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INTERNATIONAL PACIFIC HALIBUT COMMISSION

Space-time modelling of survey data

Agenda item 6.2

IPHC-2019-IM095-07 Rev_1

Presentation updated 26 Nov 2019

Overview

1. Review of survey data sources and space-time modelling
2. Space-time model estimates of WPUE and NPUE
3. Regulatory Area 2C gear comparison
4. 2019 Fishery-Independent Setline Survey expansions
   - IPHC Regulatory Areas 3A and 3B
5. FISS rationalisation
   - Methods
   - Plan for 2020

Review of survey data sources

- IPHC fisheries-independent setline survey (FISS):
  - Primary data source for space-time modelling of WPUE and NPUE indices
  - 10 nmi grid design since 1998, with fixed FISS stations and standardised fishing methods
    - Grid design ensures all habitat is sampled in proportion to its occurrence (on average)
    - Fixed FISS stations reduces variance in trend estimates
  - Gaps in annual coverage
    - Accounted for using data from other surveys, FISS expansions, and space-time model predictions into unsurveyed habitat

Review of survey data sources

- NMFS fisheries-independent Bering Sea trawl survey:
  - Important data source for WPUE and NPUE indices in the Bering Sea (Regulatory Areas 4A and 4CDE)
  - 20 nmi grid design since 1982, with higher station density in some regions
  - Northern expansions fished in 2010, 2017-19
  - Data are calibrated with IPHC Bering Sea setline survey expansion data from 2006 and 2015
    - Provides WPUE and NPUE indices consistent with those from the IPHC setline survey
- ADFG fisheries-independent Norton Sound trawl survey:
  - Data source for WPUE and NPUE indices in the northern Bering Sea (Regulatory 4CDE)
  - Fished triennially until 2014, and annually from 2017

Review of 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

- Manuscript on space-time modelling of Pacific halibut survey data submitted to Canadian Journal of Fisheries and Aquatic Sciences

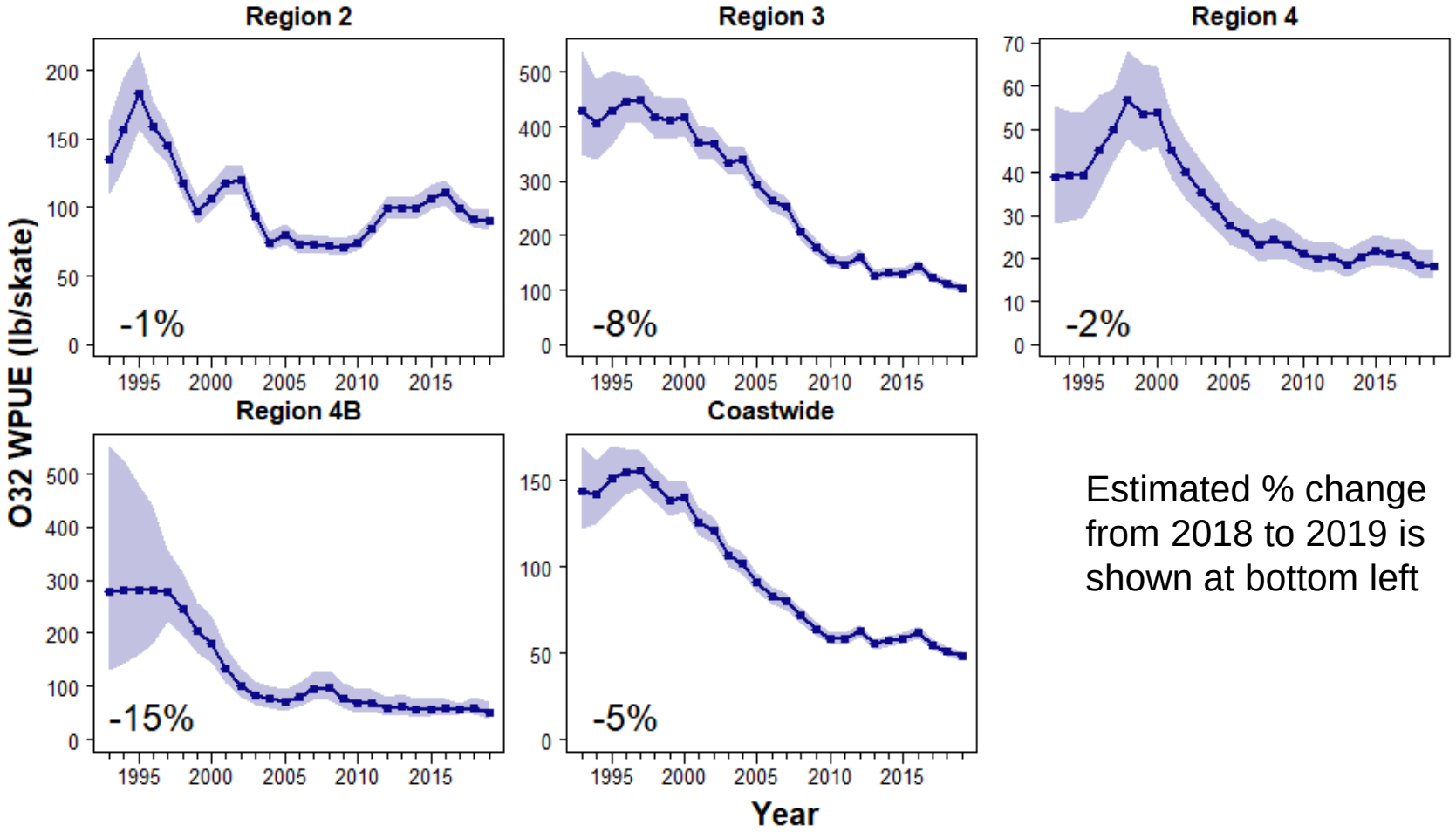
  "Monitoring change in a dynamic environment: spatio-temporal modelling of calibrated data from different types of fisheries surveys of Pacific halibut." R. A. Webster, E. Soderlund, C. L. Dykstra and I. Stewart

  – Currently in revision following favourable reviews

Space-time model estimates of WPUE and NPUE

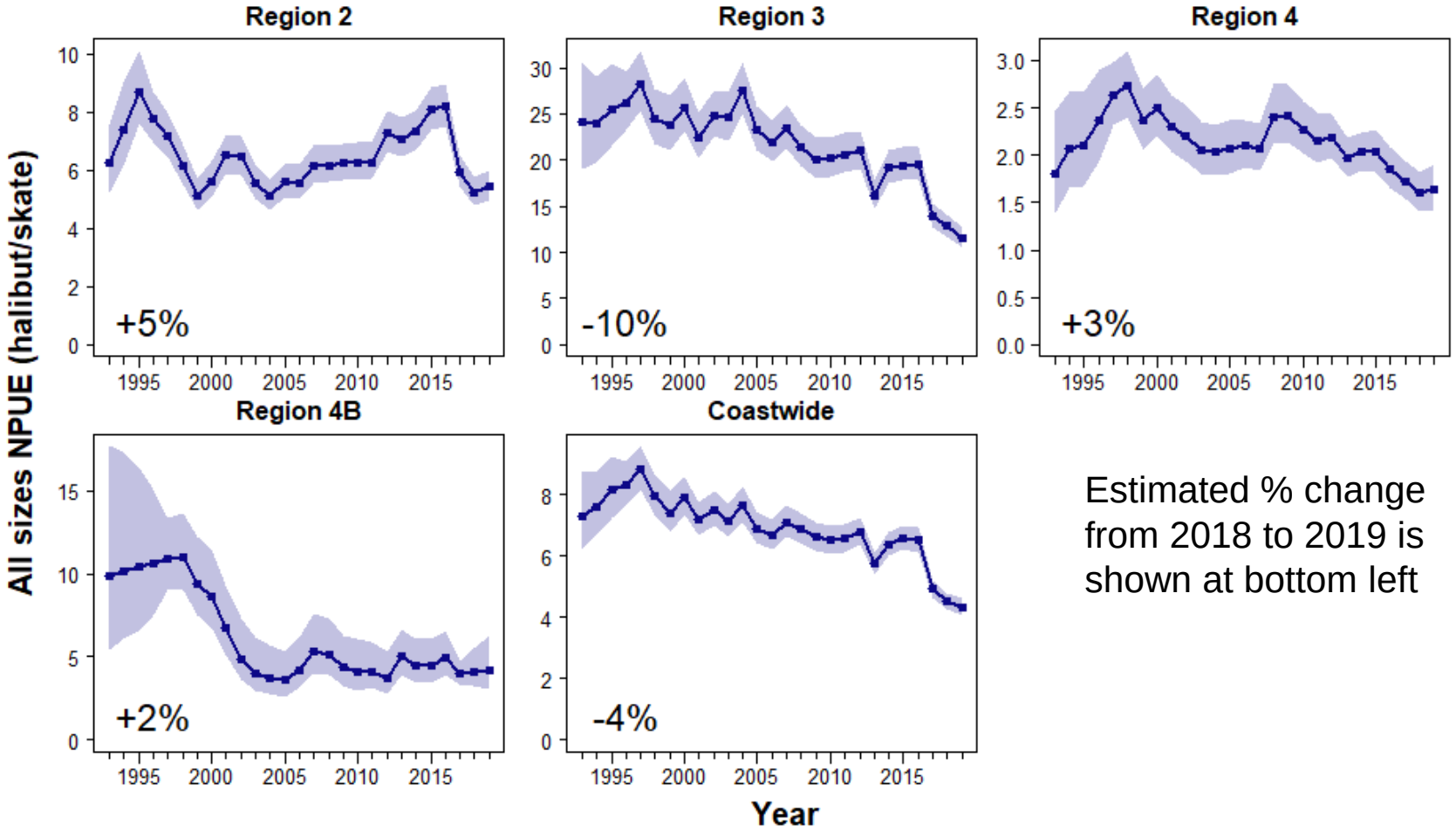
- As in 2016-18, the space-time modelling was used to estimate WPUE and NPUE indices
- Estimates computed for:
  - Biological Regions
  - IPHC Regulatory Areas
  - Coastwide IPHC Convention waters, from San Francisco Bay to Bering Strait

O32 WPUE by biological region



Estimated % change from 2018 to 2019 is shown at bottom left

All sizes NPUE by biological region



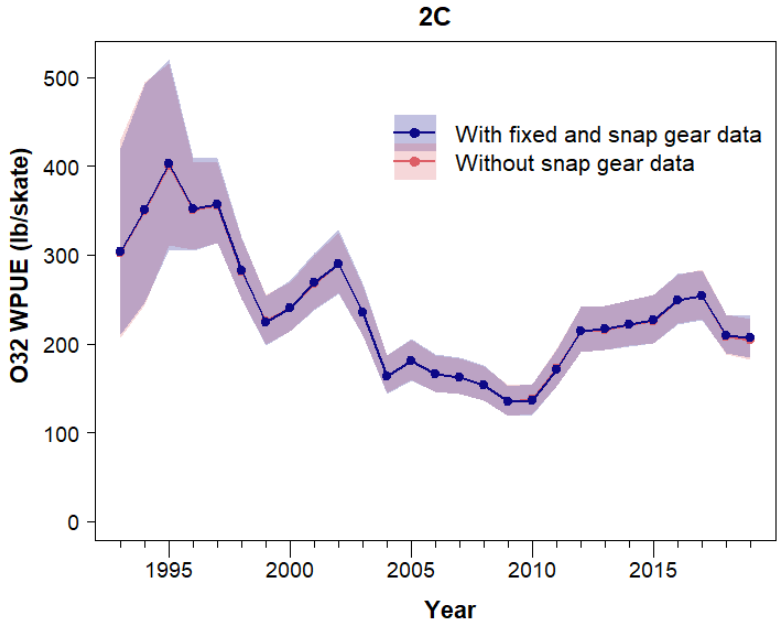
Estimated % change from 2018 to 2019 is shown at bottom left

Gear comparison study

- Each station in Regulatory Area 2C was fished twice, once with fixed gear, and once with snap gear
- Space-time modelling included parameters allowing for gear differences in catch rates
- There was some evidence that snap gear had lower catch rates than fixed gear
  - Model estimated WPUE and NPUE on snap gear was 86% of that on fixed gear
  - Uncertainty was high, with 95% intervals of 75-100%
- Results imply the need to collect additional data
  - to better understand the relative efficiency of the gears
  - to understand potential variability over time and space

Gear comparison study

- Nevertheless, with the gear calibration accounted for in the model, we did include snap gear data in the models used to produce indices for Regulatory Area 2C in 2020
- Inclusion of snap gear data together with fixed gear data had no meaningful effect on estimates of WPUE and NPUE time series
- As estimation of calibration coefficient between snap and fixed gear improves, data from both gears will likely be of equal value

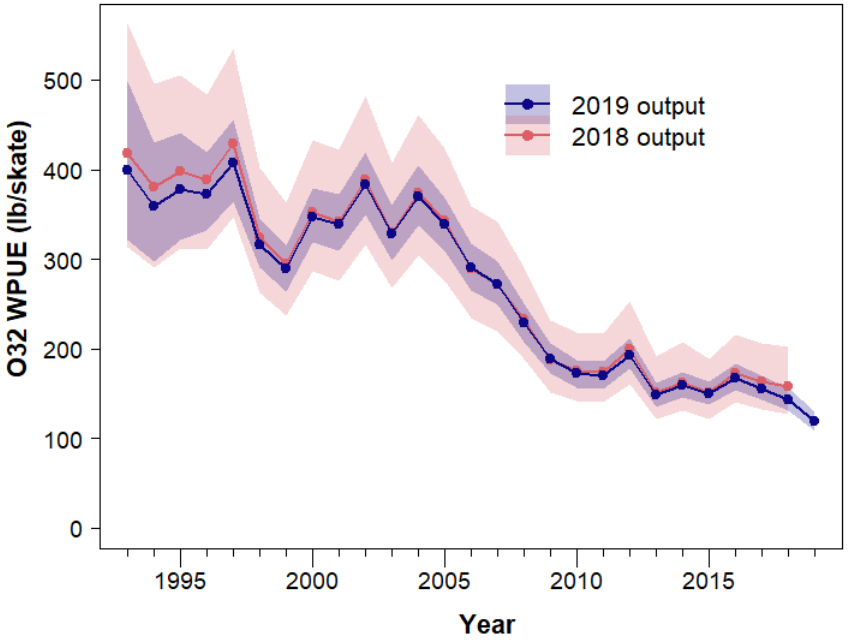


2019 setline survey expansions

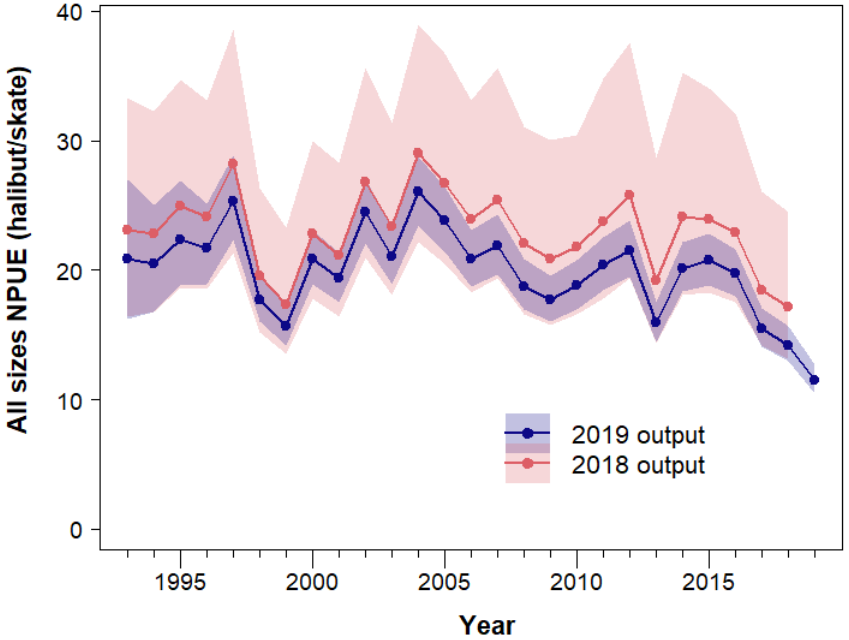
- 2019 was the 6th and final year of a program of setline survey expansions
- The goal was to collect data in previously unsurveyed regions to reduce bias and uncertainty in WPUE and NPUE indices
- Setline survey expansions to date (with previously unsampled % of stations):
  - 2014: Regulatory Areas 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%)**

Regulatory Area 3A

O32 WPUE

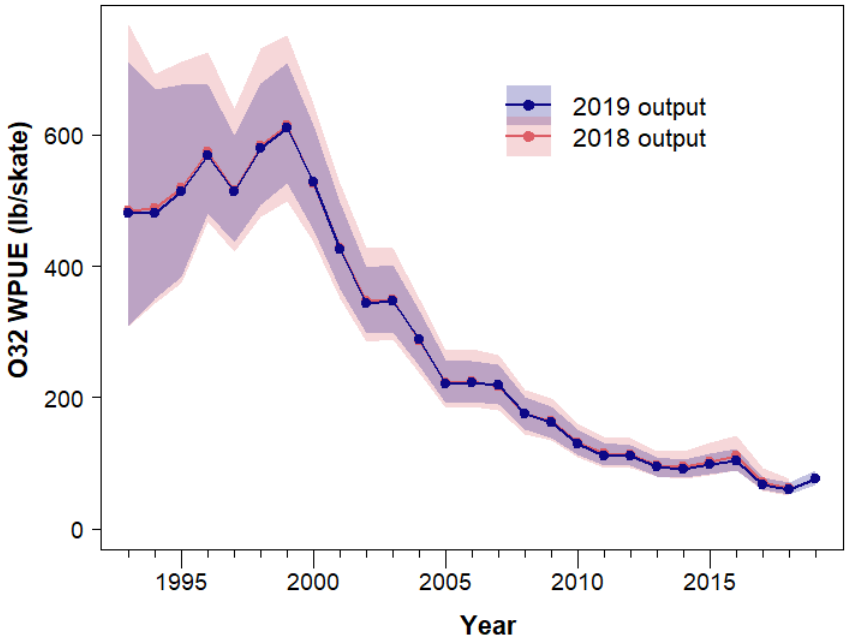


All sizes NPUE

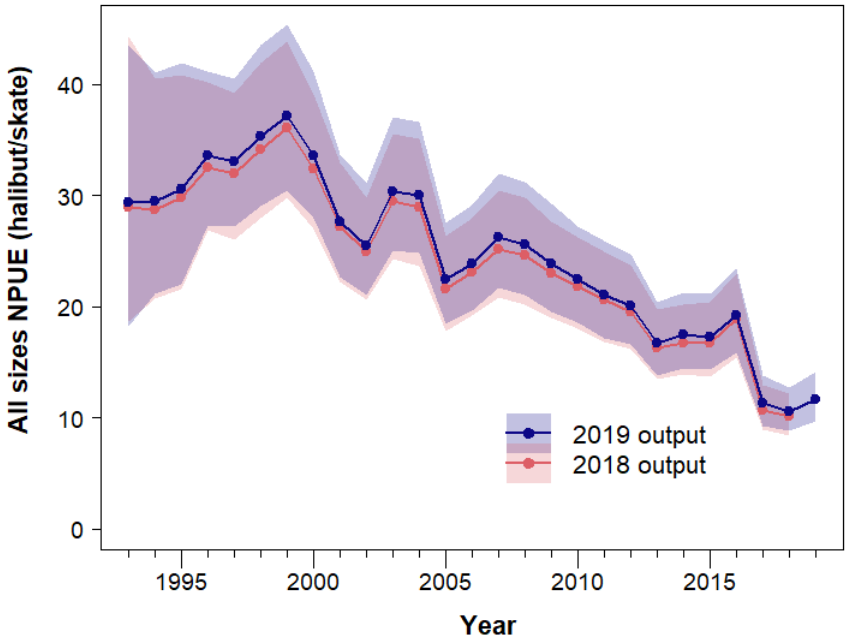


Regulatory Area 3B

O32 WPUE



All sizes NPUE



FISS expansion summary

- The FISS occupied for the first time 34% of the full grid that had previously been unsurveyed
- 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
- Moving forward, revisiting the “new” stations from the 2014-19 expansion is unlikely to have such large effects on the entire time series

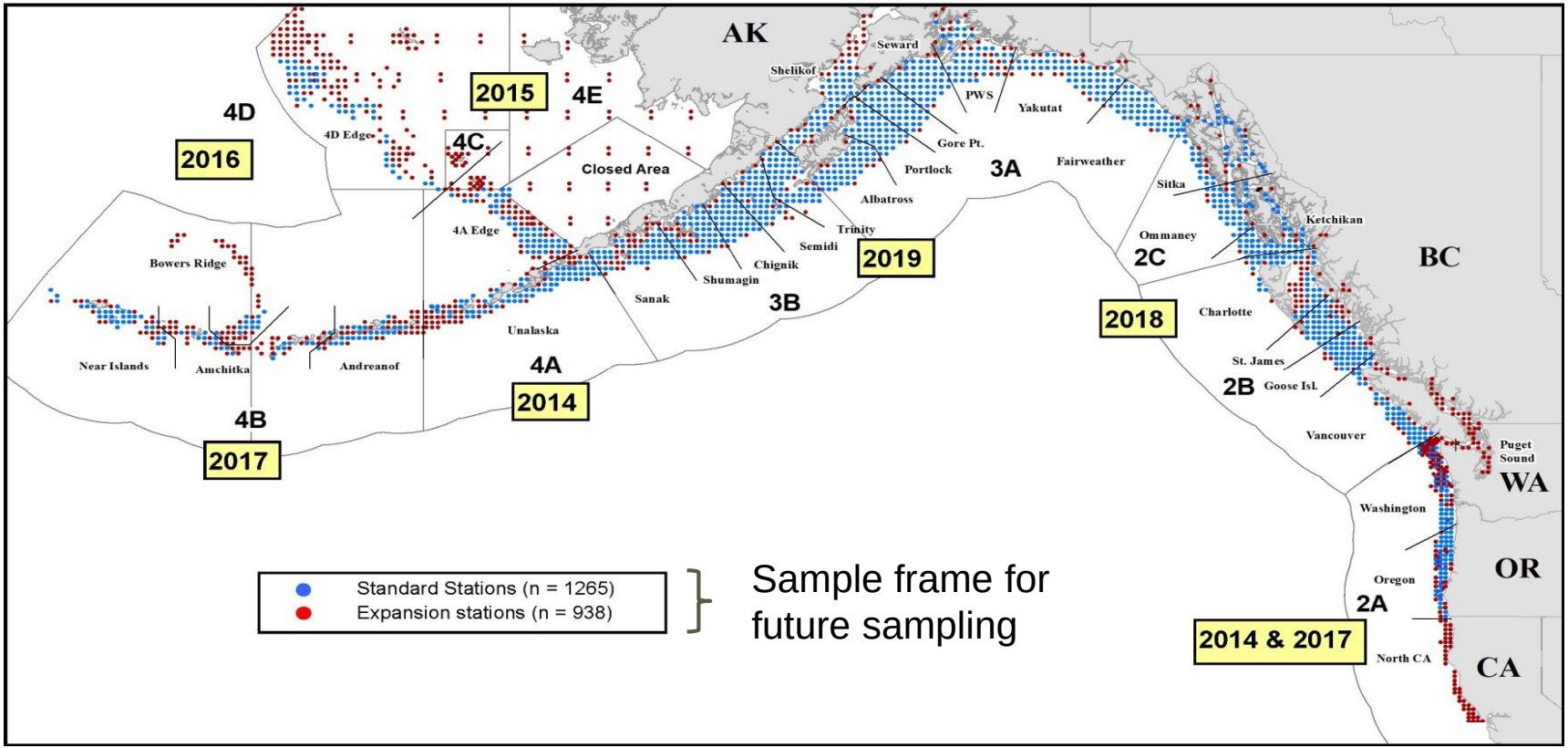
FISS rationalisation

- The full setline survey footprint developed during the expansion program is too large to sample annually, in terms of both cost and logistics
- We need to establish a set of methods for determining annual FISS designs that meet sampling goals subject to FISS cost constraints

Summary of methods for FISS rationalisation

- Propose data quality targets
- Determine geographic sampling priorities and sampling frequency
- Test designs on simulated data sets
- Propose design options
- Estimate design costs

Expanded FISS design



Precision targets

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

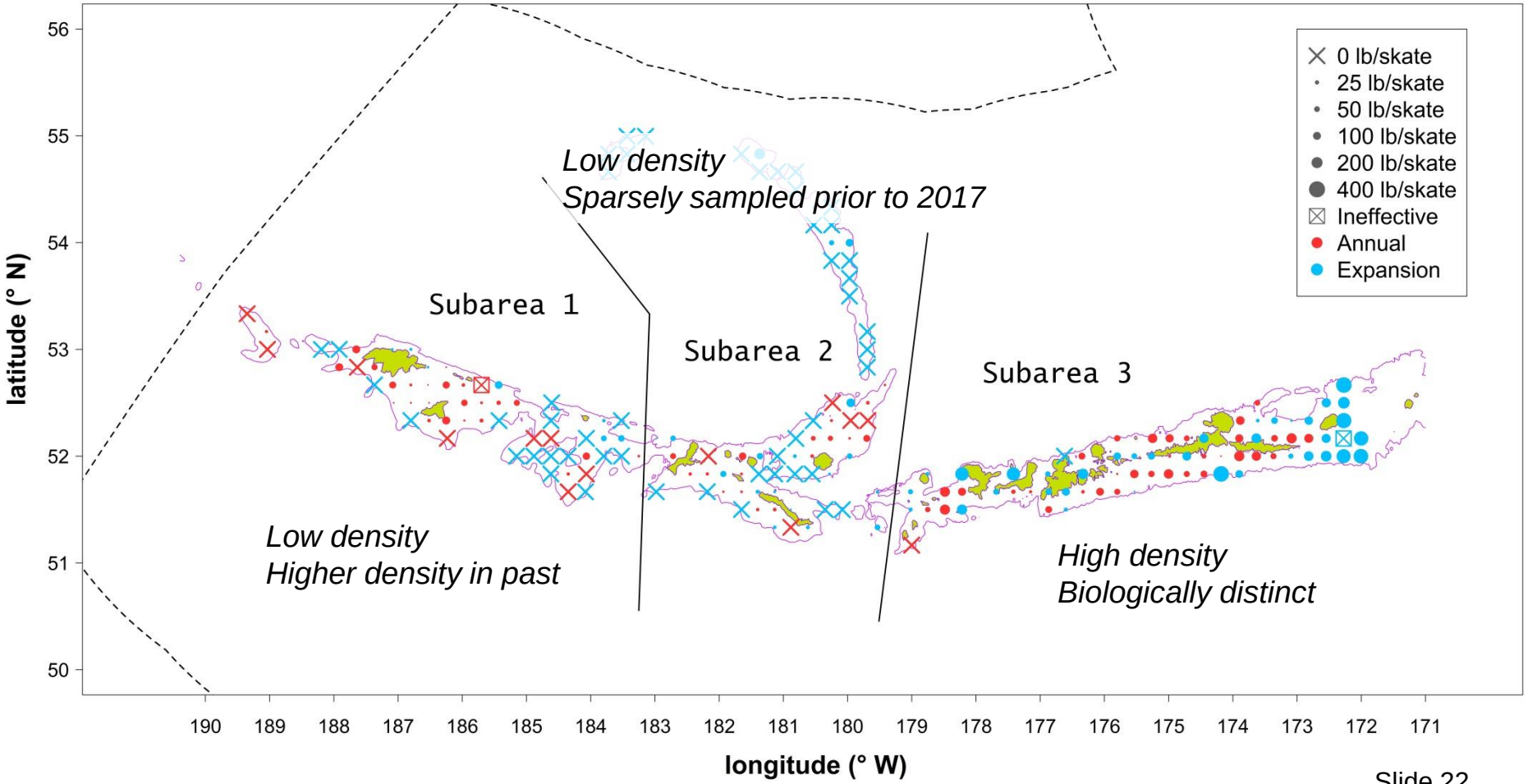
Management unit	O32 WPUE	All sizes WPUE	All sizes NPUE
Reg Area (all)	15%	15%	NA
Bio Regions 2, 3, 4	10%	10%	10%
Bio Region 4B	15%	15%	15%
Coastwide	NA	NA	10%

Potential for bias

- Failure to observe and account for changes in WPUE or NPUE in an unsurveyed subarea can lead to bias
- Therefore, it is important to undertake setline surveys frequently enough to keep any bias small
- In this, we are guided by the past, as we'll see through the example that follows

Example: Regulatory Area/Region 4B

- Proposed target CV of 15% for all indices
- Expanded survey in 2017
- We proposed dividing 4B into three subareas, based on biology, sampling history and density


0 lb/skate
25 lb/skate
50 lb/skate
100 lb/skate
200 lb/skate
400 lb/skate
Ineffective
Annual
Expansion
Low density
Sparsely sampled prior to 2017
Subarea 1
Subarea 2
Subarea 3
Low density
Higher density in past
High density
Biologically distinct
latitude (° N)
longitude (° W)
56
55
54
53
52
51
50
190
189
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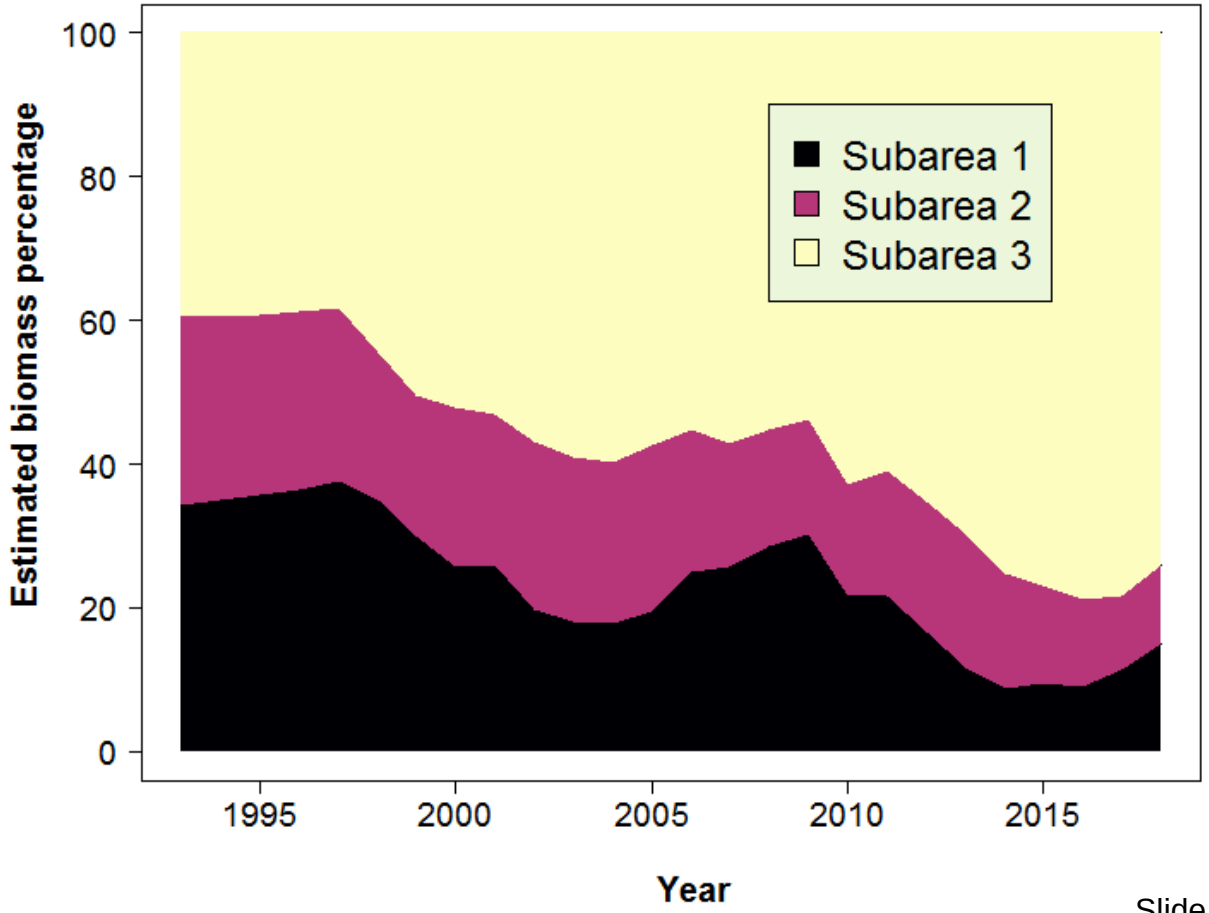
Reg Area 4B biomass % by subarea and year



Reg Area 4B sampling priorities (part 1)

- For recent years, we estimate Subarea 3 to have 70-80% of Reg Area 4B biomass
  - Implies it should be the first priority for future sampling
  - Note that with this type of data, variance is generally proportional to the mean, suggesting more effort should be placed where catch rates are highest

How frequently to sample each subarea?

- We consider how quickly the biomass proportions have changed in the past
  - Faster changes imply need for more frequent sampling
  - Stability implies less frequent sampling required

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

Reg Area 4B sampling priorities (part 2)

1. Subarea 3: 70-80% of biomass since 2013
2. Subarea 1: Frequent changes of ≥10% of biomass % over short periods (3-4 years)
3. Subarea 2: Generally low and stable biomass % (but likely affected by sparse historic sampling)

Options for sampling: 2020-2022

2020. Subarea 3 only (73 stations)

2021. Subarea 3 only (73 stations)

2022. Three options considered:

- Subarea 3 only (73 stations)
- Subarea 1 only (57 stations)
- Subareas 1 and 2 (130 stations)

Evaluation of options

- Fit models using simulated data for future years
- Models can take a long time to run: full simulation study using many data sets not practical
- Instead, for each year, single simulated sample data sets were taken from the posterior samples from the modelling

Summary of results for Reg Area 4B

- Sampling Subarea 3 from 2020-22 is sufficient to maintain CVs below 15%
- However, bias concerns mean it is desirable to sample Subarea 1 every 3 years
- Sampling Subarea 1 alone in 2022 is not sufficient to meet the 15% target
- We expect that sampling both Subareas 1 and 2 in 2022 to meet the target

Planning beyond three years?

- As new data become available each year, sampling priorities and bias potential for subsequent years can be re-evaluated
  - Subarea definitions and sampling priorities will evolve with changes in relative density of Pacific halibut
- Given the likely future changes in density and distribution, we did not consider evaluating sampling designs beyond three years

Biological sampling

- The IPHC also has biological sampling targets in each regulatory area.
  - 2000 otoliths/Reg Area
- Those targets are already difficult to meet in some areas, particularly Reg Areas 2A and 4CDE.
- Any reduction in the annual survey footprint will make meeting those targets more challenging
- Where possible, additional skates/set can be used to mitigate reductions in stations

Other Regulatory Areas

- Regulatory Areas 2A, 4A
  - Like Regulatory Area 4B, most biomass is concentrated in only part of each Regulatory Area
  - Subarea sampling priorities were identified based on halibut density and variability over time
- Regulatory Areas 2B, 2C, 3A and 3B
  - Comprise the core of the current stock
  - Relatively high densities throughout most parts of these areas
  - More difficult to identify subareas based on density, geographic regions, or biological differences
  - Instead, IPHC FISS regions were considered as basic sampling units (subareas)
  - Sample high-density or temporally variable FISS regions annually
  - Rotate sampling of other FISS regions to ensure precise estimates and low bias

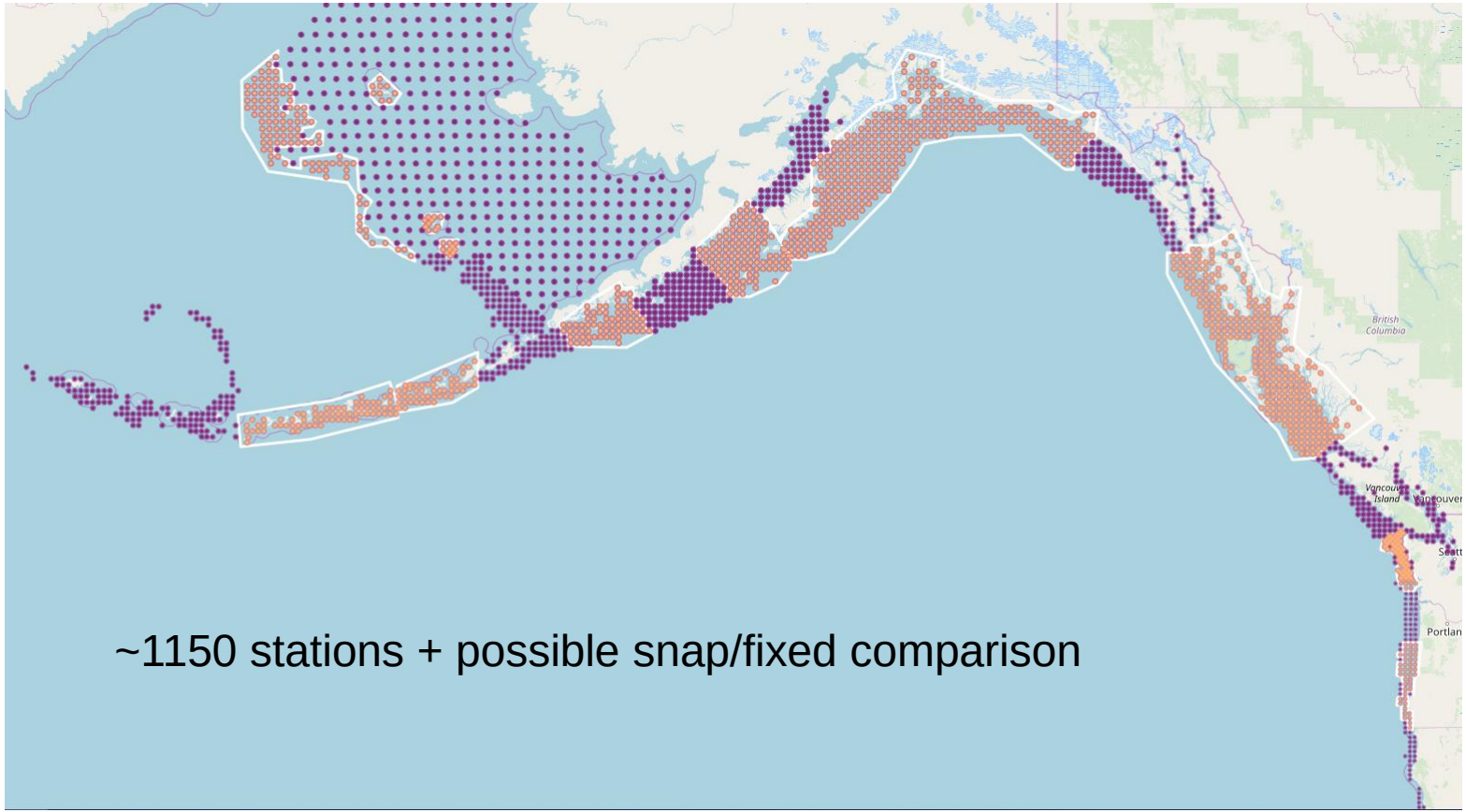
Putting it all together

- Determine priorities and costs for each Regulatory Area (or Biological Region) for the next three years
  - For Bio Region purposes, whole Reg Areas could be omitted from the survey in some years
- If necessary, rearrange the timing of subareas to be fished in order to avoid exceeding overall budget limits
- Each year, re-evaluate priorities and projected costs following data collection on the setline survey
- Modify subsequent years' plans if necessary to reflect new data and revised cost projections

Regulatory Area 4CDE in 2020

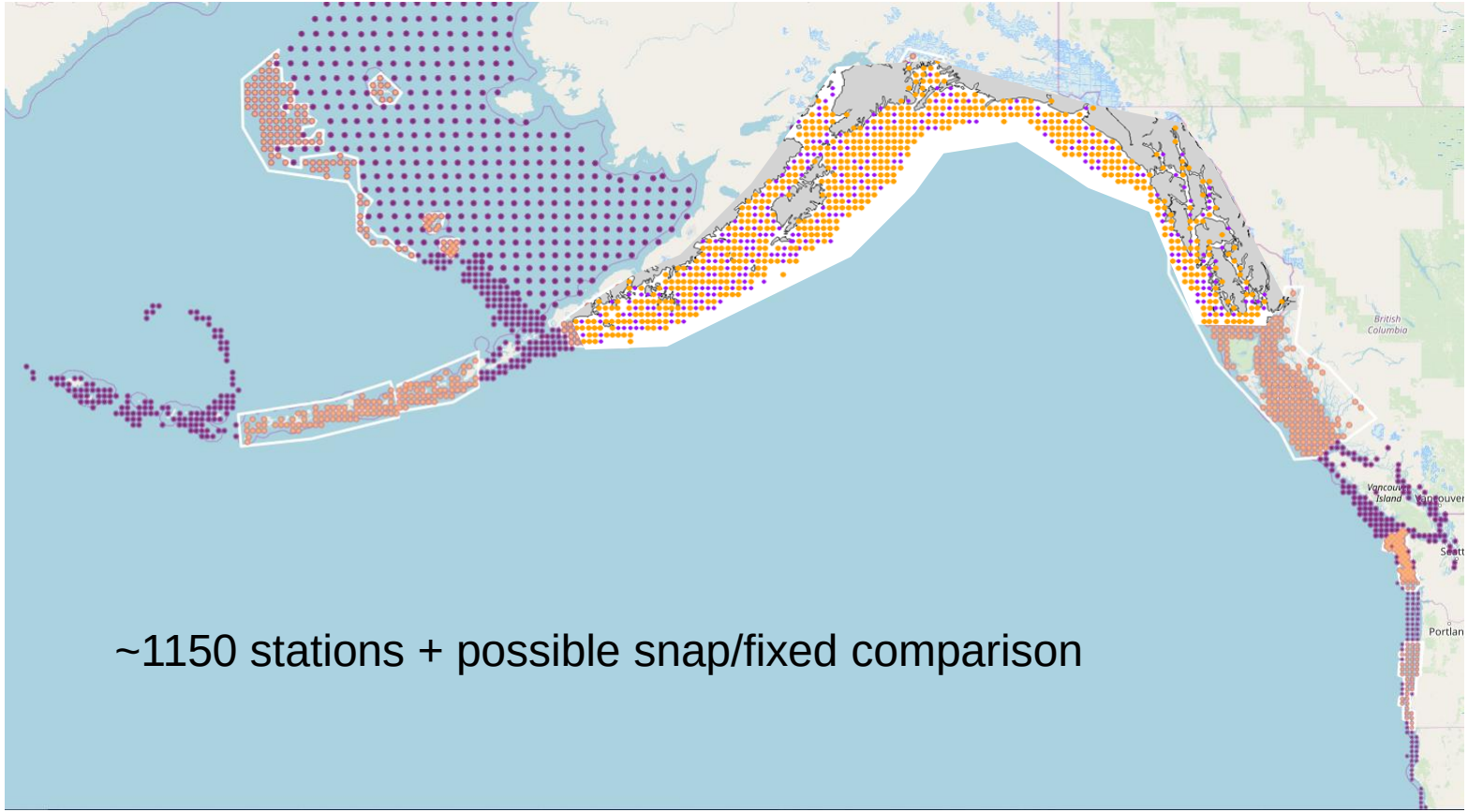
- Reg Area 4CDE estimation depends heavily on other surveys
- While it may be possible to reduce FISS sampling and still meet precision/bias targets, we note:
  - Ecosystem conditions have been anomalous in the Bering Sea for several years, making the Pacific halibut distribution more difficult to predict in unsurveyed habitat
  - The IPHC has increased interest in better understanding density trends and possible links with Russian waters
- Therefore, we propose repeating the full FISS grid on the Regulatory Area 4D shelf edge, last fished in 2016

Original proposed 2020 design

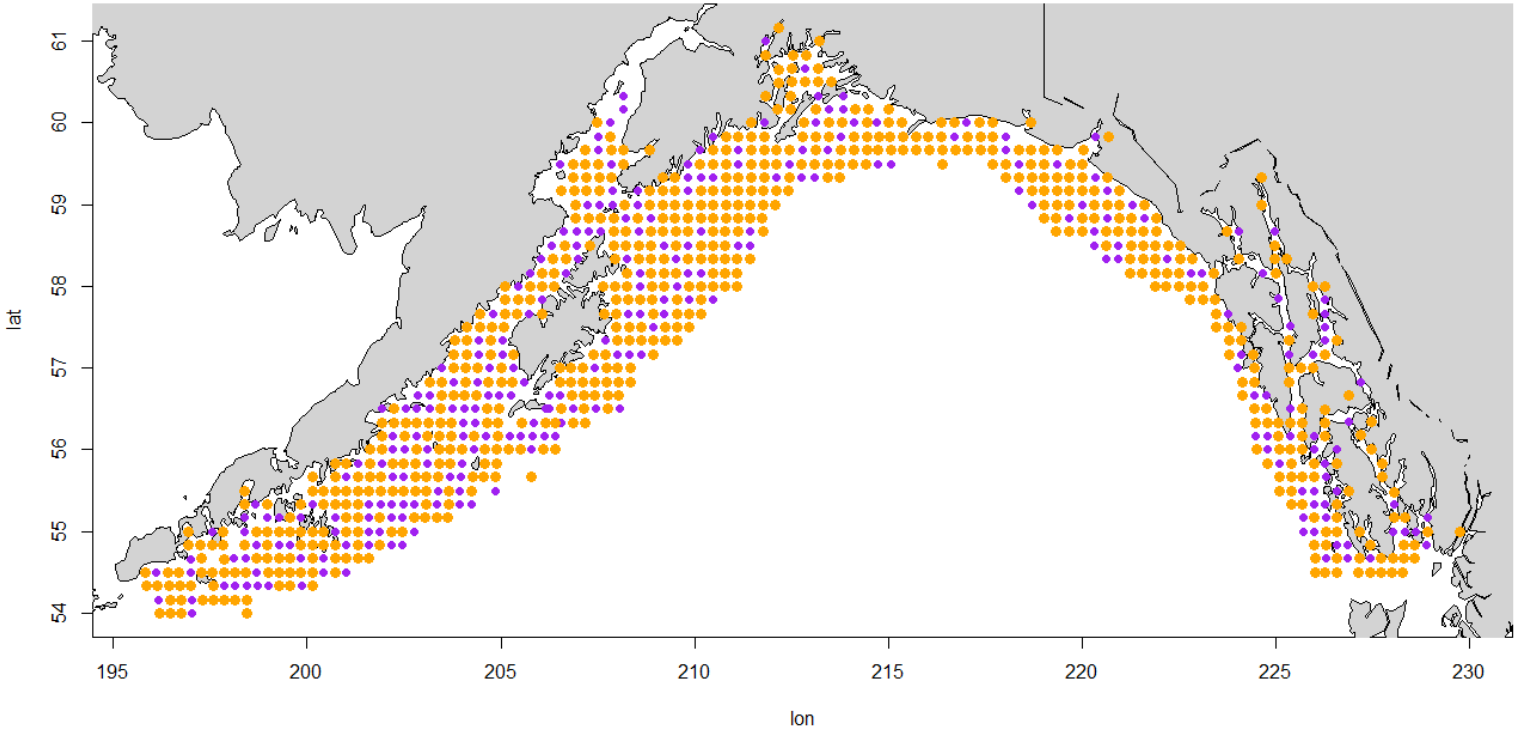


~1150 stations + possible snap/fixed comparison

Modified 2020 design



Thinned design for 2C, 3A and 3B



Modified minimum design proposal for 2020

- Use original proposed design for Regulatory Areas 2A, 2B, 4A, 4B and 4CDE
  - expected CVs within targets
  - low expected bias
- Use thinned design for Regulatory Areas 2C, 3A and 3B
  - expected CVs within targets
  - no bias due to randomization
- Secretariat may add stations for cost or scientific purposes
- Commissioners can request the addition of stations intersessionally or at AM096

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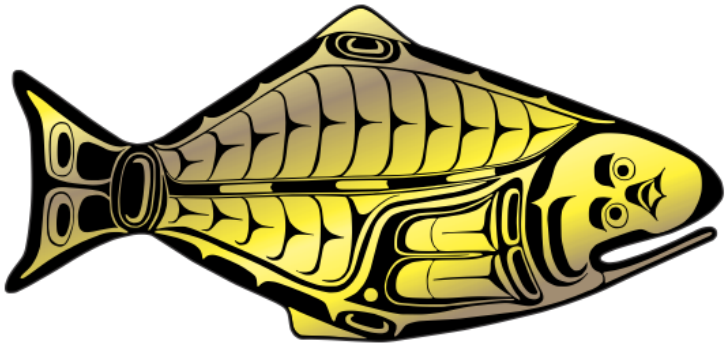

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