2027-31 FISS design evaluation and modelling updates

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PART 1: 2027-31 FISS DESIGN EVALUATION

PURPOSE

To present the Scientific Review Board with potential FISS designs for 2027-31, including a preliminary cost evaluation of the 2027 Base Block design, along with potential modular add-ons for 2027.

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. Annual FISS designs are developed by selecting a subset of stations for sampling from the full 1890-station FISS footprint (Figure 1).

In recent years, financial constraints due to reduced catch rates and the combined impact of factors affecting revenue and costs (FISS accounting changes, Pacific halibut sales prices, charter vessel and bait costs) have resulted in the implementation of FISS designs with reduced spatial footprints (Figure 2). Effort has been concentrated in IPHC Regulatory Areas 2B, 2C, 3A and 3B (the core of the stock), with limited sampling in other areas in most years (Figure 3).

The **Base Block design** was presented to the Commission at the September 2024 Work Meeting and the 14th Special Session of the IPHC (SS014, IPHC-2024-SS014-03) as a more efficient approach to annual sampling in the core of the stock compared to previous designs based on random selection of FISS stations. The Commission has noted that "the use of the Base Block Design will be the focus of future planning and annual FISS proposals from the Secretariat" (e.g., IPHC-2026-AM102-R, para. 72). The Base Block design ensures that all charter regions in the core areas are sampled over a three-year period, while prioritizing coverage in other areas based on minimizing the potential for bias and maintaining CVs below 25% for each IPHC Regulatory Area. The Base Block design also includes some sampling in all IPHC Biological Regions in each year, ensuring that trend and biological data from across the spatial range of Pacific halibut are available to the stock assessment and for stock distribution estimation.

Since 2016, spatio-temporal (geostatistical) modelling has been used to estimate time series of WPUE and NPUE, and to estimate the stock distribution of Pacific halibut among IPHC Regulatory Areas and Biological Regions (Webster et al. 2020). The IPHC space-time models are fitted through the R-INLA package using R (R Core Team, 2026).

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 featured 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 in 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. The 400-fathom maximum depth is understood to cover almost all Pacific halibut summer habitat. A second expansion in IPHC Regulatory Area 2A was completed in 2013, with a pilot survey in California waters between the latitudes of 40 and 42°N.

The full expansion program began in 2014 and continued through 2019, sampling the entire FISS design of 1890 stations in the shortest time logistically possible, as well as replicating the 2006 calibration with the Bering Sea trawl survey. 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, 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 2027-29. 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.

Rationalized FISS, 2020-26

Following the 2011-2019 program of FISS expansions, rationalized FISS designs were approved for 2020 based on random selection of over 50% of stations in the core of the stock (IPHC Regulatory Areas 2B, 2C, 3A and 3B) and sampling of all stations in selected subareas of the remaining IPHC Regulatory Areas. For the latter areas, sampling priorities were determined based on maintaining precise estimates of area-specific indices of density and ensuring low bias in index estimators. That year, the COVID19 pandemic led to a reduced FISS with sampling only in the core areas. The 2021-22 FISS sampling proceeded largely as designed, although planned stations in western IPHC Regulatory 4B in 2022 were unsampled due to a lack of viable charter bids. In some charter regions in the core areas, 100% of stations were sampled in order to achieve revenue goals.

Four years of spatially-reduced designs followed the 2022 FISS:

2023 (IPHC-2023-AM099-R)

- Little sampling outside of the core areas due to large projected revenue losses from designs that included extensive sampling in IPHC Regulatory Areas 2A, 4A, 4B and 4CDE
- Limited sampling in northern IPHC Regulatory 2A
- Planned stations around the IPHC Regulatory Area 4A/4B boundary not sampled due to a lack of charter bids

2024 (IPHC-2024-AM100-R)

- High sampling rates in IPHC Regulatory Areas 2B and 2C
- A small number of charter regions in IPHC Regulatory Areas 3A and 3B
- Sampling of the southern shelf edge and Bering Sea islands in IPHC Regulatory Area 4CDE

2025 (Figure 2, IPHC-2025-AM101-R)

- Charter regions in IPHC Regulatory Areas 3A and 3B selected to complement coverage in recent years
- Sampled stations in IPHC Regulatory Areas 2A, 4A and 4B that had not been sampled for three or more years

2026 (Figure 4)

- Increases spatial coverage relative to 2023-25
- Complements the 2025 design by including ten charter regions not sampled last year

FISS DESIGN OBJECTIVES (Table 1)

Primary objective: *To sample Pacific halibut for stock assessment and stock distribution estimation.*

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 management. 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.

Secondary objective: *Cost effectiveness.*

The FISS is intended to be cost-effective without compromising the scientific integrity of the design. Any implemented design must consider logistics and cost together with scientific integrity.

Tertiary objective: *Minimise removals and assist others where feasible on a cost-recovery basis.*

Consideration is also given to the total expected FISS removals (impact on the stock), data collection assistance for other agencies, and emerging IPHC informational needs.

Table 1. Prioritized 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	Cost effectiveness without compromising the scientific integrity of the FISS design.	Balance operational feasibility/logistics, cost/revenue, and scientific needs. Includes an aspirational target reserve of US$4,000,000
Tertiary	Minimise removals, assist others where feasible on a cost-recovery basis, address specific Commission informational needs.	Removals: minimise 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

Annual design review, endorsement, and finalisation process

Since the completion of the FISS expansions in 2019, a review process has evolved for annual FISS designs created according to the above objectives:

- Step 1: The Secretariat presents preliminary design options based on the primary objective (Table 1) to the SRB for three subsequent years at the June meeting, based on analysis of prior years' data. Commencing in 2024, this has included preliminary cost projections based on prior year fiscal details (revenue) and current year vessel contract cost updates;

- Step 2: Updated design options for the following year that account for both primary and secondary objectives (Table 1) are reviewed by the Commission at the September work meeting, recognising that revenue and cost data from the current year's FISS are still preliminary at this time;
- Step 3: At their September meeting, the SRB reviews design options accounting for both primary and secondary objectives (Table 1) for comment and advice to the Commission (recommendation). FISS revenue and cost information from the current year is near-final at this time;
- Step 4: Designs are further modified to account for 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 annual Interim Meeting;
  - Ad-hoc modifications to the design for the current year (due to unforeseen issues arising) are possible at the IPHC Annual Meeting;
  - The endorsed design for the current year is then modified (if necessary) to account for any additional tertiary objectives or revisions to inputs into the evaluation of secondary objectives prior (i.e., updated cost estimates) and logistical considerations raised by the operators of contracted vessels 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 direct stakeholder input during public meetings (Interim and Annual Meetings).

Although 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 assists the Secretariat with medium-term planning of the FISS, and allows reviewers (SRB, Commission) and stakeholders to see more clearly the planning process for sampling the entire FISS footprint over multiple years.

POTENTIAL DESIGNS FOR 2027-31

BASE BLOCK DESIGN

At AM102, Secretariat staff presented the Base Block design for 2026 and subsequent years based a rotational block design (IPHC-2025-AM102-13). This design implements sampling of complete FISS charter regions (subsets of stations generally sampled by a single vessel via multiple trips) in each area rather than randomly selected stations as was previously done in the core of the stock. Sampled charter regions are rotated over two or three years depending on area. Block designs are potentially more efficient from an operational perspective than a randomized design as they involve less running time between stations, leading to cost reductions on a per station basis. The proposed Base Block designs for 2027-31 are shown in Figures 5 to 9.

Using posterior samples generated from the fitted 2025 space-time models as simulated data for 2026-29, we projected the coefficient of variation (CV, a relative measure of precision) for mean O32 WPUE for each year of the design by area. As CVs are generally greater in the terminal year of the time series and that year is usually the most relevant for informing management, the CV values in Table 2 are for the final year of the modelled time series. For example, the CVs for 2027 were projected by fitting the model to the data for 1993-2027, with simulated data used for 2026-27.

Table 2. Projected coefficients of variation (CVs, %) of mean O32 WPUE for the 2026 design and the potential 2027-29 Base Block designs by terminal year of time series and IPHC Regulatory Area and Biological Region.

Regulatory Area	**Year** 2026	2027	2028	2029
2A	27	26	16	22
2B	6	5	10	7
2C	5	6	6	6
3A	11	8	7	7
3B	17	14	12	9
4A	19	24	12	19
4B	17	16	17	14
4CDE	9	9	9	8
Biological Region				
Region 2	4	5	5	4
Region 3	9	7	6	6
Region 4	9	11	7	9
Region 4B	17	16	17	14
Coastwide	5	4	4	4

Projected terminal year CVs for the Base Block design (2027-29) are 25% or less for all IPHC Regulatory Areas except 2A, which has a 26% projected CV in 2027. In the core areas (2B, 2C, 3A and 3B), CVs are projected to be 15% or less (Table 2) following this year's FISS. All Biological Region CVs, except that of Region 4B, are at most 11%, while the coastwide CV is projected to be 4% for the 2027-29 Base Block designs.

Due to the CV for IPHC Regulatory Area 2A exceeding the target range of 25% or less, the 2027 Base Block design (Figure 4) was revised from the version used to project the CVs through the addition of 20 stations off the Oregon coast. With this change, the Base Block design is expected to maintain precise estimates of indices of Pacific halibut density and abundance across the range of the stock. At the same time, the rotating nature of the sampled blocks means that almost all FISS stations will be sampled within a 5-year period (2-3 years within the core areas) resulting in low risk of missing important stock changes and therefore a low risk of large bias in estimates of trend and stock distribution. By 2030, we expect to no longer have any significant biases that result from unmonitored stock changes in regions that were unsampled for several years.

PRELIMINARY COST PROJECTIONS FOR 2027

The proposed 2027 **Base Block design** is projected to result in an operating loss of approximately **US$131,000** (Table 3). Preliminary cost and revenue projections for the Base Block design are based on the following assumptions:

1. Designs are optimised for numbers of skates, with sets of 4, 6 or 8 100-hook skates used, depending on projected catch rates and bait costs.
2. Projected Pacific halibut average sales price for 2027 in each charter region is unchanged from our current best estimate of 2026 FISS values (based on both 2025 data and 2026 data received to date)
3. Projected Pacific halibut average landings per station remain unchanged in each charter region from 2026 FISS values (based on both 2025 data and 2026 data received to date).
4. The price of chum salmon bait remains at the average 2026 price of US$2.40/lb.

Table 3. Preliminary projected costs and revenue for the proposed 2027 Base Block ($US). (Totals may not equal the sum of individual rows due to rounding.)

Design		**2027 Base Block design**
Income	**Pacific halibut sales**	3,874,000
	Byproduct sales	103,000
	Total	**3,977,000**
Expenses	**Base HQ (staff salary and wages, and benefits x 4)**	(547,000)
	Vessel contracts	(1,545,000)
	Field staff (salary and wages, and benefits)	(475,000)
	Bait	(509,000)
	Non-IPHC fish sales[@]	(432,000)
	Other expenses*	(601,000)
	Total	**(4,108,000)**
Net revenue		**($131,000)**

[@]Sales revenue from both byproduct and Pacific halibut that are paid to a third party (e.g. vessel share, ADF&G)

*Other costs include staff training, personnel expenses, mailing and shipping, travel, technology, gear replacement, customs fees, bait storage fees, field supplies and equipment, equipment maintenance fees, facility rental fees, and communication fees.

Note: Cost estimates are preliminary and do not fully account for 2026 realized costs as the FISS is in progress at the time of writing. Therefore, it is important to note there is considerable uncertainty in the catch and cost projections for 2027. Projected income and expenses for the 2027 design will be updated once FY2026 has been reconciled (expected late October 2026) and will be used to refine the projections provided in this report at that time.

MODULAR ADD-ONS

Ten potential modular add-ons to the proposed 2027 Base Block design are presented below, with the following aims:

1) Reduce the projected net loss of the FISS in 2027;
2) 'Catch up' on FISS regions that were part of the 2026 **Base Block design** but were not fished;
3) Reduce the heterogeneity in net revenue among future years by sampling in 2027 some of the more costly regions planned in future years;
4) Set the FISS station charter rate at a higher value to increase the chance of receiving bids for challenging charter regions (i.e. Adak in IPHC Regulatory Area 4B);
5) Fully clear the 'backlog' of uncertainty created by the reduced designs implemented in 2023-2026 to provide the most informative data in 2027 for the stock assessment and management decisions.

With the 2027 **Base Block design** as Option 1 in Table 4, Options 2 to 11 are as follows:

- **Options 2 and 3** add revenue-positive charter regions in IPHC Regulatory Areas 2C and 3A, respectively, to the design to further reduce the projected net loss.
- **Options 4, 5 and 6** would add charter regions from IPHC Regulatory Areas 3A and 4B that were included in the approved 2026 Base Block design but were not fished in 2026 for reasons of cost (3A) or a lack of charter bids (4B). In the case of IPHC Regulatory Area 4B, the region is split into two (2) components (west and east, 29 stations each) to allow more flexibility for those considering submitting a bid for 2027 FISS work.
- **Option 7** brings sampling in IPHC Regulatory Area 4A forward from 2028 to reduce costs in that year, which is otherwise projected to have a large net loss.
- **Options 8 and 9** bring sampling of the northern and central Bering Sea shelf edge (IPHC Regulatory Area 4CDE) forward from 2028 and 2029, respectively, potentially reducing net losses in those years. If adopted, these options would result in complete sampling of standard FISS stations in IPHC Regulatory Area 4CDE in 2027.
- **Option 10** brings forward sampling of stations in IPHC Regulatory Area 2A from 2028, reducing costs in that year, along with stations in deep and shallow waters and the Salish Sea that have not been sampled since 2018 but were not planned until after 2031.
- **Option 11** fixes the charter rate at $5,500 per station in the Adak region of IPHC Regulatory Area 4B, which would be a 28% increase over the previous highest accepted bid. It expands sampling over Options 5 and 6 (58 stations combined) to include all 118 stations in the Adak charter region.

Figure 10 presents a map of stations included in Options 2 to 11.

The United States of America has agreed to voluntarily provide US$749,000 in supplementary funding for the 2027 FISS in order to fund modular Options 4 to 9 of Table 4 as additions to the 2027 Base Block design (Figure 4).

Table 4. Modular changes to Option 1 (2027 Base Block design), including projected expenses, income, net revenue, and benefits to the IPHC. Each of modular Options 2 to 10 can be added in any combination to Option 1, with the net revenue of the resulting FISS design found by summing the revenue changes for the Base Block design and each selected option. Option 11 is an alternative to Options 5 and 6 combined.

Option	Design	Sampled IPHC Regulatory Areas (with number of FISS charter regions)	Projected expenses (US$)	Projected income (US$)	Projected net revenue	Benefit/rationale
1	Base Block	2A(3), 2B(2), 2C(2), 3A(4), 3B(2), 4B(1), 4CDE(1)	($4,108,000)	$3,977,000	($131,000)	Optimal long-term design
	Design change	**Change in sampling**	**Projected change in expenses ($US)**	**Projected change in income ($US)**	**Projected change in net revenue**	
2	Add Sitka	2C(+1)	($208,000)	$253,000	$45,000	Revenue positive: reduces overall net loss.
3	Add Gore Pt	3A(+1)	($221,000)	$238,000	$17,000	Revenue positive: reduces overall net loss.
4	Add Shelikof	3A(+1)	($245,000)	$226,000	($19,000)	3A catch-up. Last sampled 2024.
5	Add Adak West	4B(+1)	($196,000)	$103,000	($93,000)	4B catch-up. Last sampled 2021.
6	Add Adak East	4B(+1)	($196,000)	$103,000	($93,000)	4B catch-up. Last sampled 2025.
7	Add Unalaska	4A(+1)	($367,000)	$99,000	($268,000)	Reduces costs in 2028.
8	Add 4CDE North	4CDE(+1)	($168,000)	$12,000	($155,000)	Reduces costs in 2029. Last sampled 2021.
9	Add 4CDE Central	4CDE(+1)	($188,000)	$67,000	($121,000)	Potential to reduce costs in 2030. Last sampled 2022.
10	Expand 2A sampling to include all stations north of 40°N	2A(+2)	($239,000)	$89,000	($150,000)	Reduces costs in 2028. Includes deep, shallow, and Salish Sea stations not sampled since 2018.
11	Fixed Contract rate[1] for expanded Adak (alternative to Options 5-6)	4B(+2)	($937,000)	$419,000	($519,000)	Reduces probability of receiving no bids for this region (as occurred in 2023 and 2026)

[1] This option provides for a fixed 28% increase in inflation-adjusted charter costs paid to the contracting vessel over previous accepted bids.

DISCUSSION

The **Base Block design** has a preliminary projected net loss of US$131,000 for 2027 and therefore can be implemented using FISS reserves without the need for supplementary funding. It is projected that adding two revenue-positive charter regions from IPHC Regulatory Areas 2C and 3A would reduce the net loss to US$69,000. With supplementary funding, the design is able to add charter regions in IPHC Regulatory Areas 3A and 4B that were part of the approved 2026 Base Block design but were not fished this year and bring forward other revenue-negative regions to reduce projected costs in 2028 and subsequent years.

RECOMMENDATION

That the Scientific Review Board **NOTE** paper IPHC-2026-SRB029-08 (Part 1), which presents potential Base Block designs for 2027-31, including a preliminary projection of revenue and expenses for the 2027 design and potential modular add-ons to this design.

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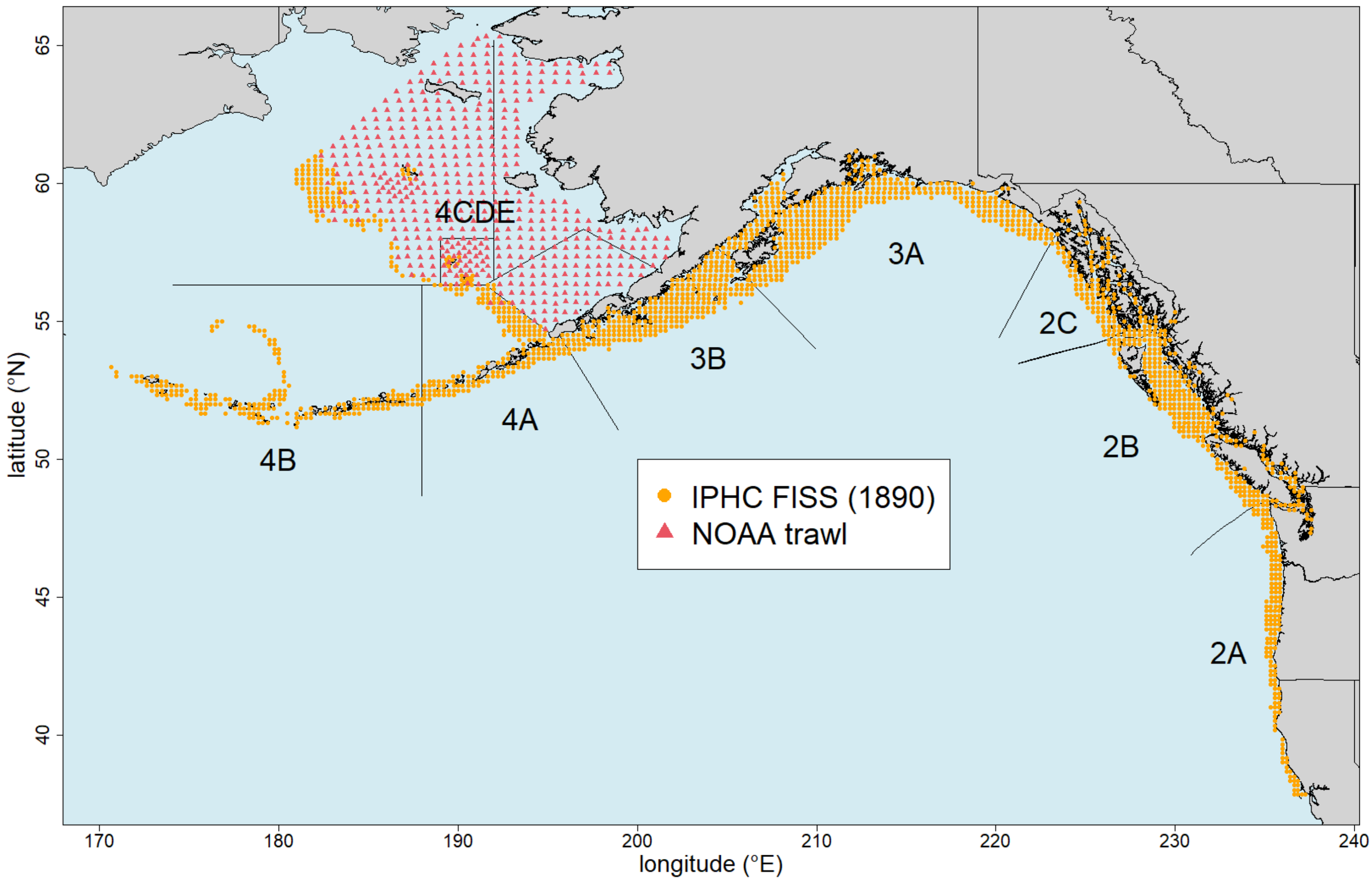

Figure 1. Map of the full 1890 station FISS design, with orange circles representing stations available for inclusion in annual sampling designs. Red triangles represent standard locations of NOAA trawl stations used to provide complementary data for Bering Sea modelling (actual NOAA trawl design can vary year-to-year).

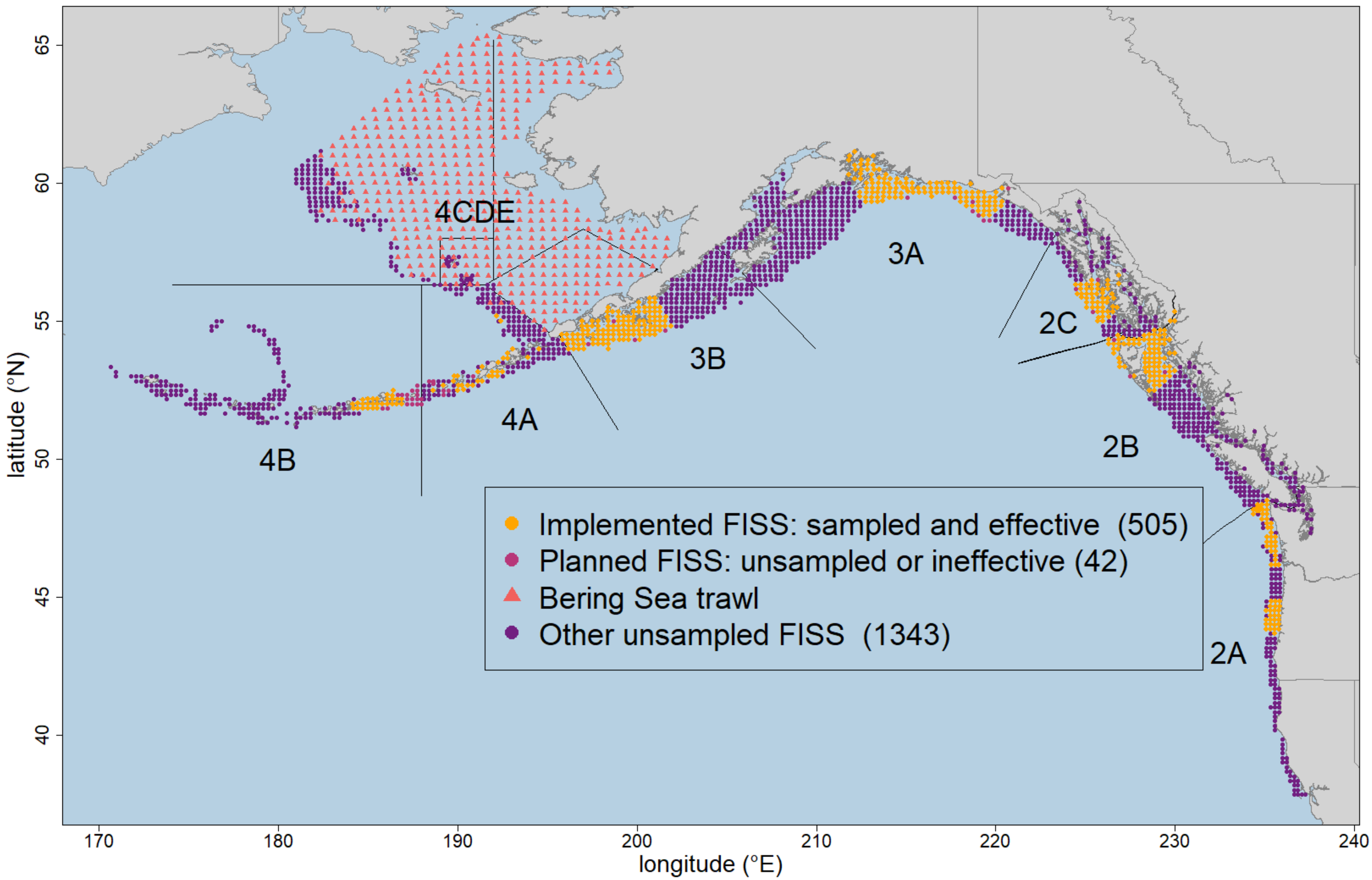

Figure 2. Map of implemented 2025 sampled FISS design showing sampled stations with data used in modelling (orange circles for FISS, red triangles for trawl), along with planned but ineffective FISS stations, FISS grid stations fished off grid as vessel captain stations and other unsampled FISS stations.

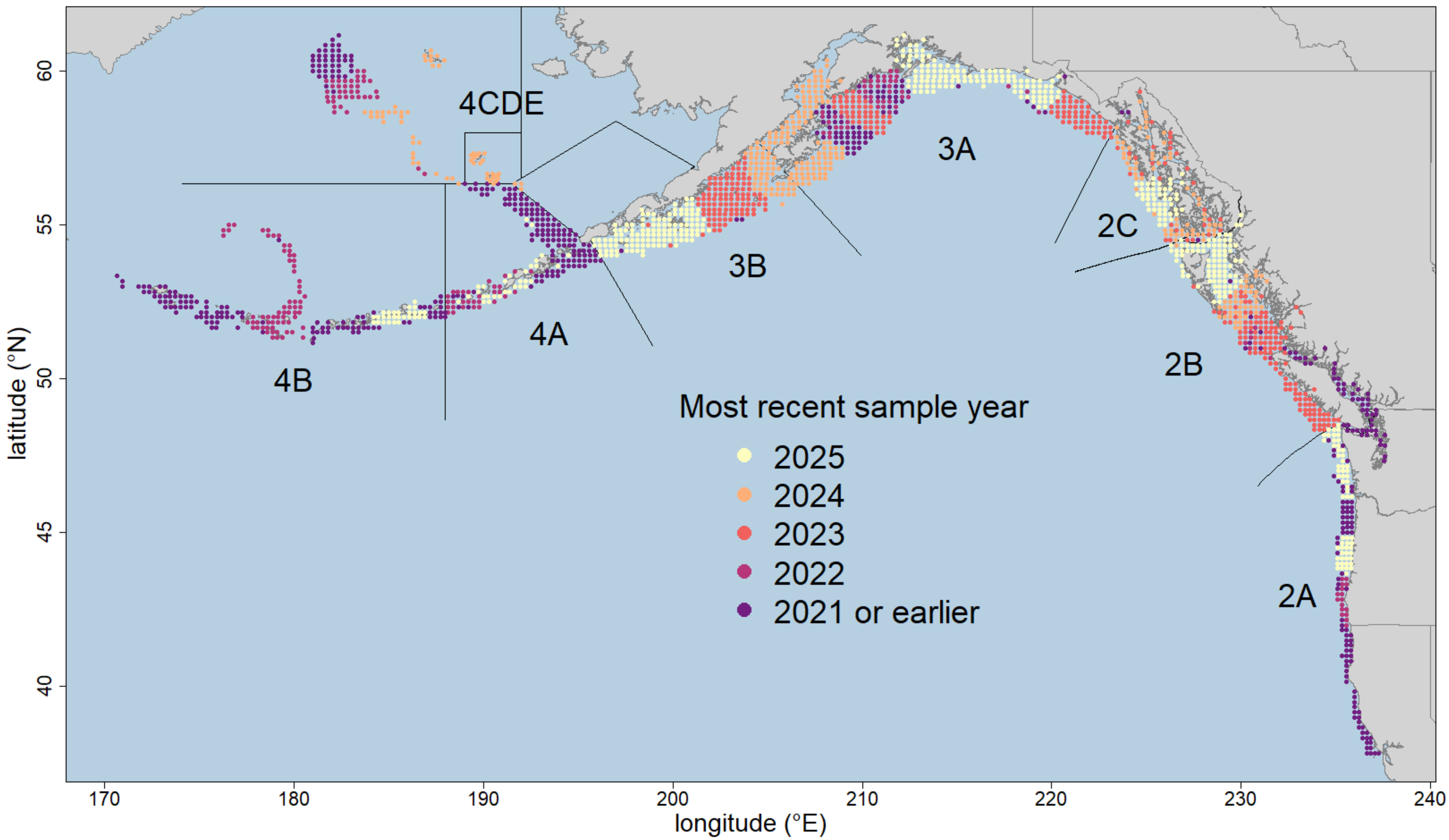

Figure 3. Map showing the most year that each station on the full FISS grid was successfully sampled.

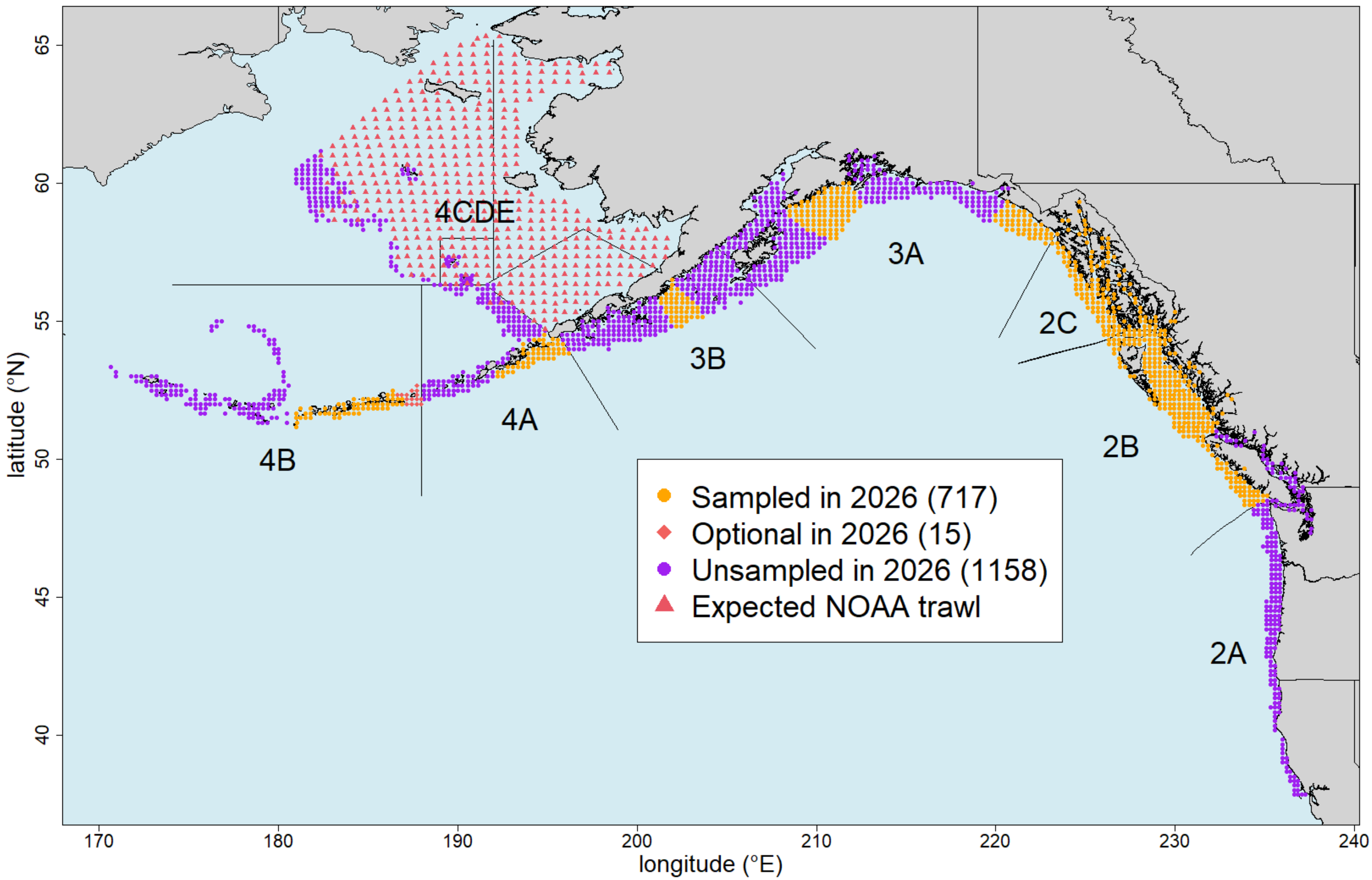

Figure 4. Adopted 2026 FISS design, with planned FISS stations shown as orange circles.

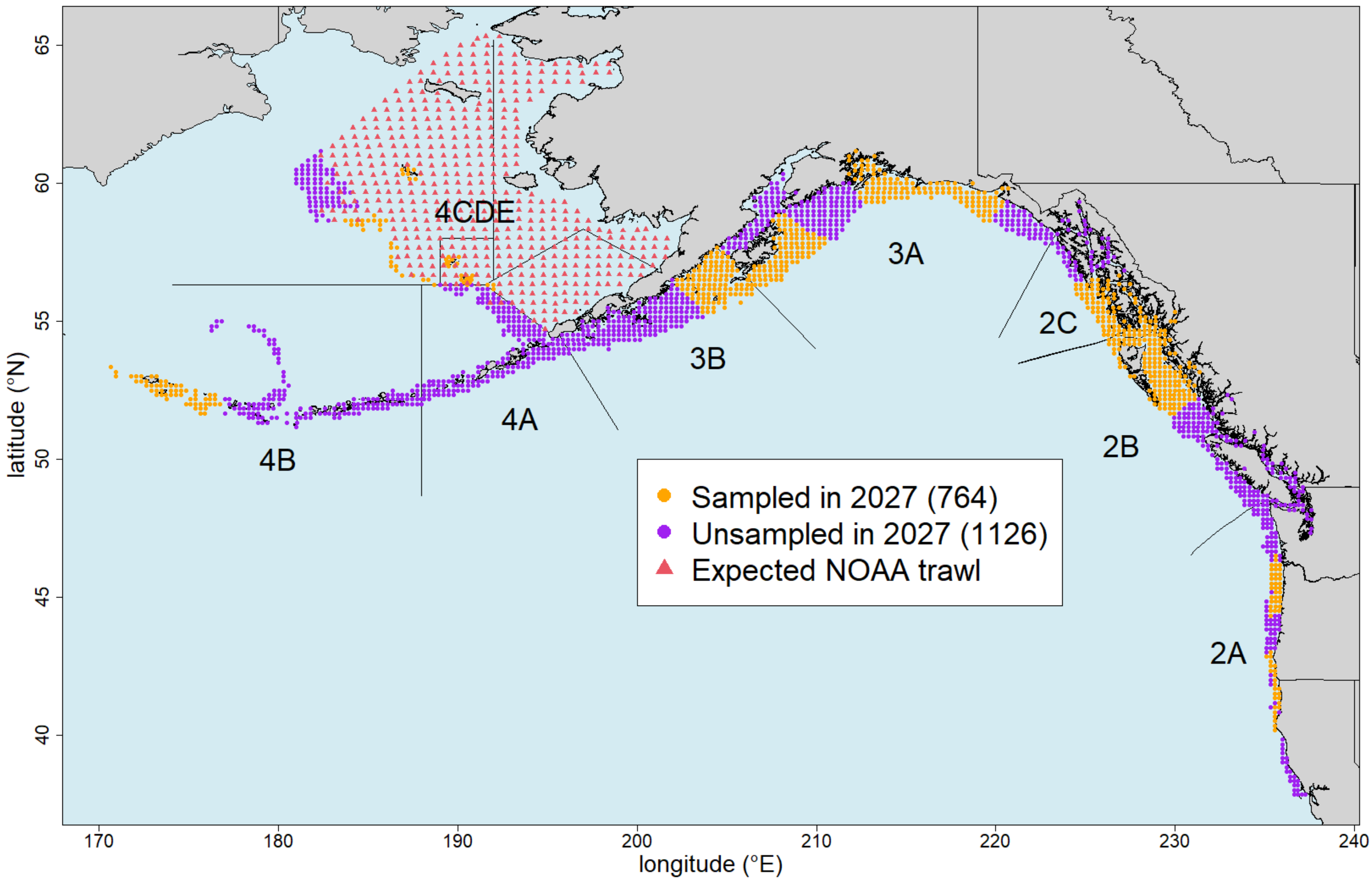

Figure 5. Base Block design for 2027 (orange circles). Design is based on fishing 2-4 complete blocks of stations (charter regions) in the core areas (2B, 2C, 3A and 3B) and previously implemented subareas elsewhere.

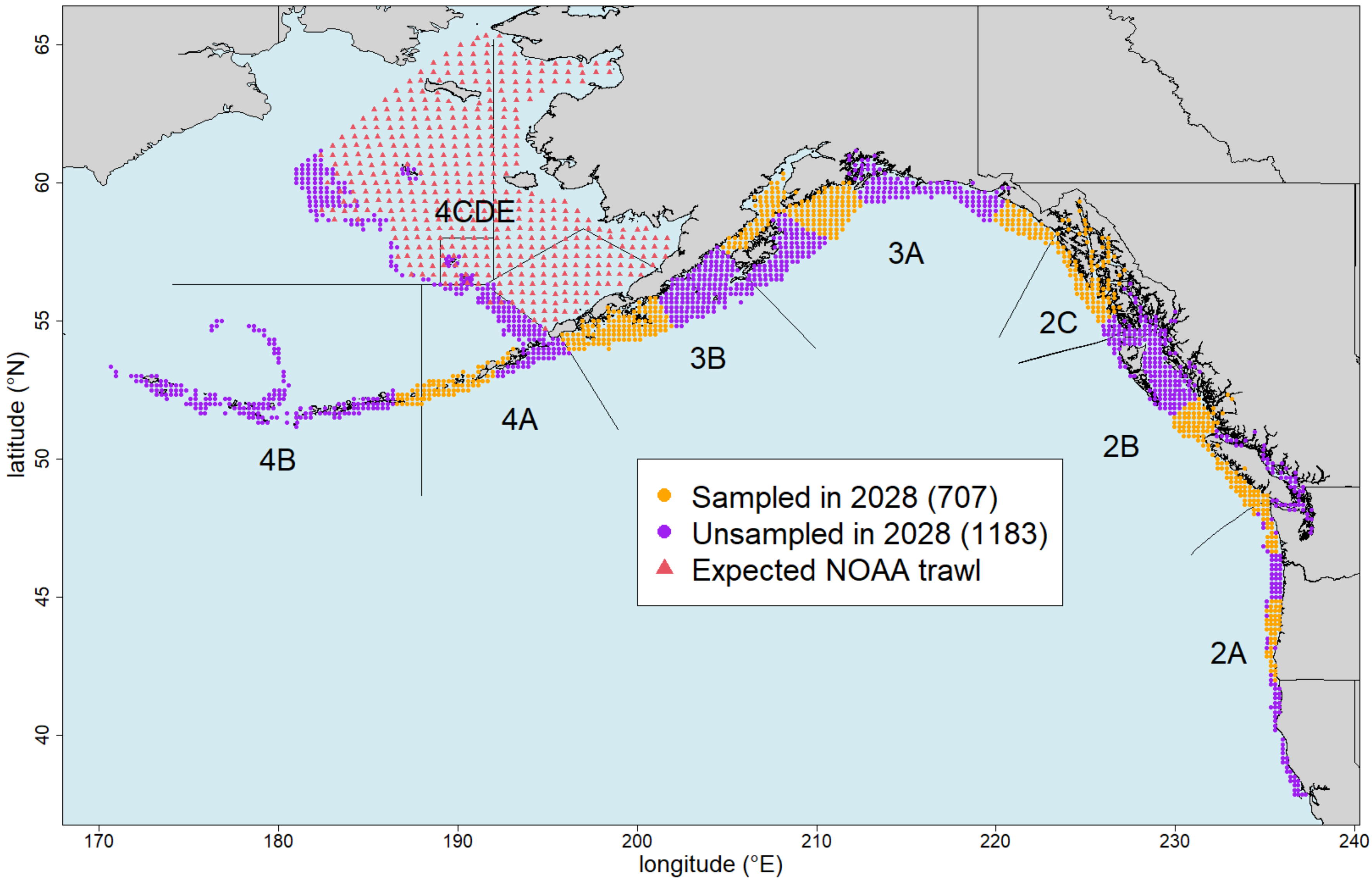

Figure 6. Base Block design for 2028 (orange circles). Design is based on fishing 2-4 complete blocks of stations (charter regions) in the core areas (2B, 2C, 3A and 3B) and previously implemented subareas elsewhere.

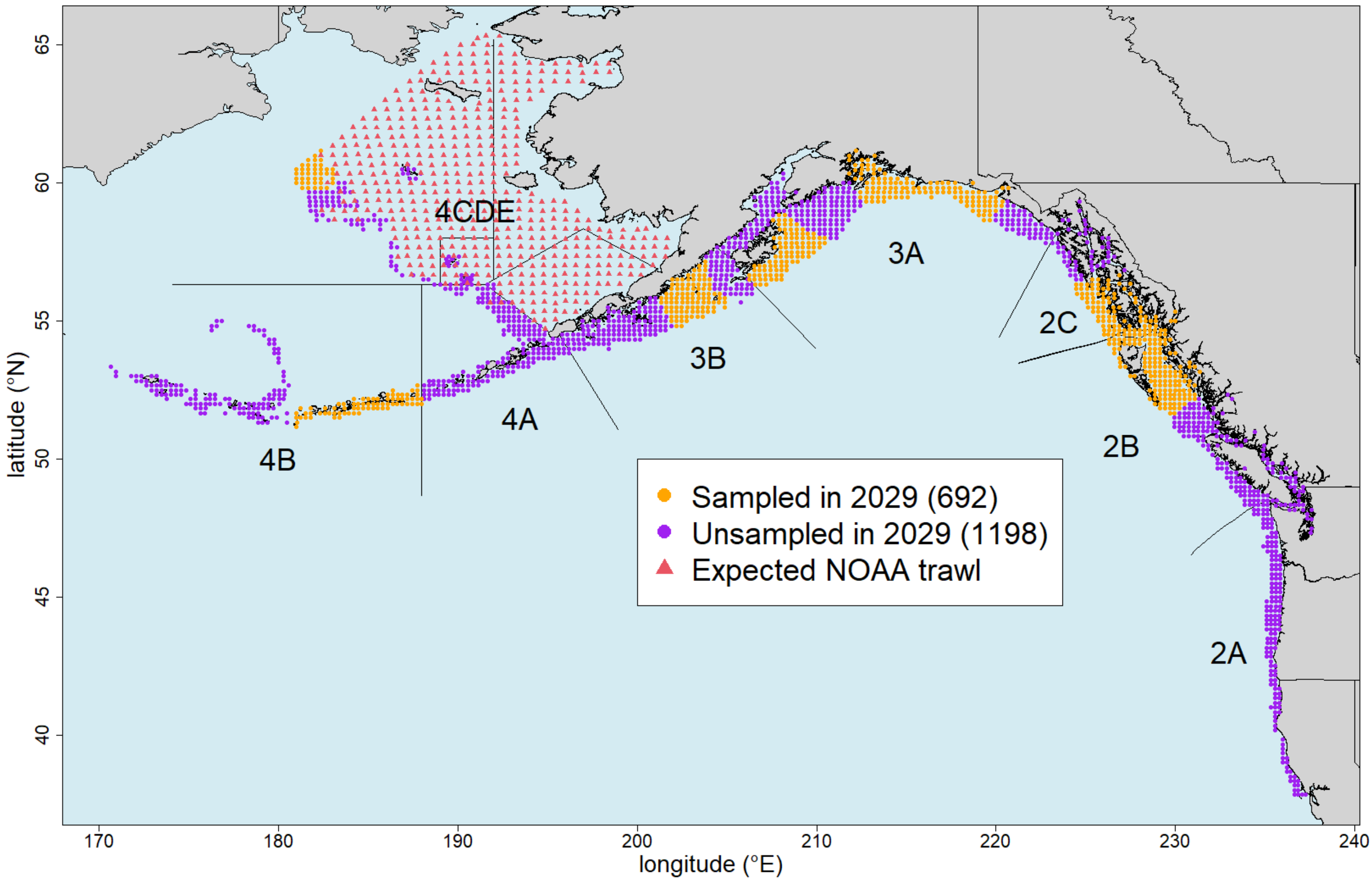

Figure 7. Base Block design for 2029 (orange circles). Design is based on fishing 2-4 complete blocks of stations (charter regions) in the core areas (2B, 2C, 3A and 3B) and previously implemented subareas elsewhere.

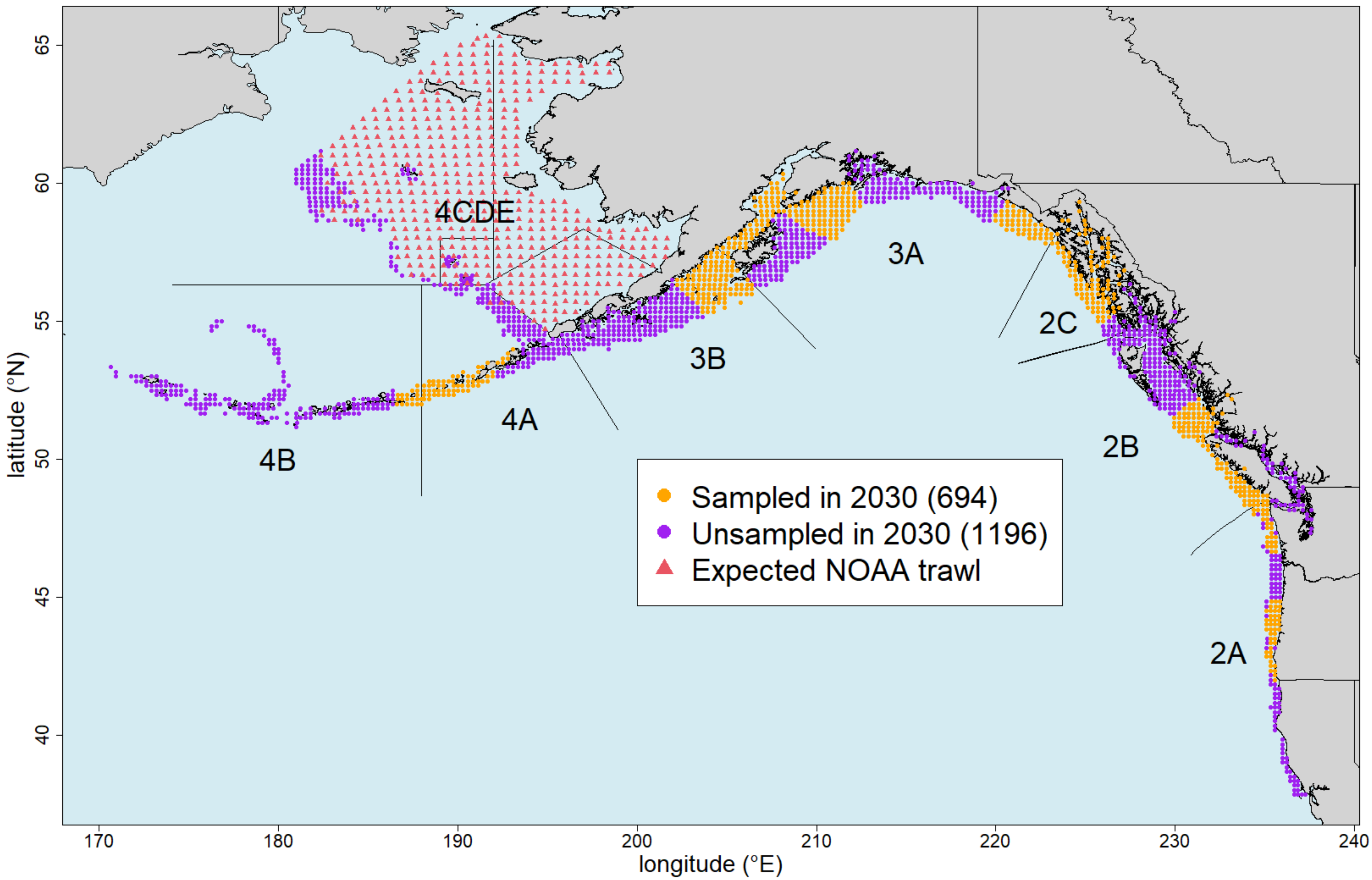

Figure 8. Base Block design for 2030 (orange circles). Design is based on fishing 2-4 complete blocks of stations (charter regions) in the core areas (2B, 2C, 3A and 3B) and previously implemented subareas elsewhere.

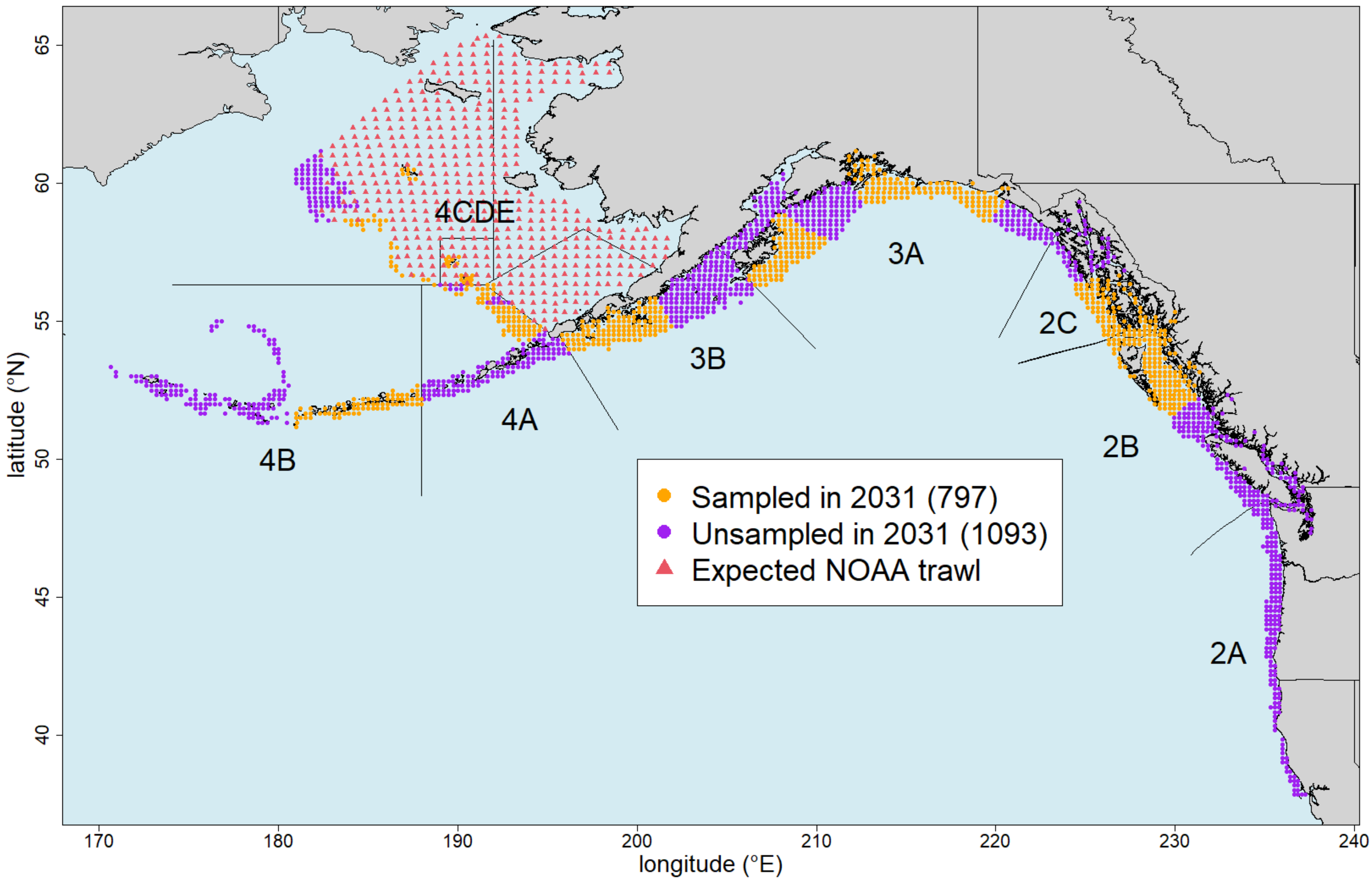

Figure 9. Base Block design for 2031 (orange circles). Design is based on fishing 2-4 complete blocks of stations (charter regions) in the core areas (2B, 2C, 3A and 3B) and previously implemented subareas elsewhere.

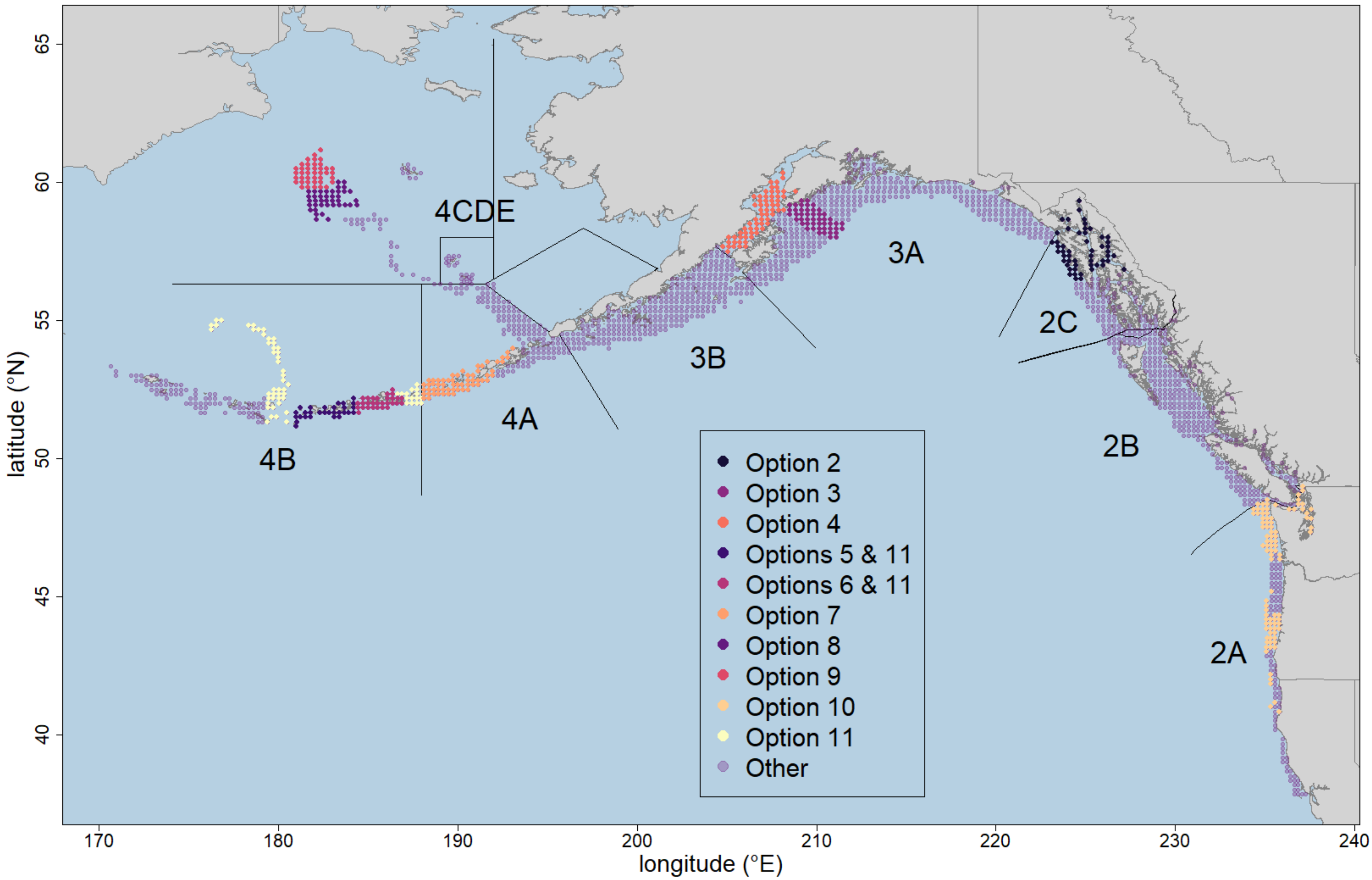

Figure 10. IPHC FISS modular Options 2 to 11 (Table 4) for 2027.

PART 2: MODELLING UPDATES

PURPOSE

To update the SRB on recent work on coastwide modelling of Pacific halibut survey data, with particular application to maturity data (histological and visual) collected on the IPHC's fishery-independent setline survey from 2002-24.

BACKGROUND

At SRB027, we presented some preliminary results from fitting coastwide models to IPHC maturity data (Webster et al. 2025, Part 2, and accompanying presentation). This is part of a broader effort to simplify the space-time modelling of FISS data, which since its first application in 2016, has relied on modelling data at the level of IPHC Regulatory Area. Background material from SRB027 is included as Appendix A in this report.

Currently, generalized additive models (GAMs) are used to estimate the relationship between maturity probability and age by IPHC biological region. The GAM models allow flexibility from a strict logistic model (i.e., linear on the logit scale) but require the assumption of independent observations. At SRB027 (Webster et al. 2025), we discussed results of fitting several spatial models of differing complexity for modelling the relationship of maturity probability and age, including:

- Logistic models, with fixed effects for intercept and slope that vary by IPHC Biological Region, with spatially-dependent errors
- Logistic models with spatially-varying intercept and slope (i.e., slope and intercept are spatially-dependent random effects)
- Versions of the models above with added "GAM-like" flexibility through a random walk term in the age relationships.

These models were fitted to the 2022-24 histological assessment data, which provided model output that was broadly consistent with GAM modelling results (Planas et al. 2025) that showed lower A50 values in Biological Region 3 (Gulf of Alaska) than in adjacent Biological Regions 4 (eastern Aleutians and Bering Sea) and 2 (Southeast Alaska, British Columbia and the West Coast).

The preliminary modelling was based on only three years of data from a sampling design with partial and inconsistent spatial coverage across the three years. For this reason, those models used combined data across years and did not account for temporal dependence. The IPHC has visual assessments of maturity data for Pacific halibut from 2002, including for the individual sampled fish with histological data from 2022-24. Combining the histological and visual data into a single model allows us to:

- Estimate a calibration between visual and histological maturity curves using the paired data from 2022-24
- Model the entire 2002-24 time series of maturity curves, including modelling of both spatial and temporal correlation in model parameters
- Predict histology-based maturity curves across space and time

As with the shorter 2022-24 time series modelled previously, coastwide maturity curves can be calculated by predicting maturity probability at age for each survey station, and computing weighted averages at age using station-level mean NPUE values from the space-time modelling of catch-rate data as weights. Ongoing work includes exploring other options for flexibility in maturity relationships and computing cross-validation metrics for model comparisons.

Modelling results are currently being processed for inclusion in the presentation of this material at SRB029.

RECOMMENDATION

That the Scientific Review Board **NOTE** paper IPHC-2026-SRB029-08 (Part 2), which provides an update on recent work on coastwide modelling of Pacific halibut survey data, using histological maturity data as a test case.

References

Bakka, H., Vanhatalo, J., Illian, J. B., Simpson, D., and Rue, H. (2019). Non-stationary Gaussian models with physical barriers. Spatial Statistics 29: 268-288. https://doi.org/10.1016/j.spasta.2019.01.002

Lindgren, F., and Rue, H. (2015). Bayesian spatial modelling with R-INLA. J. Stat. Softw. 63: 1–27. https://doi.org/10.18637/jss.v063.i19

Planas, J., Dykstra, C., Jasonowicz, A., and Jones, C. (2025). Report on Current and Future Biological and Ecosystem Science Research Activities. IPHC-2025-SRB026-06. 27 p.

Webster, R., Steward, I., Ualesi, K. and Wilson, D. (2025). 2026-28 FISS design evaluation and modelling updates. IPHC-2024-SRB027-09. 31 p.

Appendix A: Background to coastwide modelling of IPHC survey data

At present, the IPHC models Pacific halibut survey data by fitting a spatio-temporal model (Webster et al. 2020) to data from each individual IPHC Regulatory Area, and aggregates model output to produce estimate for larger geographical units (Biological Regions, coastwide waters). The advantages of this approach versus a single coastwide model include:

- Smaller modelling regions allow for finer meshes (see below) without leading to prohibitively long runtimes
- Faster model runtimes due to both smaller datasets and smaller modelling regions
- Easily allows model parameters to differ among areas

The main drawbacks of splitting modelling into smaller components are (1) that there may be discontinuities at area boundaries due to differences in model parameter values between adjacent areas, and (2) samples drawn from posterior predictive distributions (used to create time series of variables of interest) will not be spatially correlated across boundaries as each area's samples are drawn independently from each other. These drawbacks have been relatively minor for the catch rate (weight and numbers per unit effort, WPUE and NPUE) data modelled to date, with no obvious discontinuities appearing on maps of model predictions (see the maps at the IPHC Space-time Explorer), and the range parameter for spatial models being small relative to the size of each area. The latter means spatial correlation declines relatively steeply with increasing distance and independence between samples on either side of an area boundary has little impact on estimates of standard deviations or coefficients of variation for estimates based on combining areas (i.e., to form Biological Region or coastwide estimates).

Recent improvements in the runtime of the spatio-temporal models (fitted via the R package, R-INLA, www.r-inla.org) have made it more likely that fitting models to coastwide data sets will not result in prohibitive computation time. While fitting coastwide models for Pacific halibut WPUE and NPUE data may now be feasible, coastwide models have utility beyond estimating time series of indices of density and abundance. The FISS also collects biological data on individual Pacific halibut, some of which has been collected over a shorter timeframe than the modern 33-year FISS, and in some instances, spatial coverage may be less spatially consistent. This is also true of oceanographic monitoring data, which sometimes has gaps in coverage due to loss or failure of the water column profiler units or recent reductions in FISS coverage. In such cases, modelling on a coastwide basis should lead to more powerful inference than restricting models to data subsets based on IPHC Regulatory Areas or a similar geographical unit.

The IPHC has collected histological data on Pacific halibut maturity on the FISS since 2022 (see Planas et al, 2025, for details). Maturity is assessed on individual female Pacific halibut, and each fish has an approximate capture location given by the midpoint of the location of the FISS set on which it was captured. Previous modelling of the relationship of maturity probability and age has used statistical methods that assume each fish is sampled independently, which ignores the likelihood of spatial correlation in the probability of maturity and the fact that fish are sampled in clusters on each set. Spatial (or spatio-temporal) modelling can account for this lack of independence.

Coastwide mesh and barrier models

The INLA approximation uses a set of basis functions defined on a triangulated mesh covering the region of interest (Lindgren and Rue 2015). IPHC data imply that Pacific halibut do not inhabit depths greater than 732 m (400 fathoms) at non-negligible densities during the summer survey period, and therefore our starting point for a modelling region is all USA and Canadian waters within 0 to 732 m from northern California to the southern Chukchi Sea. To provide an additional buffer at the region's outer edge, we extended the region a depth of 800 fathoms and further into Russian waters in the Bering Sea to account for the fact that this is not a hard boundary and that there is some correlation between values in sampled US waters and those in adjacent unsampled Russian waters. Other offsets were made to the mesh boundaries to smooth the edge and avoid narrow inlets within which R-INLA's mesh creation function would have to include many vertices and thereby increase the dimensionality of the modelling problem. The smoothing and offsetting can remove or reduce the size of islands and peninsulas, and we therefore selected values that preserved such features as much as possible to ensure that nonexistent pathways were not created in the mesh space. The coarseness of the mesh itself was defined so that the number of vertices allowed comprehensive spatial coverage without being so numerous that the model processing would become prohibitively slow. Another consideration in approximating the coastline with the triangulated mesh was ensuring that sample locations (survey stations) did not end up falling on "land". This was particularly challenging in the narrow inlets of IPHC Regulatory Areas 2B and 2C, and ultimately the selected mesh required the exclusion of a single FISS station: alternative refinements of the mesh definition led to the exclusion of more stations located on "land".

In addition to the mesh defined within IPHC habitat, the functions in R-INLA were used to define the land and deeper waters as barriers, which when used with a non-stationary barrier model (Bakka et. al, 2019) ensure that the model's correlation structure cuts off pathways through land, including large islands and peninsulas, along with areas of deeper water that Pacific halibut do not inhabit. Barrier models achieve this without additional computational cost by defining the range parameter (the distance at which the correlation between two points is small, i.e., ≈0.1) on land to be a small fraction of the value on water. The coastwide mesh for IPHC survey data, including barriers shaded in yellow, is presented in Figure 11.

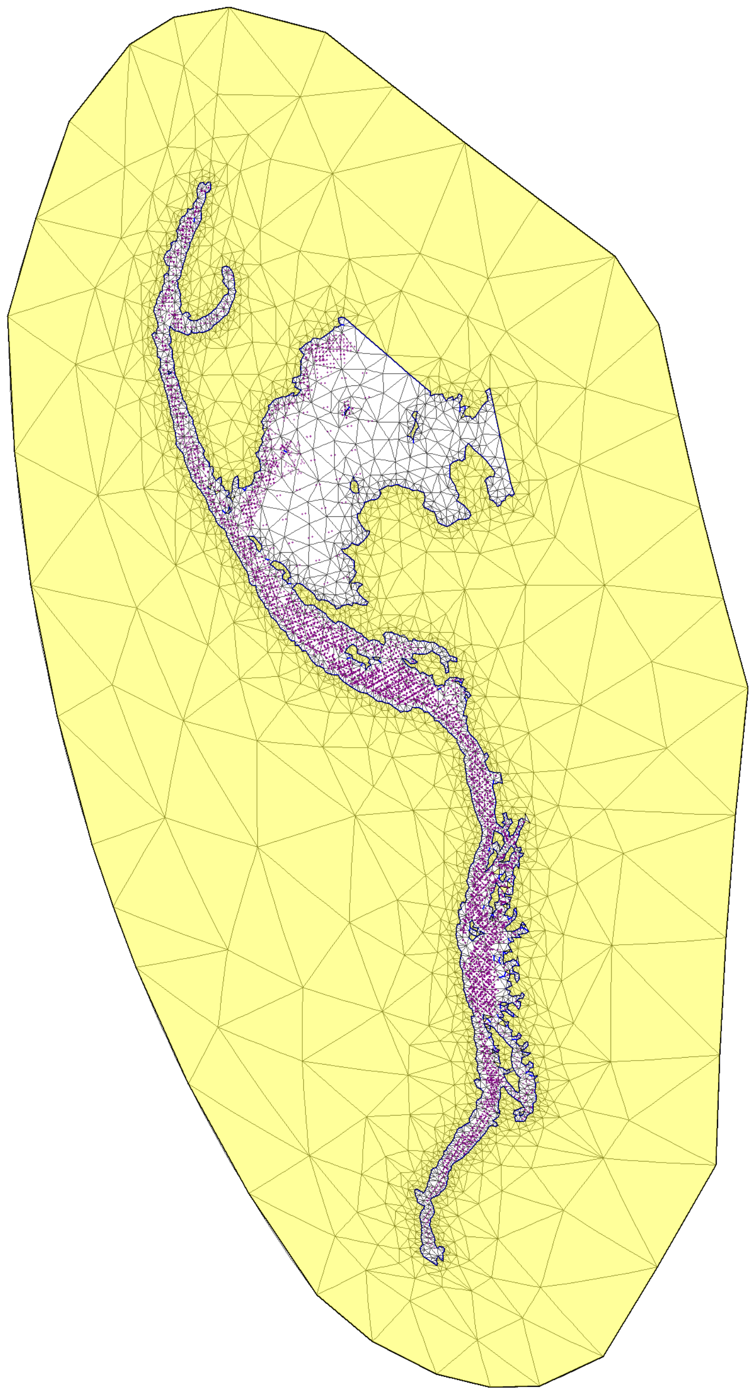

Figure 11. Triangulated mesh used in spatio-temporal modelling of histological maturity data. Barriers are shown with yellow shading**.**

References

Bakka, H., Vanhatalo, J., Illian, J. B., Simpson, D., and Rue, H. (2019). Non-stationary Gaussian models with physical barriers. Spatial Statistics 29: 268-288. https://doi.org/10.1016/j.spasta.2019.01.002

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