# 2024-26 FISS design evaluation

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## PURPOSE

To present the proposed designs for the IPHC's Fishery-Independent Setline Survey (FISS) for the 2024-26 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 2024-26. 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 standardize 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 the R software.

*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 rationalized 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 |

*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 finalized 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 (late November) 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 is 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 2024-26

The designs proposed for 2024-26 (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, historically a logistically feasible footprint for the annual FISS.

In 2022, designs for 2024-25 were also endorsed subject to later revision (IPHC-2022-IM098-R). However, the original proposed design for 2023 (IPHC-2022-SRB020-05) was not endorsed by the Commissioners. To meet the secondary objective of long-term revenue neutrality, they instead endorsed a spatially-reduced design with minimal sampling in IPHC Regulatory Areas 2A, 4A and 4B (16 FISS grid station per area), and no sampling in IPHC Regulatory Area 4CDE (IPHC-2022-IM098-R). For this reason, almost all stations in IPHC Regulatory Areas 2A, 4A, 4B and 4CDE that were proposed but not endorsed for 2023 are again proposed for the 2024 FISS. The one exception is in IPHC Regulatory Area 4A, where the sample timing of two subareas has been switched.

Thus, the following changes from the previous 2024 proposal presented at SRB020 have been made (see Figure 2):

- IPHC Regulatory Area 2A: Sample the highest-density waters of IPHC Regulatory 2A in northern Washington and central/southern Oregon and add the moderate density waters

of southern Washington/northern Oregon and northern California **(original 2023 SRB proposal)**.
- IPHC Regulatory Area 4A: Sample both the higher-density western subarea of IPHC Regulatory Area 4A and the lower-density southeastern subarea in 2024 **(previous 2025 SRB proposal)**.
- IPHC Regulatory Area 4B: Sample the high-density eastern subarea and the western subarea in 2024 **(original 2023 SRB proposal)**.

One change was made to last year's 2025 proposal (Figure 3):

- IPHC Regulatory Area 4A: Sample both the higher-density western subarea of IPHC Regulatory Area 4A and the medium-density Bering Sea shelf subarea in 2025 **(previous 2023 SRB proposal)**.

The 2026 proposal (Figure 4) includes sampling in the high-density subareas of IPHC Regulatory Areas 2A, 4A, and 4B, along with full sampling of FISS stations in IPHC Area 4CDE.

Stations in the moderate-density waters of IPHC Regulatory 2A proposed for 2024 sampling have not been sampled since 2017 (California) or 2019 (WA/OR), and thus 2024 sampling will occur 5-7 years since they were last sampled. We have also received anecdotal reports of increasing recreational catch rates in northern California, providing additional motivation for 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 2024 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 3), 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 was sampled due to a lack of charter vessel bids for the western subarea. Thus, the western subarea has been added to the 2024 proposal to reduce the risk of bias due to the potential for otherwise unmonitored changes in density.

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 2027-28, 10-11 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 in a single year, although it was fished over in two parts over the 2021-22 period. 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 randomized 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). Thus, we invite the SRB's discussion of alternative designs such as randomized cluster sampling or the use of subarea sampling in the core areas as more operationally efficient alternatives.

## 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 has resulted in meeting targets for the larger geographic units.

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

- Where a randomized 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 4 additional years of simulated data (current calendar year plus three years for proposed designs), where the FISS designs reflect the sampling priorities identified above.
- Project precision estimates and quantify bias potential of proposed designs.

At the time of writing, it has become clear that the endorsed FISS design in IPHC Areas 4A and 4B did not receive viable bids, and our analysis therefore assumes a design with no 2023 sampling in these areas.

Table 2 shows projected CVs following completion of the proposed 2024-26 FISS designs together with the expected 2023 FISS sampling. With these designs, we are projected to maintain CVs within the target range in all years. 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 2024 FISS, which are also within the target range.

**Table 2.** Projected CVs (%) for 2023-26 for O32 WPUE estimated after completion of the proposed 2024-26 FISS designs, and (final column) after completion of the proposed 2024 FISS design only.

| Reg. Area | 2023 | 2024 | 2025 | 2026 | **2024** (After 2024 FISS) |
|---|---|---|---|---|---|
| **2A** | 12 | 11 | 12 | 14 | 12 |
| **4A** | 14 | 9 | 9 | 12 | 10 |
| **4B** | 16 | 9 | 10 | 12 | 9 |

*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 (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: our goal is to sample frequently enough so that each subarea's biomass proportion has a low chance of changing by more than 10% between successive surveys of the subarea. (The 10% value was chosen to provide a threshold that was meaningful in terms of bias without either resulting in large unmonitored change - e.g., 20% or more - or change so small it would require annual sampling of all stations – e.g., 5% or less - to detect reliably.

At SRB021, we presented a new method for quantifying the risk of bias due to not sampling a particular subregion of an IPHC Regulatory Area for a specified number of years (see IPHC-2022-SRB021-06). The method uses samples from the posterior predictive distribution from the space-time modelling to estimate the probability of at least a 10% absolute change in a subarea's biomass proportion over a period of time equal to the number of years since it was last sampled. We denote this probability by $q_{sy}$, where $s$ is the subarea and $y$ is the number of years since last sampling. $q_{sy}$ is estimated for all possible years in the historical time series, but greatest interest is in the most recent values, which are most relevant for current FISS design proposals.

IPHC REGULATORY AREA 2A:

Figure 5 shows $q_{s2}$ by year for all three subareas of IPHC Regulatory Areas 2A. Subarea 1 is the one with greatest Pacific halibut density, and by 2024 it will have been largely unsampled for just two years (hence $y$=2 in the $q$ subscript). The subarea 1 plot (top panel) shows a modest risk ($q_{1,2}$≈20-30%) of two-year changes of at least 10% in biomass proportion for this area over the three most recent years. We could accept this risk and not propose sampling subarea 1, but as it comprises the core of the area's stock, it is the most important area to sample to monitor the overall trend and maintain high precision.

Subarea 2 was last sampled in 2019 (WA/OR) and 2017 (northern CA). Using the longest of these intervals ($y$=7 years) $q_{s7}$ is shown in Figure 6. Values of $q_{2,7}$ (middle panel) are close to 50% in the most recent three years, meaning the risk of a change of at least 10% in biomass proportion is relatively high for this subarea over a seven-year period. We considered this risk when including this subarea in our proposal for 2024. Subarea 3 also has been largely unsampled since 2017, but the risk of large change over a seven-year period remains low (bottom panel).

Subarea 3 was last sampled in 2018 (Salish Sea in WA) and 2017 (southern CA stations), and is not proposed for sampling earlier than 2027. The values of $q_{3,9}$ (i.e., subarea 3 in 2026, nine years since 2017) are 20-25% for the most recent years, and we regard this as acceptable for this historically very low-density subarea.

IPHC REGULATORY AREA 4A:

Subarea 1 was last sampled in 2022, so the proposed sampling in 2024 represents a two-year period since previous sampling. Figure 7 shows very high risk that this area has changed by 10% or more in terms of biomass proportion over a two-year period in recent years, and is a high priority for sampling in 2024 (and indeed, we have been proposing it for annual sampling).

Subarea 2 also has increasing risk of large changes over two years, yet the proposed 2024 sampling represents five years since it was last sampled. If we consider the risk of at least a 10% change over five years, this value is almost 90% for 2022 (Figure 8). This very high risk of unmonitored change is the reason that sampling subarea 2 has been brought forward to 2024. Subarea 3, on the other hand, shows relatively low risk of such a change over a five-year period. Subarea 4 represents a small part of IPHC Regulatory Area 4A with annual coverage provided by the NMFS trawl survey and is not at present considered for future FISS sampling.

IPHC Regulatory Area 4B:

Subarea 3 (eastern Aleutians) has been the highest-density component of IPHC Regulatory Area 4B in recent years, and it was last sampled (albeit incompletely) in 2021. The risk for this subarea over a three-year period is 20-30% in the most recent years (Figure 9), but as this subarea is the core of the IPHC Regulatory Area 4B's stock, we continue proposing it for near-annual sampling to maintain precise estimates of density indices.

Subarea 2 was sampled in the 2022 and is not proposed for sampling in 2024-26. Figure 10 (middle panel) shows a low risk of at least a 10% change in biomass proportion for this area over a four-year period.

The western Aleutian Islands make up subarea 1 of IPHC Regulatory 4B, and these have not been sampled since 2019. Sampling in 2024 would mean five years since subarea 1 was last sampled. Due to increasing uncertainty in this subarea, Figure 11 (top panel) shows the most recent estimates of risk to be around 35% that this subarea's biomass proportion has changed by at least 10% over a five-year period.

*Post-sampling evaluation for 2022*

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 2022 design based on using simulated data for 2022 and estimated from fitting the models including observed 2022 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 2021) and estimated CVs (%) for O32 WPUE for 2022 by IPHC Regulatory Area.

| Regulatory Area | 2022 projected CV (%) | 2022 estimated CV (%) |
|---|---|---|
| 2A | 14 | 16 |
| 4A | 10 | 14 |
| 4B | 14 | 19 |

Projected CVs in all three areas were lower than those estimated once the observed 2022 data were incorporated into the modelling. The projections for 2022 were made prior to the start of the 2021 FISS. As noted in IPHC-2022-SRB020-05, the 2021 FISS in IPHC Regulatory Areas 4A and 4B did not complete all planned stations due to logistical issues. In both areas, the unfished stations covered some of the most productive habitat in recent years. This affected both the projections for 2021 and 2022, which assumed a complete survey. Further, the western subregion of IPHC Regulatory Area 4B was planned to be sampled in 2022 but due to lack of viable charter bids, the FISS did not sample there.

The difference between projected and estimated CVs in IPHC Regulatory Area 2A was relatively small. Last year (IPHC-2022-SRB020-05) we noted an apparent increase in the underlying variability of Pacific halibut density in this area. The 2022 data did not show evidence for higher variability than other recent years, and the combined effect of 2021 and 2022 data was an estimated CV that was closer to the projection than last year.

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, and 3A were all 6% in 2022, with a CV of 10% in IPHC Regulatory 4CDE. The CV for IPHC Regulatory Area 3B was 14%, but this was anomalous as it was due to unforeseen logistical issues leaving many stations unsampled. Typically, the CV is around 7% in this area.

### 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 was 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 and 2023). This has implications for data quality, particularly if such reductions in effort relative to proposed designs continue over multiple years. In the 2021 and 2022 surveys, it was sufficient to include additional stations in core IPHC Regulatory Areas to generate a revenue-neutral coastwide design and so there were no planned reductions in coverage. The 2023 FISS balances the primary science objective with the secondary objective of long-term revenue neutrality by greatly reducing sampling outside of the core areas of the stock (IPHC-2022-IM098-R).

## RECOMMENDATIONS

That the SRB:

1) **NOTE** paper IPHC-2023-SRB022-06 that provides background on and a discussion of the IPHC fishery-independent setline survey design proposals for the 2024-26 period;
2) **ENDORSE** the 2024 FISS design as presented in Figure 2, and
3) Provisionally **ENDORSE** the 2025-26 designs (Figures 3 and 4), recognizing that these will be reviewed again at subsequent SRB meetings.

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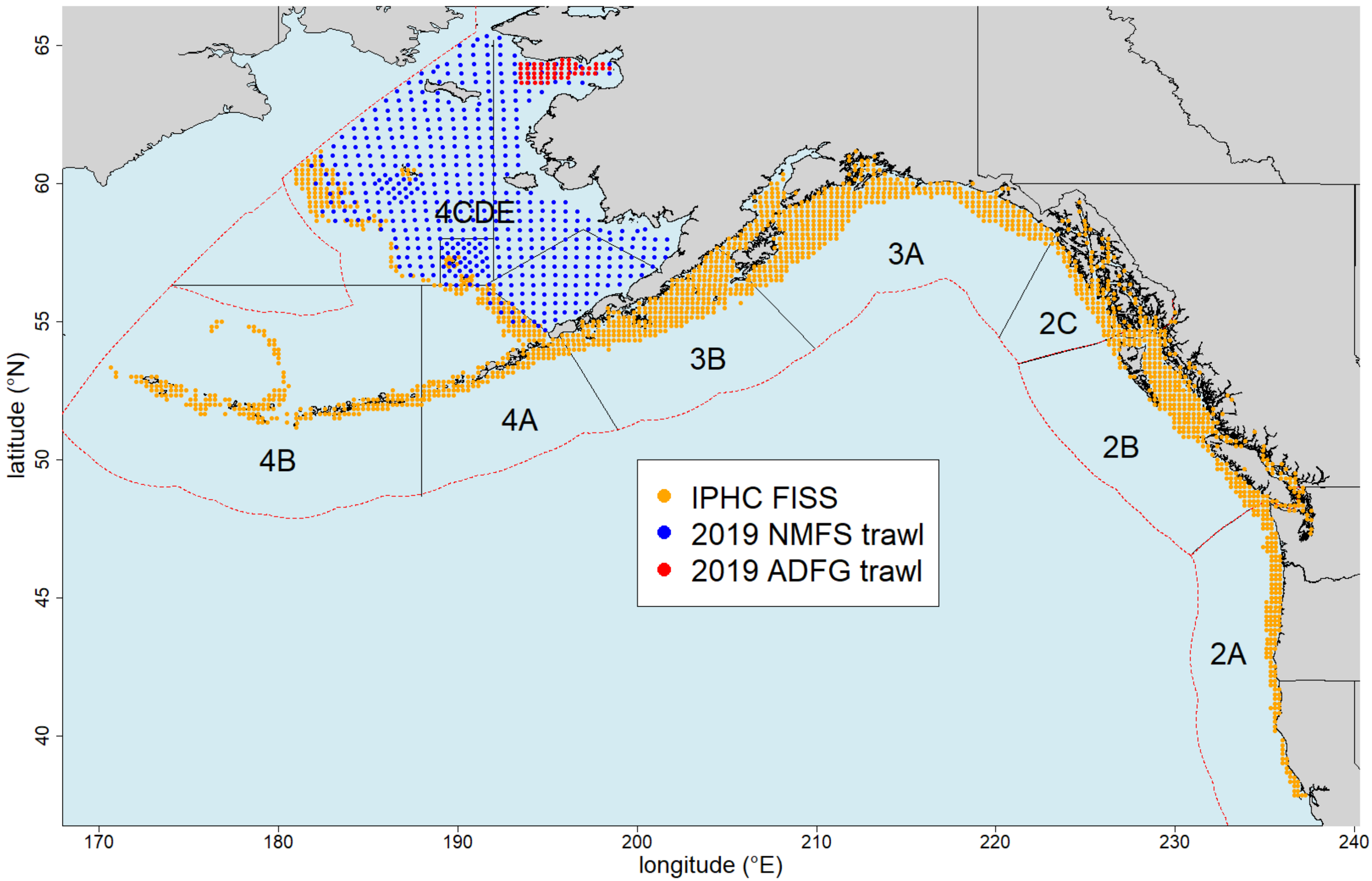


**Figure 1.** Map of the full 1890 station FISS design, with orange circles representing stations available for inclusion in annual sampling designs, and other colours representing trawl stations from 2019 NMFS and ADFG surveys used to provide complementary data for Bering Sea modelling.

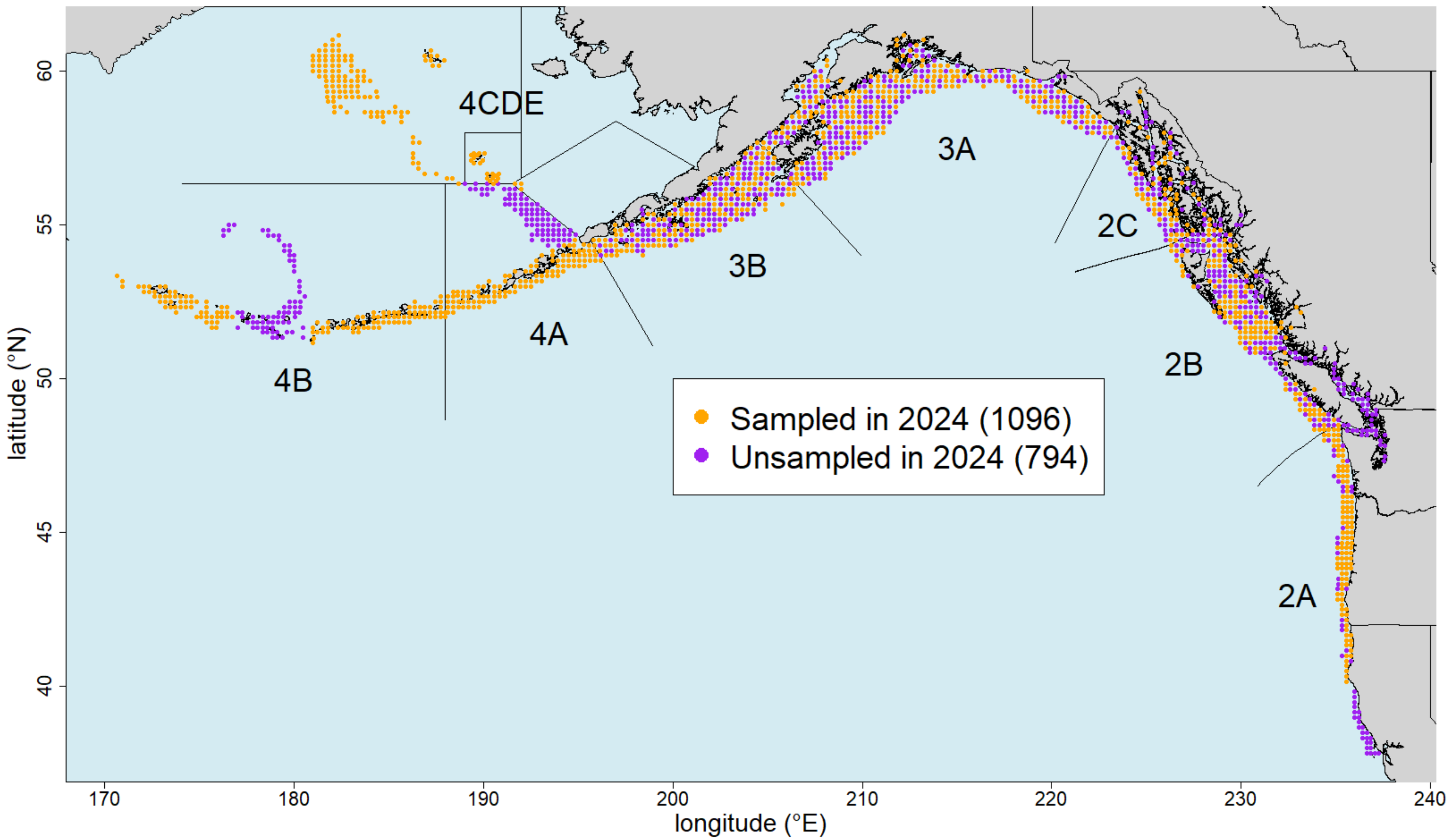


**Figure 2.** Proposed minimum FISS design in 2024 (orange circles) based on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

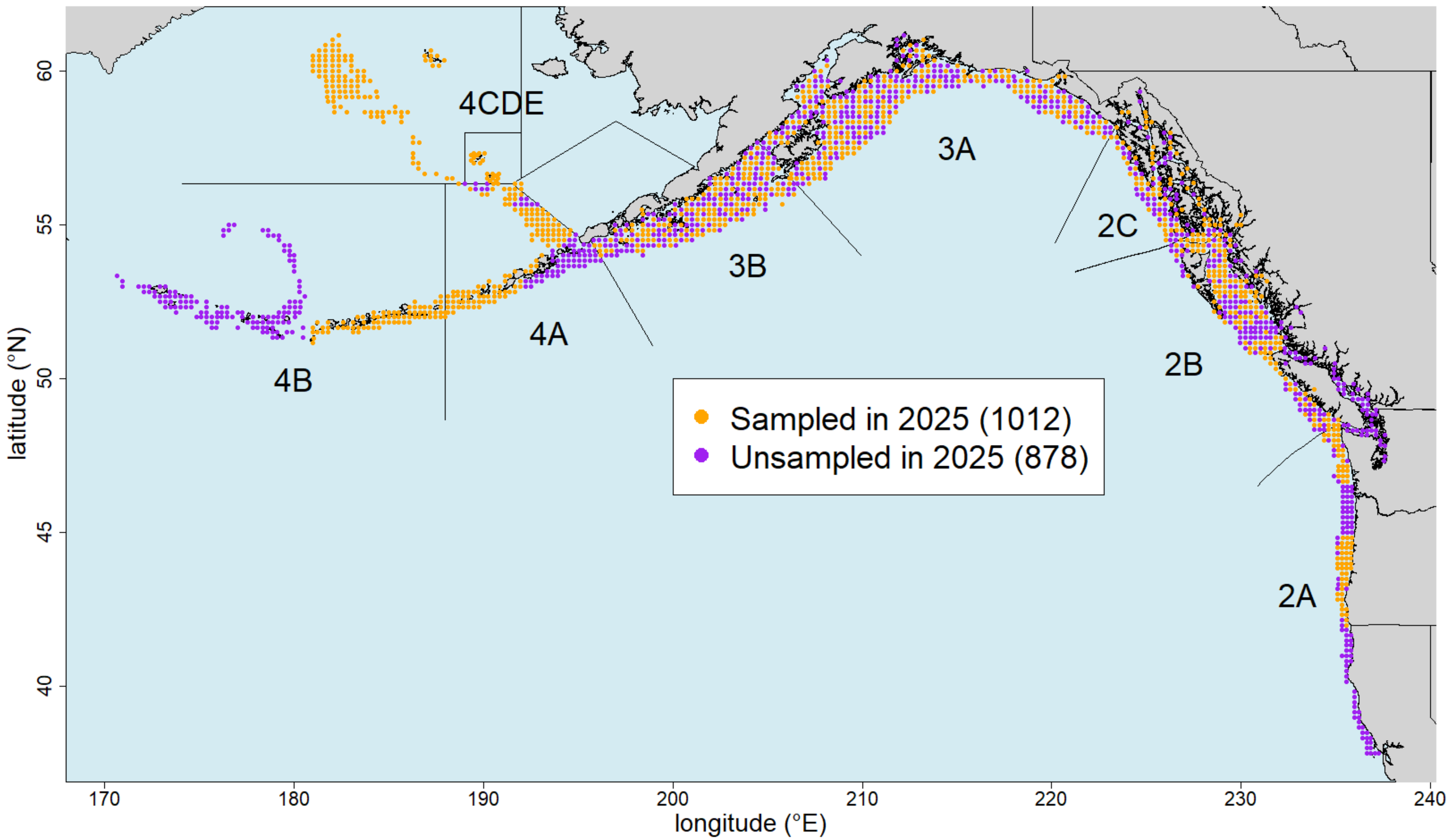


**Figure 3.** Proposed minimum FISS design in 2025 (orange circles) based on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

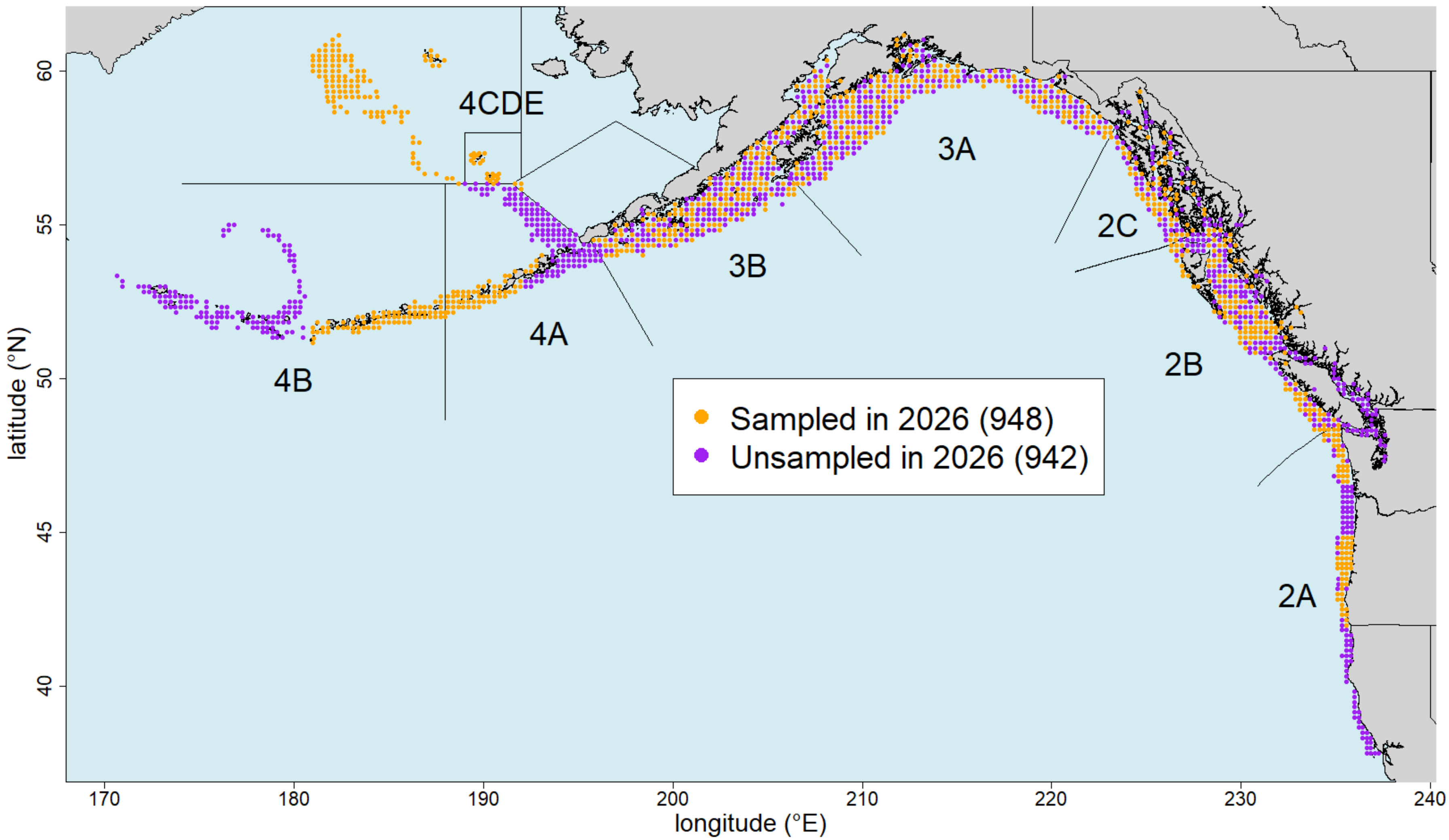


**Figure 4.** Proposed minimum FISS design in 2026 (orange circles) based on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

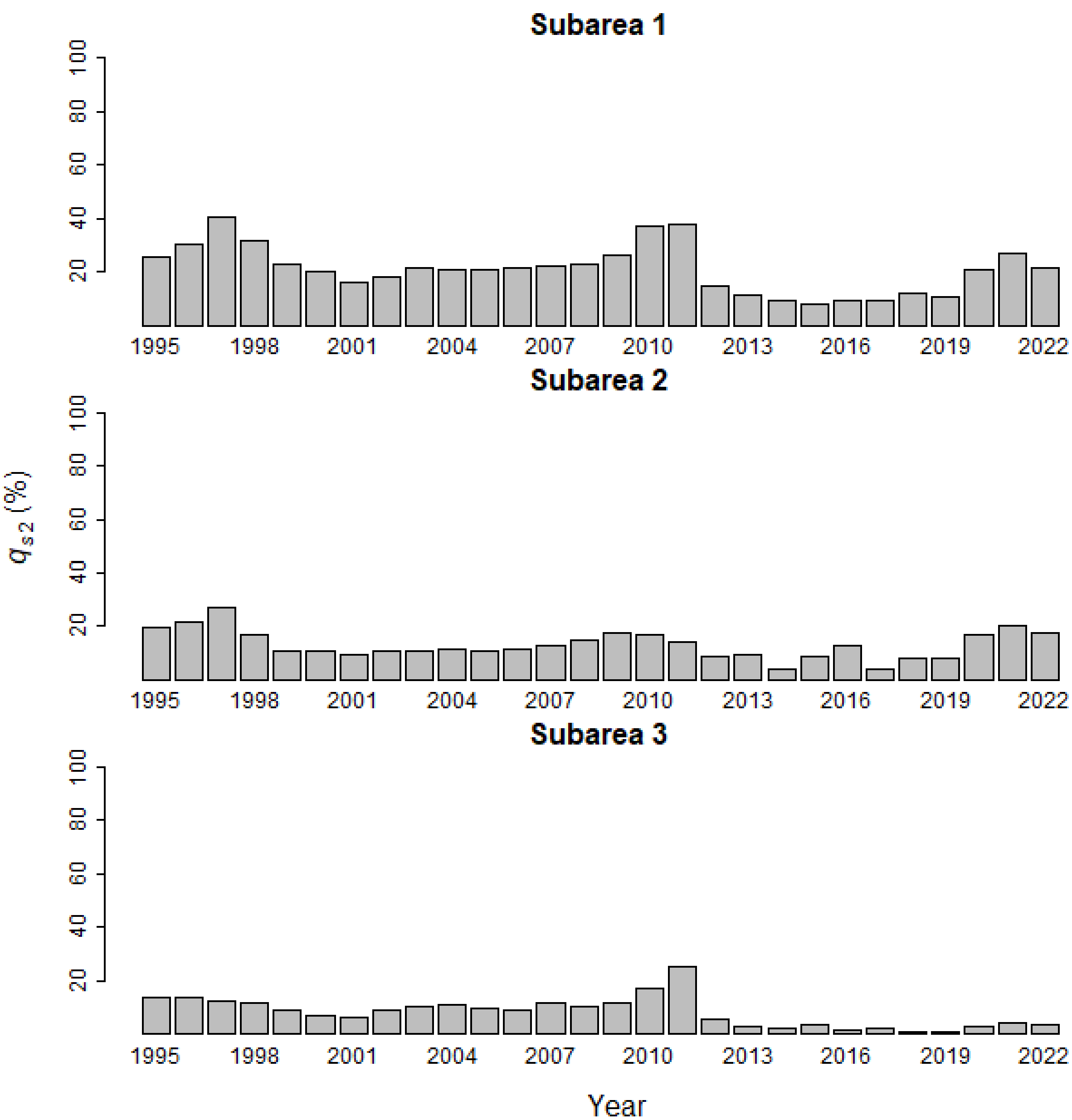


**Figure 5.** Risk ($q_{s2}$, %) of at least a 10% change in biomass proportion over the last 2 years for IPHC Regulatory 2A, by subarea, *s*, and year. Values for the most recent years are of greatest relevance to proposals for future FISS designs.

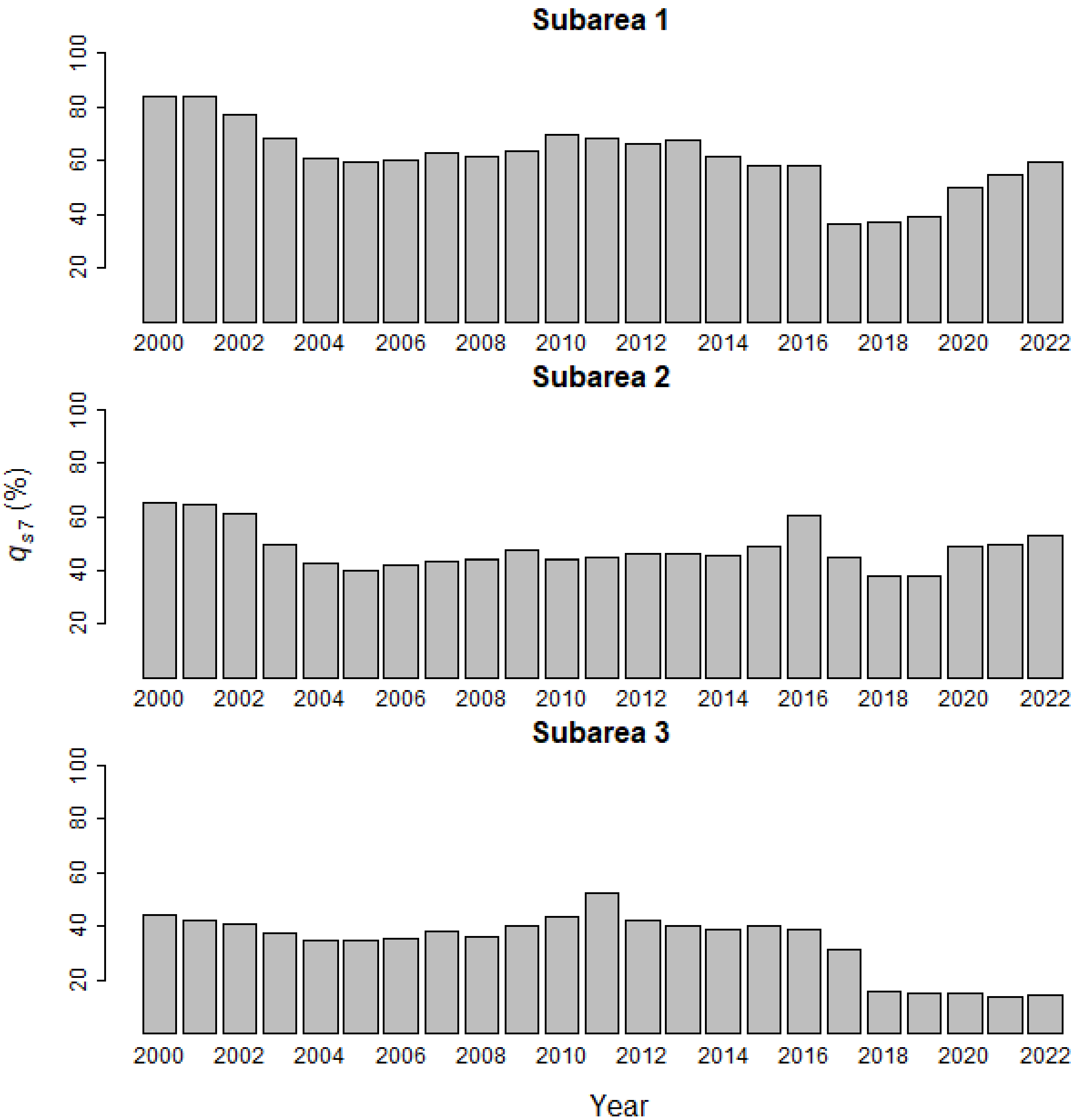


**Figure 6.** Risk ($q_{s7}$, %) of at least a 10% change in biomass proportion over the last 7 years for IPHC Regulatory 2A, by subarea, *s*, and year. Values for the most recent years are of greatest relevance to proposals for future FISS designs.

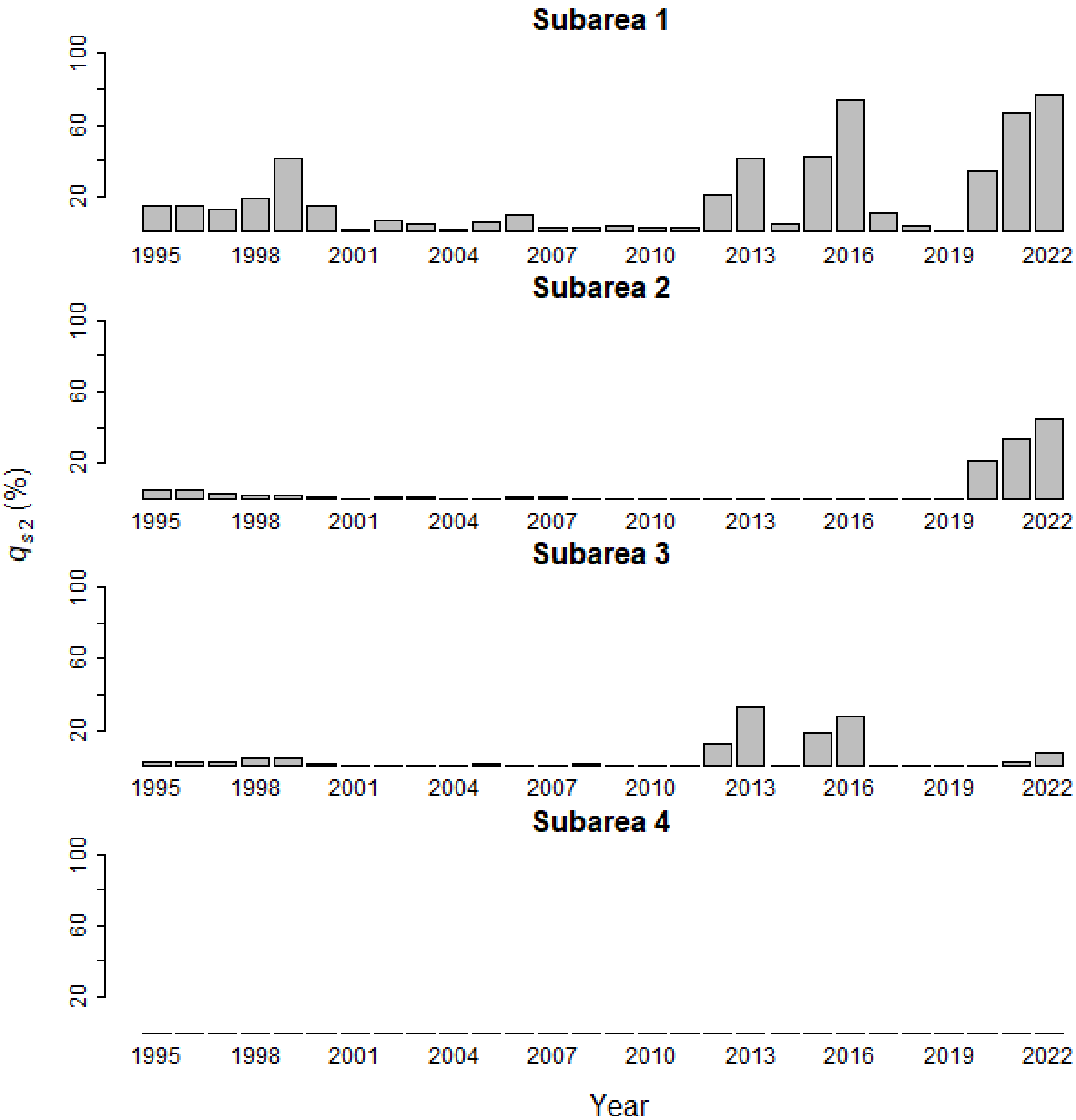


**Figure 7.** Risk ($q_{s2}$, %) of at least a 10% change in biomass proportion over the last 2 years for IPHC Regulatory 4A, by subarea, *s*, and year. Values for the most recent years are of greatest relevance to proposals for future FISS designs.

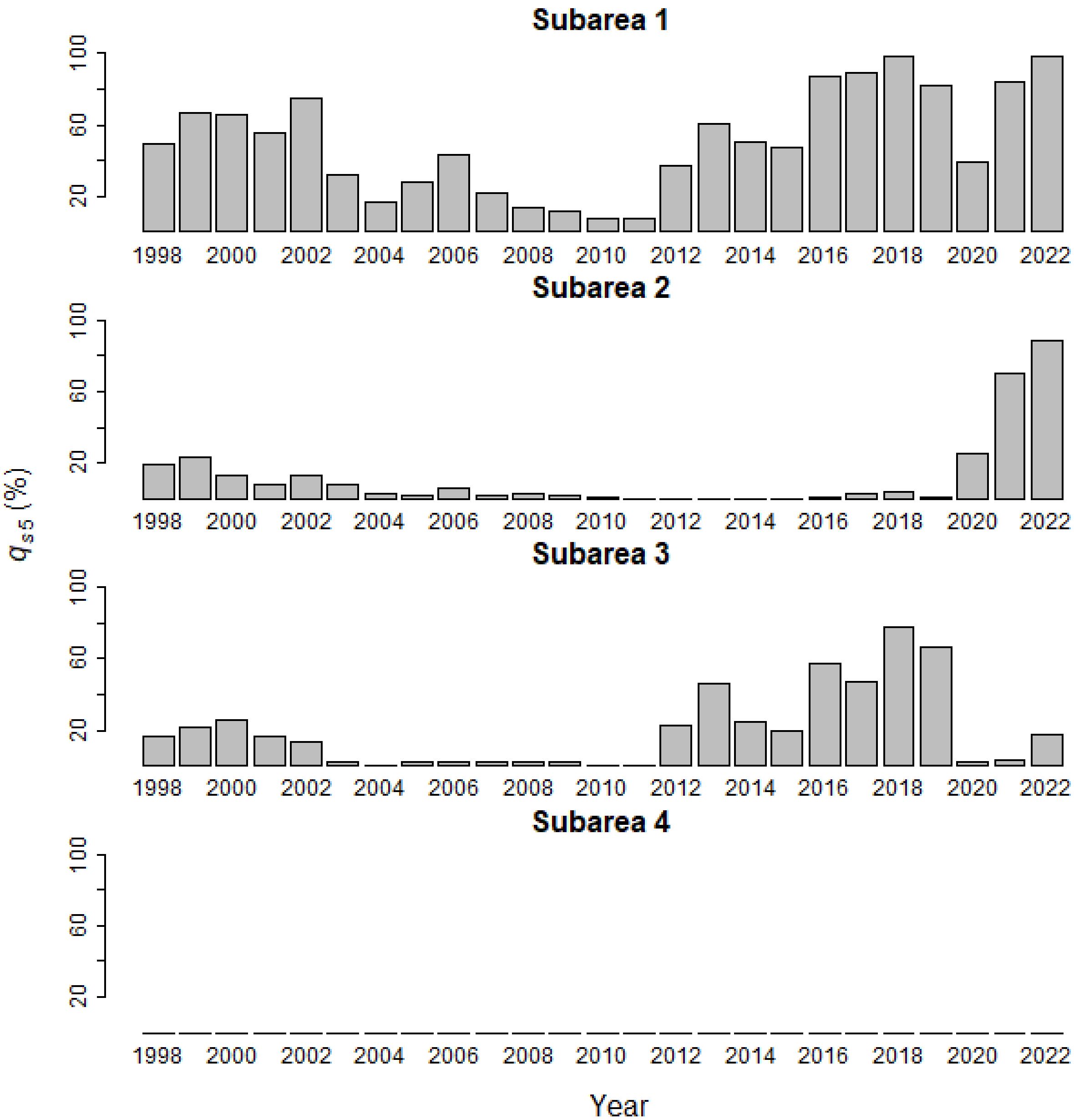


**Figure 8.** Risk ($q_{s5}$, %) of at least a 10% change in biomass proportion over the last 5 years for IPHC Regulatory 4A, by subarea, *s*, and year. Values for the most recent years are of greatest relevance to proposals for future FISS designs.

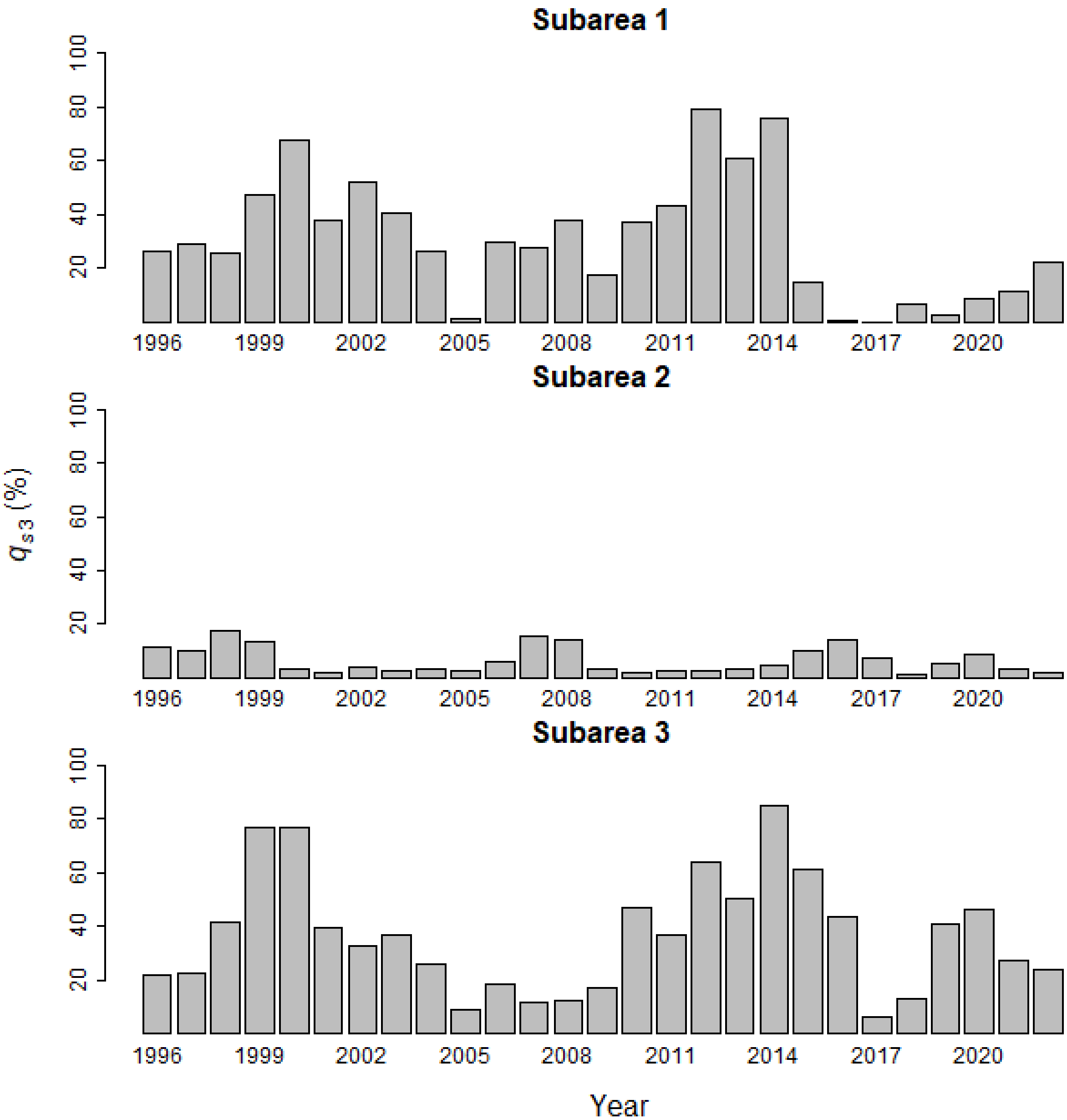


**Figure 9.** Risk ($q_{s3}$, %) of at least a 10% change in biomass proportion over the last 3 years for IPHC Regulatory 4B, by subarea, *s*, and year. Values for the most recent years are of greatest relevance to proposals for future FISS designs.

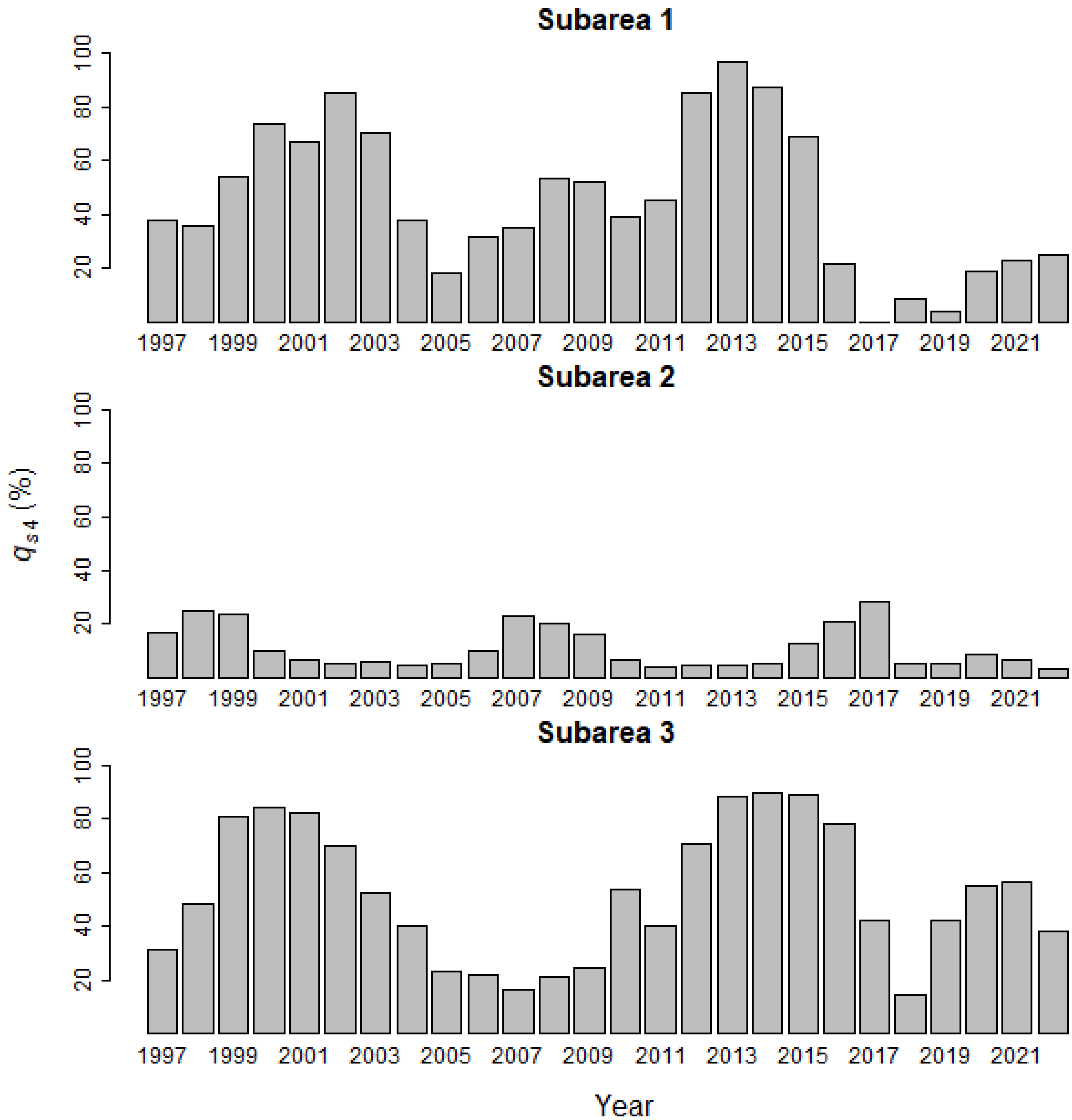


**Figure 10.** Risk ($q_{s4}$, %) of at least a 10% change in biomass proportion over the last 4 years for IPHC Regulatory 4B, by subarea, *s*, and year. Values for the most recent years are of greatest relevance to proposals for future FISS designs.

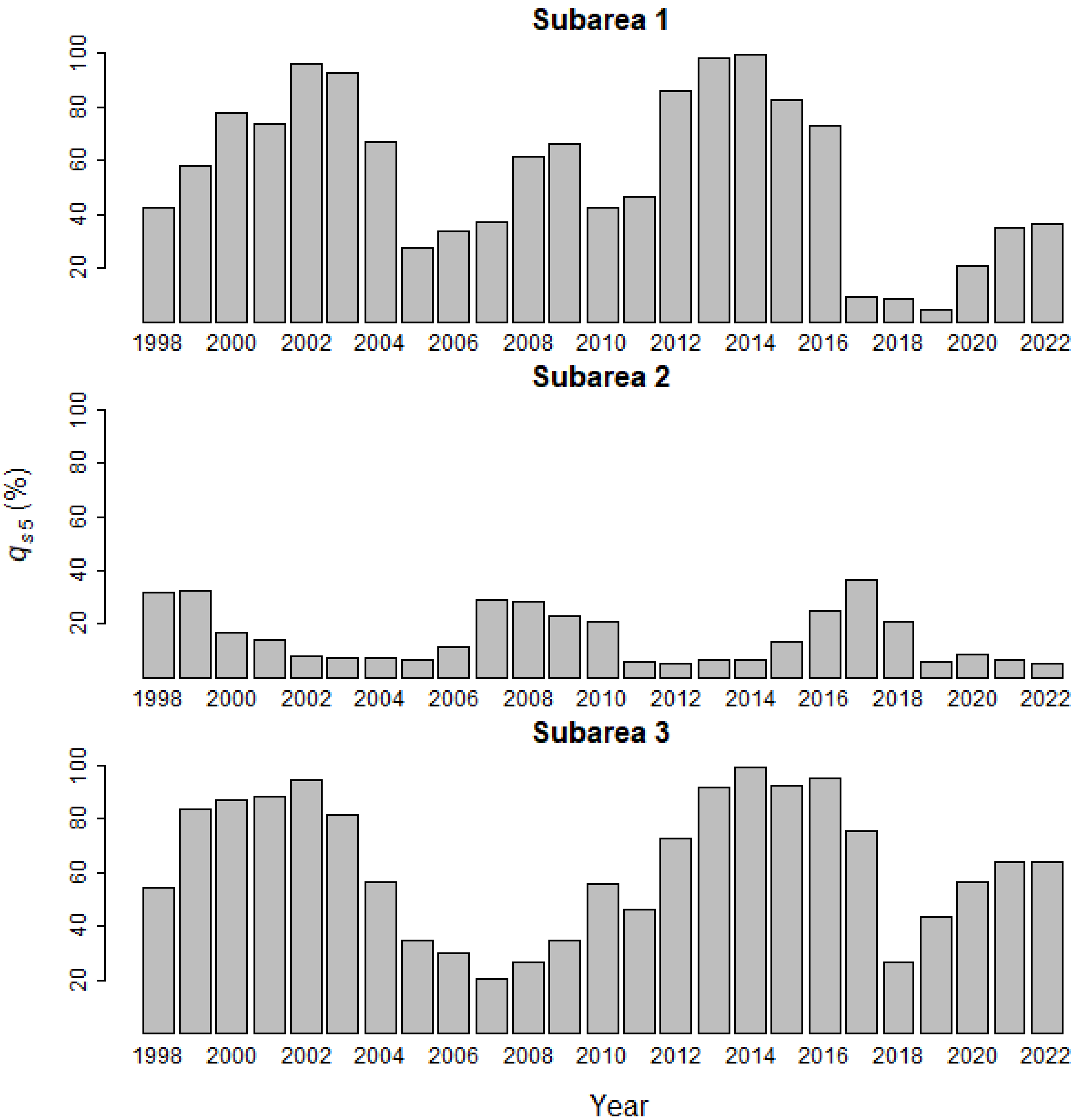


**Figure 11.** Risk ($q_{s5}$, %) of at least a 10% change in biomass proportion over the last 5 years for IPHC Regulatory 4B, by subarea, *s*, and year. Values for the most recent years are of greatest relevance to proposals for future FISS designs.