INTERNATIONAL PACIFIC HALIBUT COMMISSION

Fishery-Independent Setline Survey (FISS) design evaluation

Agenda item: 4.1

IPHC-2020-SRB016-05

Summary

- Background
  - IPHC history of FISS, 1993-2010
  - FISS expansions 2011-19
  - Space-time modelling
  - FISS design objectives
  - Review process
- FISS design evaluation
  - Precision targets
  - Potential for bias
  - Analytical methods

Summary

- Sampling design options
  - ‘Core’ areas vs ends of stock
- Design proposals for 2020-22
  - ‘High efficiency’ subarea proposal
  - Compromise proposal
- Consideration of cost
- Proposed revision for 2021-23
- Implications of the 2020 design

IPHC FISS

- Provides data for estimating weight and numbers per unit effort (WPUE and NPUE) indices of density and abundance of Pacific halibut
  - Used to estimate stock trends
  - Used to estimate stock distribution
  - Important input in the IPHC stock assessment
- Provides biological data for use in the stock assessment

FISS history 1993-2010

- A standardised FISS has been conducted by the IPHC each year since 1993
  - Standardised for bait and fishing gear
- From 1993-97 coverage was limited and generally restricted to IPHC Regulatory Areas 2B, 2C, 3A and 3B
- The modern FISS design on a 10 nmi grid began in 1998
- By 2001, annual coverage occurred in all IPHC Regulatory Areas
  - Depth range 20-275 fathoms in Gulf of Alaska and Aleutian Islands
  - Depth range 75-275 fathoms along Bering Sea shelf edge

FISS history 2011-2019

- By 2010, data from other sources showed that not all Pacific halibut habitat was covered by the FISS
  - Pacific halibut were present outside the FISS depth range, in both deep and shallow waters
  - All IPHC Regulatory Areas had coverage gaps within the standard depth range
- Such unsampled habitat meant there was the potential for bias in estimates derived from FISS data
- This led IPHC staff to propose expanding FISS coverage to include the unsurveyed habitat

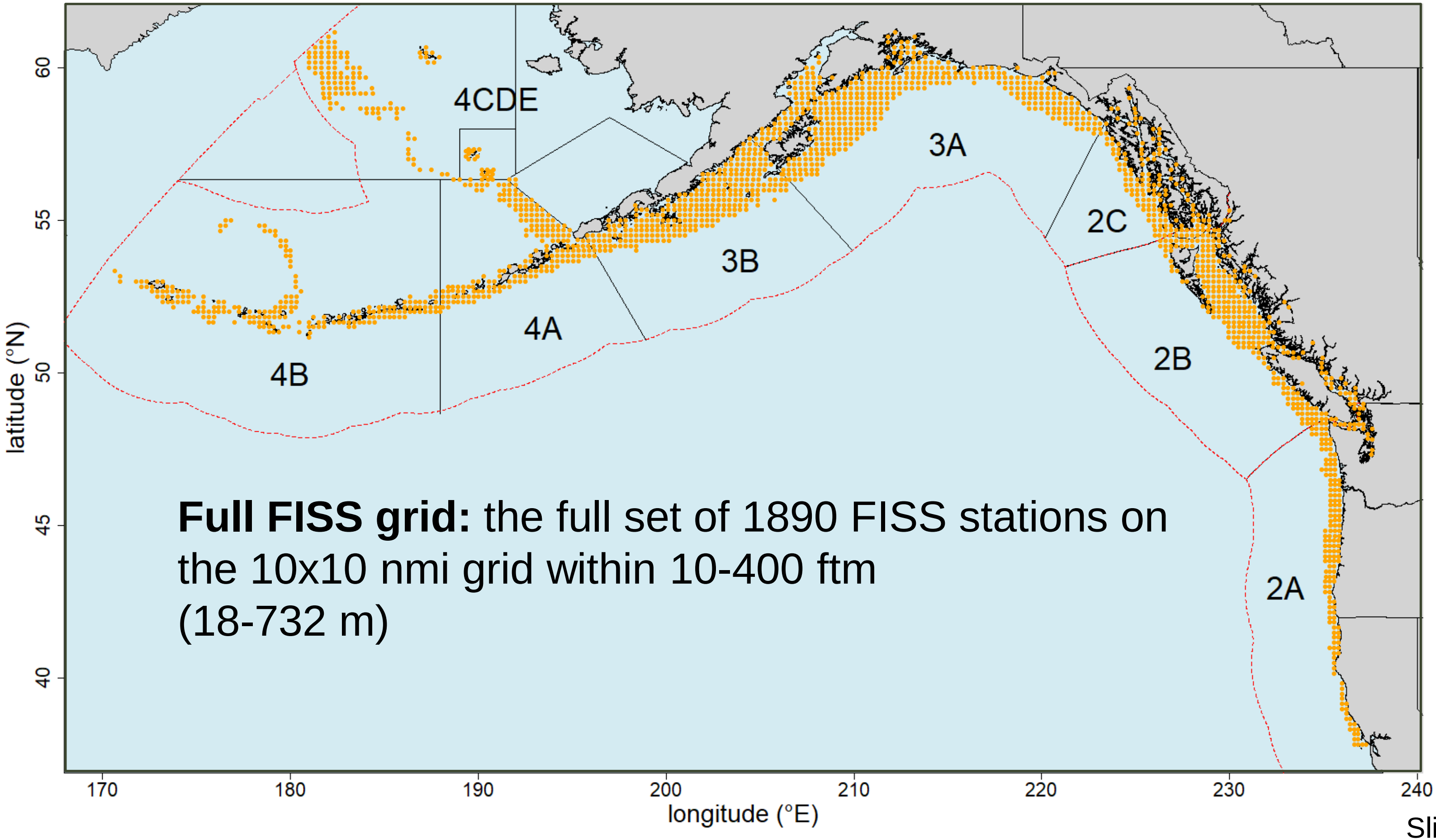
FISS history 2011-2019

- Pilot FISS expansions were undertaken in IPHC Regulatory Area 2A in 2011 (deep, shallow waters, other “missing” stations) and 2013 (northern California)
- From 2014-19, a planned program of FISS expansions took place in all IPHC Regulatory Areas as follows (with previously unsampled % of stations):
  – 2014: Regulatory Areas 2A and 4A (42%)
  – 2015: Regulatory Area 4CDE eastern Bering Sea flats
  – 2016: Regulatory Area 4CDE shelf edge (62%)
  – 2017: Regulatory Areas 2A (46%) and 4B (55%)
  – 2018: Regulatory Areas 2B (42%) and 2C (25%)
  – 2019: Regulatory Areas 3A (18%) and 3B (19%)

FISS history 2011-2019

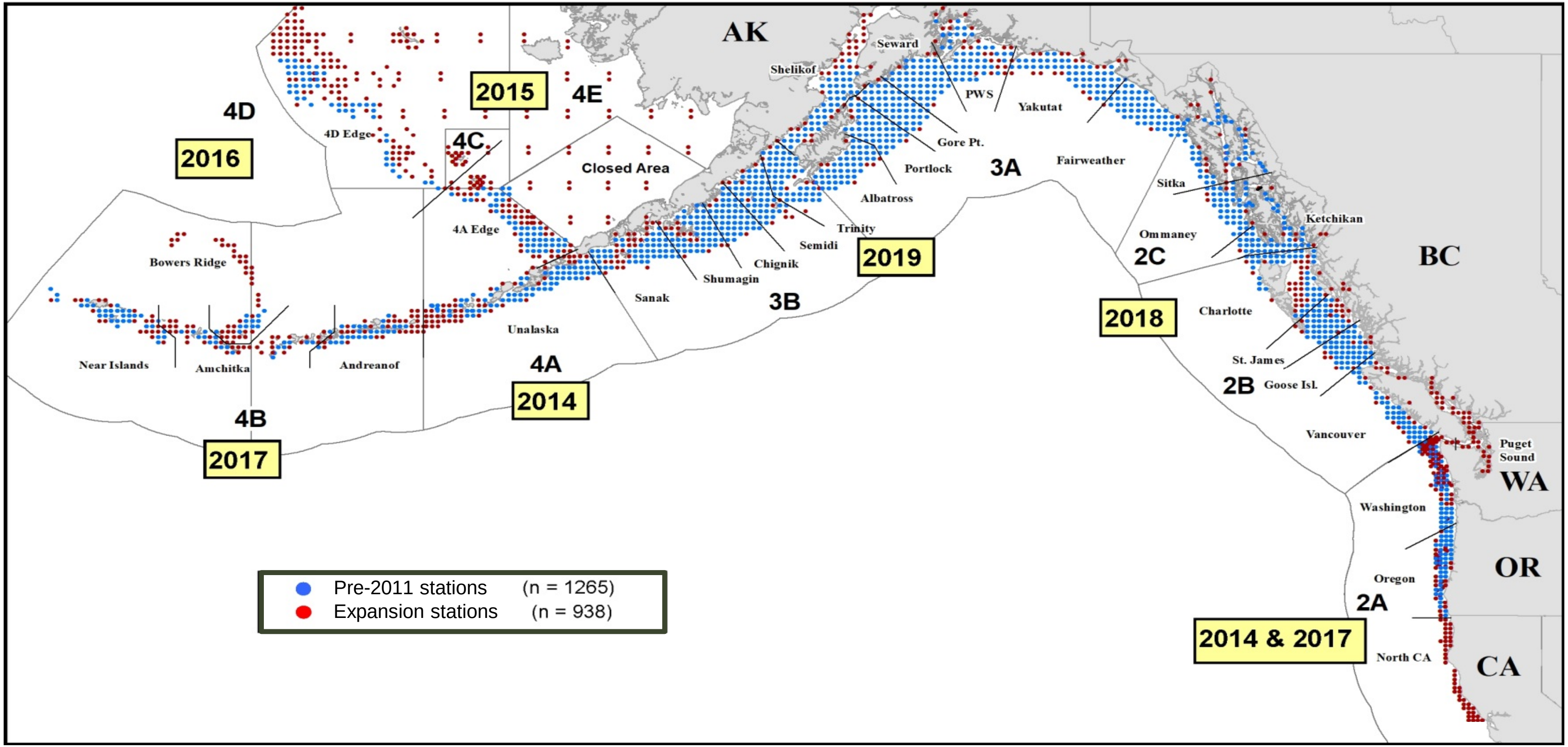
- During the expansions, the FISS occupied for the first time 34% of the stations on the full 10 nmi FISS grid that had been previously unsampled
- The result was an improved understanding of Pacific halibut density and distribution
  - Bias was reduced, with indices for several Regulatory Areas being revised upwards or downwards
  - Uncertainty in estimates of WPUE and NPUE was reduced in most Regulatory Areas
  - These improvements were apparent throughout the time series, not only in the year of the expansion
- The resulting expanded grid of 1890 stations has provided a full FISS design from which stations can be selected for sampling in each annual FISS

Full FISS grid



Full FISS grid: the full set of 1890 FISS stations on the 10x10 nmi grid within 10-400 ftm (18-732 m)

Comparison with pre-expansion stations



Space-time modelling

- Space-time modelling of survey data has been used since 2016 to produce WPUE and NPUE estimates
- The modelling has two key purposes:
  - It smooths the data in time and space
    - Makes use of information on spatial and temporal relationships among survey stations to “sort the signal from the noise”
  - It fills in gaps in survey coverage using model predictions, while accounting for uncertainty

Review of space-time modelling

- The IPHC's Scientific Review Board (SRB) has repeatedly endorsed the space-time modelling approach, e.g., in 2018:

  IPHC-2018-SRB013-R, Para. 10. *"NOTING that this is the sixth review of the space-time modelling approach, the SRB reiterated its ENDORSEMENT of the approach as cutting-edge and could be widely used.*

- The space-time modelling methods have been accepted for publication:
  - Webster et al. (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

FISS objectives and 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

Review process

- Based on these objectives, staff has developed methods for evaluating potential future FISS designs, and has presented proposed designs for review
  - Evaluation methods were reviewed at SRB014
  - Design proposals for 2020-22 were presented at IM095 and AM096
  - At AM096, Commissioners adopted an enhanced version of one of the proposed designs

Review process

- Following the completion of the coastwide FISS expansion efforts, 2019/2020 was the first year fully rationalised designs could be proposed
- It is expected that the design proposal and review process going forward will be as follows:
  - Secretariat staff present design proposals to SRB for three subsequent years at the June meeting
  - First review of design proposals by Commissioners at September work meeting, revised if necessary based on SRB input
  - Presentation of proposed designs at the November Interim Meeting
  - Designs presented and potentially modified at January/February Annual Meeting given Commissioner direction
  - Adopted AM design for current year modified for cost and logistical reasons prior to summer implementation in FISS (February-April)

Evaluating FISS design proposals

- Set data quality targets
- Determine geographic sampling priorities and sampling frequency
- Test designs on simulated data sets
- Propose design options
- If necessary, modify designs to account for cost and logistics

Precision targets

- To maintain data quality, we proposed the following targets on coefficient of variation (CV):

Management unit	O32 WPUE	All sizes WPUE	All sizes NPUE
Reg Area (all)	15%	15%	NA
Bio Regions 2, 3, 4	10%	10%	10%
Bio Region 4B	15%	15%	15%
Coastwide	NA	NA	10%

Potential for bias

- Failure to observe and account for changes in WPUE or NPUE in an unsurveyed subarea (portion of a Regulatory Area) can lead to bias
- Therefore, it is important to undertake the FISS frequently enough to keep any bias small
- For this, we proposed a threshold of a 10% absolute change in biomass percentage: how quickly can a subarea's percent of the biomass of a Regulatory Area change by at least 10%?
- Potential for appreciable bias can be minimised by sampling each subarea with sufficient frequency
  - Guided by relative changes in the historical time series for subareas within each Regulatory Area
- Methods reviewed in detail during SRB014

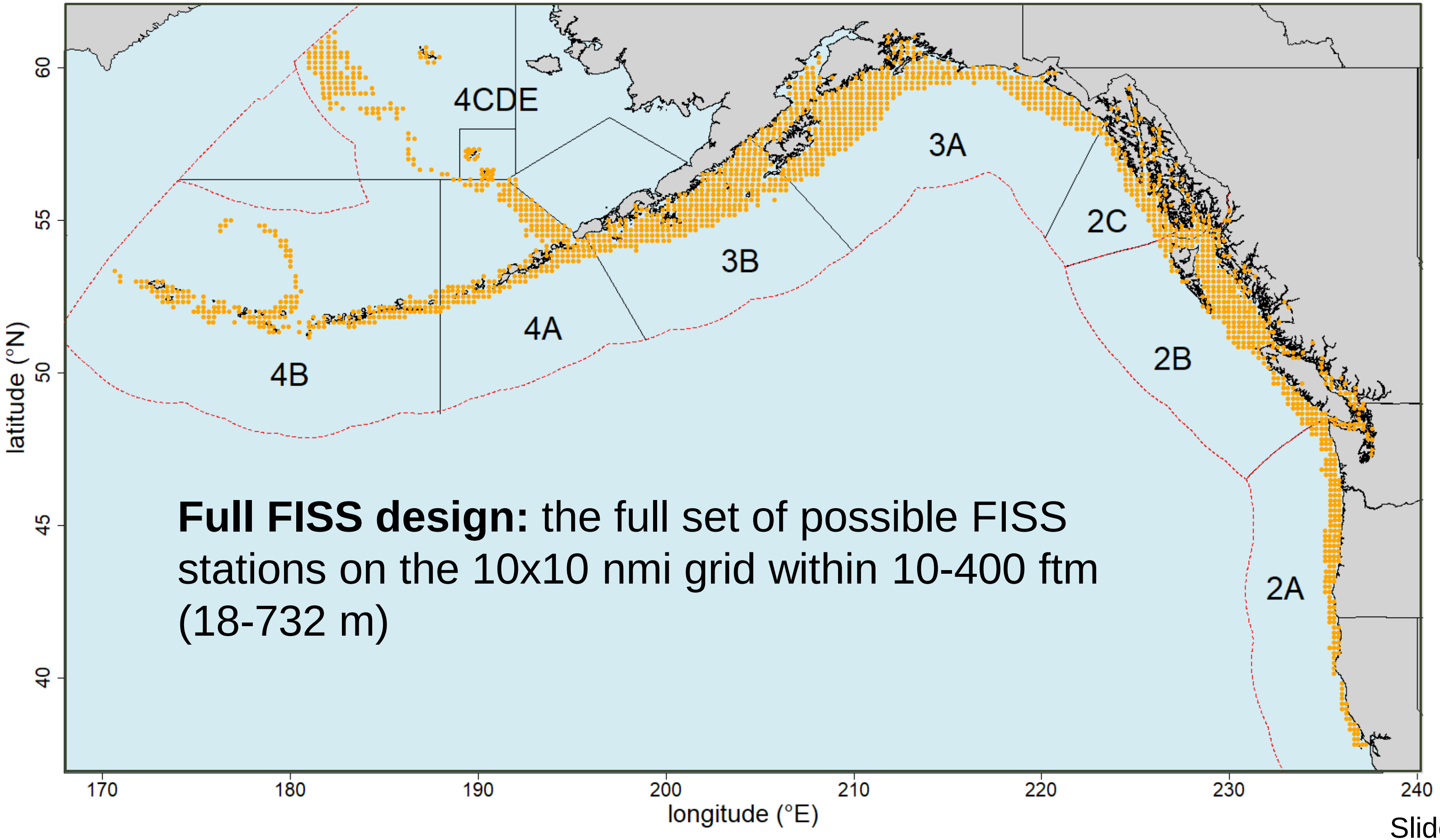
Analytical methods

- We examined the effect of subsampling a management unit on precision as follows:
  - Where a randomized design is not used, identify logistically feasible 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 was not considered worthwhile
  - Evaluation undertaken following collection of data during the one to three-year time period to substantially influence design choices for subsequent years.
  - In this manner, projected designs can be evaluated and then efficiently updated to reflect observed data as they become available.

Sampling design options

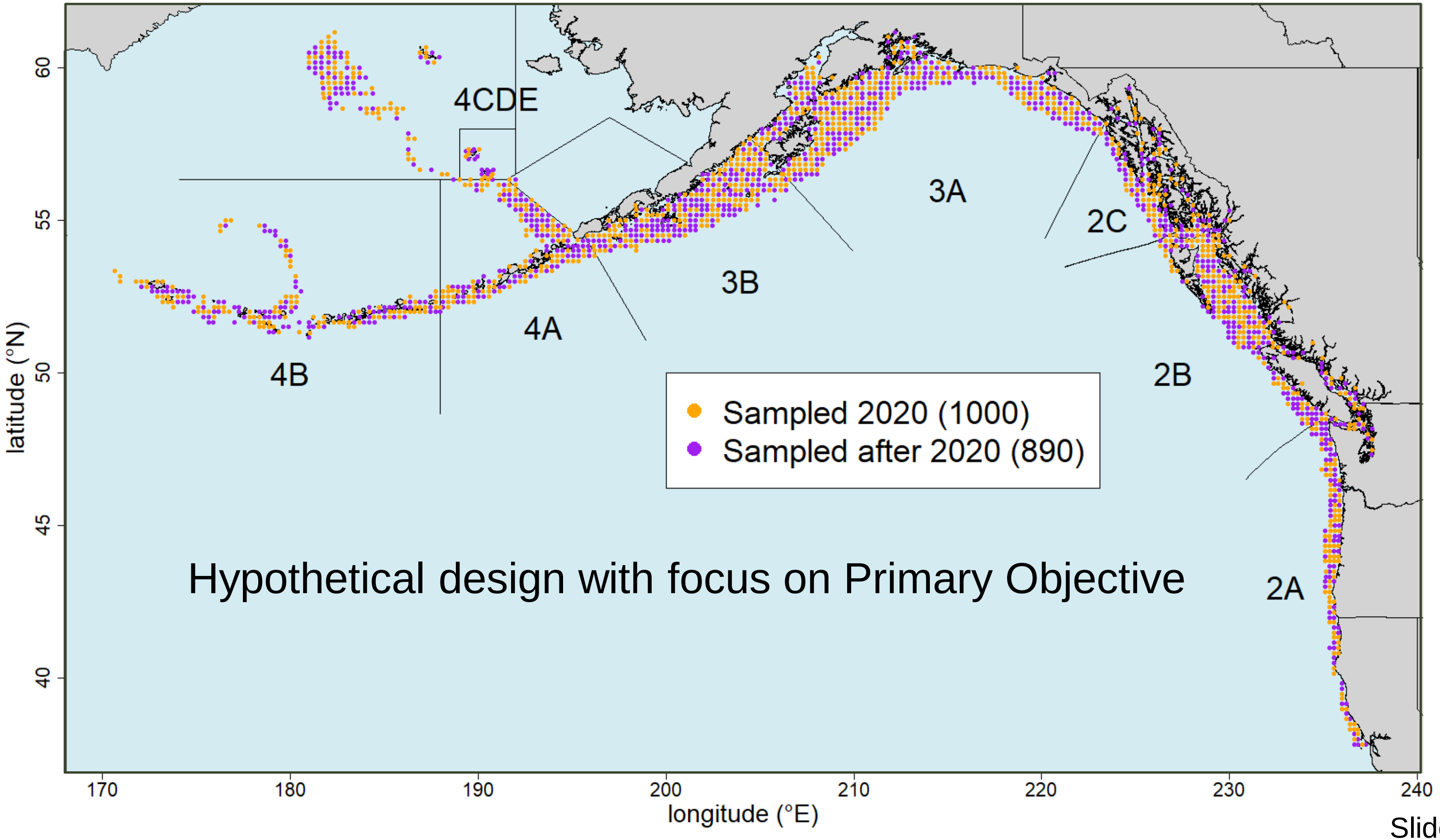
- We discussed several potential annual FISS design options during recent meetings:
  - Sample full 1890-station FISS design
  - Completely randomized sampling within each Regulatory Area
  - Randomized cluster sampling, with logistically efficient clusters of 3-4 stations sampled at random
  - Subarea sampling, where Regulatory Areas are divided into distinct subareas based on density, geography and biology

Full FISS design

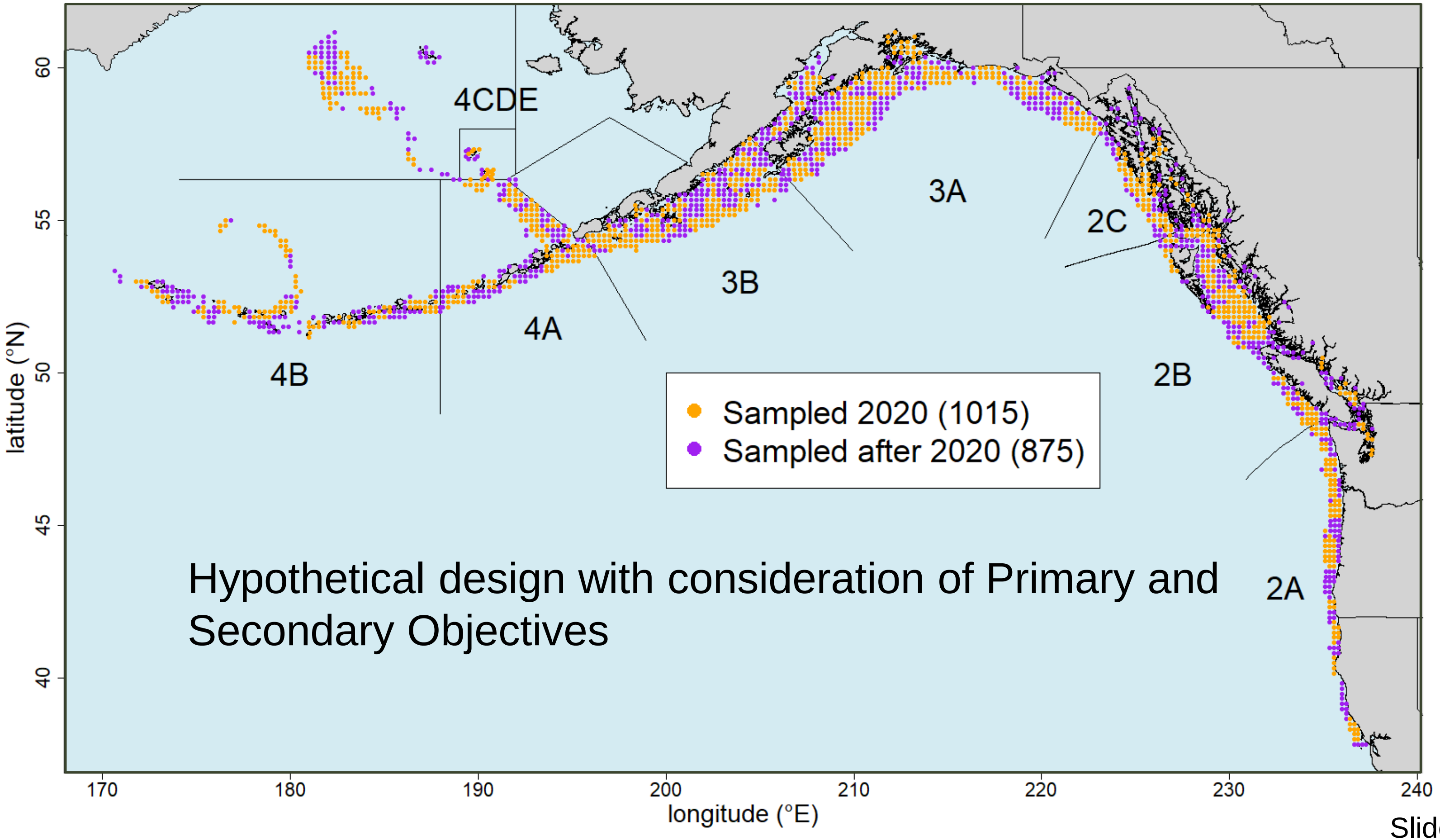


Full FISS design: the full set of possible FISS stations on the 10x10 nmi grid within 10-400 ftm (18-732 m)

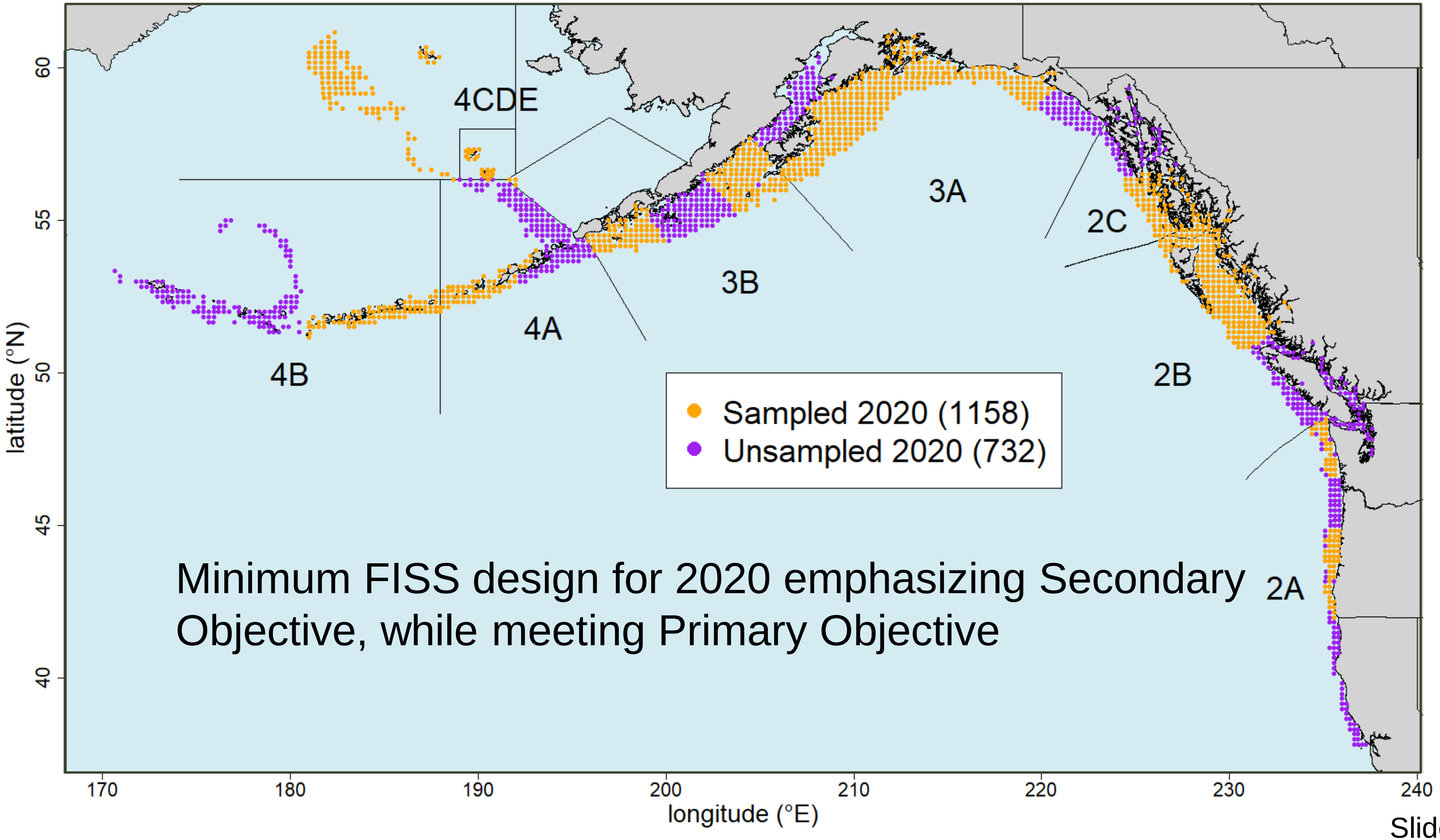
Completely randomised design



Randomized cluster design



Subarea design (a 2020 proposal)



Core Regulatory Areas

- Regulatory Areas 2B to 3B comprise the current core of the Pacific halibut stock
- Generally high relative density throughout these areas
- We considered two design options:
  1) Randomised sampling
  2) Subarea sampling, in which not all FISS regions are sampled each year
     - This option places a high priority on logistics (Secondary Objective)

Regulatory Areas 2A, 4A and 4B

- These Regulatory Areas each contain local areas of relatively high and low densities
- Evaluations of subarea-based designs show Primary Objectives can be met by
  - Prioritising the sampling of high density, temporally variable subareas by sampling these frequently (e.g. annually)
  - Sampling other subareas less frequently

Regulatory Area 4CDE

- Regulatory Area 4CDE estimation depends heavily on other surveys
- While it may be possible to reduce FISS sampling and still meet precision/bias targets, we note:
  - 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 has increased interest in better understanding density trends and possible links with Russian waters
- Therefore, in all designs we proposed repeating the full FISS grid on the Regulatory Area 4D shelf edge, last fished in 2016

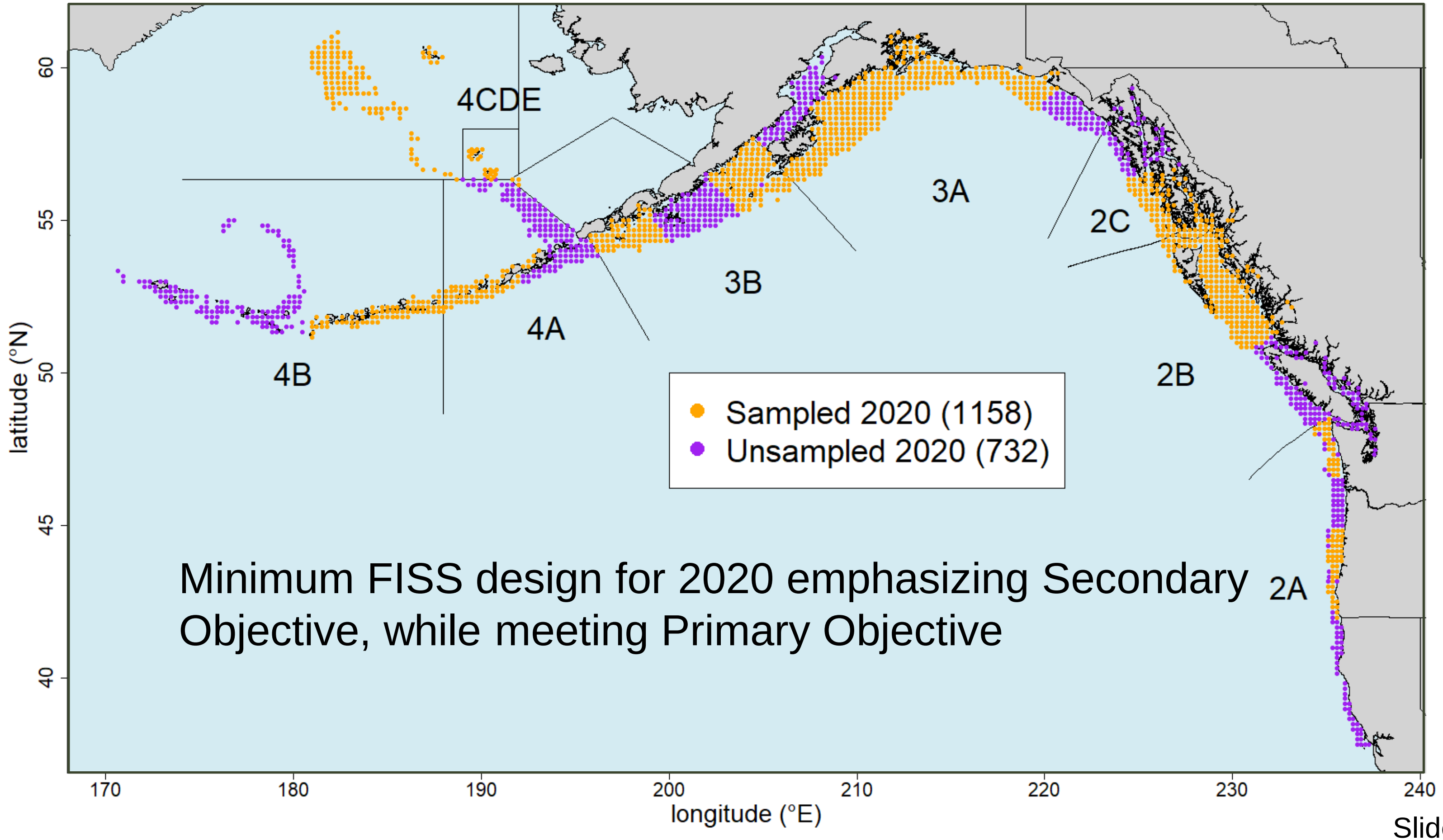
Design proposals for 2020-22

- The following designs were presented at AM096
- Designs meet the Primary Objective of sampling Pacific halibut for the assessment/stock distribution
- They could be added to in order to meet other objectives related to science, logistics/cost, and resource extraction/policy
  - Indeed, the adopted design was an enhanced version of one of the proposed designs

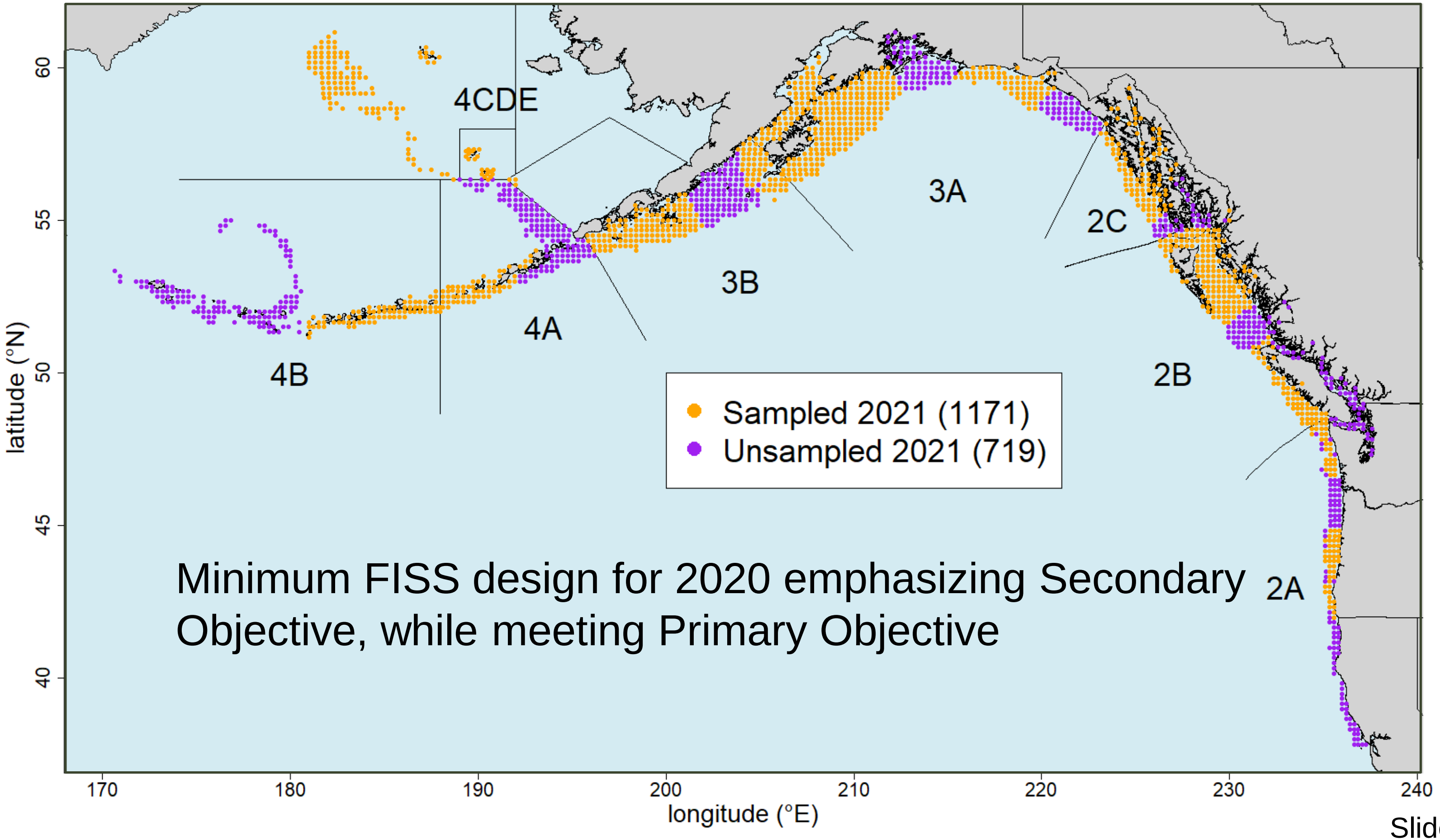
Proposal 1: “High Efficiency” subarea design

- This design depends entirely on fishing subareas, i.e. large clusters of adjacent stations
- While it meets the Primary Objective, it also heavily emphasizes the Secondary Objective by accounting for logistics and cost.

Proposal 1: High Efficiency design 2020

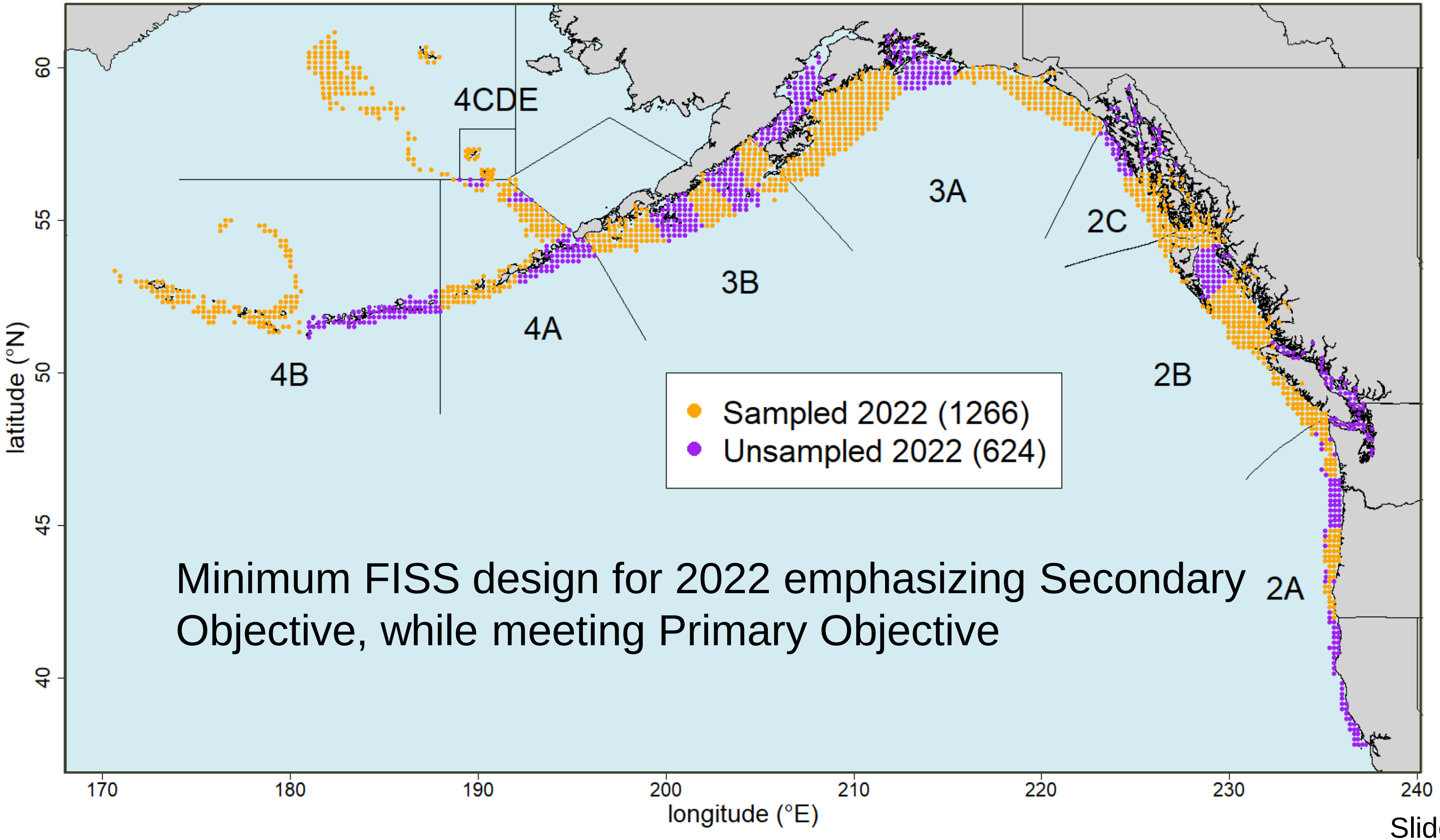


Proposal 1: High Efficiency design 2021



Minimum FISS design for 2020 emphasizing Secondary Objective, while meeting Primary Objective

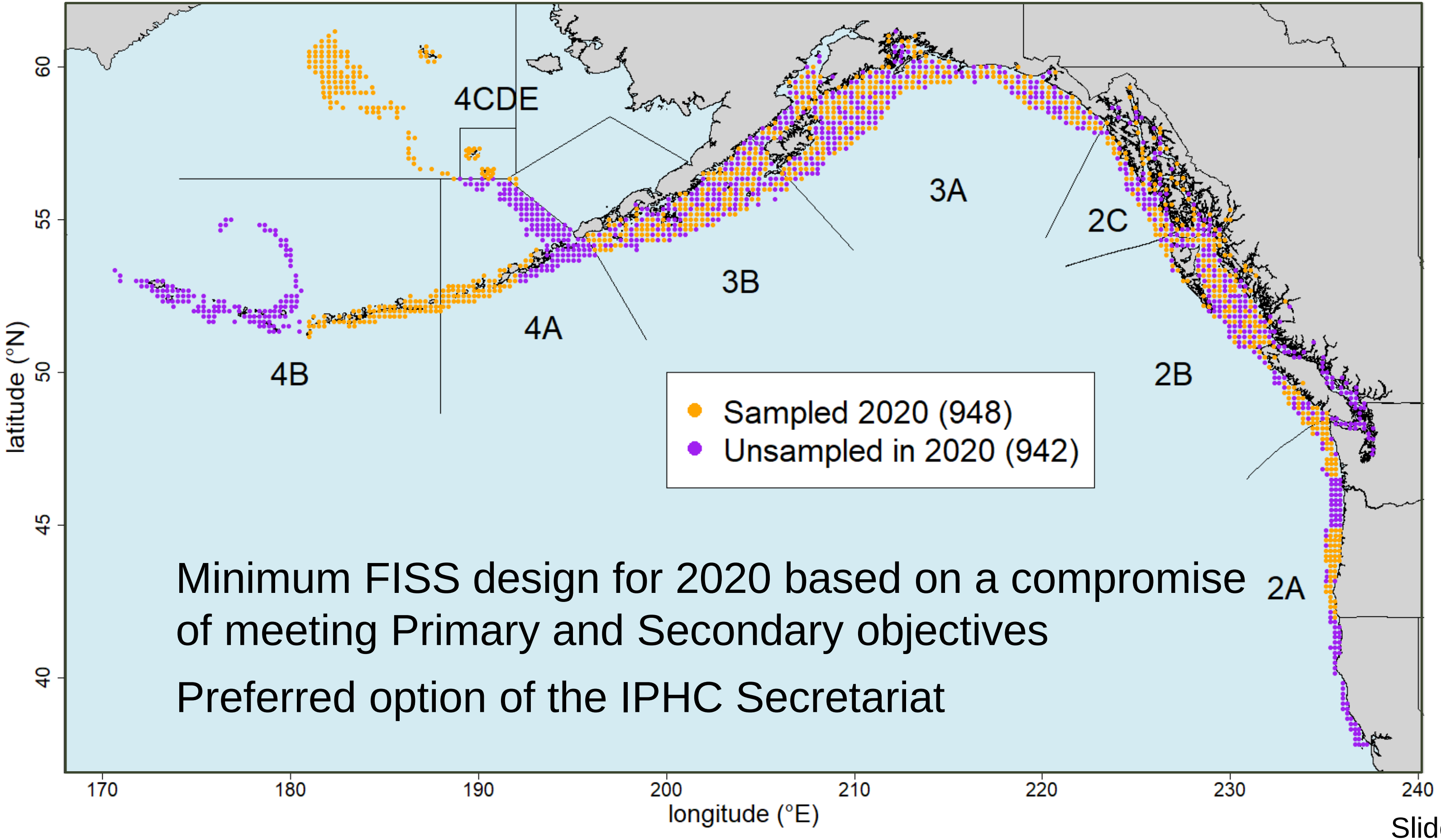
Proposal 1: High Efficiency design 2022



Proposal 2: Compromise design

- Preferred option of the IPHC Secretariat
- Uses a randomised design in the core Regulatory Areas, and a subarea design elsewhere
- The focus is on the Primary Objective, but operational efficiency is considered by fishing low-density and/or stable subareas less frequently

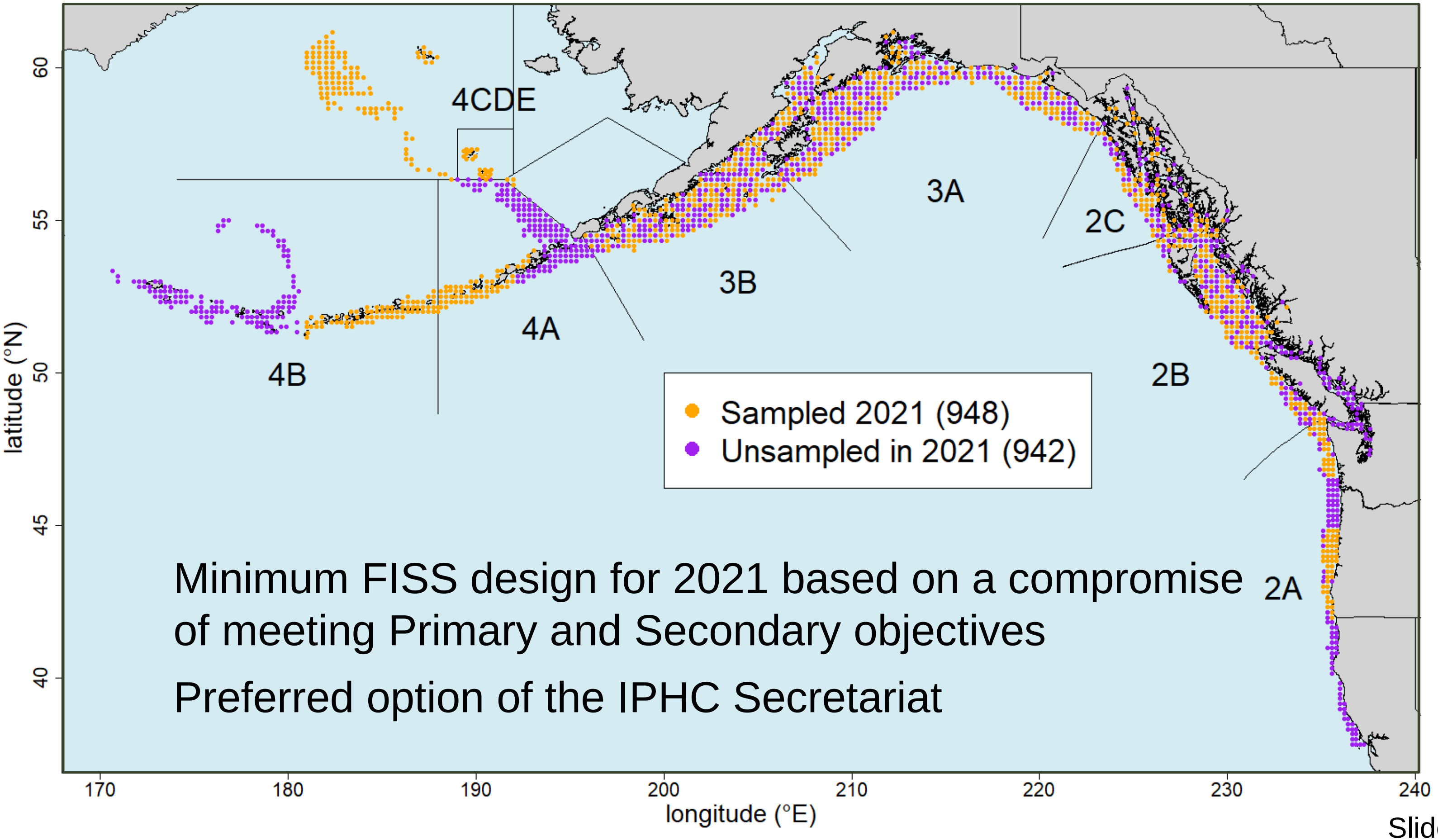
Proposal 2: Compromise design 2020



Minimum FISS design for 2020 based on a compromise of meeting Primary and Secondary objectives

Preferred option of the IPHC Secretariat

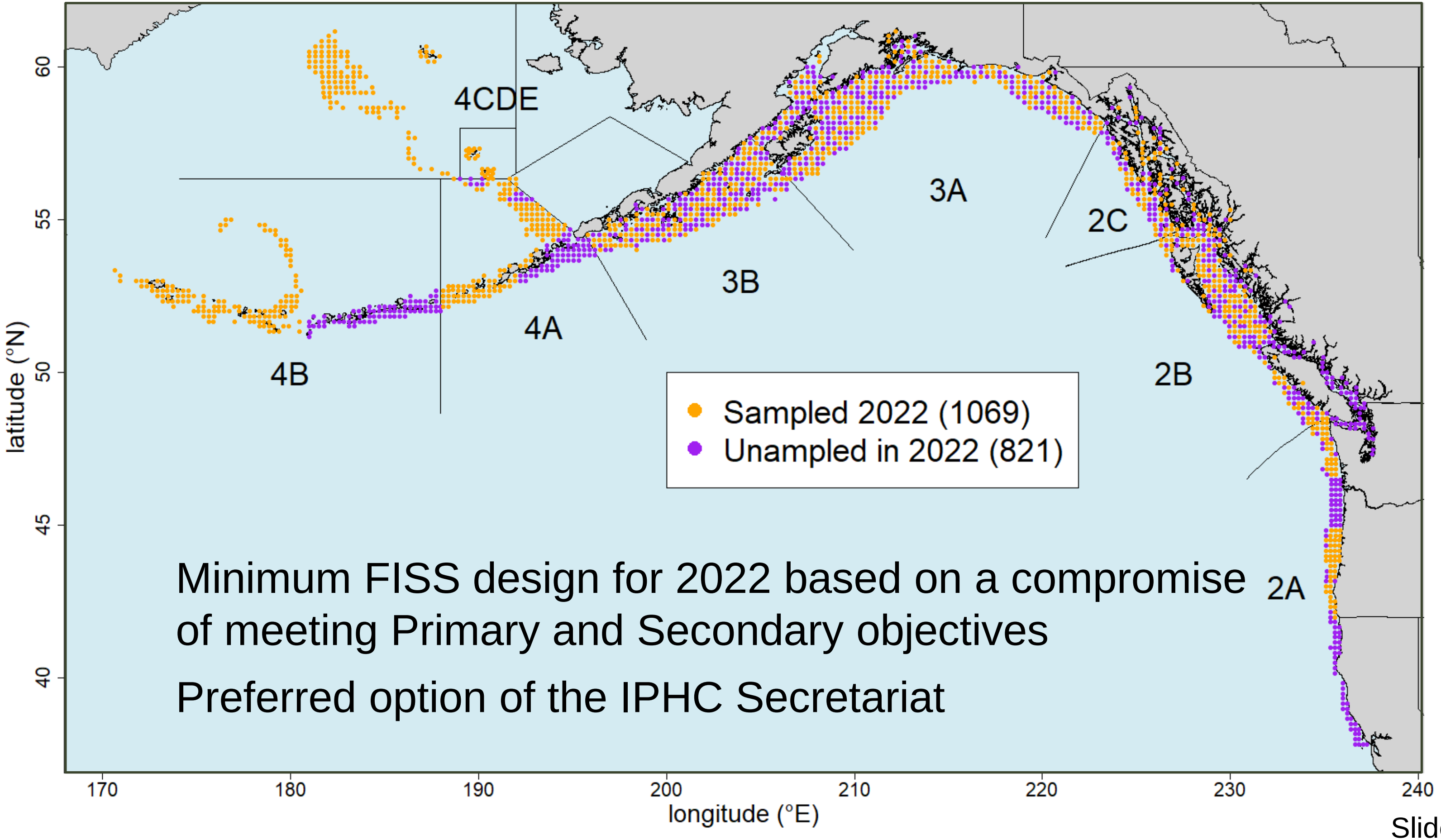
Proposal 2: Compromise design 2021



Minimum FISS design for 2021 based on a compromise of meeting Primary and Secondary objectives

Preferred option of the IPHC Secretariat

Proposal 2: Compromise design 2022



Minimum FISS design for 2022 based on a compromise of meeting Primary and Secondary objectives

Preferred option of the IPHC Secretariat

Projected CVs for 2020-22 for the compromise design. Target CV is 15% in all IPHC Regulatory Areas.

Regulatory Area	Projected CV (%)		
	2020	2021	2022
2A	13.0	13.0	14.2
2B	6.2	6.0	6.4
2C	6.4	6.3	6.7
3A	4.8	4.9	5.1
3B	8.2	8.2	8.5
4A	9.6	9.3	9.7
4B	8.7	8.7	14.2

Consideration of cost

- Both the subarea and compromise design incorporate some consideration of cost
  - Logistically efficient subarea designs in at least some IPHC Regulatory Areas.
- The goal here was to provide statistically efficient and logistically feasible designs for consideration by the Commission
- During the Interim and Annual Meetings and subsequent discussions, cost, logistics and tertiary considerations are also factored in developing the final design
- In particular, the FISS is funded by sales of captured fish and is intended to have long-term revenue neutrality, meaning that any design must also be evaluated in terms of the following factors:
  - Expected catch of Pacific halibut
  - Expected Pacific halibut sale price
  - Charter vessel costs, including relative costs per skate and per station
  - Bait costs
  - IPHC staffing costs

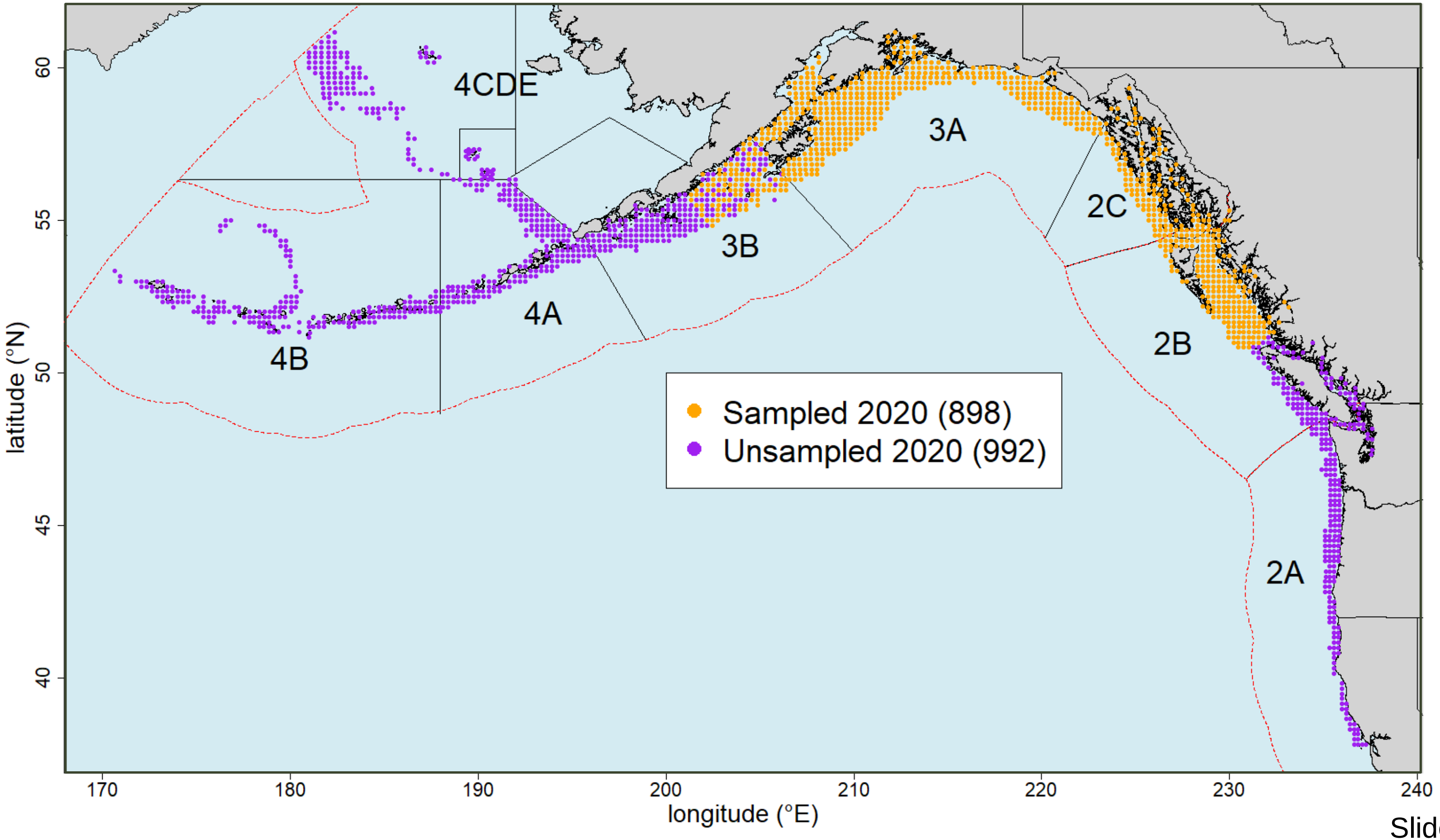
Consideration of cost

- Balancing these factors may result in modifications to the design proposals:
  - e.g., may need to increase sampling effort in high-density regions and decrease effort in low density regions
- At present, with stocks near historic lows and low prices for fish sales, the current funding model may require that some low-density habitat be omitted from the design entirely, as occurred in 2020
- This will have implications for data quality, particularly if such reductions in effort relative to proposed designs continue over multiple years.

Proposed revision for 2021-23

- Due to budgetary constraints and the impact of COVID-19, neither the proposed nor adopted AM096 designs are proceeding in 2020
- Instead, a design with sampling only within the core areas is being implemented for the 2020 FISS
- Because of this, our proposal for 2021-23 is to shift the 2020-22 Secretariat-preferred compromise proposal presented at AM096 to instead be implemented in 2021-23
- As discussed, 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
- 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.

Implemented 2020 FISS design



Implications of the 2020 design

- The reduced FISS in 2020 has implications for data quality, in 2020 and subsequent years
- IPHC Regulatory Areas 2A, 4A, 4B and 4CDE will have no FISS sampling in 2020, and WPUE and NPUE indices will almost certainly not meet precision target this year
  - Information for 2020 for these areas comes only from covariate relationships in the space-time model and from prior years' data through the modelled temporal correlation.
- Not only will the estimates for 2020 be imprecise, but the lack of data on stock trends from 2019 to 2020 means that the estimates will also potentially be biased.
- The impact of the reduced survey will propagate into subsequent years' estimates:
  - For example, the 2021 estimates will be less precise than they would have been if data had been collected in 2020.
  - However, if the proposed 2021 design is implemented, we expect this to bring the FISS back on track to meet data quality targets in coming years.

Implications of the 2020 design

- The high sampling effort in 2020 in IPHC Regulatory Areas 2B, 2C and 3A means that estimates from these areas are expected to meet data quality targets this year
- The reduced sampling in IPHC Regulatory Area 3B should be sufficient for precision targets to be met, given that CVs have been well within the 15% target in recent years in this area.
- There is potential for modest bias in IPHC Regulatory Area 3B
  - Some trend information from sampling eastern portion
  - Western portion tends to be more variable from year to year

Recommendations

That the SRB:

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

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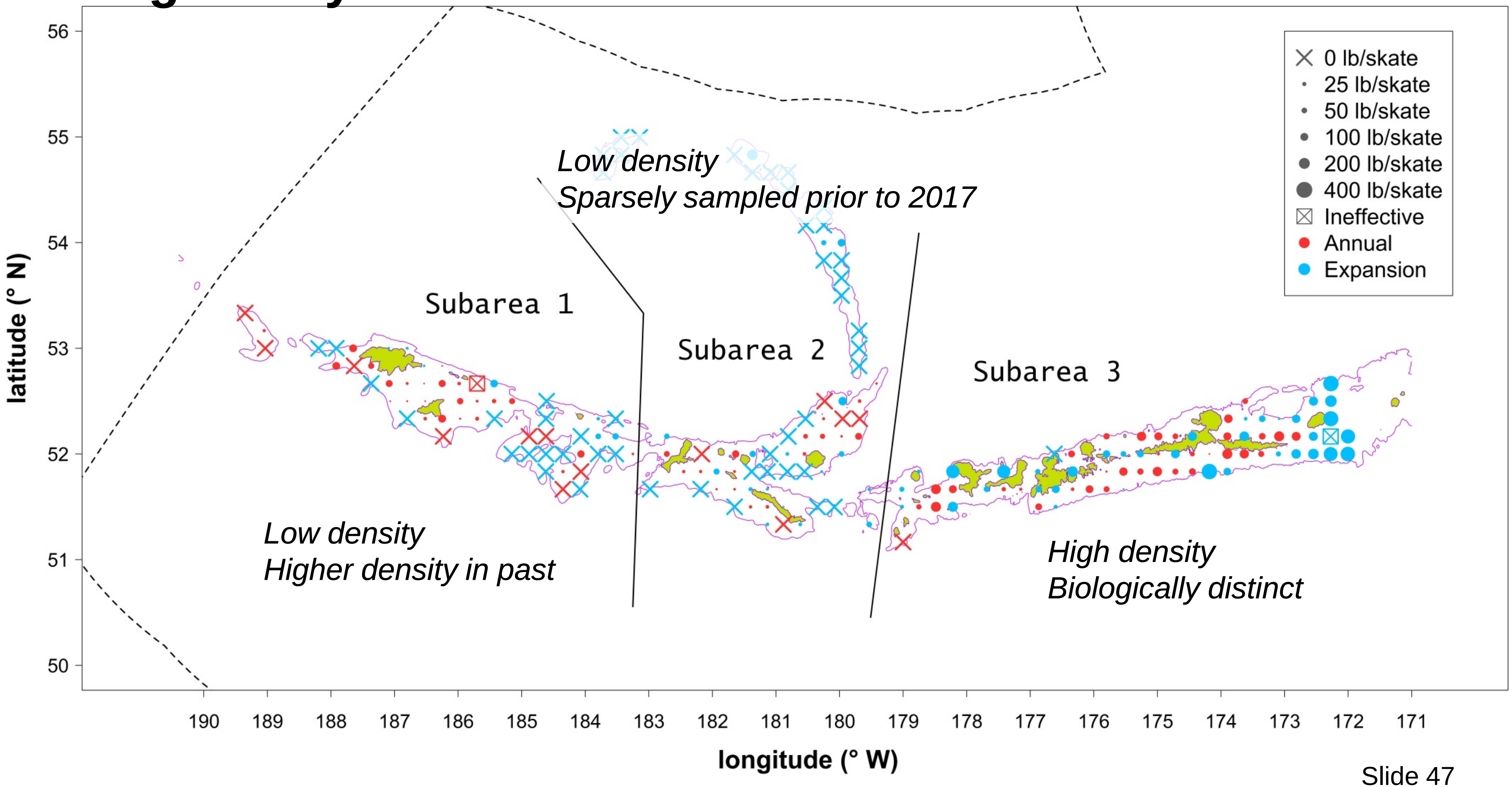
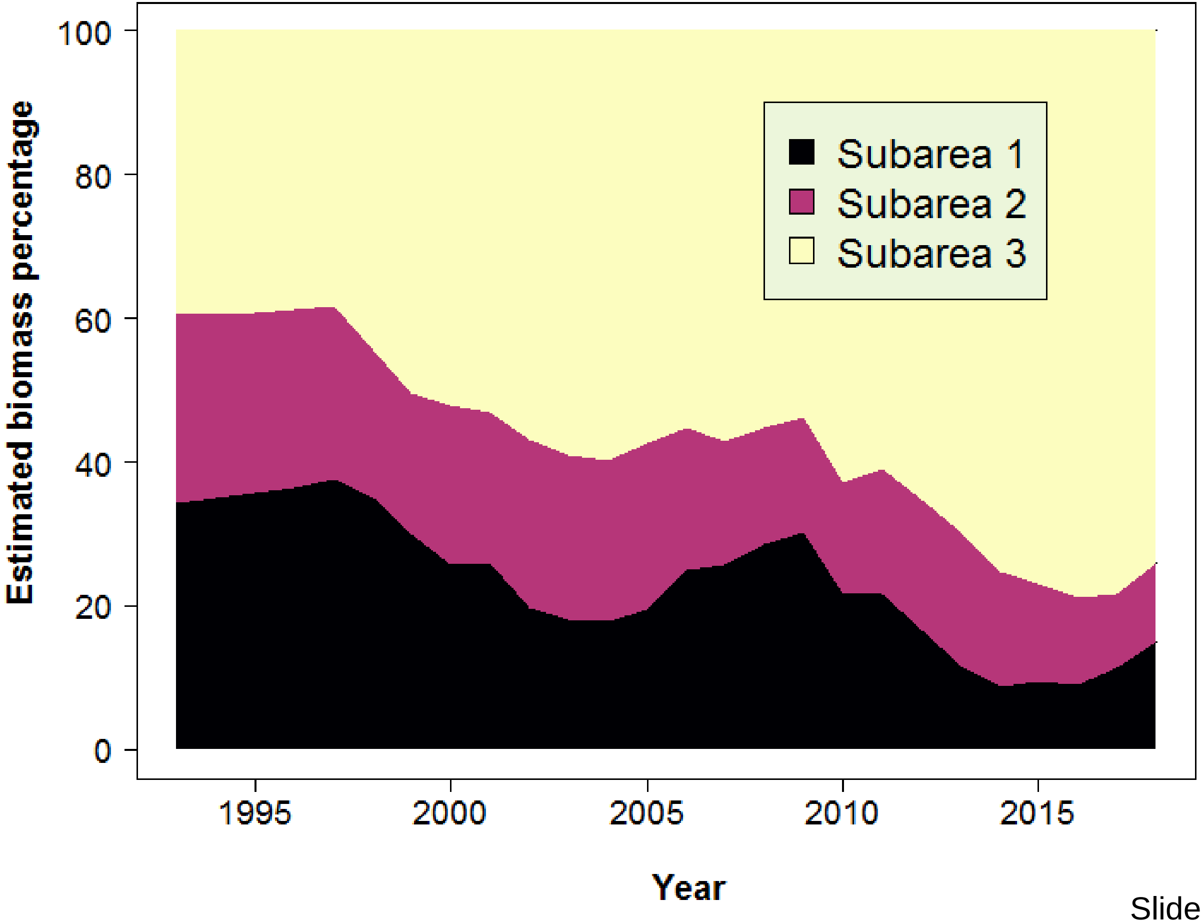
Extra slides

Regulatory Area 4B subareas



Regulatory Area 4B biomass % by subarea and year



Reg Area 4B sampling priorities

1. Subarea 3: 70-80% of biomass since 2013
2. Subarea 1: Frequent large changes in biomass % over short periods
3. Subarea 2: Generally low and stable biomass % (but likely affected by sparse historic sampling)

Proposal for sampling: 2020-2022

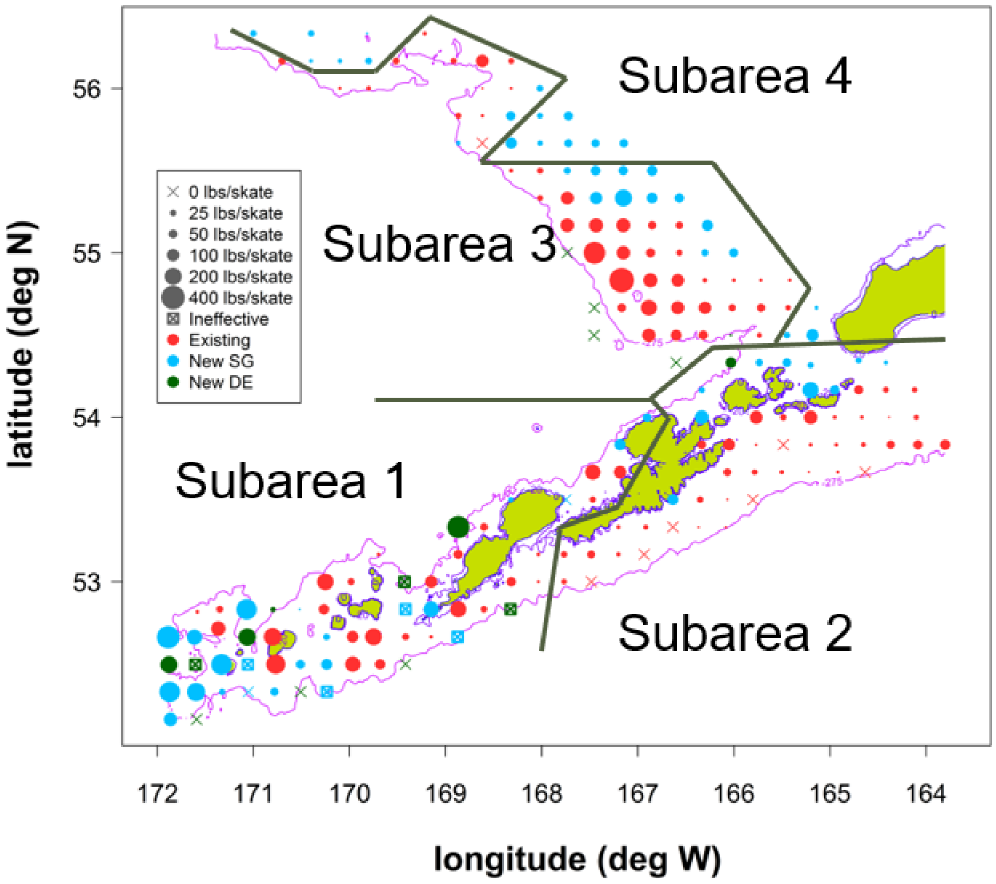
2020. Subarea 3 only (73 stations)
2021. Subarea 3 only (73 stations)
2022. Subareas 1 and 2 (130 stations)

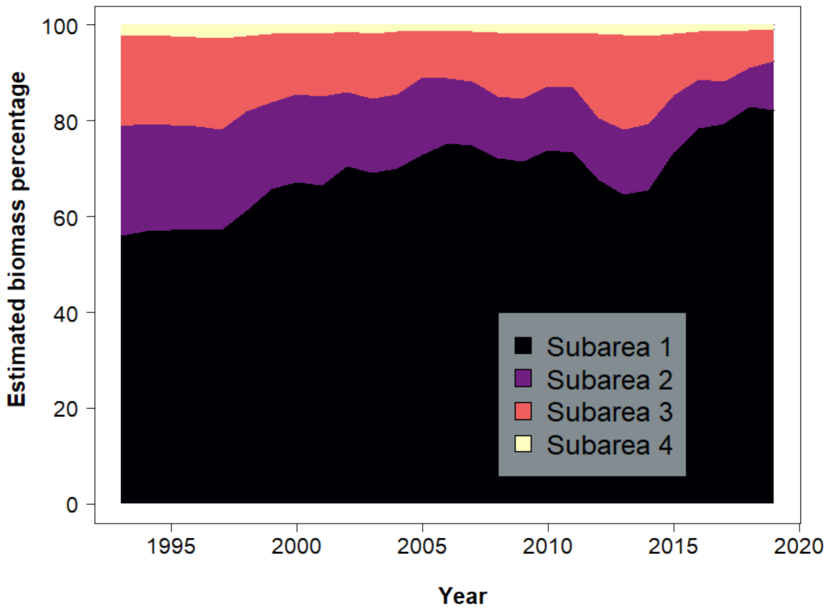
Years until ≥ 10% absolute change in biomass %

Sub-area	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18
1	9	8	7	4	3	4	3	13	12	7	5	4	4	7	6	4	3	4	3	≥7	≥6	≥5	≥4	≥3	≥2	≥1
2	17	21	20	19	18	19	≥ 19	16	16	14	13	12	11	≥ 13	≥ 12	≥ 11	≥ 10	≥9	≥8	≥7	≥6	≥5	≥4	≥3	≥2	≥1
3	6	5	4	3	2	4	11	10	11	11	10	9	8	6	6	4	3	4	3	3	≥6	≥5	≥4	≥3	≥2	≥1

- Subareas 1 and 3 should be sampled at least every 3 years to reduce risk of large bias
- Data imply Subarea 2 could be sampled no more than every 10 years
    - But most of Subarea 2 was sampled just once
    - Apparent stability could be due to lack of data and reliance on model prediction

Regulatory Area 4A subareas





Reg Area 4A sampling priorities

1. Subarea 1: 65-85% of biomass, variable biomass proportion
2. Subarea 3: Variable biomass %
3. Subarea 2: Low density, stable proportion

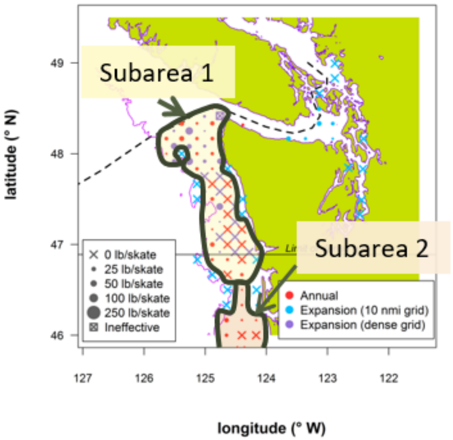
Proposal for sampling: 2020-2022

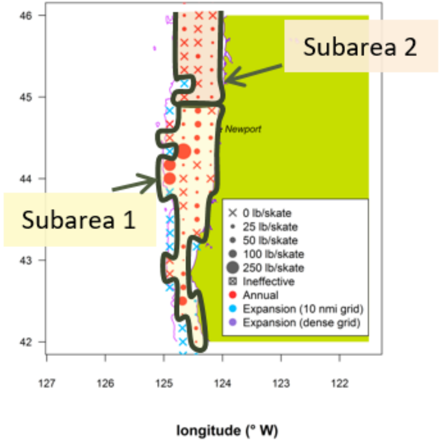
2020. Subarea 1 only (59 stations)

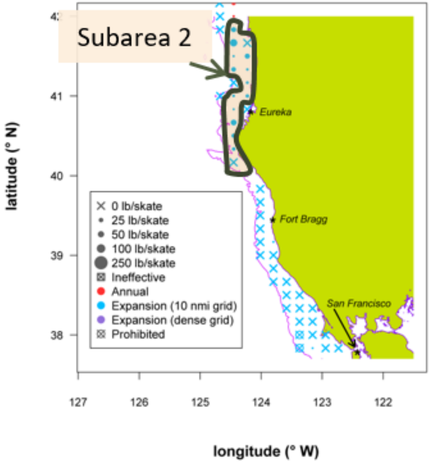
2021. Subarea 1 only (59 stations)

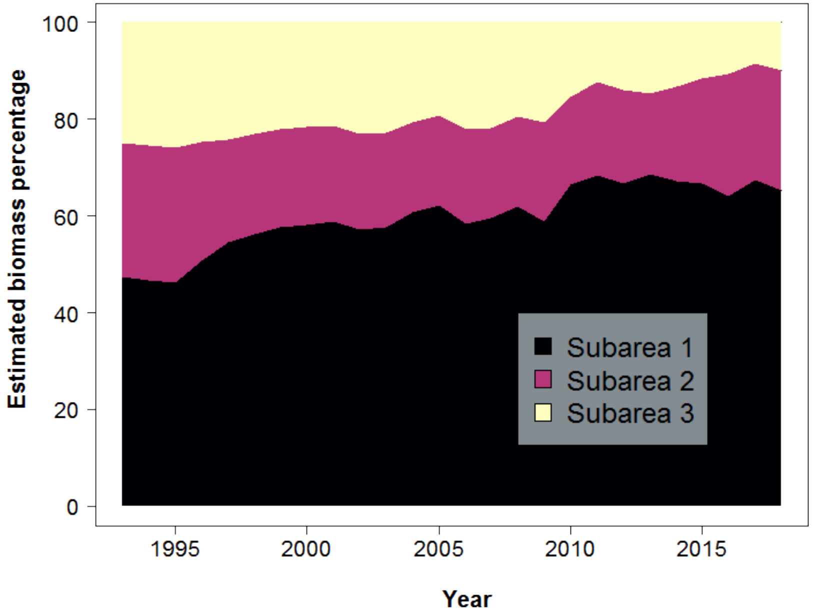
2022. Subareas 1 and 3 (122 stations)

Regulatory Area 2A subareas









Reg Area 2A sampling priorities

1. Subarea 1: 60-70% of biomass
2. Subarea 2: Moderate density, stable proportion
3. Subarea 3: Low density

Proposal for sampling: 2020-2022

2020. Subarea 1 only (72 stations)

2021. Subarea 1 only (72 stations)

2022. Subarea 1 only (72 stations)