2021-23 Fishery-Independent Setline Survey (FISS) design evaluation

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PURPOSE

To provide the Scientific Review Board (SRB) with proposed designs for the 2021-23 IPHC Fishery-Independent Setline Survey (FISS), together with a summary of the process that led to the 2020 FISS design options adopted at the 96th Session of the IPHC Annual Meeting (AM096).

INTRODUCTION

The IPHC uses data from its Fishery-independent Setline Survey (FISS) to estimate indices of density and abundance of Pacific halibut, estimate stock distribution (both estimated using spatio-temporal modelling, Webster et al. 2020), and provide biological input data to the IPHC stock assessment. The historical IPHC FISS sampling from 1998 onwards, combined with FISS expansions from 2014-2019, established a full sampling frame of 1890 stations from California to the Bering Sea shelf edge on a 10 nmi grid from depths of 10 – 400 ftm. Future annual FISS designs are expected to comprise a selection of stations from this frame, as financial and logistical constraints make it challenging to sample the entire grid on an annual basis.

At SRB014 (IPHC-2019-SRB014-05) we proposed precision targets for indices of density (weight or numbers per unit effort, WPUE/NPUE) that future designs should meet in order to maintain data quality for the stock assessment and stock distribution estimation. From a scientific perspective, more information is always better; however, sampling the full grid 1890-station is statistically unnecessary as the precision targets for the indices can be maintained with substantial subsampling. While a fully randomized subsampling design with sufficient sample size will still meet scientific needs, in several IPHC Regulatory Areas where Pacific halibut are concentrated in a subset of the available habitat, such a design can be inefficient. We therefore evaluated another type of design reviewed at SRB014 (IPHC-2019-SRB014-05) in which effort is focused in most years on habitat with highest density (which generally contributes most to the overall variance), while sampling other habitat with sufficient frequency to maintain low bias.

At the AM096 alternative designs were presented to IPHC Commissioners that had been evaluated based on scientific criteria (IPHC-2020-AM096-07), in particular, meeting specific precision targets (coefficients of variation, CVs, below 15%) for WPUE and NPUE indices, and ensuring low probability of large bias in estimators of those indices. These evaluation methods had been previously reviewed by the SRB at SRB014 (IPHC-2019-SRB014-05) with application to IPHC Regulatory Areas 4B and (in presentation) 2A, and introduced to Commissioners at IM095 (IPHC-2019-IM095-07). While development of the proposed designs focused on the Primary Objective of the FISS (Table 1), logistics and cost (Secondary Objective) were also considered in developing proposals based on annual sampling of subareas of each IPHC Regulatory Area on a rotating basis. The final design adopted by the IPHC at AM096 (IPHC-2020-AM096-R) combined the proposed subarea design in IPHC Regulatory Areas 2A, 4A and 4B, an enhanced randomized design in the core of the stock (IPHC Regulatory Areas 2B, 2C, 3A and 3B, with sample sizes in excess of those required to meet precision targets), and sampling all standard FISS stations in IPHC Regulatory Area 4CDE (Figure 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

EVALUATION METHODS

Precision targets

Prior to 2019, the IPHC Secretariat had an informal goal of maintaining a coefficient of variation (CV) of no more than 15% for mean WPUE for each IPHC Regulatory Area. Including all expansion data to date, this goal was achieved in all areas from 2011, the year of the first pilot expansion (Table 2), except Regulatory Area 4B in 2011-14 and 2019 for O32 WPUE and 2011-12 and 2019 for all sizes WPUE, and Regulatory Area 4A in 2016-19 (O32 and all sizes WPUE).

In order to maintain the quality of the estimates used for the assessment, and for estimating stock distribution, we proposed that FISS designs should meet target CVs **below 15% for 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.

Table 2. Range of coefficients of variation for O32 and all sizes WPUE from 2011-19 by Regulatory Area.

Reg Area	O32 WPUE (2011-19)				All sizes WPUE (2011-19)			
	Lowest CV (%)	Year	Highest CV (%)	Year	Lowest CV (%)	Year	Highest CV (%)	Year
2A	10	2014*	13	2019	10	2014*	13	2019
2B	5	2018*	7	2019	5	2018*	7	2012
2C	5	2018*	6	2012	5	2018*	6	2011
3A	4	2017	5	2011	5	2019	5	2011
3B	7	2019*	8	2015	9	2018	10	2015
4A	12	2014*	18	2019	10	2014*	19	2019
4B	10	2017*	16	2012	10	2017*	16	2012
4CDE	10	2017#	11	2013	5	2015*	6	2019

* Year of FISS expansion in Reg. Area. # Year of NMFS trawl expansion in Reg. Area 4CDE.

Reducing the potential for bias

With these targets set, we can proceed to using the space-time modelling to evaluate different FISS designs by IPHC Regulatory Area and Biological Region. However, when stations are not selected randomly, sampling a subset of the full data frame in any area or region brings with it the potential for bias, when trends in the unsurveyed portion of a management unit (Regulatory Area or Region) differ from the surveyed portion. To reduce the potential for bias, we also looked at how frequently part of an area or region (called a "subarea" here) 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 or Region's change by at least 10%? By sampling each subarea frequently enough to keep down the chance of its percentage changing by more than 10% between successive surveys of the subarea, we reduce the potential for appreciable bias in the Regulatory Area or Region's indices as a whole.

Analytical methods

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

- Where a randomized design is not used, identify 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

Extending the modelling beyond three years is not considered worthwhile, as we expect further evaluation undertaken following collection of data during the one to three-year time period to influence design choice to subsequent years.

Ideally, a full simulation study with many replicate data sets would be used, but this is impractical for the computationally time-consuming spatio-temporal modelling. Instead, "simulated" sample data sets for the future years will be taken from the 2000 posterior samples from the most recent year's modelling. Each year's simulated data will have to be added and modelled sequentially, as subsequent data can improve the precision of prior years' estimates, meaning the terminal year is often the least precise (given a consistent design). If time allows, the process can be repeated with several simulated data sets to ensure consistency in results, although with large enough sample sizes (number of stations) in each year, we would expect even a single fit to be informative.

In considering potential FISS designs, we distinguished between the core area of the stock, where densities are relatively high (Regulatory Areas 2B, 2C, 3A and 3B) from the margins of the stock (Regulatory Areas 2A, 4A, 4B and 4CDE), which contain subareas of higher density, along with large regions of lower density. A fully randomized design for the latter can be an inefficient way of conducting the sampling, and we proposed an alternative that makes more effective use of resources to achieve the scientific goals of the FISS.

PROPOSED 2021-23 DESIGNS

With neither the proposed nor adopted AM096 designs proceeding in 2020, we propose shifting the 2020-22 Secretariat-preferred proposal presented at AM096 to 2021-23 (Figures 3-5). This design uses efficient subarea sampling in IPHC Regulatory Areas 2A, 4A and 4B, but incorporates a randomized design 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. Outside the core areas, the subarea design allows for logistically efficient sampling, and therefore accounts for the Secondary Objective discussed above (Table 1). It is likely that this design represents the maximum effort that can be deployed outside the core areas in coming years, while still meeting the Secondary Objective.

The proposed designs maintain spatially comprehensive biological and environmental sampling in the core IPHC Regulatory Areas 2B, 2C, 3A and 3B, and the random selection of stations ensures unbiased estimation of WPUE and NPUE indices in those areas. Sample sizes under this proposal are lower than designs that have been implemented prior to 2020, but remain large and are sufficient for precise estimation of WPUE and NPUE indices using the space-time model. Specifically, CVs were estimated to remain comfortably below 10% in all four areas, well below the target CVs of 15%.

In IPHC Regulatory Areas 2A, 4A and 4B, sampling is prioritized to take place in subareas estimated to contain most of the biomass and/or have biomass proportions for each area that vary most greatly from year to year. By sampling first and most frequently in these subareas, we are able to maintain high precision and minimize the chance of appreciable bias without having to sample all subareas each year.

In IPHC Regulatory Area 2A (Figure 6), the 2021-23 proposal includes the same stations each year. The area round these stations contains 60-70% of the biomass (Figure 7), and our evaluation showed that such a design was sufficient to maintain CVs below 15% for the three-year period of evaluation. Other stations are in subareas of low density/high stability and would be rotated into the sampling design as described below.

In recent years, the proportion of IPHC Regulatory Area 4A's (Figure 8) biomass in the western subarea was 65-85% (Figure 9) and these stations are therefore proposed for annual sampling. The northern subarea, along the Bering Sea shelf edge, is next proposed for sampling in 2023. While of lower density, its biomass share is quite variable, and sampling every 3-4 years is required to ensure low bias in estimates from the space-time modelling.

In IPHC Regulatory Area 4B (Figure 10), 70-80% of the biomass is estimated to occur in the eastern subarea (Figure 11), proposed for sampling in both 2021 and 2022. However, the biomass % of the western part of this area is quite variable, and it should be sampled every 3-4 years to keep bias low. Thus, it is next proposed for sampling in 2023. The central part of IPHC Regulatory Area 4B has largely been sampled just once, in 2017, and while it is estimated to be low-density with stable biomass proportion, it is precautionary to sample it relatively soon in order to obtain more information for evaluation. Thus we also propose it for sampling in 2023. Our evaluation showed that CVs below the 15% target could be maintained by sampling the western and central subareas only in 2023, and thus the high-density eastern subarea could be omitted once in a three-year cycle (i.e., 2023).

This proposed design was evaluated prior to AM096 to ensure that the data quality targets presented to the SRB (IPHC-2019-SRB014-05) were met. The absence of sampling in some IPHC Regulatory Areas in the current 2020 design (Figure 2) may mean that some precision targets are missed under our 2021-23 proposal in those areas, but if adopted and implemented, this proposal will ensure that the FISS will be returned to a path of meeting those targets in subsequent years.

As discussed at AM096, the proposal includes fishing the full 10 nmi grid along the Regulatory Area 4CDE edge in 2021-23 (last fished in 2016). We note that ecosystem conditions have been anomalous in the Bering Sea for several years, making the Pacific halibut distribution more difficult to predict in unsurveyed habitat. The IPHC is interested in better understanding density trends and possible links with Pacific halibut in Russian waters in the Bering Sea, and the data obtained from sampling the full FISS grid would help greatly in achieving these goals.

Under this 2021-23 proposal, not all FISS stations are targeted for fishing over the next three years. The omitted subregions are all low-density and/or relatively stable, and so do not need to be sampled as frequently as those included in the 2021-23 proposal. Specifically, based on the evaluations undertaken prior to AM096, we propose those subregions be next targeted for sampling as follows:

- 2024 Regulatory Area 2A south WA/north OR coast (last fished 2019) and California north of 40°N (last fished 2017)
- 2024 Southeast Regulatory Area 4A (last fished 2019)
- 2027 Regulatory Area 2A California south of 40°N (last fished 2017)
- 2028 Regulatory Area 2B inside waters (Salish Sea) (last fished 2018)

We note further that additional stations can be included if there are specific needs beyond precision and bias criteria, such as for sampling efficiency, cost recovery, biological sampling, environmental monitoring, and IPHC policy decisions.

As new data come in each year, the proposals for subsequent years will be re-evaluated, revised if necessary, and presented to the SRB at its June meeting. We envisage sampling in areas outside of the core to follow an approximately cyclic basis, with some subareas requiring annual sampling and others rotating in and out of the sample design on a regular cycle (for example, every 5 or 10 years for the subareas listed above).

RECOMMENDATION/S

That the SRB:

a) **NOTE** paper IPHC-2020-SRB016-05 which provides proposed designs for 2021-23 IPHC Fishery-Independent Setline Survey (FISS).
b) **REQUEST** any further analyses related to this work to be provided at SRB017.

REFERENCES

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

Webster. R. 2019. Space-time modelling of IPHC Fishery-Independent Setline Survey (FISS) data. IPHC-2020-IM095-07. 19 p.

Webster. R. 2019. Methods for spatial survey modelling – Program of work for 2019. IPHC-2020-SRB014-05 Rev_1. 6 p.

Webster. R. 2019. Space-time modelling of IPHC Fishery-Independent Setline Survey (FISS) data. IPHC-2020-AM096-07. 32 p.

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

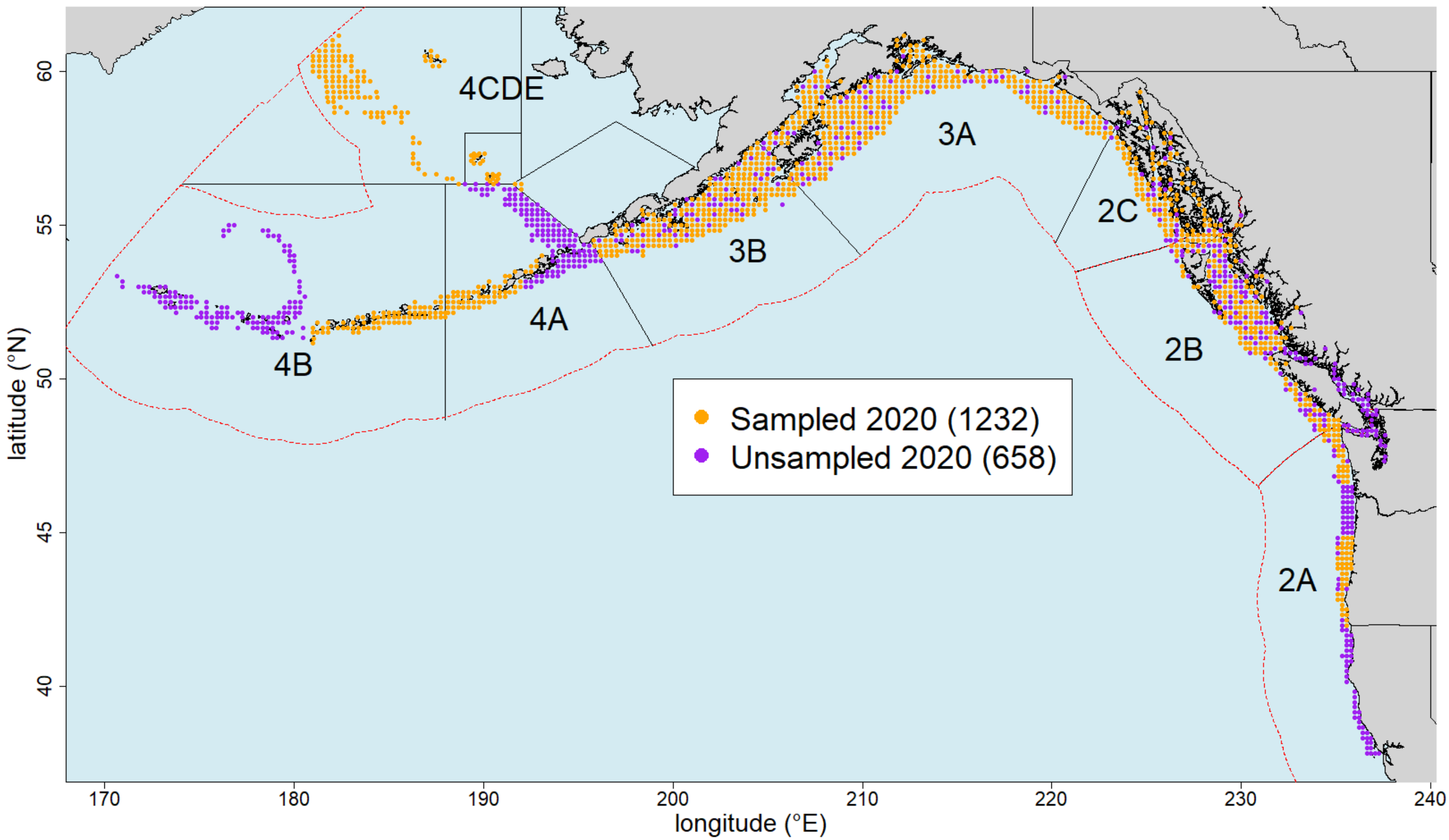

Figure 1. Map of the 2020 FISS design that was approved at AM096, with orange circles representing those stations to be fished in 2020, and purple circles representing stations to be next fished in subsequent years.

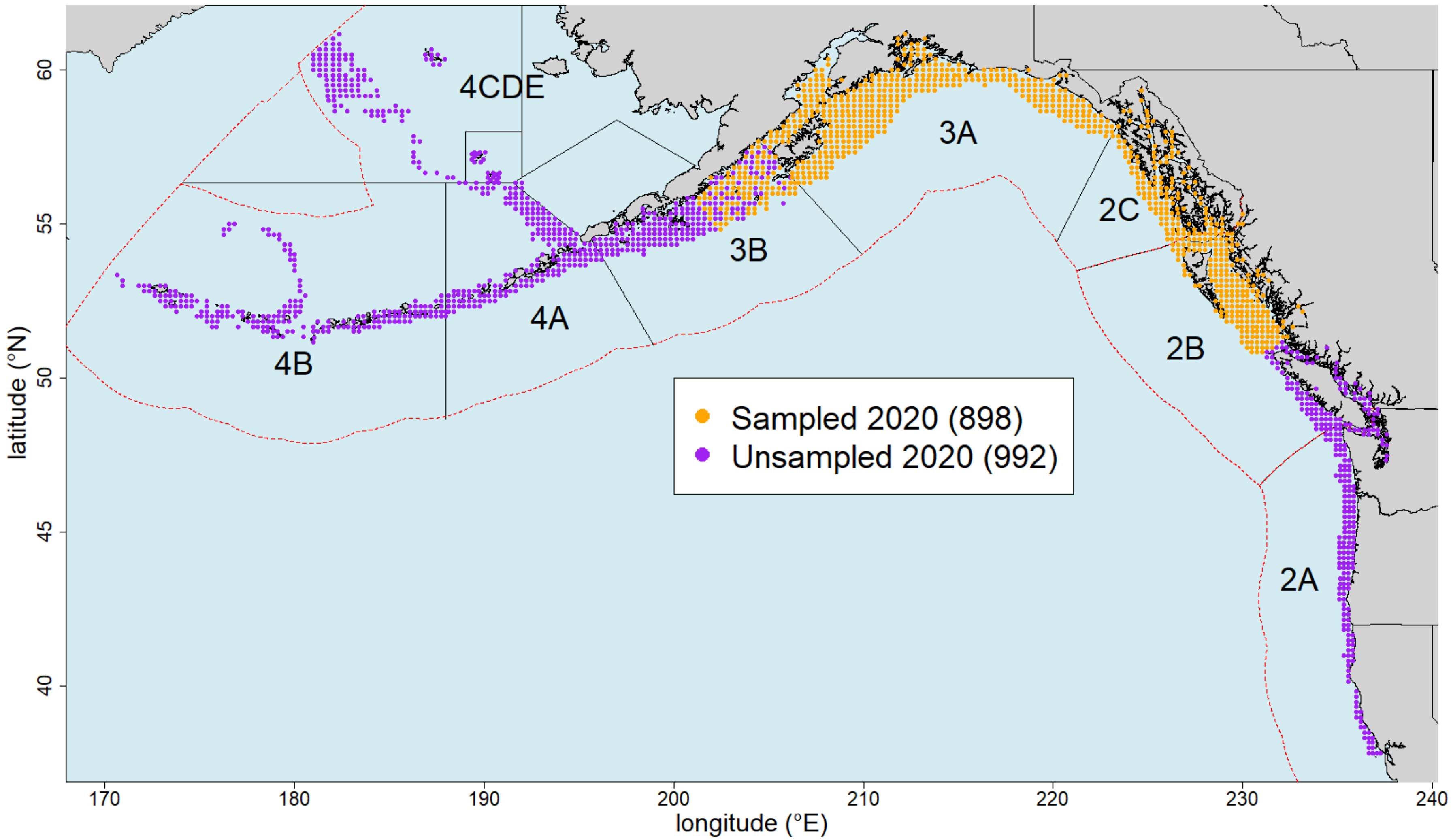

Figure 2. Map of the reduced 2020 FISS design currently under consideration, with orange circles representing those stations to be fished in 2020, and purple circles representing stations to be next fished in subsequent years.

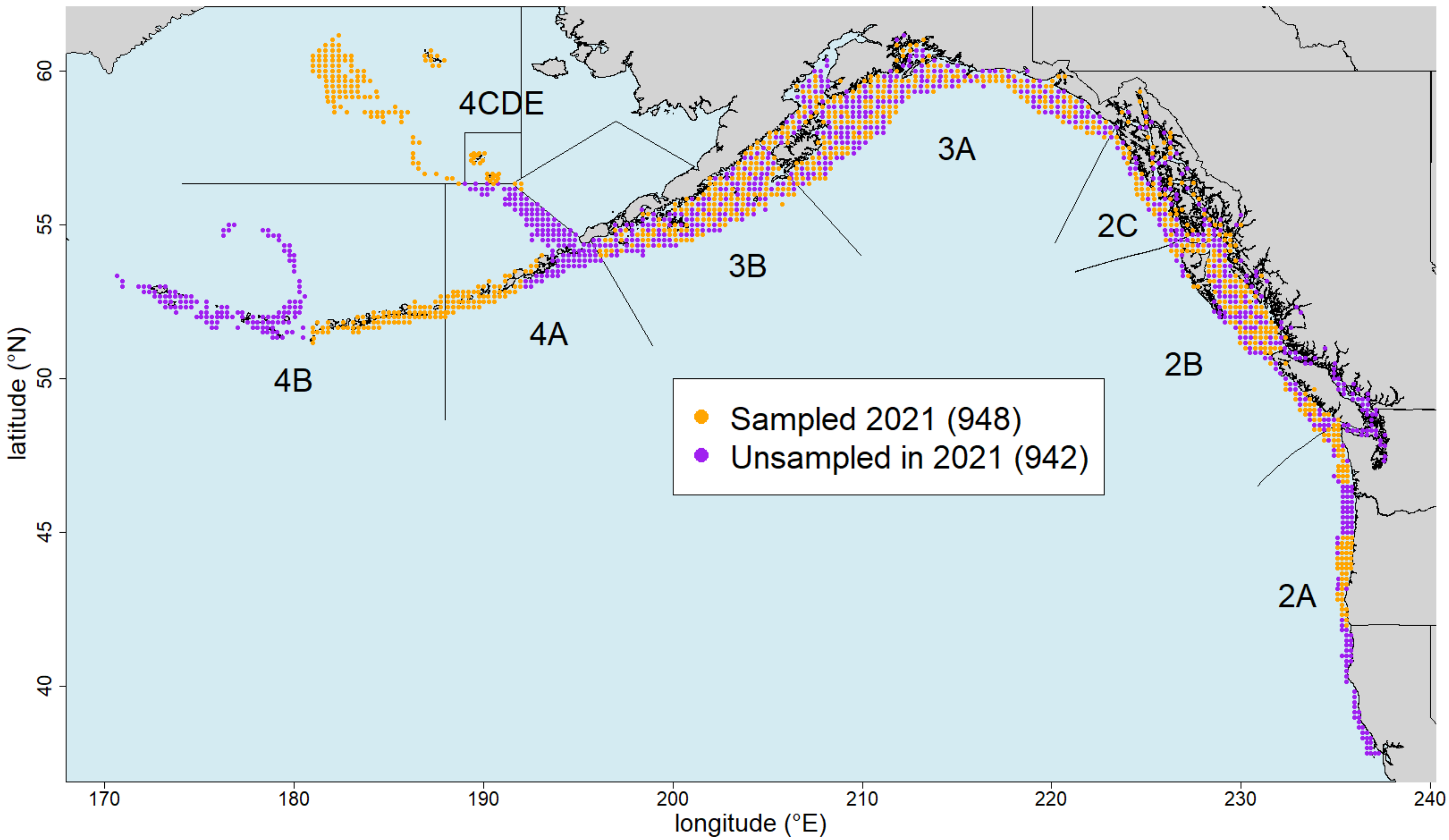

Figure 3. Proposed minimum FISS design in 2021 (orange circles) based on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

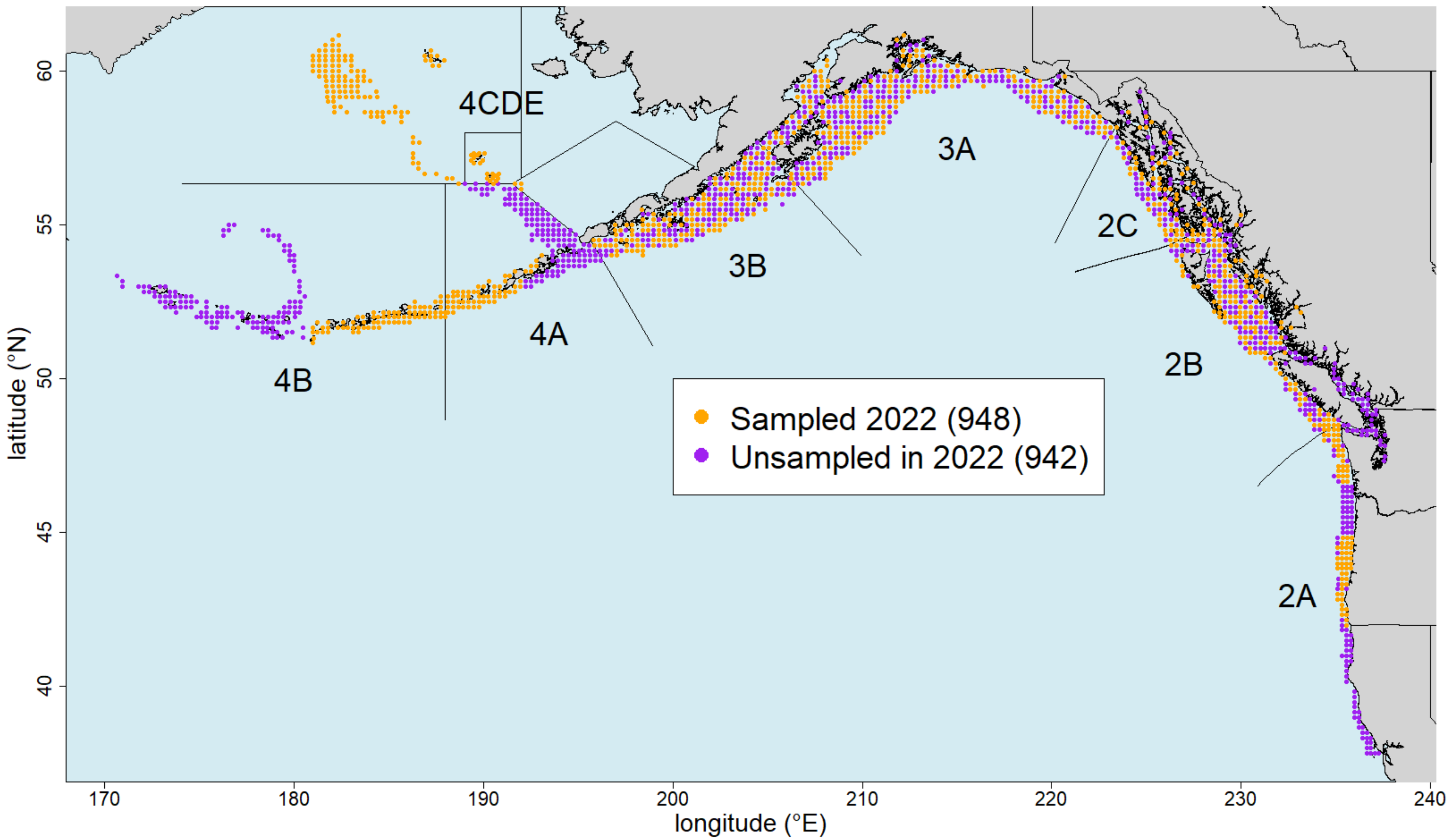

Figure 4. Proposed minimum FISS design in 2022 (orange circles) based on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

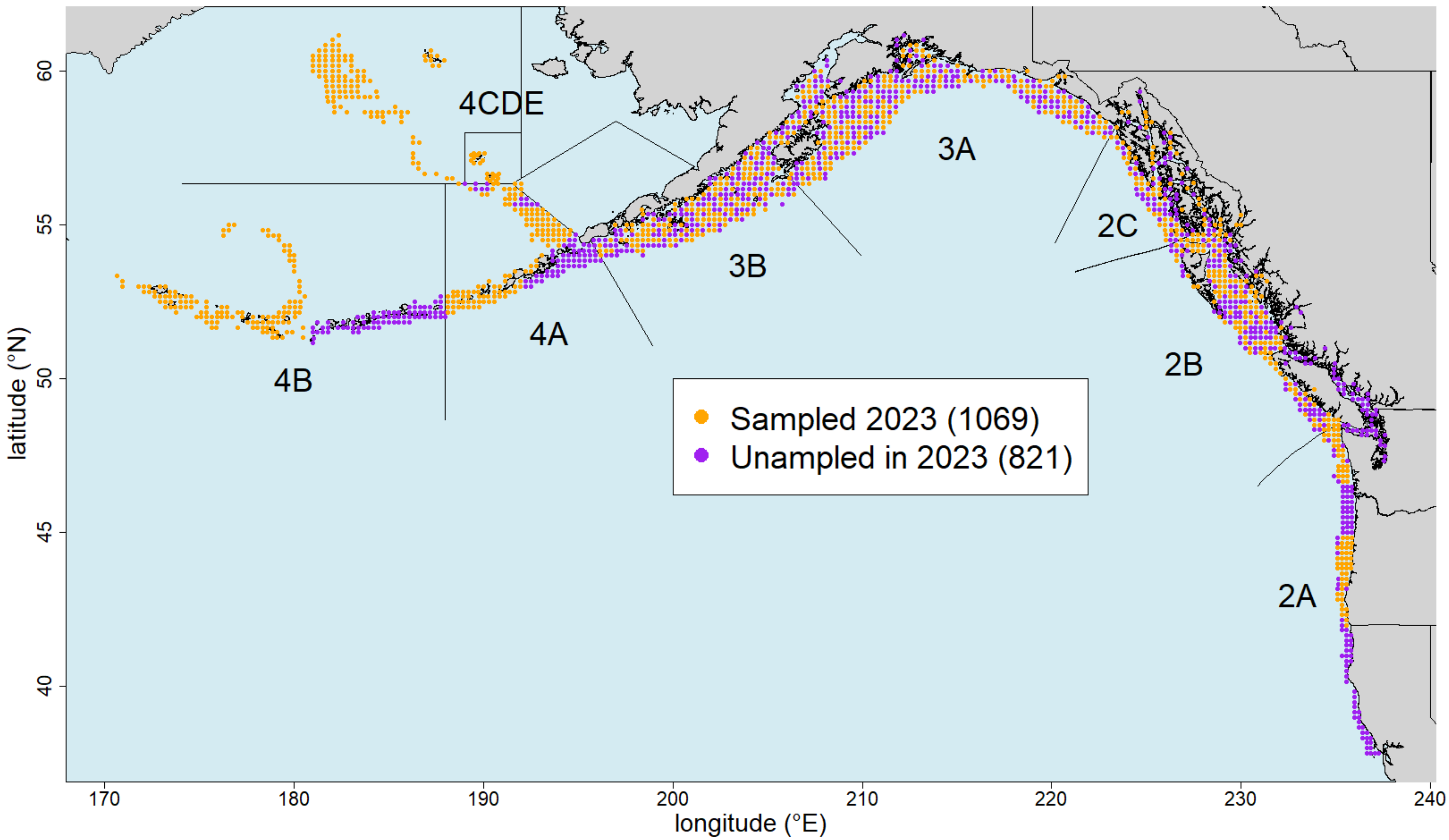

Figure 5. Proposed minimum FISS design in 2023 (orange circles) based on randomized sampling in 2B-3B, and a subarea design elsewhere. Purple circles are optional for meeting data quality criteria.

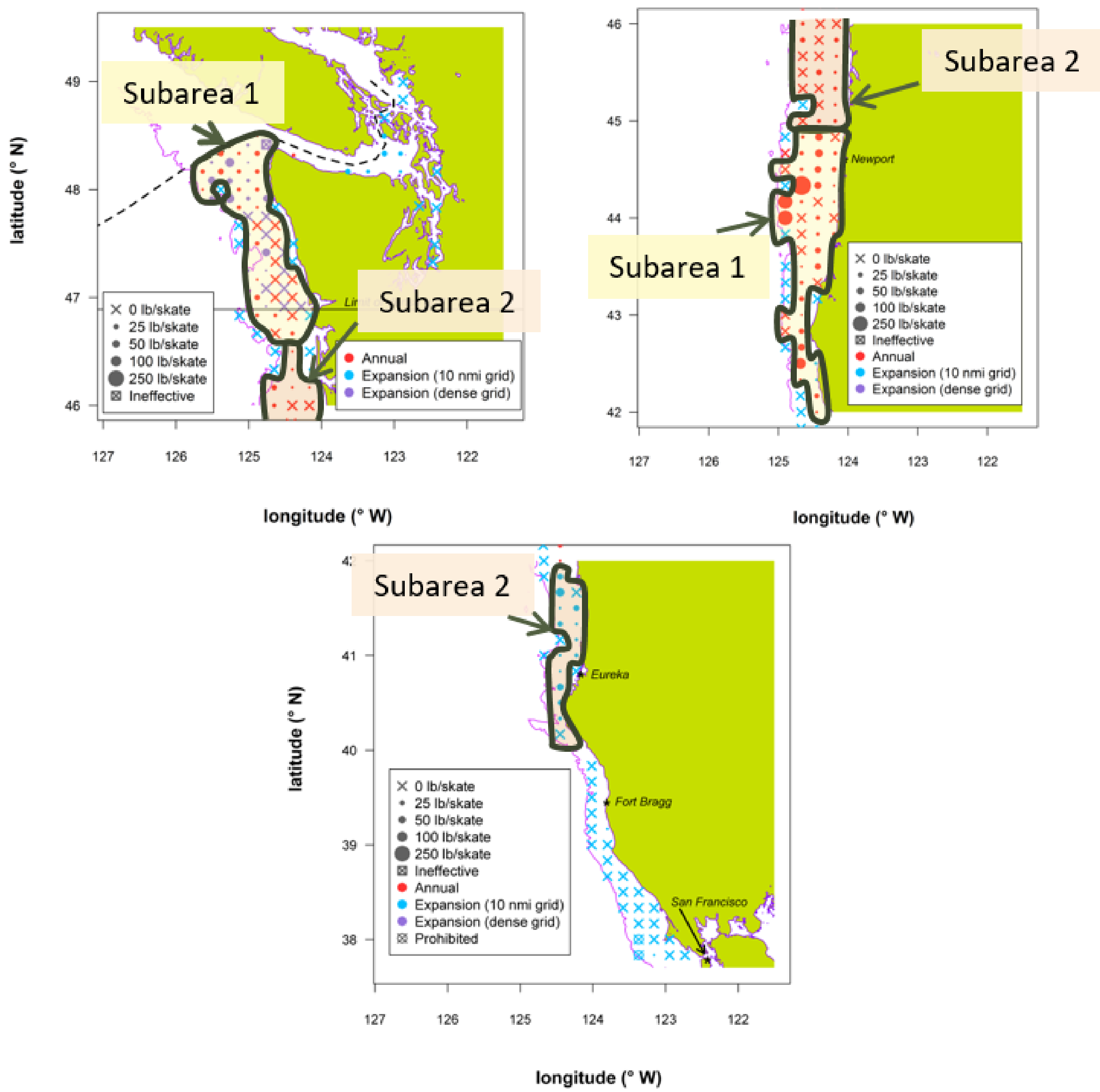

Figure 6. Subareas of IPHC Regulatory 2A used in evaluating future FISS designs. Subarea 3 consists of all stations that are not part of subareas 1 and 2. Each symbol represents a FISS station targeted for fishing when the FISS design was fully expanded in 2017.

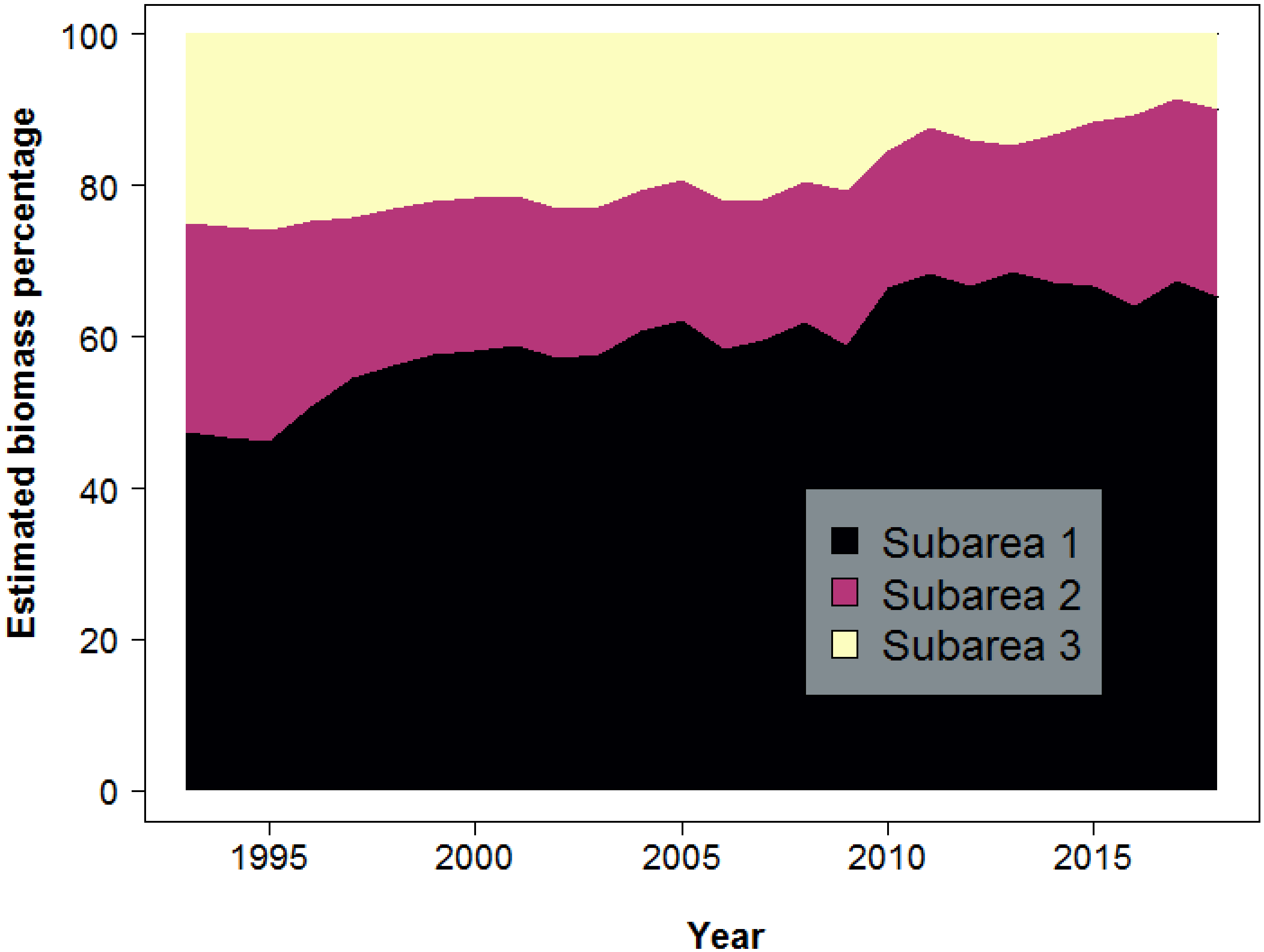

Figure 7. Estimated biomass proportions in subareas of IPHC Regulatory Area 2A.

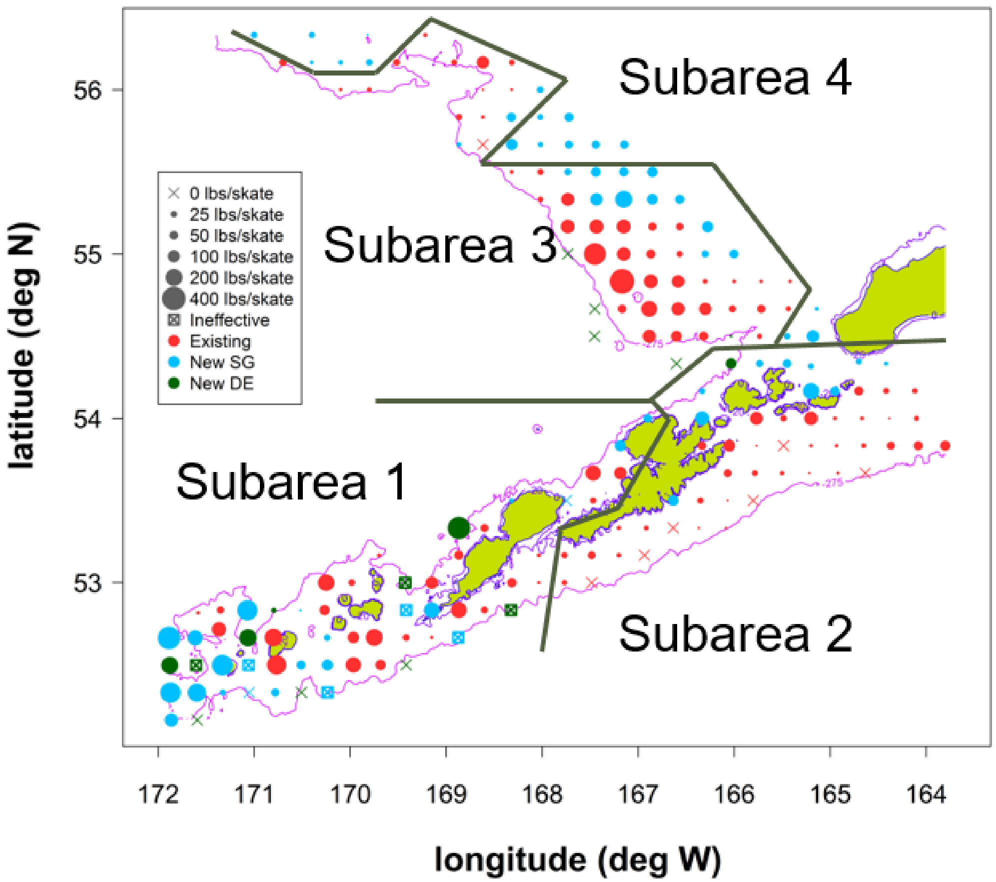

Figure 8. Subareas of IPHC Regulatory 4A used in evaluating future FISS designs. Subarea 4 is covered by the National Marine Fisheries Service's annual trawl survey, and is not proposed for future sampling by the FISS. Each symbol represents a FISS station targeted for fishing when the FISS design was expanded in 2014.

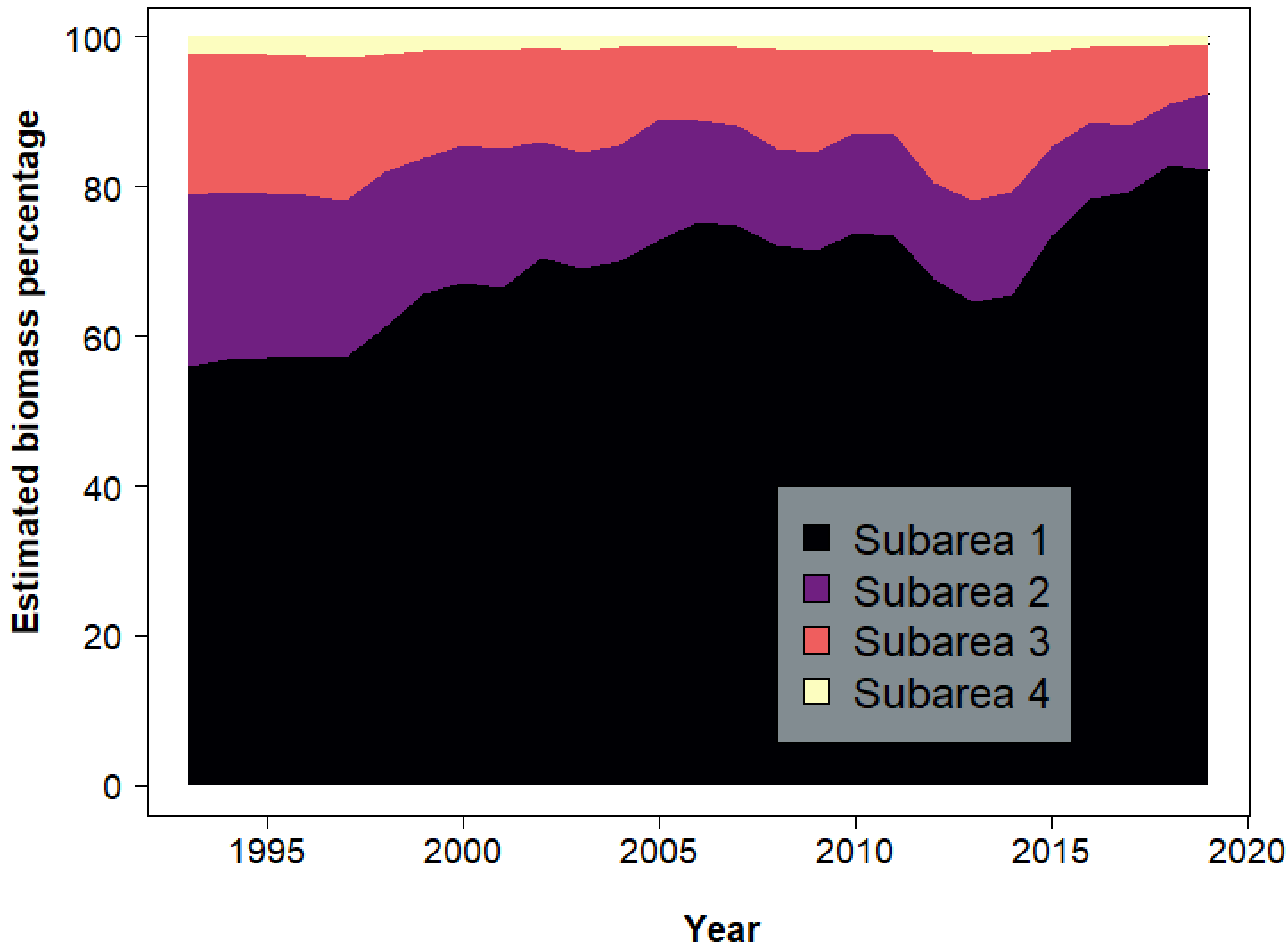

Figure 9. Estimated biomass proportions in subareas of IPHC Regulatory Area 4A.

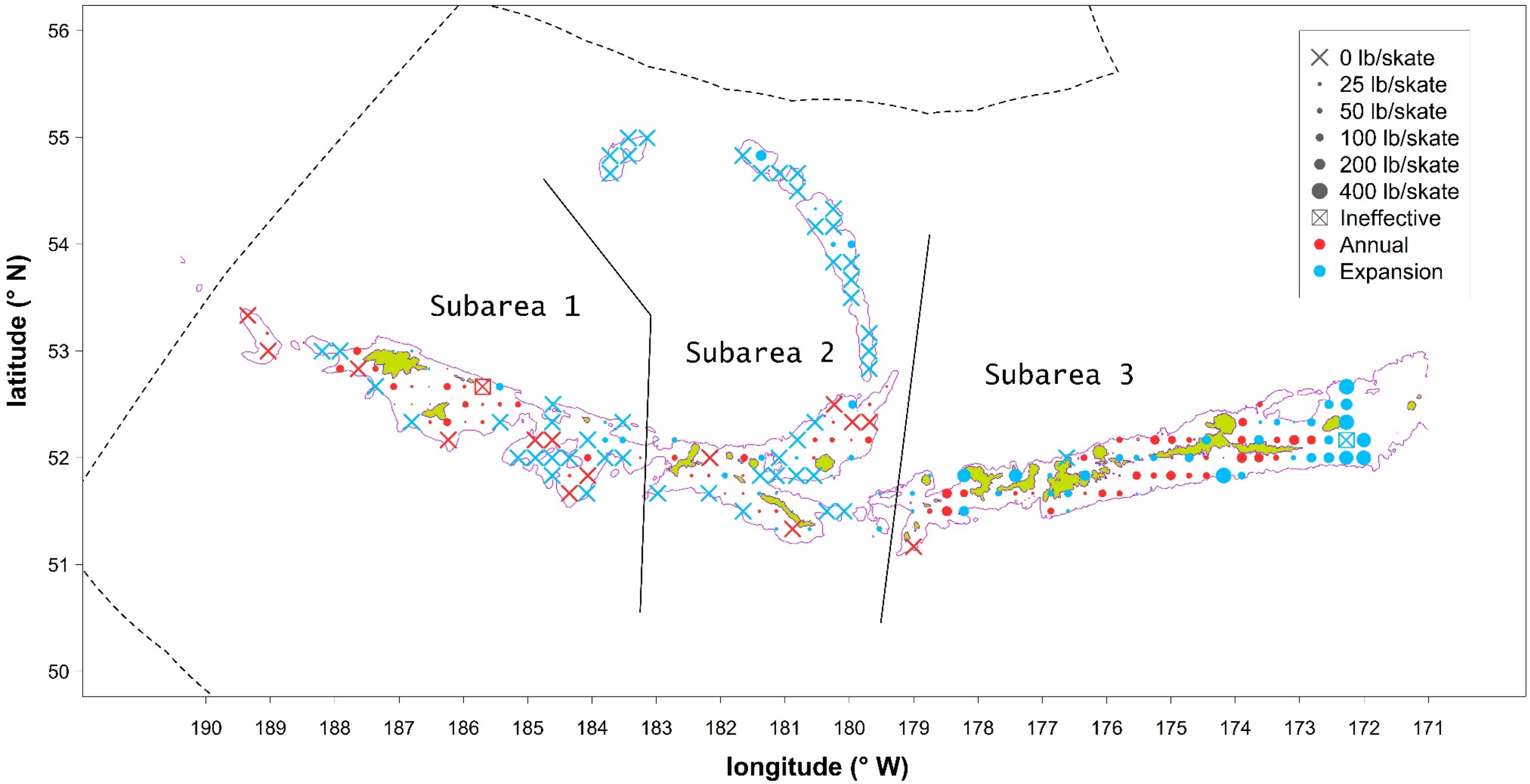

Figure 6. Subareas of IPHC Regulatory 4B used in evaluating future FISS designs. Each symbol represents a FISS station targeted for fishing when the FISS design was expanded in 2017.

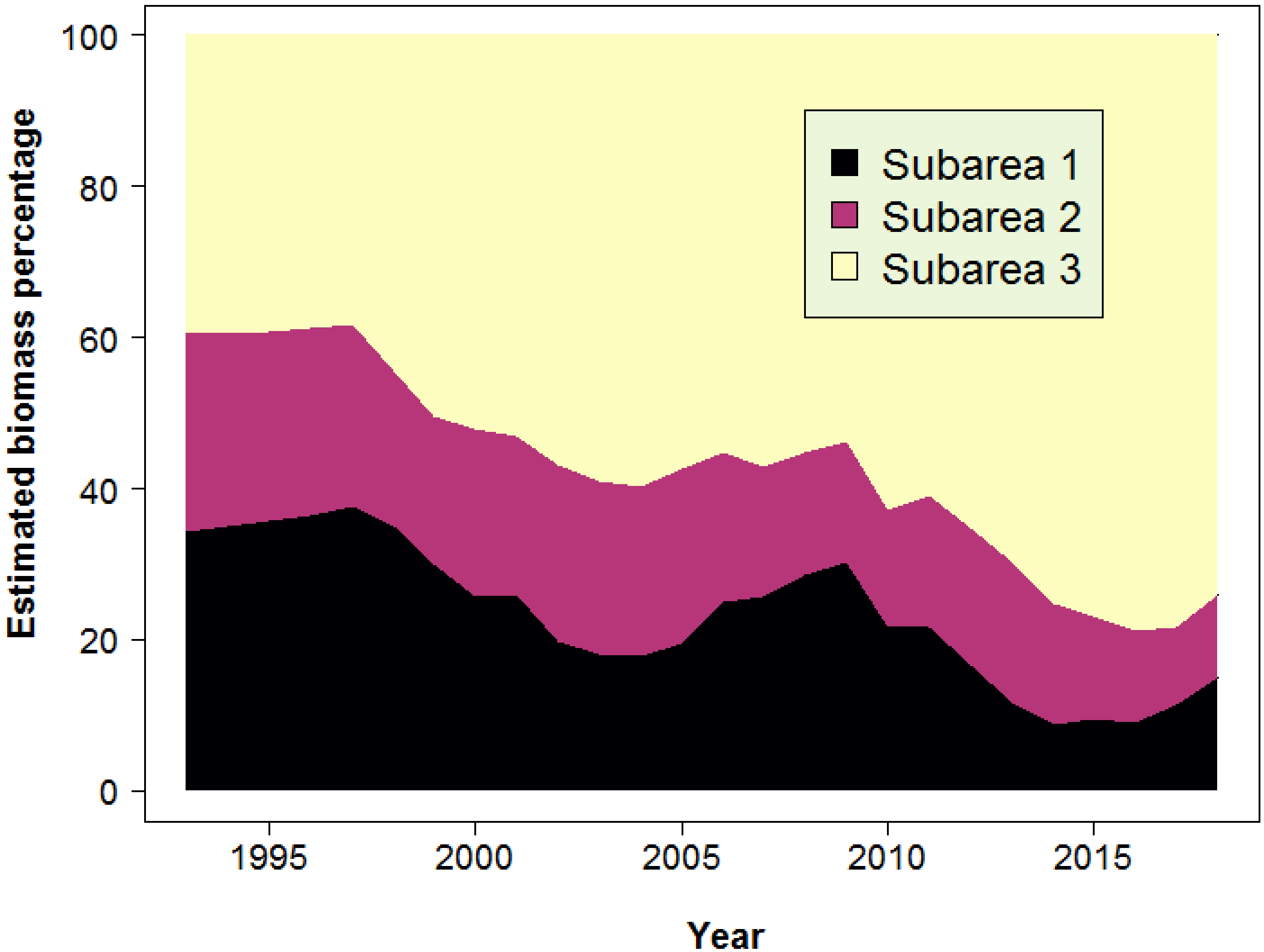

Figure 11. Estimated biomass proportions in subareas of IPHC Regulatory Area 4B.