INTERNATIONAL PACIFIC HALIBUT COMMISSION

Methods for spatial survey modelling

Agenda item 5.1

IPHC-2019-SRB014-05 Rev_1

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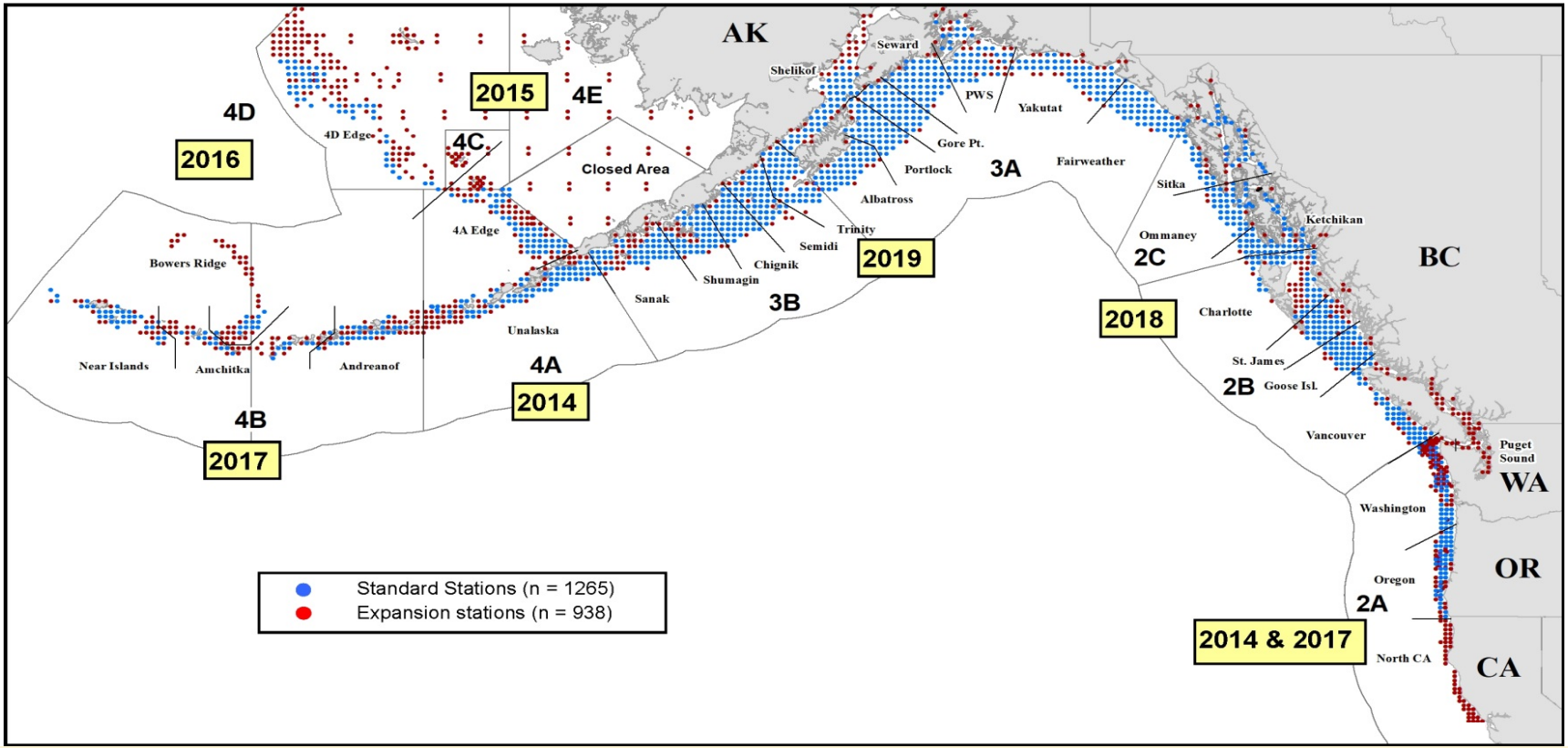
Background

- Program of planned setline survey expansions undertaken from 2014-19
- In each Regulatory Area, gaps in setline survey coverage were sampled, providing data for the full geographic extent of North American Pacific halibut for the first time
- However, this full setline survey footprint is too expensive to sample annually
- 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

- We estimated coefficients of variation for mean O32 and all sizes WPUE by IPHC Regulatory Area and biological Region since 2011 (year of first pilot FISS expansion).
- For almost all Reg Areas, CVs were below 15%
  - Exceptions: 4B in 2011-12, and 4A in 2018
- For all biological Regions except Region 4B, CVs were below 10%

Precision targets

- We estimated CVs for all sizes NPUE by biological Region and coastwide since 2011.
- CVs were below 10% for Regions 2 and 4
- CVs were 12.5-14.0% for all years for Region 3
  - Expect improvement following 2019 setline survey expansions in Reg Areas 3A and 3B
- CVs below 15% for Region 4B except 2011-12
- CVs below 10% for mean coastwide NPUE in all years

Precision targets

- To maintain data quality, we propose the following precision targets:

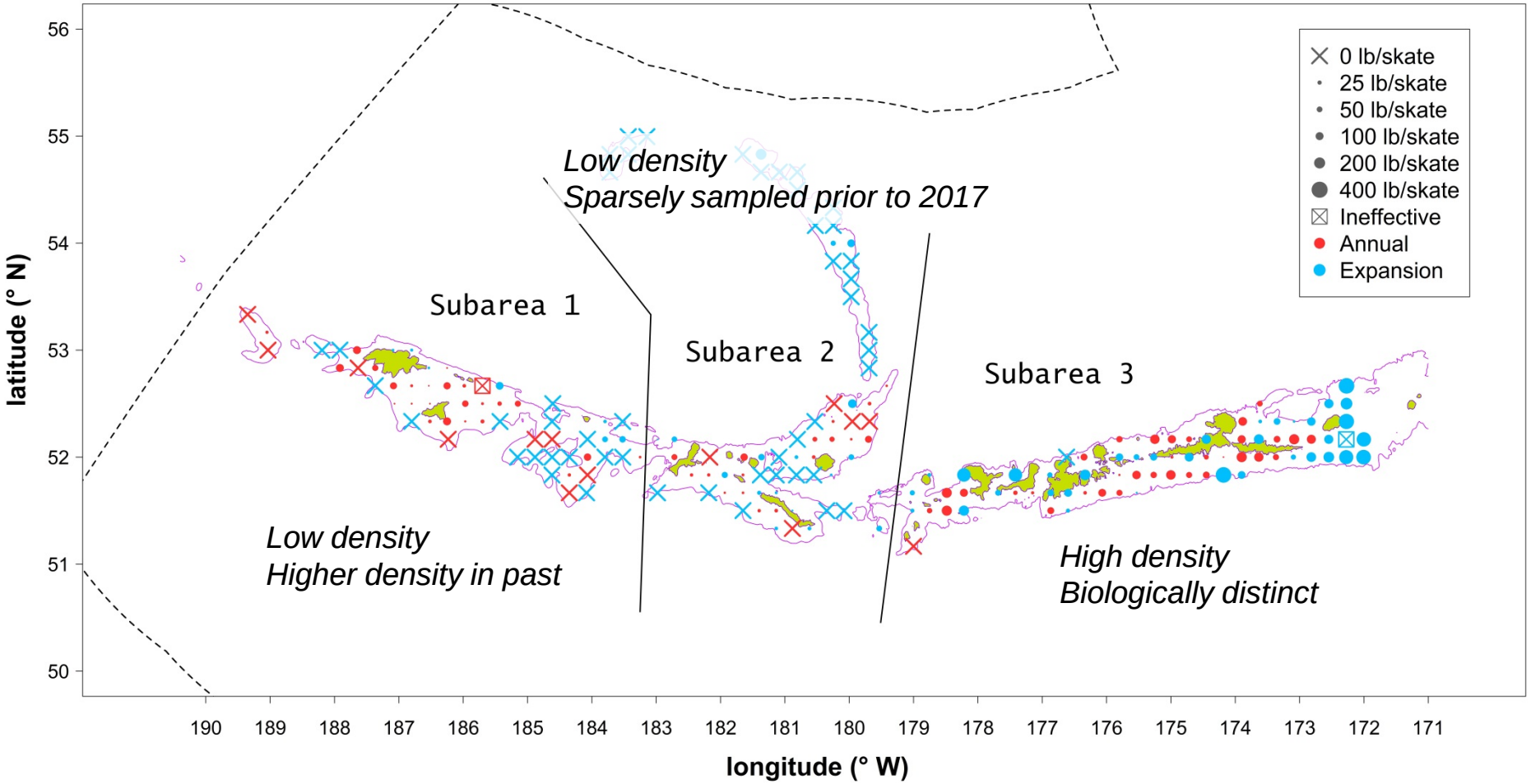
Management unit	O32 WPUE	All sizes WPUE	All sizes NPUE
Reg Area (all)	15%	15%	NA
Bio Regions 2, 3, 4	10%	10%	10%
Bio Region 4B	15%	15%	15%
Coastwide	NA	NA	10%

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(s) that follow

Example 1: Regulatory Area/Region 4B

- Proposed target CV of 15% for all indices
- Expanded survey in 2017
- We (tentatively) propose 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
188
187
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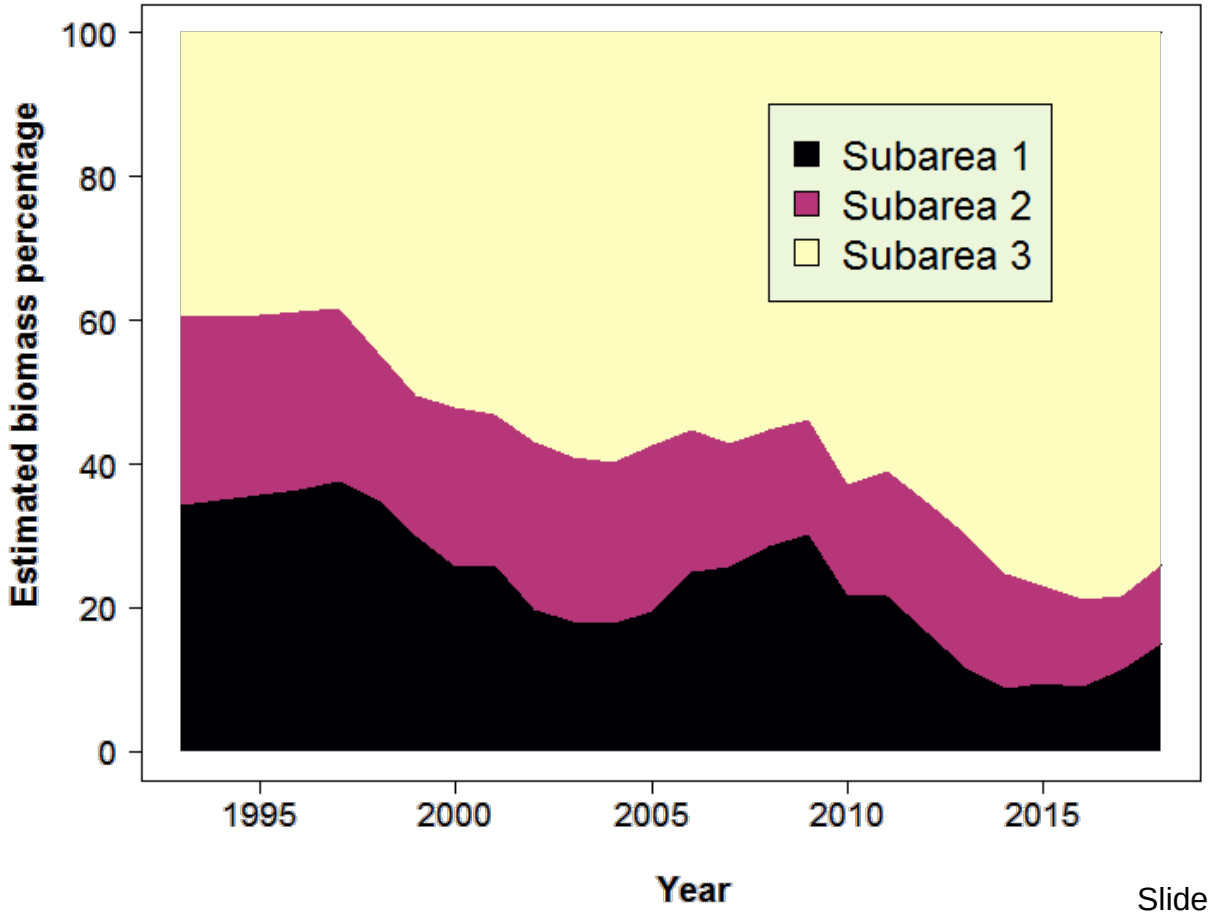
Reg Area 4B biomass % by subarea and year



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							
2	17	21	20	19	18	19		16	16	14	13	12	11													
3	6	5	4	3	2	4	11	10	11	11	10	9	8	6	6	4	3	4	3	3						

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							
2	17	21	20	19	18	19		16	16	14	13	12	11													
3	6	5	4	3	2	4	11	10	11	11	10	9	8	6	6	4	3	4	3	3						

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

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)

2022a. Subarea 3 only (73 stations)

2022b. Subarea 1 only (57 stations)

2022c. 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 2018 modelling
  - 2000 samples were stored for each Reg Area
- One simulated data set is added to the observed data sequentially for each future year of sampling
- Space-time model is fitted to this augmented data set

Results of simulations: are CV targets met?

Estimated CVs (%) by data input for Reg Area 4B. Target CV = 15%.

Data input	Sampled subareas	2017	2018	2019	2020	2021	2022
1993-2018 data		9.5	13.7				
+ 2019-20 simulated data	2020 Subarea 3	9.4	12.6	12.4	10.2		
+ 2019-21 simulated data	2020-21 Subarea 3	9.6	12.6	12.7	11.2	12.3	
+ 2019-22a simulated data	2020-22 Subarea 3	9.5	12.2	11.9	10.1	12.1	14.0
+ 2019-22b simulated data	2020-21 Subarea 3 2022 Subarea 1	9.4	12.1	12.1	10.1	10.7	17.0
+ 2019-22c simulated data	2020-21 Subarea 3 2022 Subareas 1, 2	8.8	11.0	10.7	8.7	8.7	14.2

Summary of results

- 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

Costs

- The relative costs of each potential design must also be considered during planning
  - Survey budget will constrain survey footprint each year
- At present, we are sourcing data on the relative cost and revenue for components of IPHC Regulatory Areas

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

Reg Areas, Regions and Coastwide

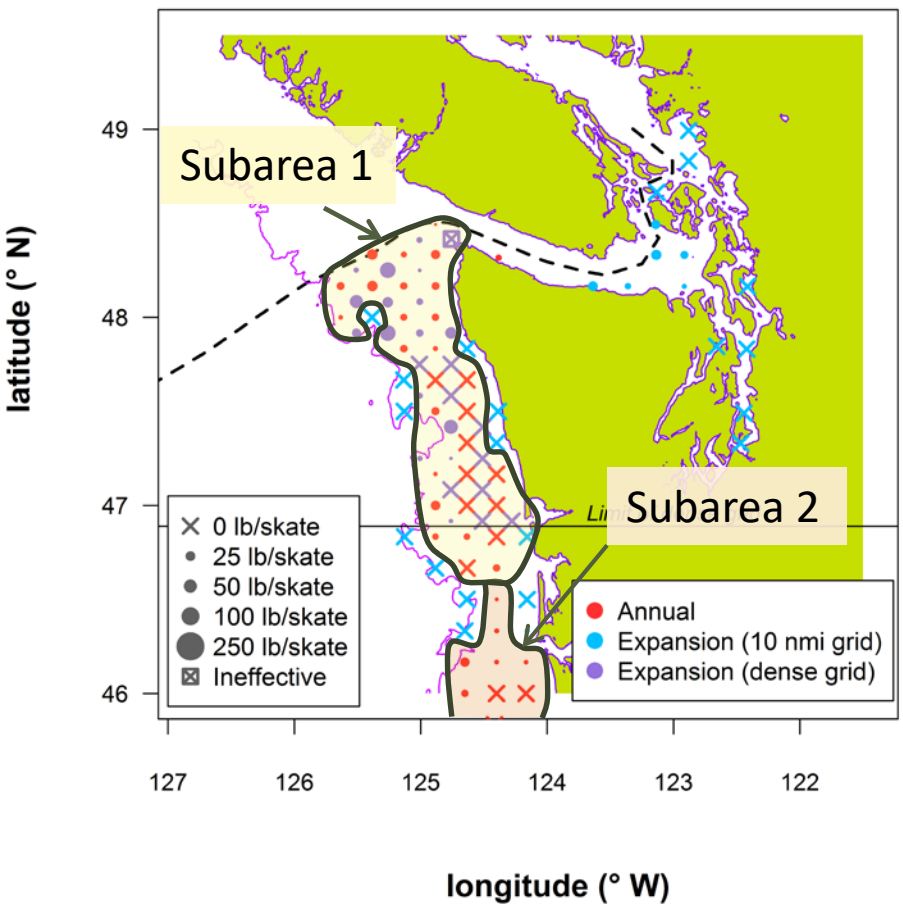
- If the management focus shifts from Reg Areas to biological regions, survey design flexibility may increase
  - For example, a precise index for Region 2 may not require annual sampling in Reg Area 2A
- Otherwise, meeting Regulatory Area data quality targets should ensure that Region and Coastwide targets are also met
  - This can be verified by compiling results of Reg Area model output to Region and Coastwide levels
- Likewise, sampling designs based on simulations for one index (O32 WPUE, all sizes WPUE or NPUE) would be expected to lead to data quality targets being met for the other indices
  - This can only be verified by repeating simulations for other indices

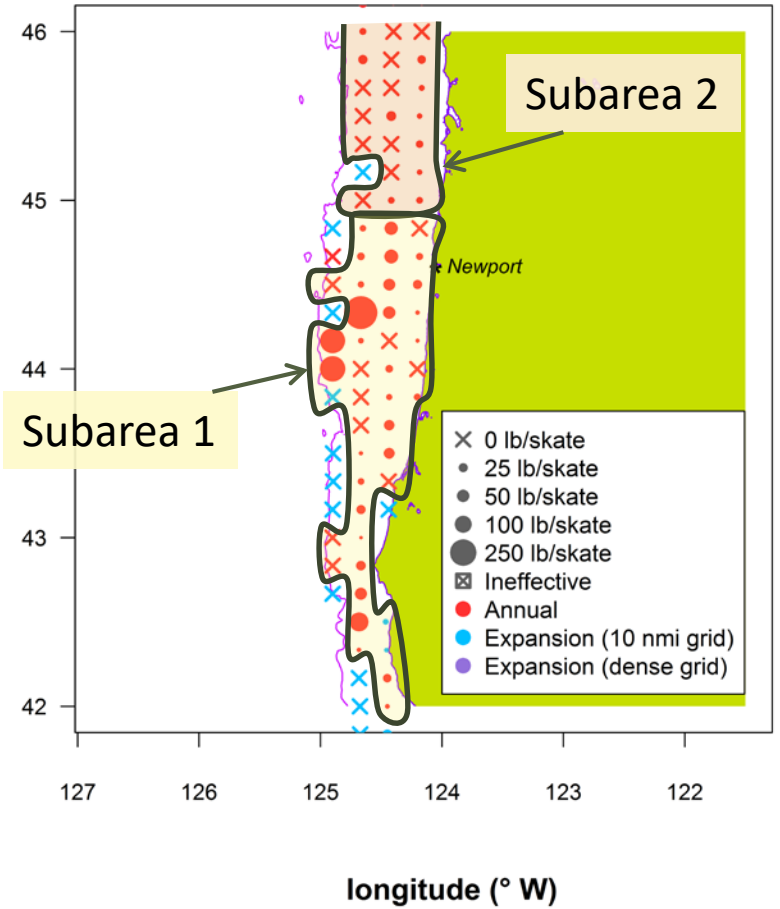
Biological sampling

- 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

Example 2: Regulatory Area 2A

- Proposed target CV of 15% for WPUE indices
- Expanded surveys in 2011, 2014 and 2017
- As with 4B, we propose dividing 2A into three subareas, based largely on density:
  - Subarea 1: highest density
  - Subarea 2: moderate density
  - Subarea 3: low density


Subarea 1
Subarea 2
0 lb/skate
25 lb/skate
50 lb/skate
100 lb/skate
250 lb/skate
Ineffective
Annual
Expansion (10 nmi grid)
Expansion (dense grid)
latitude (° N)
longitude (° W)
49
48
47
46
127
126
125
124
123
122


Subarea 2
Subarea 1
Newport
0 lb/skate
25 lb/skate
50 lb/skate
100 lb/skate
250 lb/skate
Ineffective
Annual
Expansion (10 nmi grid)
Expansion (dense grid)
longitude (° W)
46
45
44
43
42
127
126
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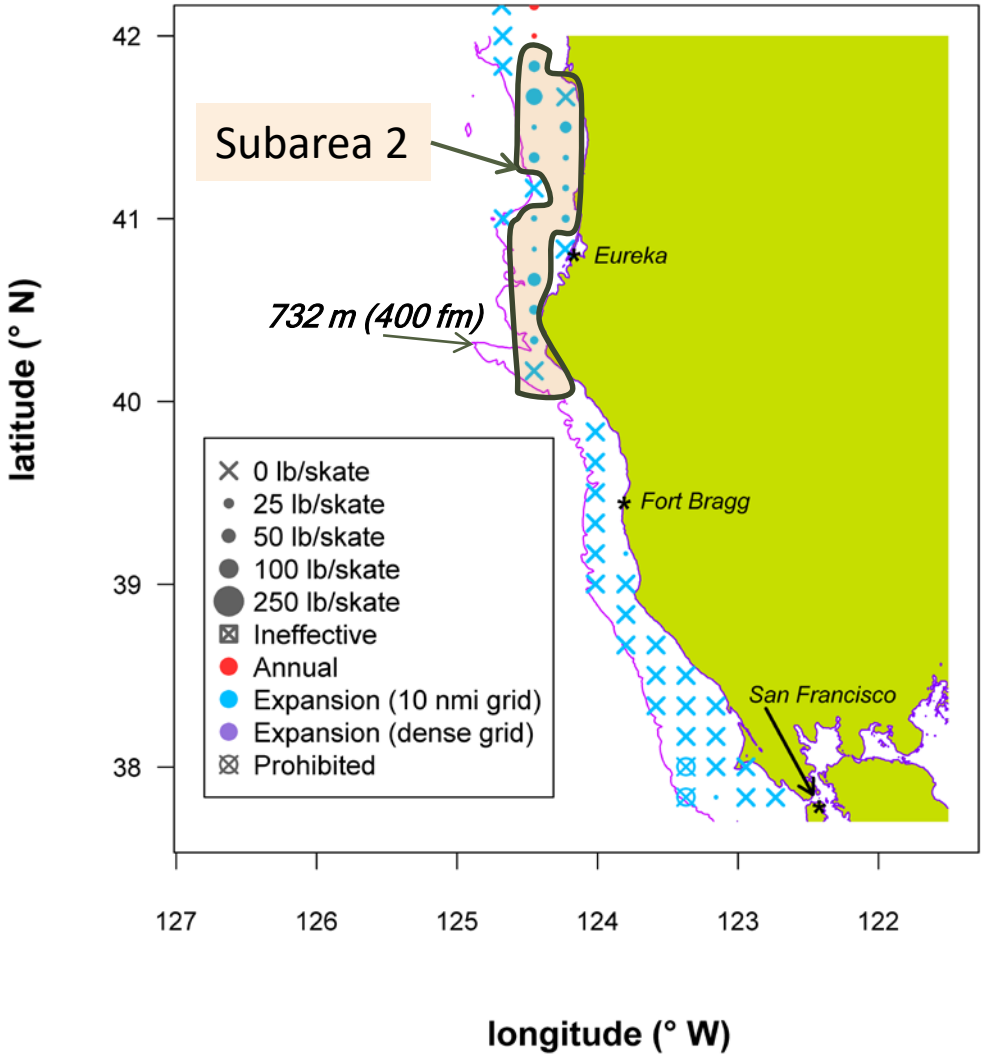
124
123
122

Reg Area 2A


Subarea 2
Eureka
732 m (400 fm)
Fort Bragg
San Francisco
0 lb/skate
25 lb/skate
50 lb/skate
100 lb/skate
250 lb/skate
Ineffective
Annual
Expansion (10 nmi grid)
Expansion (dense grid)
Prohibited
latitude (° N)
longitude (° W)
42
41
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127
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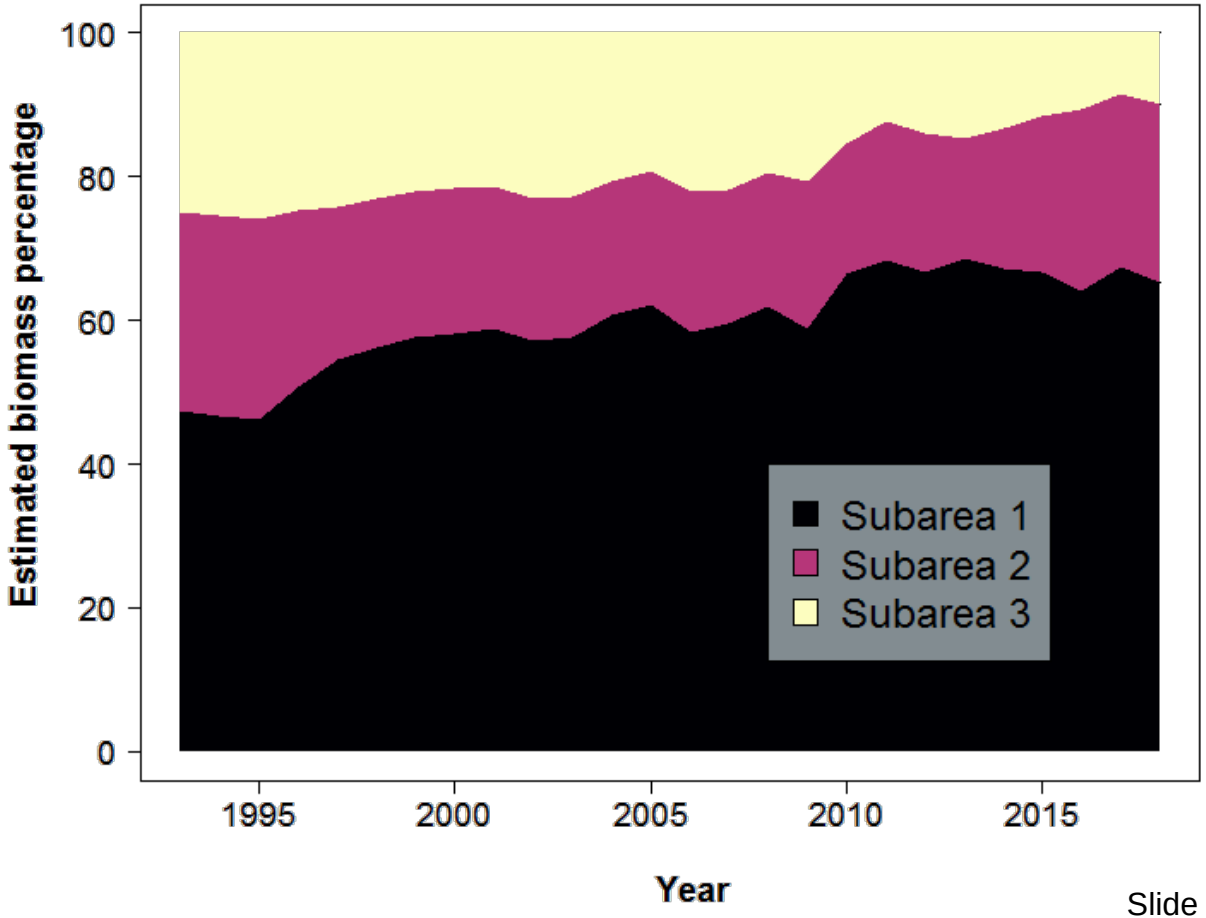
124
123
122

Reg Area 2A biomass share by subarea and year



Reg Area 2A sampling priorities (part 1)

- We estimate Subarea 1 to have had 60-70% of Reg Area 2A biomass since 2010
- Subarea 2 has had 17-25% of the biomass, and Subarea 3 has had 9-15% since 2010

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	6	5	3	8	13	12	11	≥ 19	9	8	≥ 16	≥ 15	5	≥ 13	≥ 12	≥ 11	≥ 10	≥ 9	≥ 8	≥ 7	≥ 6	≥ 5	≥ 4	≥ 3	≥ 2	≥ 1
2	20	19	18	≥ 23	≥ 22	≥ 21	≥ 20	≥ 19	≥ 18	≥ 17	≥ 16	≥ 15	≥ 14	≥ 13	≥ 12	≥ 11	≥ 10	≥ 9	≥ 8	≥ 7	≥ 6	≥ 5	≥ 4	≥ 3	≥ 2	≥ 1
3	18	16	15	15	14	13	16	16	15	9	8	12	12	9	8	9	7	≥ 9	≥ 8	≥ 7	≥ 6	≥ 5	≥ 4	≥ 3	≥ 2	≥ 1

- All subareas are estimated to have had stable biomass proportions in recent years
- In the past, Subareas 1 and 3 have changed their proportion of biomass more quickly than Subarea 2

Reg Area 2A sampling priorities (part 2)

1. Subarea 1: 60-70% of biomass since 2010
2. Subarea 3: Low density, but less stable than Subarea 2, and with high proportion sampled once (much of N. California in 2017)
3. Subarea 2: Moderate density, but very stable

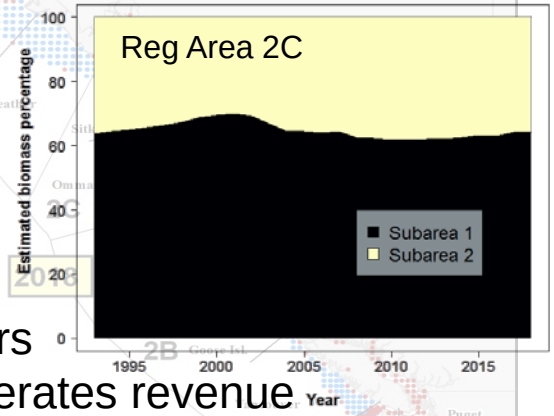
Results of simulations: are CV targets met?

Estimated CVs (%) by data input for Reg Area 2A. Target CV = 15%.

Data input	Sampled subareas	2017	2018	2019	2020	2021	2022
1993-2018 data		9.9	11.7				
+ 2019-20 simulated data	2020 Subarea 1	10.0	11.5	11.9	13.4		
+ 2019-21 simulated data	2020-21 Subarea 1	10.7	11.7	11.6	12.4	13.6	
+ 2019-22 simulated data	2020-22 Subarea 1	10.6	11.9	11.6	13.0	13.0	14.2

Other Regulatory Areas

- Area 4CDE
  - Area 4CDE shelf edge: sample less frequently
- Area 4A
  - Area 4A shelf edge: sample less frequently
  - Western 4A (Aleutian Islands): sample annually
- Area 2C
  - Outside waters: 62-64% of biomass since 2011
  - Inside waters: lower density, sample every 2-3 years
  - But still high catch rates relative to elsewhere: generates revenue
- Area 2B
  - Salish Sea, W Coast Vancouver Is, east of Haida Gwaii: lower density ⇒ less frequent sampling
- Areas 3A and 3B
  - Awaiting 2019 setline survey expansion



Putting it all together

- Determine priorities and costs for each Regulatory Area (or biological region) for the next three 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

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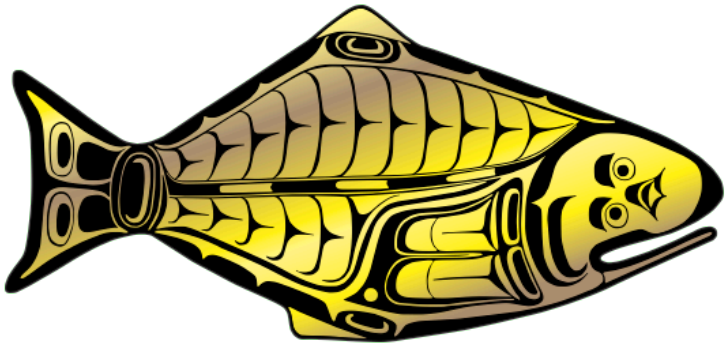

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