2026-28 FISS design evaluation and modelling updates

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PART 1: 2026-28 FISS DESIGN EVALUATION

PURPOSE

To present the Scientific Review Board with potential FISS designs for 2026-28, including a preliminary cost evaluation of the 2026 design options.

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, lower sales prices and higher costs have led to the implementation of FISS designs with reduced spatial footprints. Effort has been concentrated in IPHC Regulatory Areas 2B, 2C, 3A and 3B, with limited sampling in other areas (Figures 2 and 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 recent designs based on random selection of FISS stations. 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 include 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. For 2025, high projected financial costs for this design meant that it was not viable to undertake without substantial supplementary funding. Therefore, IPHC Secretariat staff developed a "fiscally viable" design for 2025 that would have reduced spatial coverage for the third year in a row but at a projected loss that could be covered by revenue, supplementary funding and IPHC reserve funds. Following SS014, the final 2025 FISS design was approved via inter-sessional agreement (IPHC-2024-CR-030, IPHC-2024-CR-031; Figure 3). This design included sampling of FISS charter regions in IPHC Regulatory Areas 3A, 3B, 4A and 4B that were unsampled in either 2023, 2024 or both.

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 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 the vast majority of 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, 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 , 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.

Rationalized FISS, 2020-25

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 (see below). The 2023 FISS design had more limited spatial coverage, with almost no FISS 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 was carried out in northern IPHC Regulatory 2A, while planned stations around the IPHC Regulatory Area 4A/4B boundary were not sampled due to a lack of charter bids. The adopted 2024 FISS design (IPHC-2024-AM100-R) included high sampling rates in IPHC Regulatory Areas 2B and 2C, a small number of charter regions in IPHC Regulatory Areas 3A and 3B, and sampling of the southern shelf edge and Bering Sea islands in IPHC Regulatory Area 4CDE (Figure 2). The 2025 design includes stations in IPHC Regulatory Areas 3A and 3B that complement coverage in recent years (Figure 3), along with stations in IPHC Regulatory Areas 2A, 4A and 4B that have not been sampled for three or more years and is therefore expected to reduce the potential for bias in most IPHC Regulatory Areas relative to recent years (Figure 4).

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 correlation in Pacific halibut density, along with information from covariates such as depth (see Webster 2016, 2017). It also allowed a more complete accounting of uncertainty; for example, prior to the use of space-time modelling, uncertainty due to unsurveyed regions in each year was ignored in the estimation. Prior to the application of the space-time modelling, these unsampled regions were either imputed 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) and to integrate multiple surveys off the Pacific coast of Canada (e.g., Thompson et al. 2023). The IPHC space-time models are fitted through the R-INLA package in the R software (R Core Team, 2024).

FISS DESIGN OBJECTIVES (Table 1)

Note that the secondary objective was revised at AM101 (IPHC-2025-AM101-R, para. 61).

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: *Minimize 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$2,000,000
Tertiary	Minimize removals, assist others where feasible on a cost-recovery basis, address specific Commission informational needs.	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

Annual design review, endorsement, and finalisation process

Since completion of the FISS expansions in 2019, a review process has been developed 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 Commissioners 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 November/December Interim Meeting;
  - Ad-hoc modifications to the design for the current year (due to unforeseen issues arising) are possible at the Annual Meeting of the Commission;
  - The endorsed design for current year is then modified (if necessary) to account for any additional tertiary objectives or revision 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 instead of the next year only assists the Secretariat with medium-term planning of the FISS, and allows reviewers (SRB, Commissioners) and stakeholders to see more clearly the planning process for sampling the entire FISS footprint over multiple years.

POTENTIAL DESIGNS FOR 2026-28

BASE BLOCK DESIGN

At AM101, Secretariat staff presented the Base Block design for 2025 and subsequent years based a rotational block design (IPHC-2025-AM101-14). 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. This type of design was first proposed in 2019 (IPHC-2019-IM095-07 Rev_1, Figure 4) to complement the similar subarea design proposed and adopted for areas at the ends of the stock (2A, 4A and 4B). Block designs are potentially more efficient from an operational perspective than a randomized design, as they involve less running time between stations, possibly leading to cost reductions on a per station basis.

The Base Block designs shown in Figures 5 to 7 for 2026-28 were revised from the designs presented to Commissioners at AM101 to account for the Commission-approved 2025 design. In particular, charter regions not selected in IPHC Regulatory Areas 3A and 3B in 2025 were prioritized for sampling in 2026.

Using samples generated from the fitted 2024 space-time models as simulated data for 2025-28, 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 values for 2027 were found by fitting the model to the data for 1993-2027, with simulated data used for 2025-27.

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

Regulatory Area	Year 2026	2027	2028
2A	21	22	14
2B	11	7	10
2C	6	6	6
3A	8	7	8
3B	11	15	11
4A	18	22	13
4B	15	16	17
4CDE	9	9	8
Biological Region			
Region 2	6	5	5
Region 3	7	7	7
Region 4	9	10	7
Region 4B	15	16	17
Coastwide	4	4	4

Projected terminal year CVs for the Base Block design are 25% or less for all IPHC Regulatory Areas. In the core areas (2B, 2C, 3A and 3B), CVs are projected to be 15% or less (Table 2). All Biological Region CVs, except that of Region 4B, are at most 10%, while the coastwide CV is projected to be 4% in all years. The Base Block design is therefore 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 are 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.

The 'global average' research survey CVs has been estimated to be approximately ~20%; however, this value includes estimated observation and process error (based on lack of fit in the stock assessments), and so is larger than the survey-only observation CVs projected in this report (Francis et al. 2003). In NOAA Fisheries trawl survey results in the Bering Sea (roughly analogous to one Biological Region for Pacific halibut), commercially important species showed a range of average annual model-based CVs, including: Pacific cod (5%), Walleye pollock (7%), Northern rock sole (6%), and yellowfin sole (5%) over 1982-2019 (DeFilippo et al. 2023). These values are comparable to the projected 5-9% CVs for IPHC Biological Regions that would be expected from the base block design (with the exception of Biological Region 4B), but lower than corresponding values for the Core Block and Reduced Core designs.

REDUCED LOSS DESIGN

The Base Block design is projected to result in a substantial operating loss (Table 3) and would require supplementary funding to be viable. As an alternative, the Secretariat staff has developed a preliminary design that would result in a net operating loss of approximately $500,000 (Figure 8). This Reduced Loss design maintains sampling in two revenue positive charter regions in IPHC Regulatory Area 2C, adds a revenue positive charter region to IPHC Regulatory Area 2B, and includes a subsample of 30 stations in each of three other revenuenegative charter regions from the Base Block design in IPHC Regulatory Areas 2B and 3A.The three regions with partial sampling were prioritized for 2026 as they are among the regions not sampled in the last two to three years.

Table 3 gives preliminary cost and revenue projections for Base Block and Reduced Loss designs. Projections include the following assumptions:

1. Designs are optimized for numbers of skates, with 4, 6 or 8 skate-sets used, depending on projected catch rates and bait costs.
2. 2026 Pacific halibut price and landings decline 15% and 5% respectively from 2025 values.

Regarding (2), there was a large average increase in price from 2024 to 2025, but without fully understanding the reasons for this increase, it seems precautionary to assume that prices will return to values closer to those experienced in previous years. Further, raw FISS catch rates to date imply that in most regions, the landings continue to decline and therefore it is reasonable to assume a further decline from 2025 to 2026. Prices for chum salmon bait are also anticipated to increase substantially (by 58%) based on current information.

Table 3. Comparison of preliminary projected costs and revenue for the 2026 Base Block and Reduced Loss designs ($US). (Totals may not equal the sum of individual rows due to rounding.)

Design		**Base Block**	**Reduced Loss**
Projected costs	**Base HQ (incurred even with no FISS)**	(534,000)	(534,000)
	Vessel bids	(1,306,000)	(436,000)
	Field staff expenses	(492,000)	(246,000)
	Bait	(409,000)	(195,000)
	Non-IPHC fish sales	(182,000)	(147,000)
	Other costs*	(471,000)	(279,000)
	Total costs	**(3,394,000)**	**(1,838,000)**
Projected revenue	**Total Pacific halibut sales**	1,460,000	1,260,000
	Total byproduct sales	46,000	41,000
	Total sales	**1,507,000**	**1,302,000**
Projected net revenue		**($1,887,000)**	**($537,000)**

*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.

Cost estimates are largely based on information from the 2025 FISS as of mid-July 2025, together with outcomes of the 2025 charter bidding process, and it is important to note

there is still high uncertainty in the catch and cost projections for 2026 at this point. Final cost and accounting information will be available at the end of the 2025 fiscal year and will be used to refine the cost projections at that time.

Intermediate Designs

Here we present several intermediate designs that could be considered if supplementary funding became available or if greater losses might be considered acceptable to the Commission (Table 4). **Importantly, cost and revenue estimates are preliminary and subject to change as inputs are revised following the 2025 FISS season.**

Option 1 in Table 4 is the Reduced Loss design (Figure 8), and Options 2 through 6 successively add stations or charter regions based on scientific priorities. Option 2 (Figure 9) samples the same charter regions as Option 1, but the partial regions are now fully sampled. IPHC Regulatory Area 4B is added in Option 3 (Figure 10), which is therefore the least expensive of the options in Table 4 that includes sampling of some kind in all Biological Regions (assuming the NOAA trawl survey provides coverage in Region 4). Option 4 (Figure 11) improves spatial coverage in Biological Region 3 by adding a charter region in IPHC Regulatory Area 3B, while Option 5 (Figure 12) adds FISS sampling to Region 4 with a charter region in IPHC Biological Region 4A. Option 6 (Figure 13) includes all charter regions from the Base Block design (Option 7, Figure 5), together with one revenue-positive region in Biological Region 2 that is not part of the Base Block Design.

Table 4. Comparison of 2026 preliminary revenue projections for the Reduced Loss design, the Base Block design and design options providing intermediate coverage. For each design, the final column shows the difference in projected revenue from the design in the previous row.

Design	Sampled IPHC Regulatory Areas (with number of FISS charter regions)	Projected net revenue ($US)	Difference ($US)
Option 1: Reduced Loss	2B(1 full, 2 partial), 2C(2), 3A(1 partial)	($537,000)	
Option 2	2B**(3)**, 2C(2), **3A(1)**	($591,000)	($54,000)
Option 3	2B(3), 2C(2), 3A(1), **4B(1)**	($856,000)	($265,000)
Option 4	2B(3), 2C(2), 3A(1), **3B(1)**, 4B(1)	($1,019,000)	($163,000)
Option 5	2B(3), 2C(2), 3A(1), 3B(1), 4A(1), **4B(1)**	($1,252,000)	($233,000)
Option 6	2B(3), 2C(2), 3A**(4)**, 3B**(2)**, 4A(1), 4B(1)	($1,843,000)	($591,000)
Option 7: Base Block	2B(2), 2C(2), 3A(4), 3B(2), 4A(1), 4B(1)	($1,887,000)	($44,000)

Whereas Table 4 presents options in the form of complete FISS designs, each change between design options can be thought of as a series of optional modular add-ons (Table 5) that can be added or removed from the design in any order. The order of additions presented in Tables 4 and 5 broadly represents scientific priorities, including prioritizing sampling in all IPHC Biological Regions and sampling regions that have not been included in the most recent implemented FISS designs (to reduce the risk of bias in estimates derived from FISS data). Other factors such as Commission priorities or accounting for the Secondary Objective (Table 1, e.g. by prioritizing less costly additions) may result in a different ordering than Table 5.

Table 5. Preliminary cost projections of modular changes to the Reduced Loss design that result in intermediate designs between the 2026 Reduced Loss and Base Block designs. Each of Options 2 to 7 can be added in any combination to Option 1, with the total cost found by summing the additional costs for each option selected. Note that due to rounding, some combinations may result in total cost projections that differ slightly from the values in Table 4. For reference, FISS charter regions are shown in Figure 14.

Option	Design or design change	Sampled IPHC Regulatory Areas (Option 1) (with FISS charter regions) or change from previous options (Options 2 to 7)	Net cost (Option1) or additional cost (Options 2 to 7)	Benefit/rationale
1	Reduced Loss	2B(1 full, 2 partial), 2C(2), 3A(1 partial)	($537,000)	
2	Add full sampling in all charter regions to Option 1	**2B(+2 partial)**, **3A(+1 partial)**	($54,000)	Fully sampled regions may more easily attract bids
3	Add east Adak	**4B(+1)**	($265,000)	Adds sampling in Biological Region 4B
4	Add Chignik	**3B(+1)**	($163,000)	Adds 3B sampling. Last sampled 2023.
5	Add east Unalaska	**4A(+1)**	($233,000)	Adds 4A sampling. Last sampled 2019.
6.1	Add Gore Pt	**3A(+1)**	($136,000)	Improves 3A coverage. Last sampled 2023.
6.2	Add Fairweather	**3A(+1)**	($153,000)	Improves 3A coverage. Last sampled 2023.
6.3	Add Semidi	**3B(+1)**	($159,000)	Improves 3B coverage. Last sampled 2023.
6.4	Add Shelikof	**3A(+1)**	($141,000)	Improves 3A coverage. Last sampled 2024.
7	Remove St James	**2B(−1)**	($44,000)	Removes lower-priority revenue positive region. Last sampled 2024.

Discussion

The **Base Block** design has a projected net loss of around $1,887,000 and therefore will rely on supplementary funding for implementation. Unlike the Base Block design, the preliminary **Reduced Loss** design does not have extensive spatial coverage, with sampling concentrated in regions of greatest Pacific halibut density in IPHC Biological Region 2, only 30 FISS stations in Biological Region 3, and no FISS sampling in Biological Regions 4 and 4B. Such a design comes with a greater risk of bias relative to the Base Block design due to the increased chance of stock changes being unobserved. Despite the uncertainty being properly propagated, of increasing concern is the potential for the space-time model expectations to move toward the long term mean in the absence of new data. This increased uncertainty in the index of abundance is likely to cause the assessment model to rely more heavily on the commercial fishery catch-per-unit-effort index, as was the case in 2024. Given current spatial variability and uncertainty in the magnitude of younger year classes (2016 and younger), the limited biological information from the core of the stock distribution (Biological Region 3) makes it unclear whether the stock assessment will detect a major change in year class abundance, either up or down. Although the stock assessment methods can remain unchanged, a greater portion of the actual uncertainty in stock trend and demographics will not be able to be quantified due to missing FISS data from a large fraction of the Pacific halibut stock's geographic range.

The implications for the assessment would be of increasing concern if designs like the Reduced Loss design were implemented beyond 2026 due to increasing uncertainty and risk of bias in stock trend estimates and the unrepresentativeness of the biological samples. Further, as was evident at AM100 and AM101, reduced FISS designs that do not fully inform stock distribution with annual sampling in all IPHC Regulatory areas lead to reduced stakeholder confidence in the FISS results and in the aggregate scientific information from the stock assessment. As it did with the relatively conservative mortality limits set for 2025, this may have a strong effect on the perception of risk and on decision making by the Commission if reduced survey designs continue to be consecutively implemented.

Water column profiler information from the in-progress FISS in IPHC Regulatory Area 2A shows evidence for hypoxia in parts of that area. Catch rates are well below predicted values based on the most recent surveys. We intend to prioritize the processing of dissolved oxygen data from the profiler so that these data are available prior to the 2025 Interim Meeting to help inform management regarding catch limit decisions and FISS priorities in Biological Region 2.

RECOMMENDATION

That the Scientific Review Board **NOTE** paper IPHC-2025-SRB027-09 (Part 1), which presents an evaluation of design options for 2026-28, including a preliminary option accounting for the secondary FISS objective of cost effectiveness.

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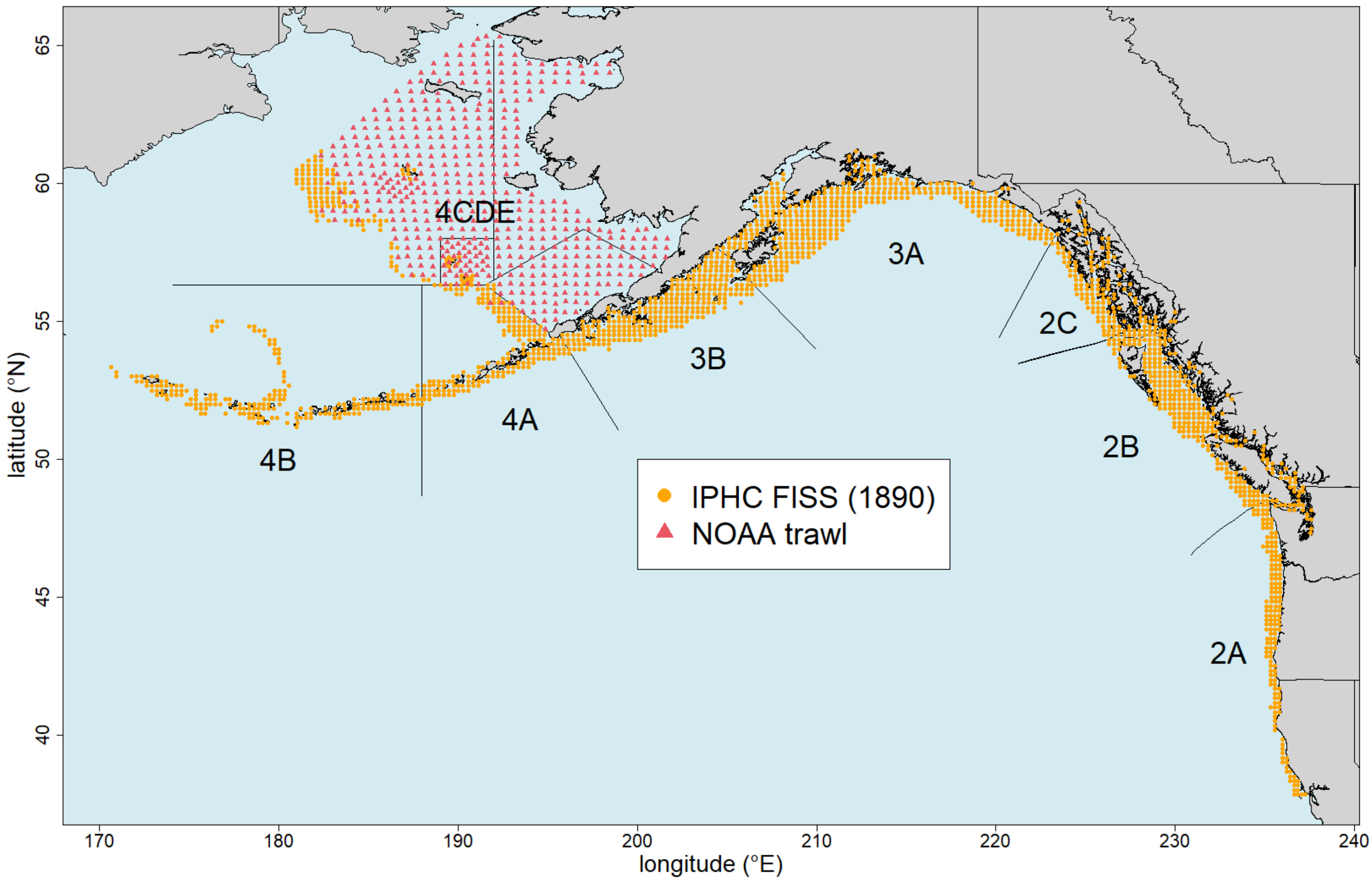

Figure 1. Map of the full 1890 station FISS design, with orange circles representing stations available for inclusion in annual sampling designs. Red triangles represent standard locations of NOAA trawl stations used to provide complementary data for Bering Sea modelling (actual NOAA trawl design can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

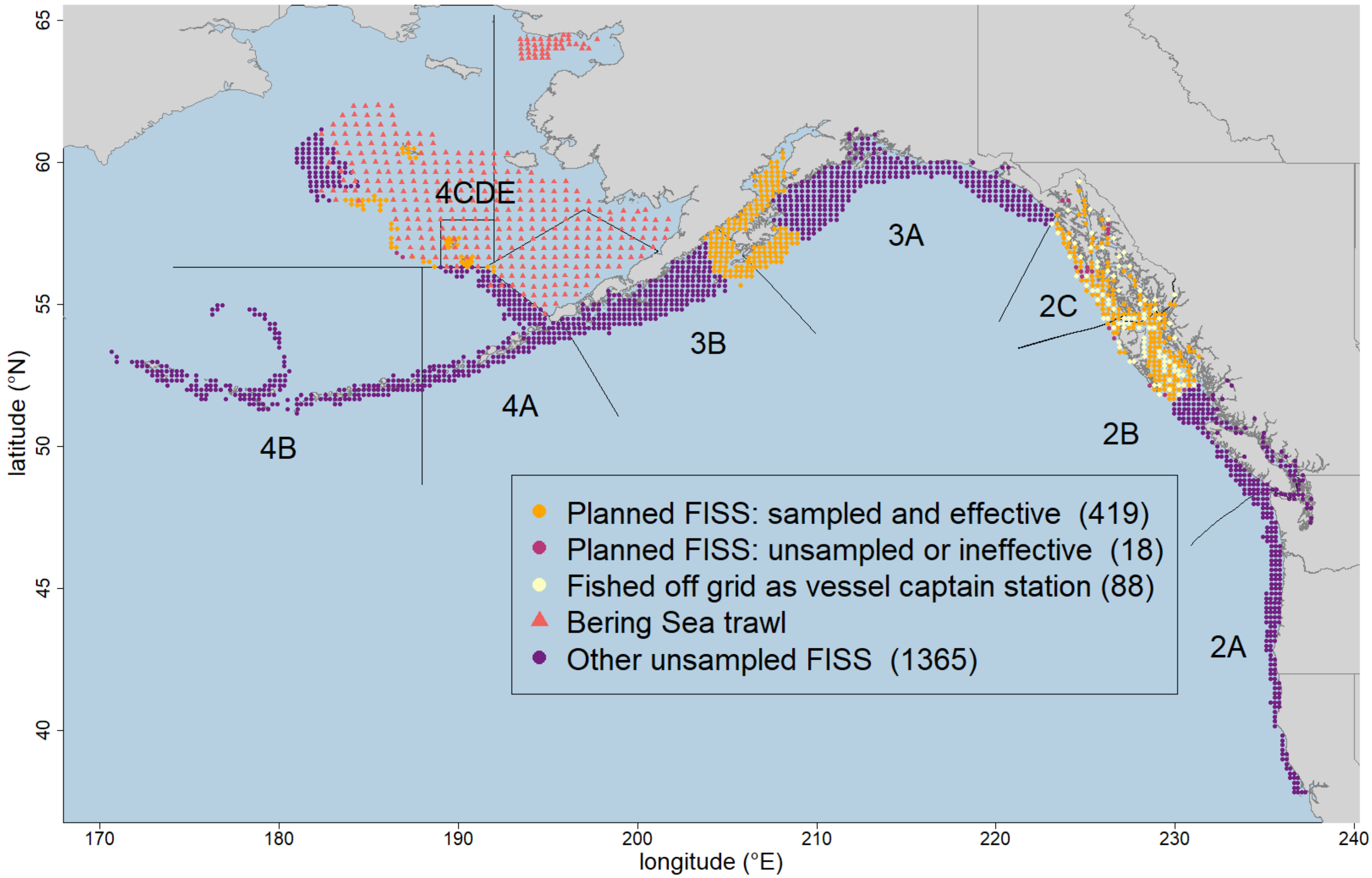

Figure 2. Map of implemented 2024 sampled FISS design showing sampled stations with data used in modelling (orange circles for FISS, red triangles for trawl), along with planned but ineffective FISS stations, FISS grid stations fished off grid as vessel captain stations and other unsampled FISS stations.

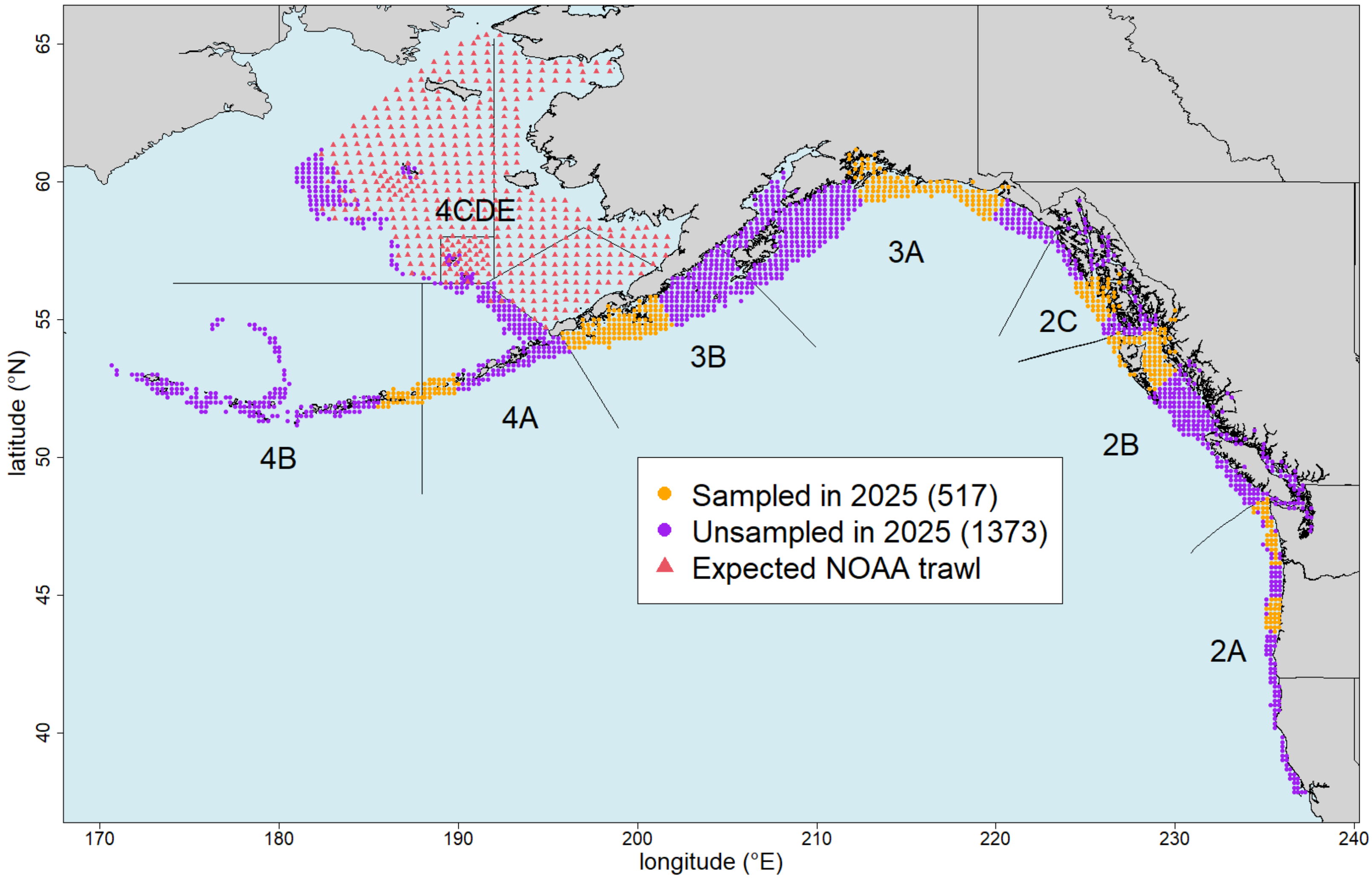

Figure 3. Adopted 2025 FISS design, with planned FISS stations shown as orange circles.

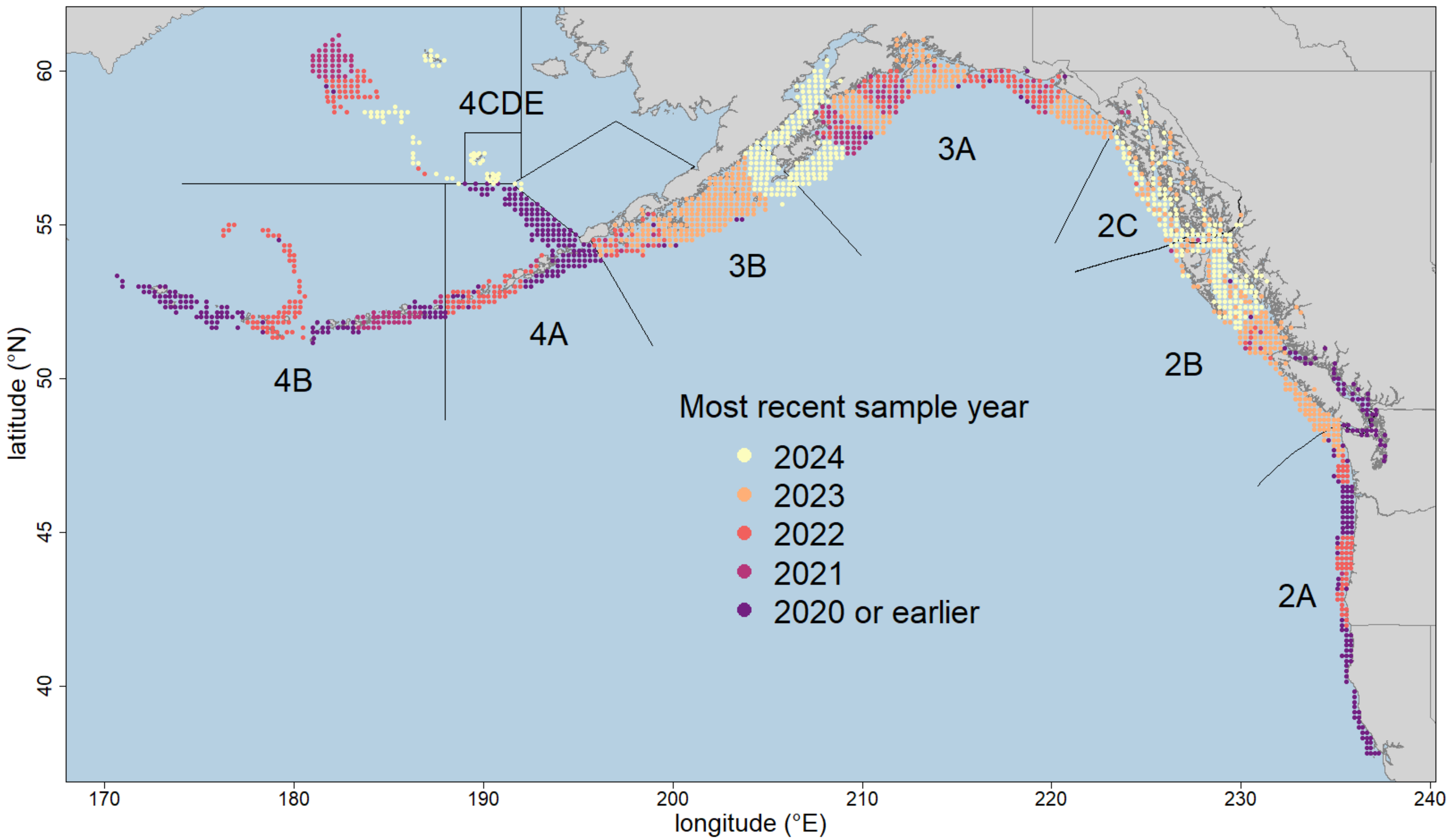

Figure 4. Map showing the most recent sample year of each station on the full FISS grid.

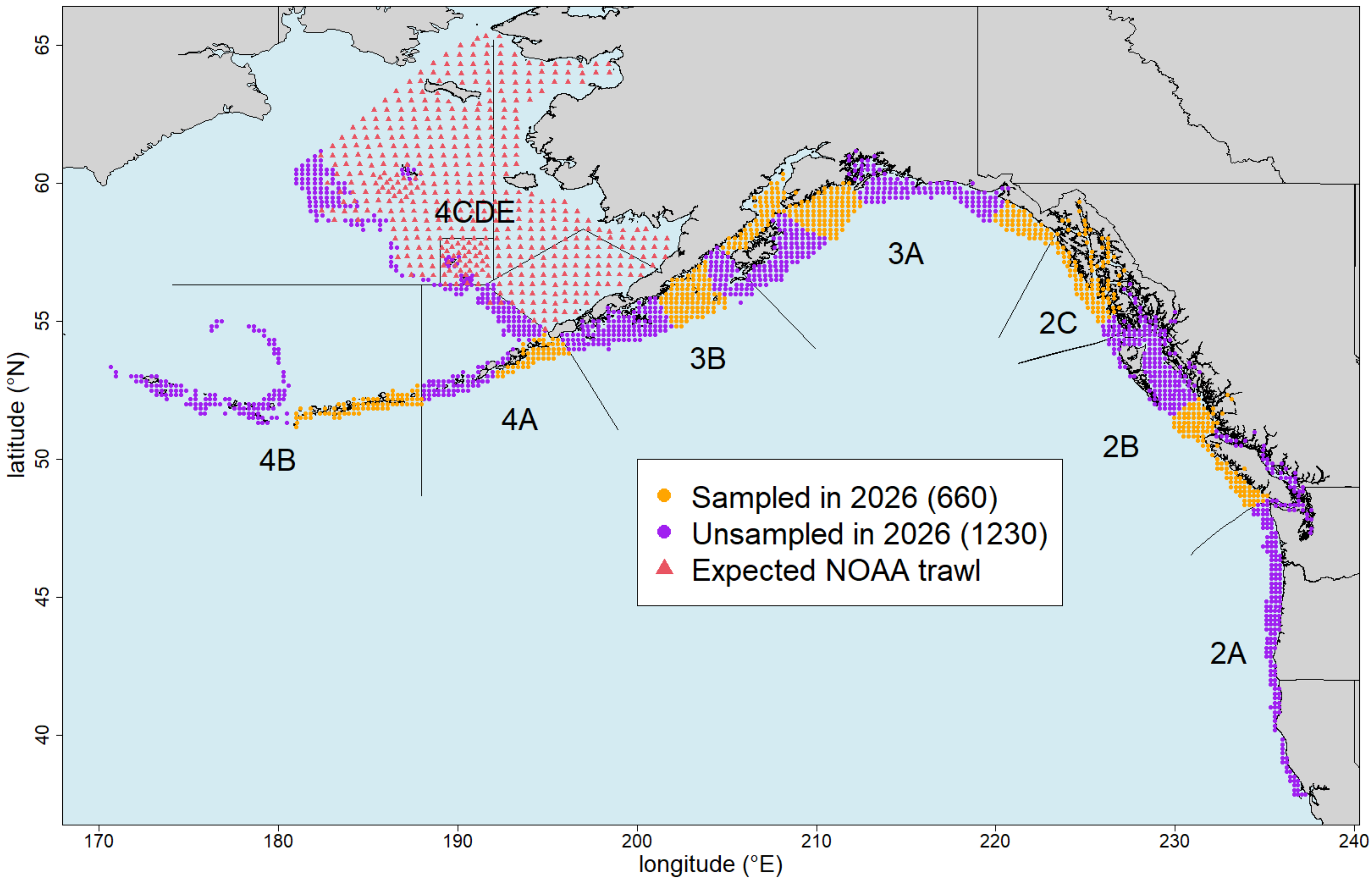

Figure 5. Base Block design for 2026 (orange circles). Design is based on fishing 2-4 complete blocks of stations (charter regions) in the core areas (2B, 2C, 3A and 3B) and previously implemented subareas elsewhere.

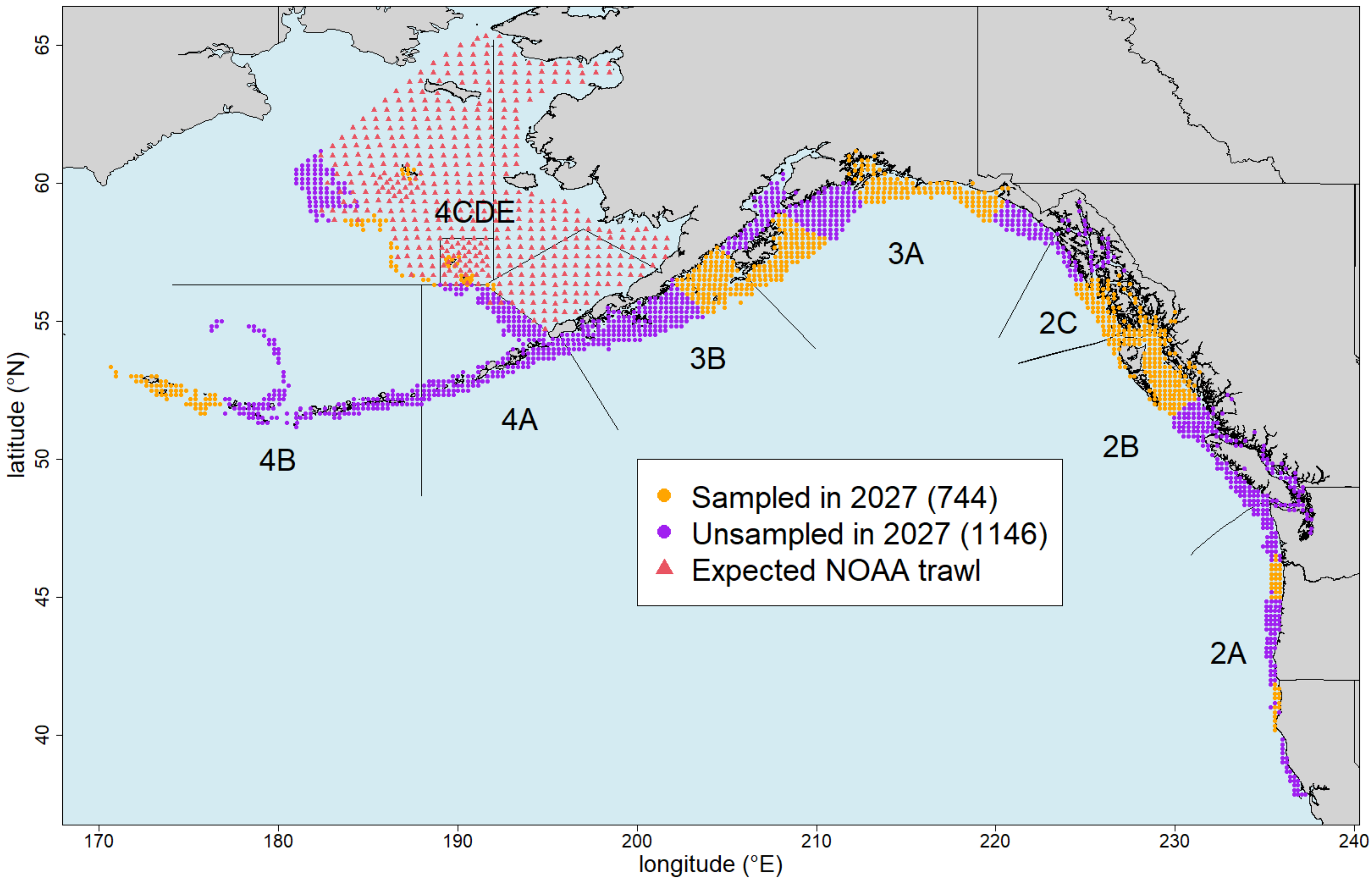

Figure 6. Base Block design for 2027 (orange circles). Design is based on fishing 2-4 complete blocks of stations (charter regions) in the core areas (2B, 2C, 3A and 3B) and previously implemented subareas elsewhere.

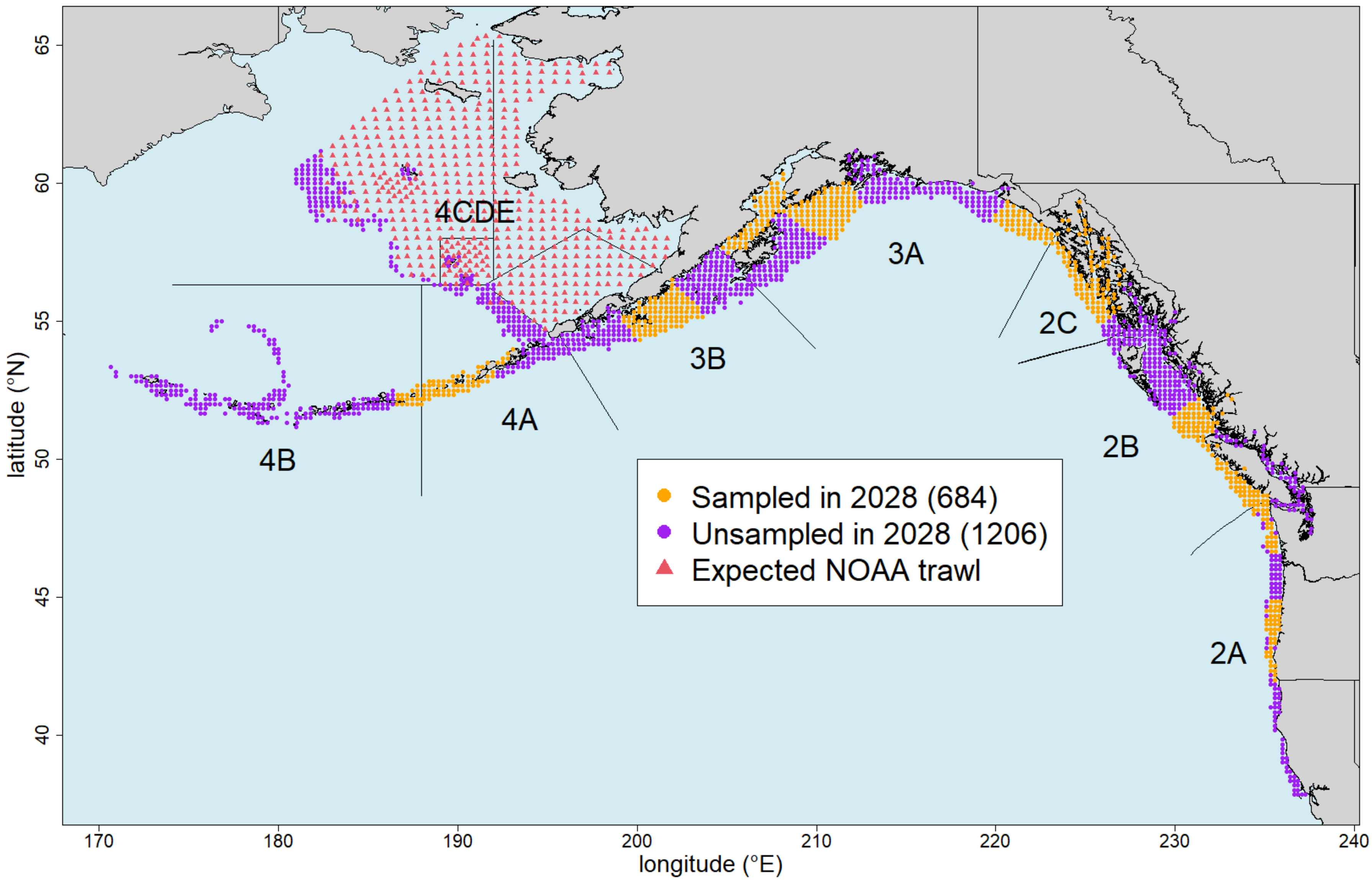

Figure 7. Base Block design for 2028 (orange circles). Design is based on fishing 2-4 complete blocks of stations (charter regions) in the core areas (2B, 2C, 3A and 3B) and previously implemented subareas elsewhere.

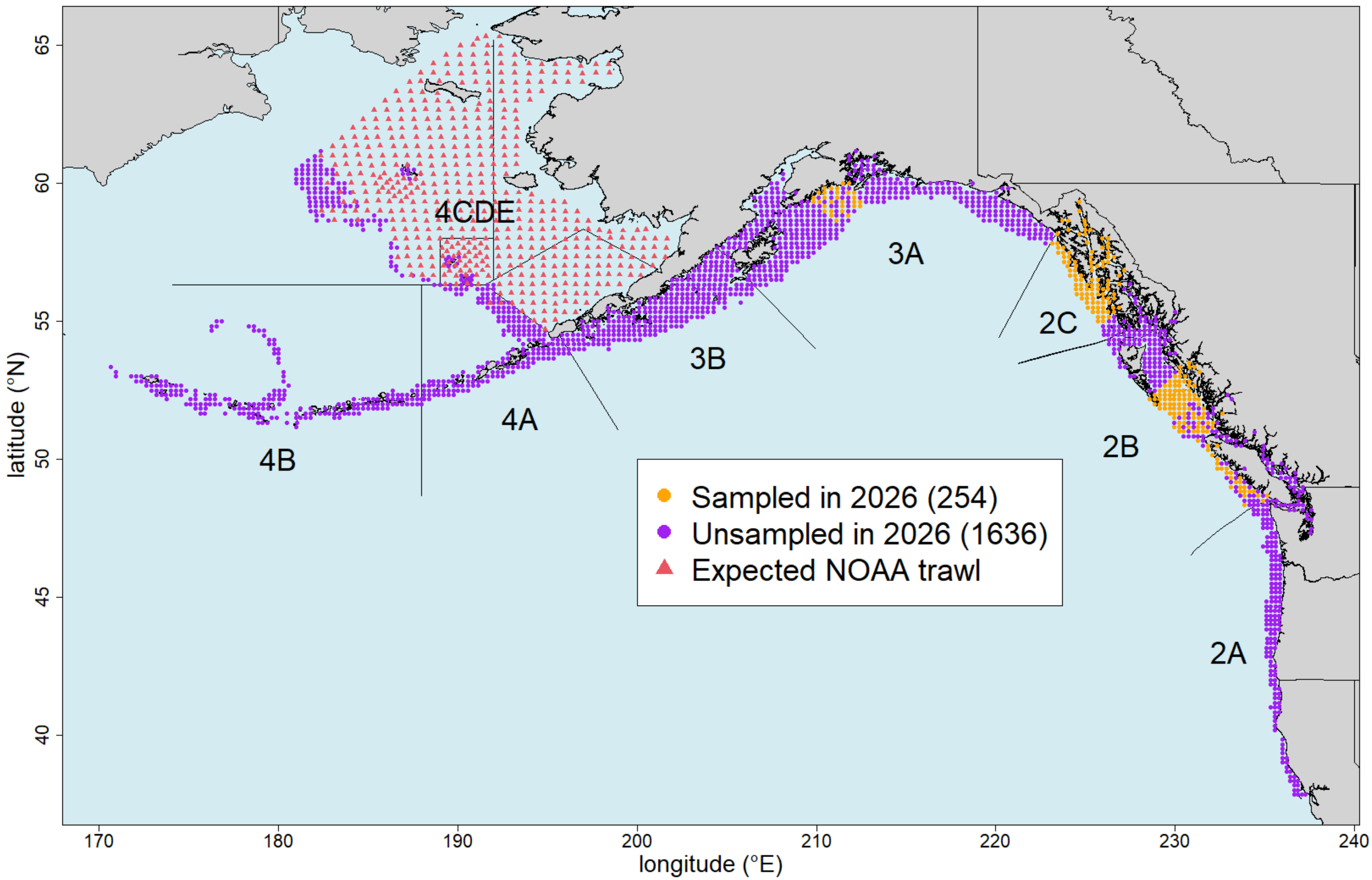

Figure 8. Preliminary Reduced Loss design for 2026 (orange circles). Note that stations in partially-sampled charter regions (2B and 3A) are only for the purpose of illustrating the spatial extent of the design. Actual stations to be fished within partially-sampled charter regions will be selected at a later date based on the priorities in Table 1.

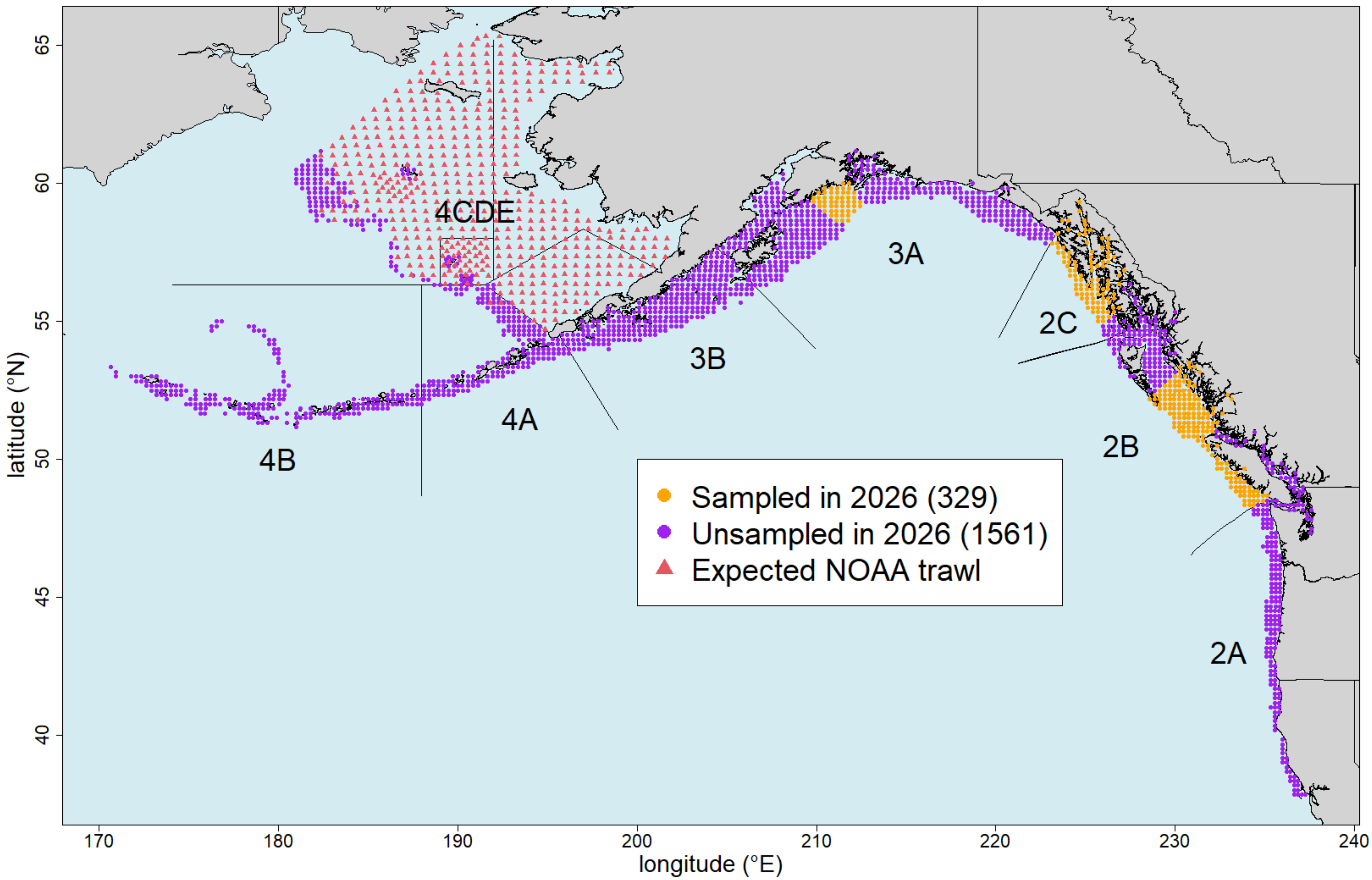

Figure 9. Preliminary Option 2 design for 2026 (orange circles).

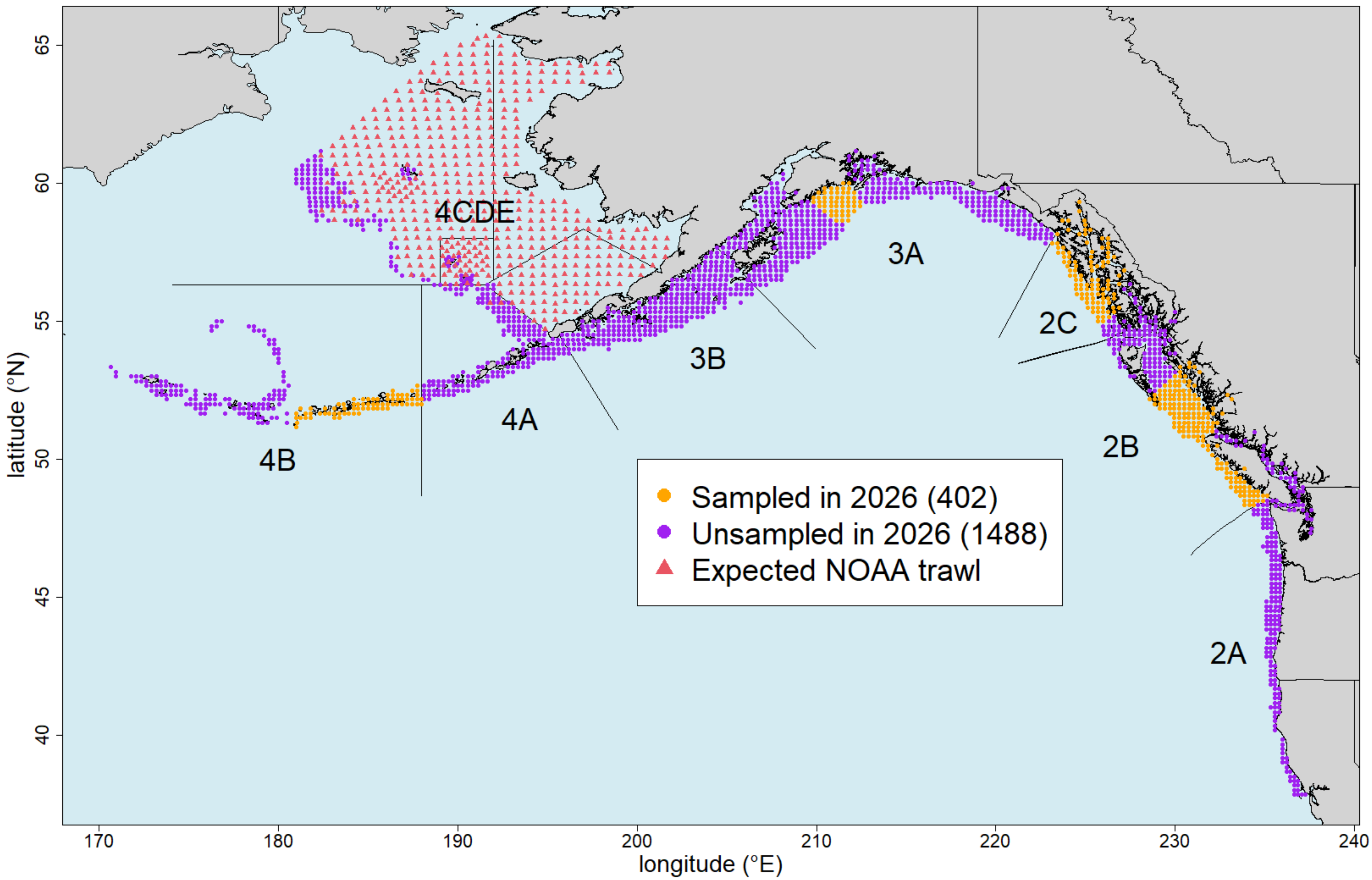

Figure 10. Preliminary Option 3 design for 2026 (orange circles).

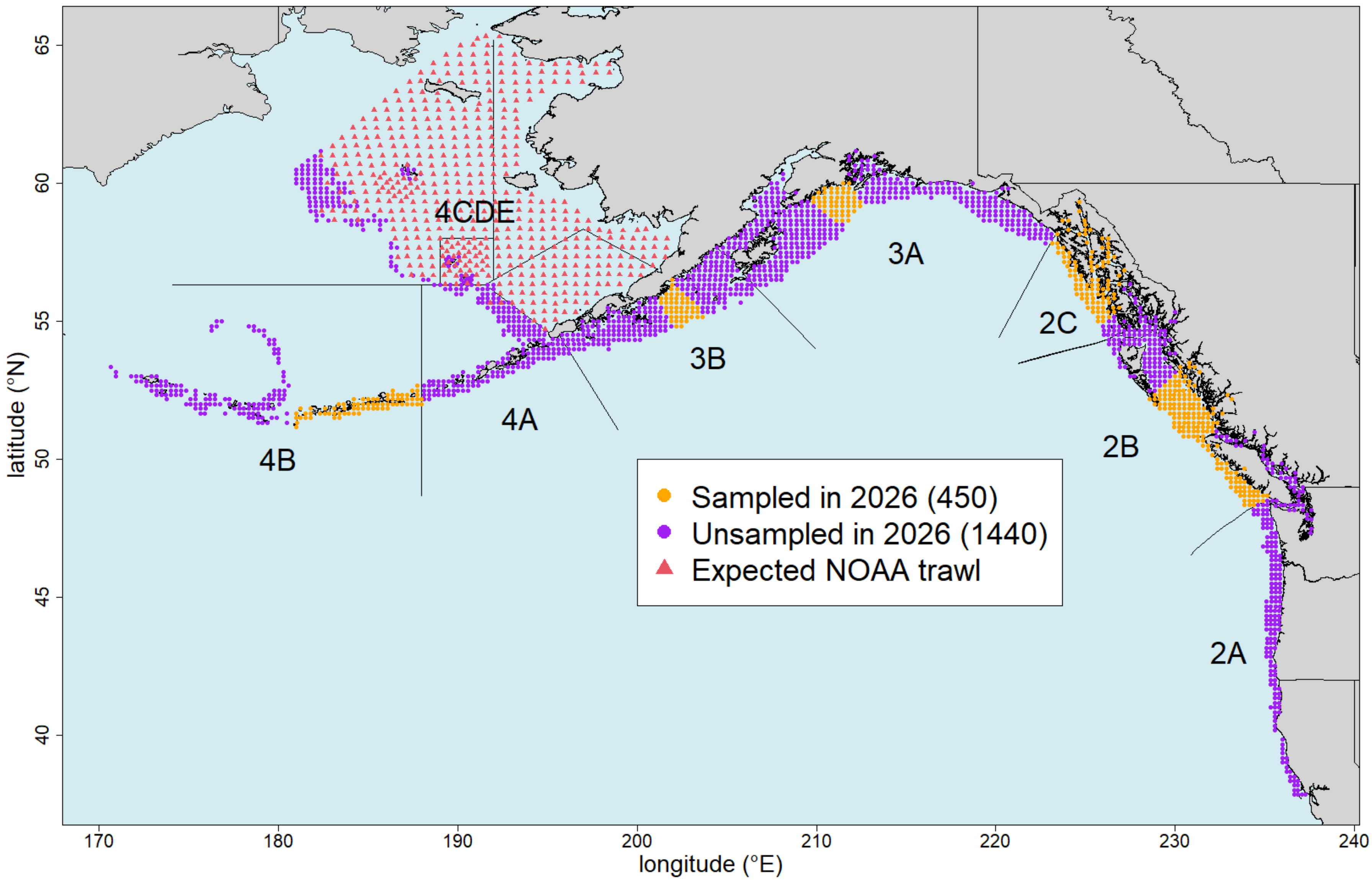

Figure 11. Preliminary Option 4 design for 2026 (orange circles).

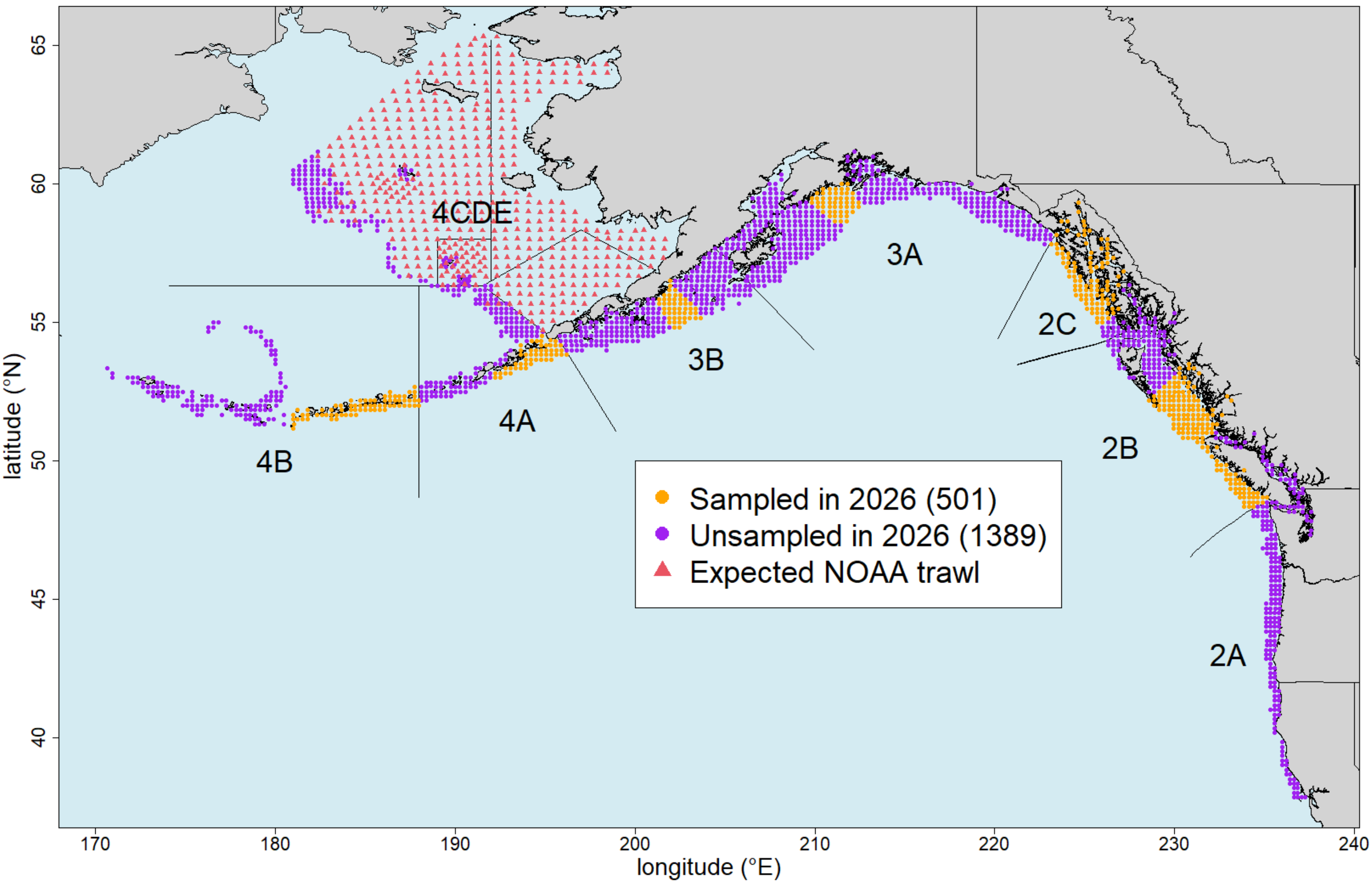

Figure 12. Preliminary Option 5 design for 2026 (orange circles).

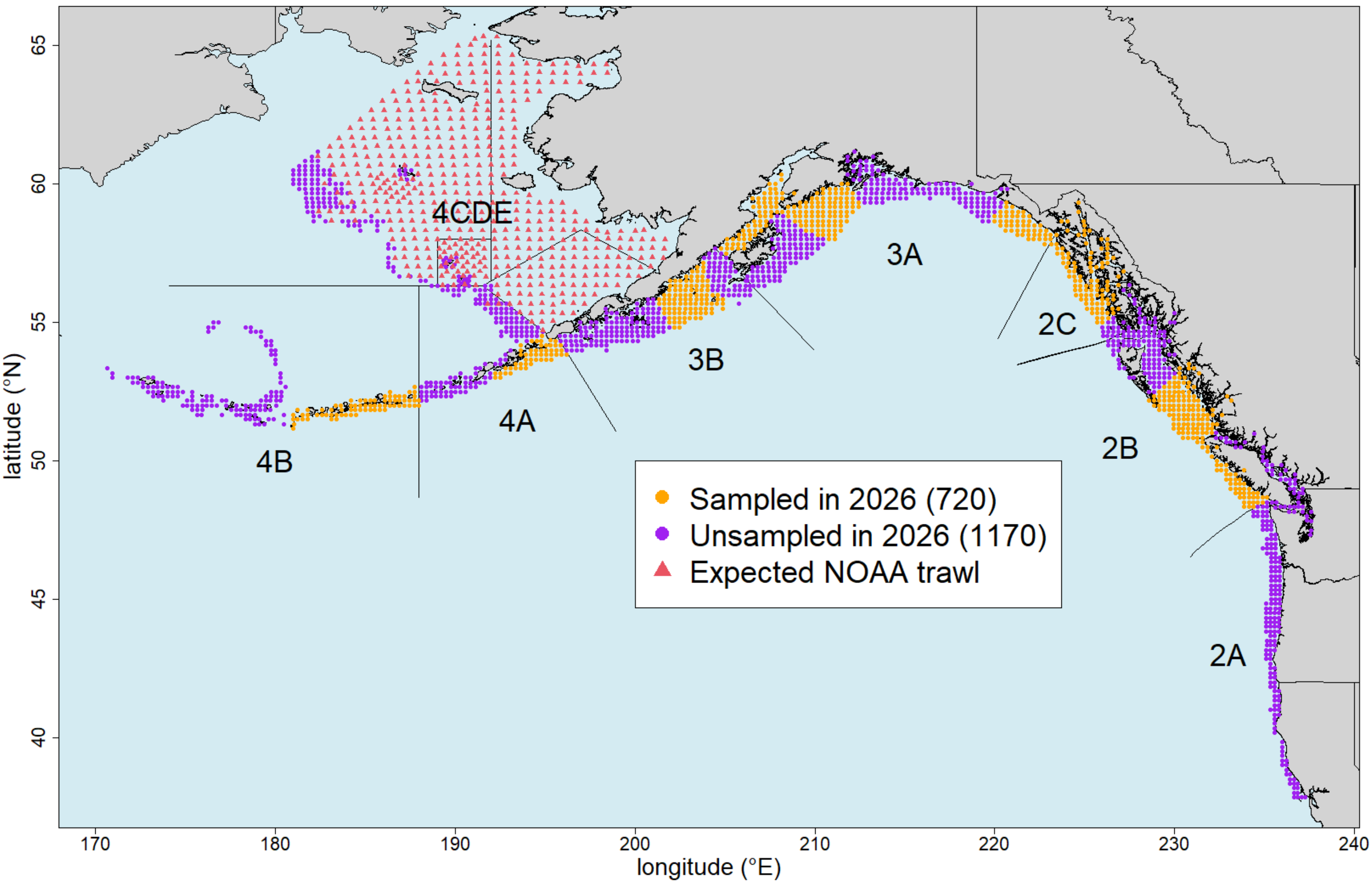

Figure 13. Preliminary Option 6 design for 2026 (orange circles).

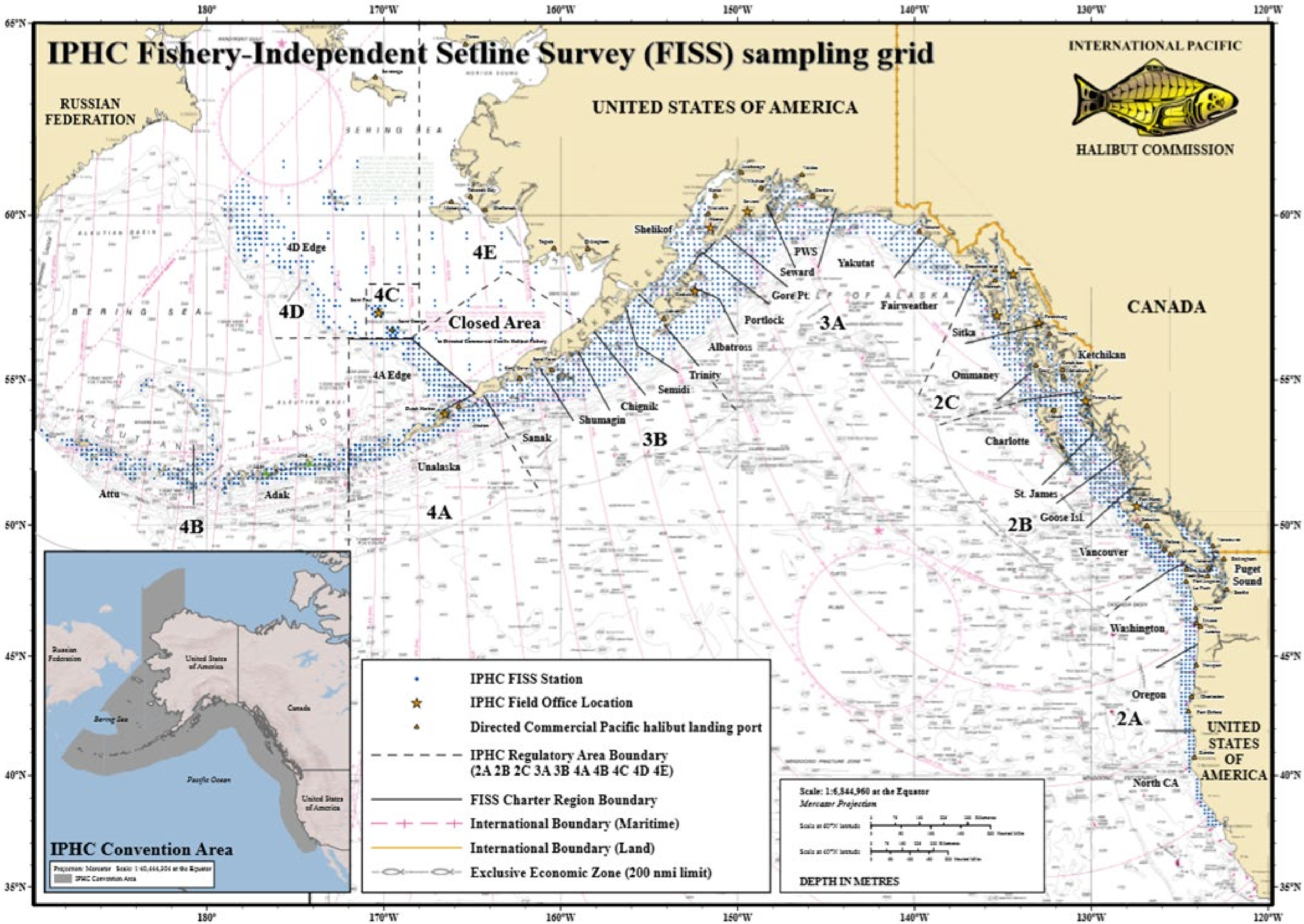

Figure 14. IPHC FISS showing full station grid and current FISS charter regions.

PART 2: MODELLING UPDATES

PURPOSE

To summarise recent work on coastwide modelling of Pacific halibut survey data, with application to histological data collected on the IPHC's fishery-independent setline survey from 2022-24.

BACKGROUND

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 15.

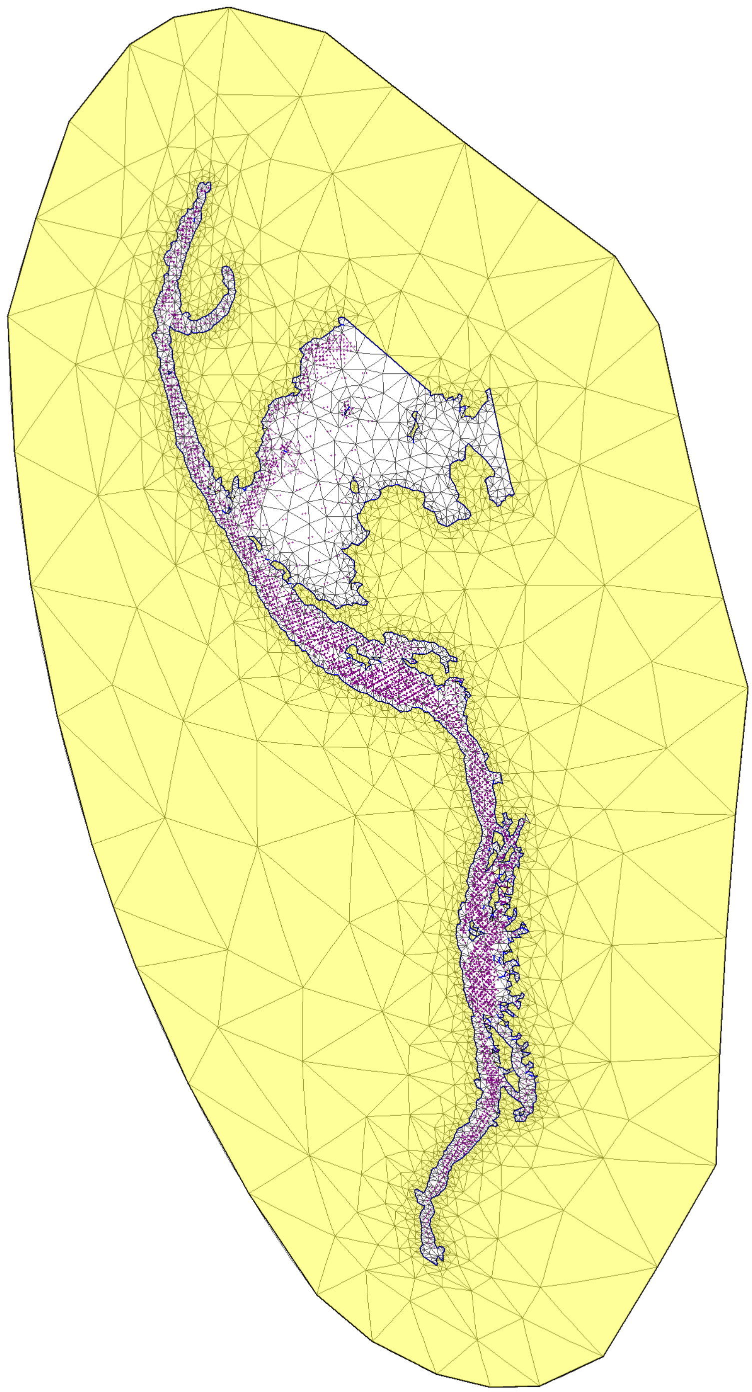

Figure 15. Triangulated mesh used in spatio-temporal modelling of histological maturity data. Barriers are shown with yellow shading**.**

Test case: histological data modelling

Currently, generalized additive models (GAMs) are used to estimate the relationship between maturity probability and age by IPHC biological region. The GAM models allows flexibility from a strict logistic model (i.e., linear on the logit scale), but as noted, still require the assumption of independent observations.

Spatio-temporal modelling of histological maturity data is still in its early stages, but to date we have fitted several 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.

Early model fitting to the 2022-24 data suggests that logistic models with spatially-varying parameters provide a better fit and more meaningful results than those with fixed effects for region. The latter models show sharp discontinuities at regional boundaries, something that makes no sense in biology, while the former project smooth variation in model output across space, as illustrated by A50 estimates in Figure 16. Note that the output in this figure is broadly consistent with previous GAM modelling results (Planas et al. 2025) that show 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). However, the model output in Figure 16 is also able to show variation in A50 values *within* each Biological Region. Further output will be shown in the accompanying presentation at SRB027.

Coastwide 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, expanding models to include year effects and temporal correlation, and computing cross-validation metrics for model comparisons.

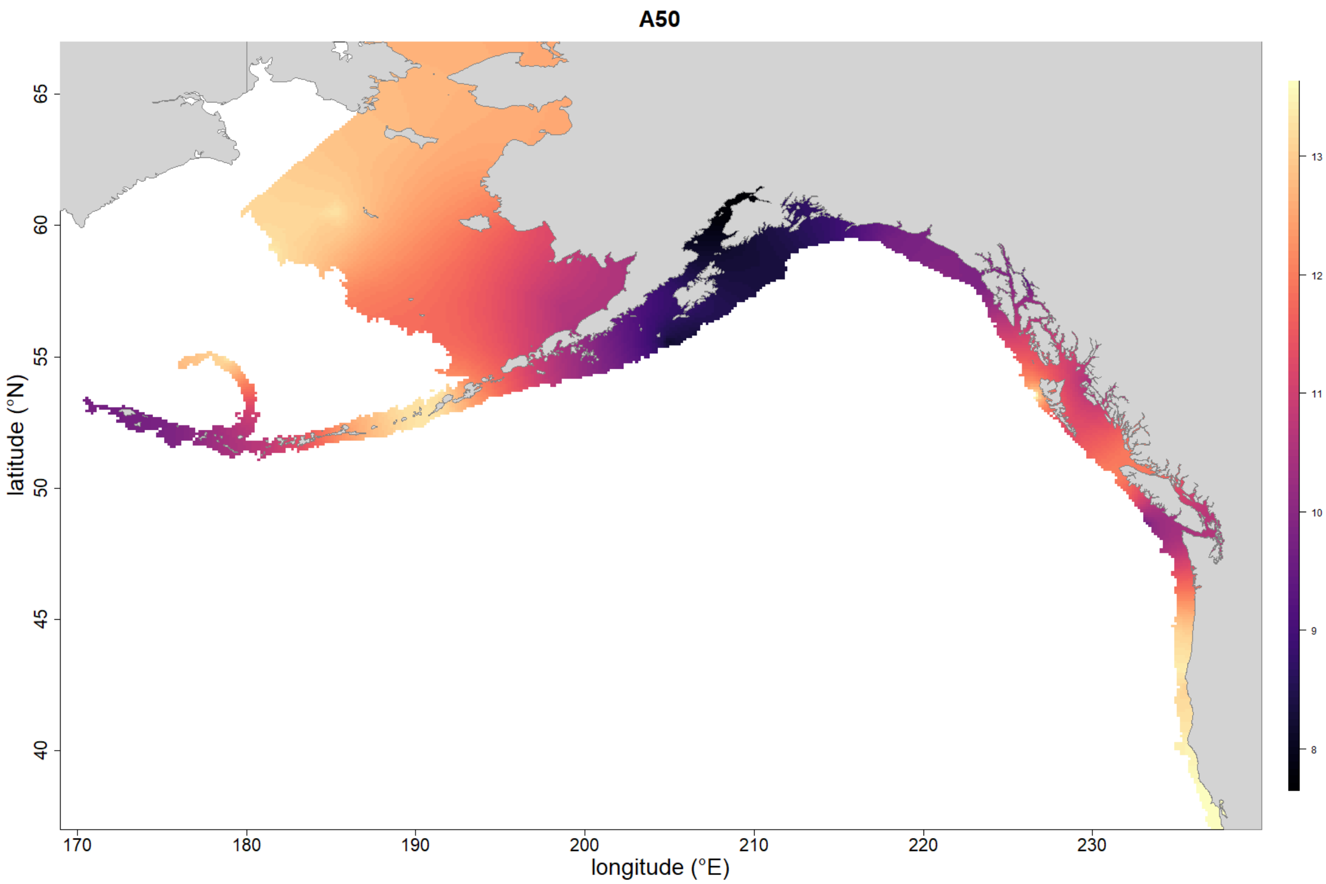

Figure 16. Projected A50 values from fitting a spatial model to 2022-24 histological maturity data with spatially-varying slope and intercept values.

RECOMMENDATION

That the Scientific Review Board **NOTE** paper IPHC-2025-SRB027-09 (Part 2), which summarises recent work on coastwide modelling of Pacific halibut survey data, using histological maturity data as a test case.

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