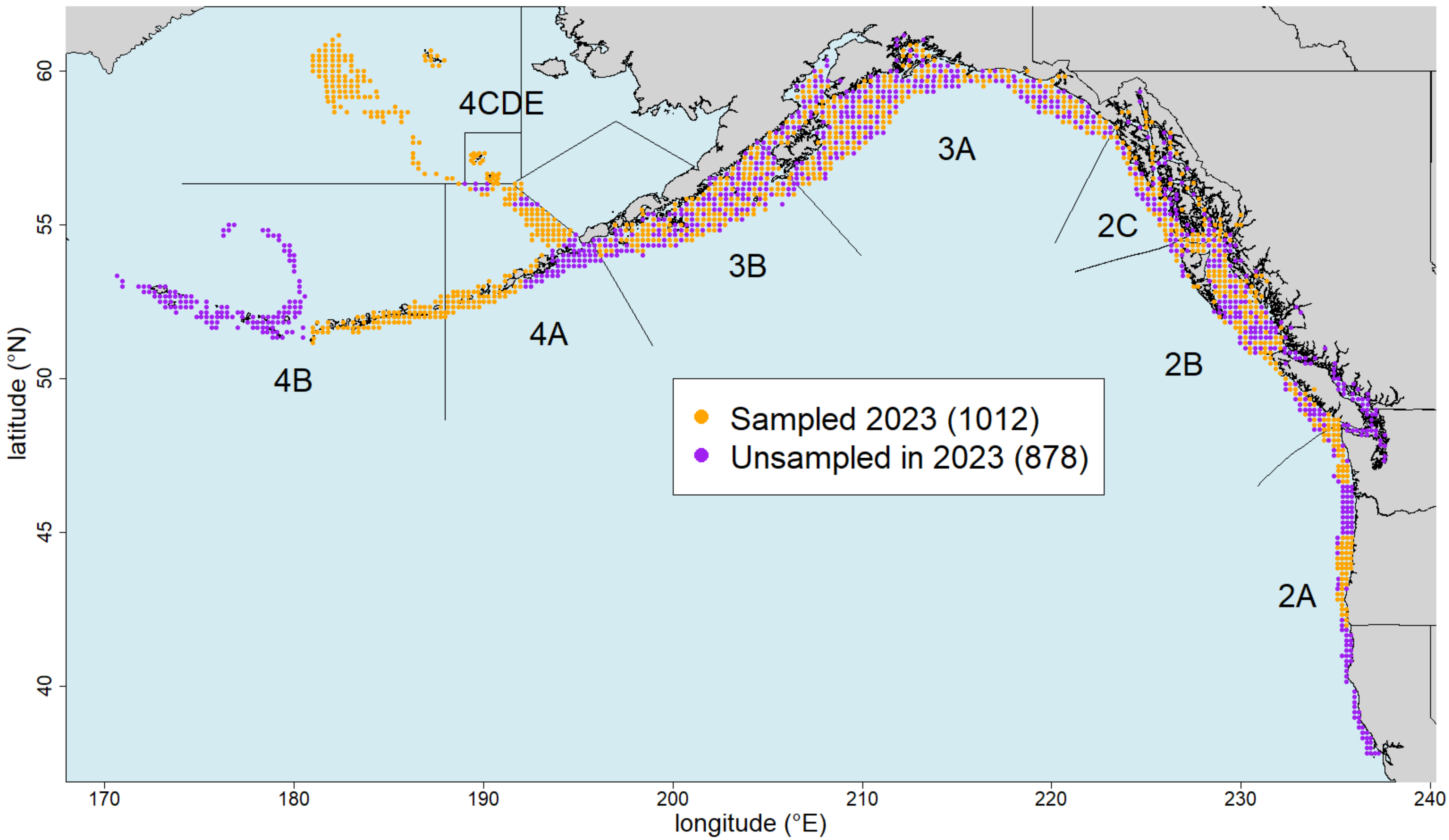
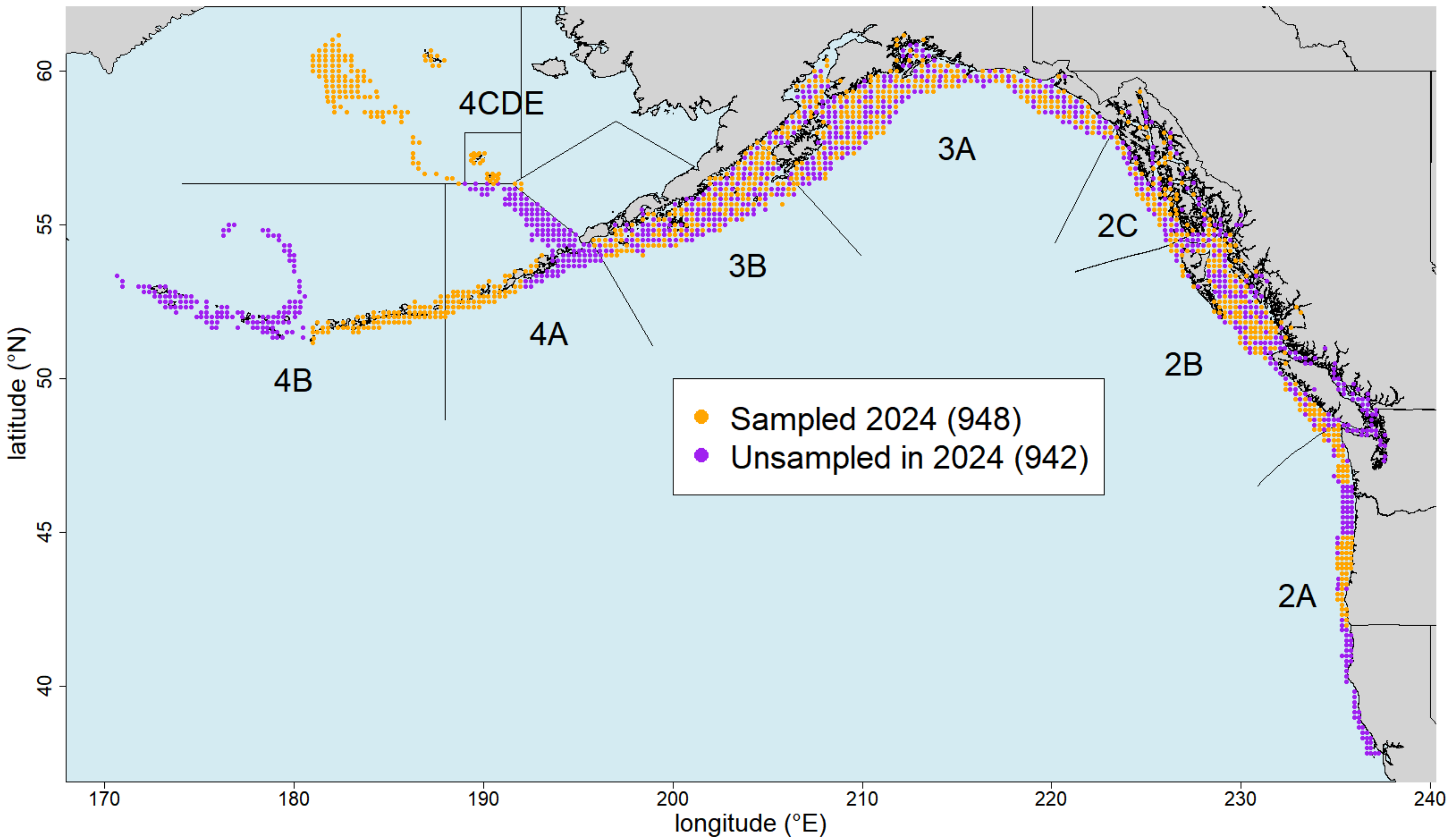



**Figure 1.** Map of the full 1890 station FISS design, with orange circles representing stations available for inclusion in annual sampling designs, and other colours representing trawl stations from 2019 NMFS and ADFG surveys used to provide complementary data for Bering Sea modelling.


4CDE
3A
2C
3B
4A
2B
4B
2A
Sampled 2022 (1005)
Unsampled in 2022 (885)
latitude (°N)
longitude (°E)
60
55
50
45
40
170
180
190
200
210
220
230
240


4CDE
3A
2C
3B
4A
4B
2B
2A
Sampled 2023 (1012)
Unsampled in 2023 (878)
latitude (°N)
60
55
50
45
40
170
180
190
200
210
220
230
240
longitude (°E)


4CDE
4A
4B
3A
3B
2C
2B
2A
Sampled 2024 (948)
Unsampled in 2024 (942)
latitude (°N)
longitude (°E)
60
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50
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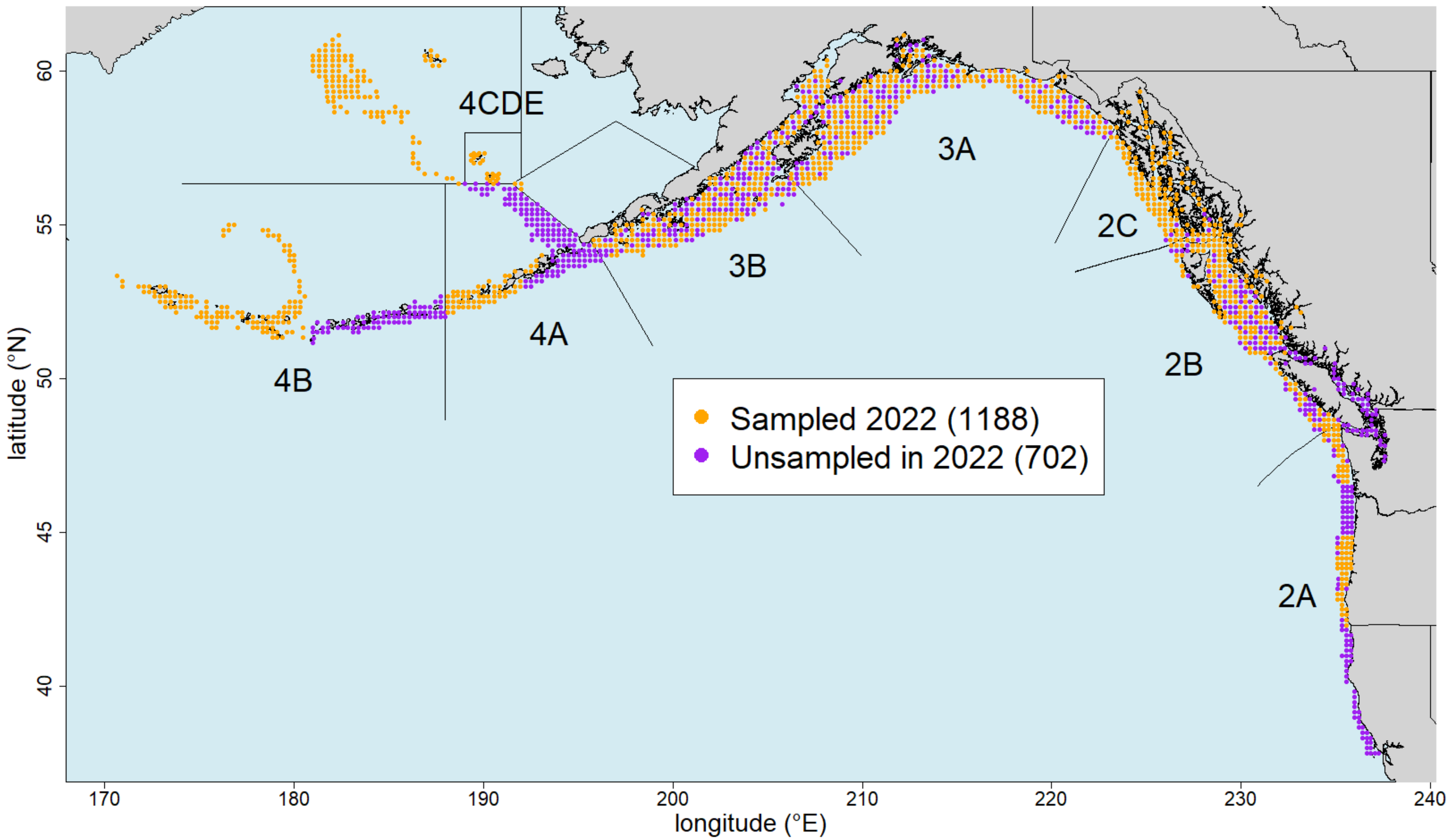


**Figure 5.** Optimized FISS design for 2022, with original design endorsed at SRB018 augmented with additional stations in IPHC Regulatory Areas 2B, 2C, 3A, and 3B in order to help achieve the secondary objective of long-term revenue neutrality.

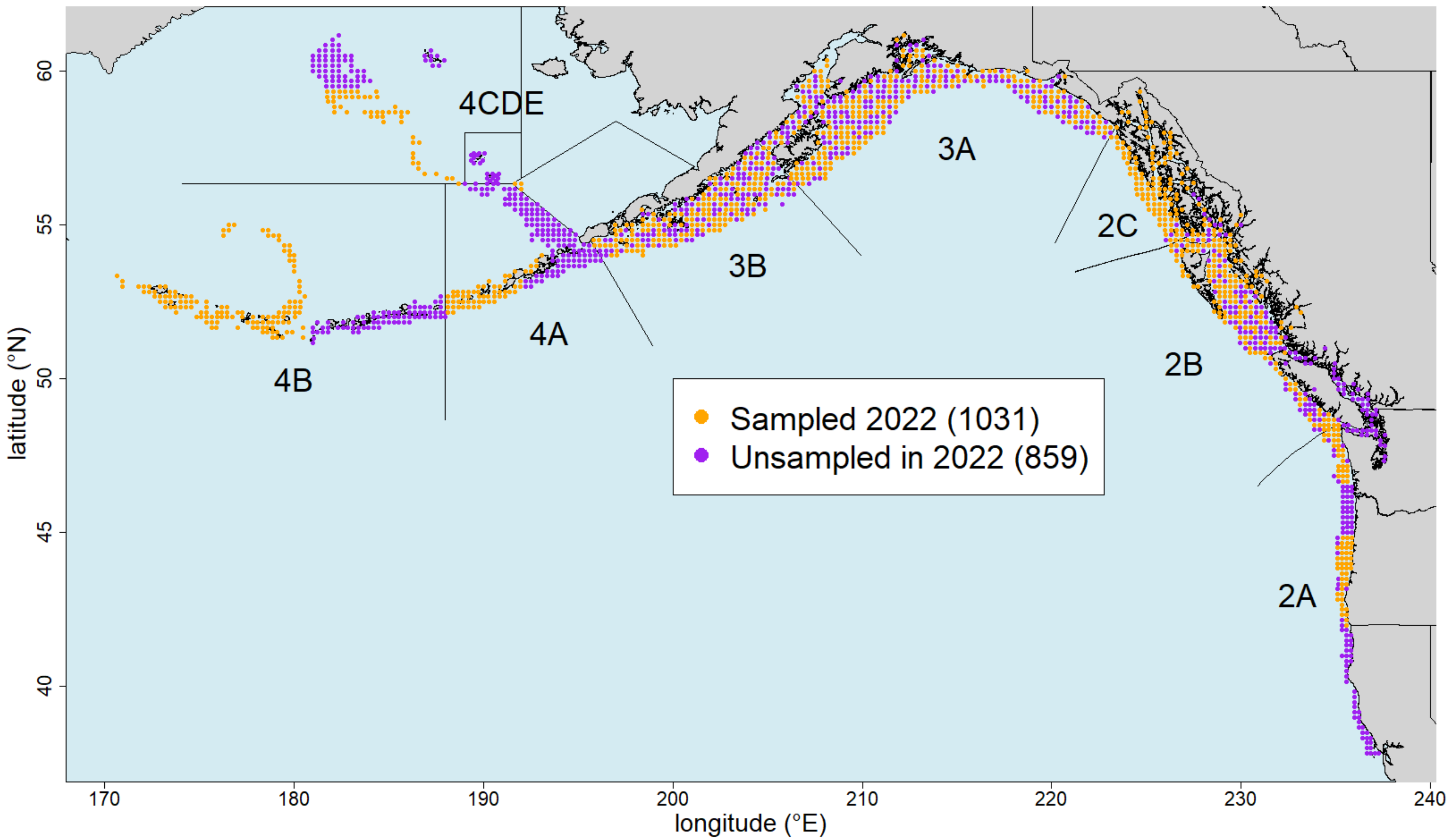


**Figure 6.** Optimized FISS design for 2022, with original design endorsed at SRB018 modified to remove northern Bering Sea shelf edge stations fished in 2021 augmented with additional stations in IPHC Regulatory Areas 2B, 2C, 3A, and 3B in order to help achieve the secondary objective of long-term revenue neutrality.