INTERNATIONAL PACIFIC
HALIBUT COMMISSION

IPHC Fishery-Independent Setline Survey (FISS) and commercial data modelling

Agenda item 4.1

IPHC-2021-SRB019-05

(R. Webster)

Topics

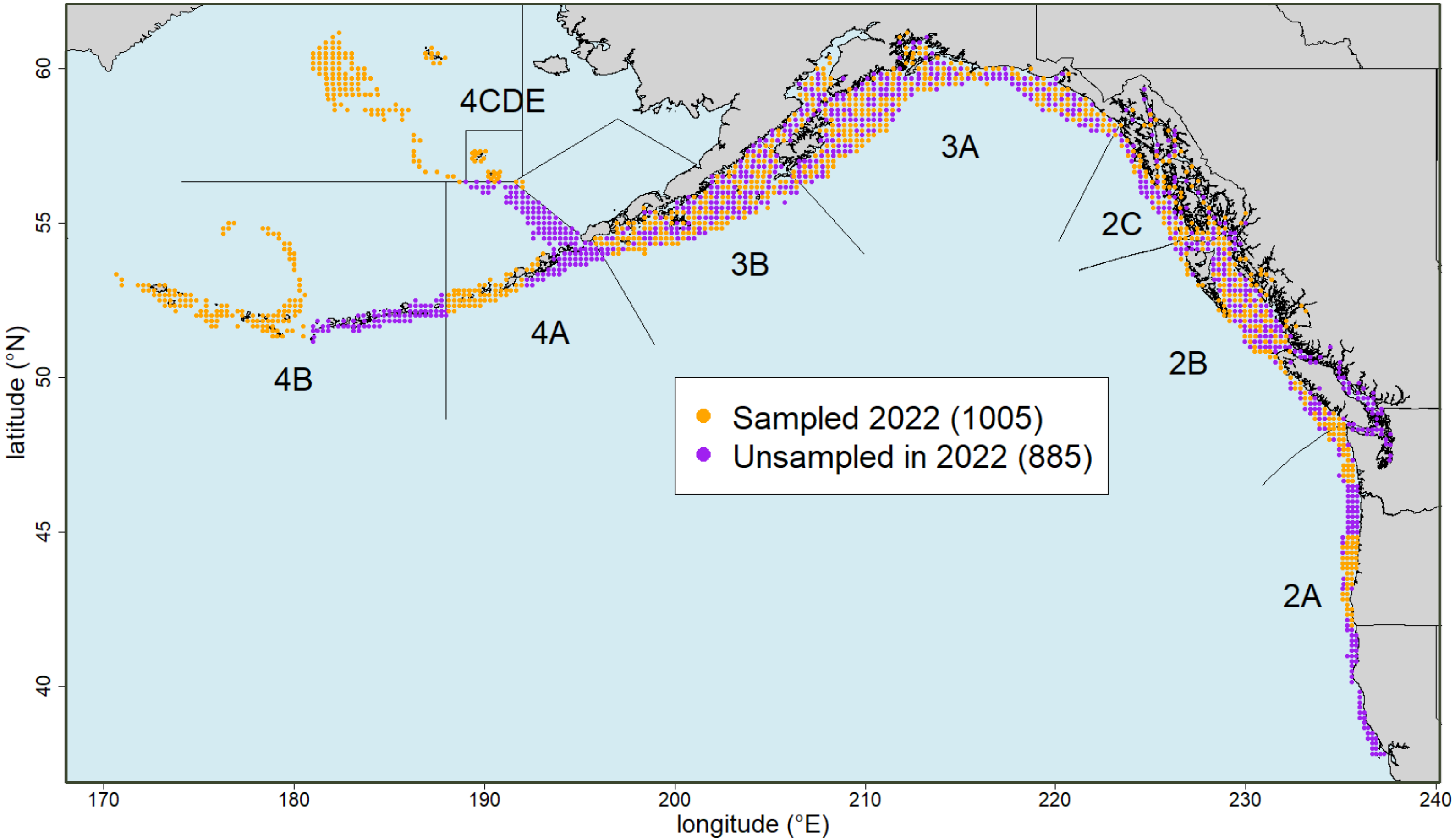
1. 2022-24 FISS design evaluation
2. Modelling of IPHC length-weight data
3. Review of IPHC hook competition standardization
4. Accounting for the effects of whale depredation on the FISS

1. 2022-24 FISS design evaluation

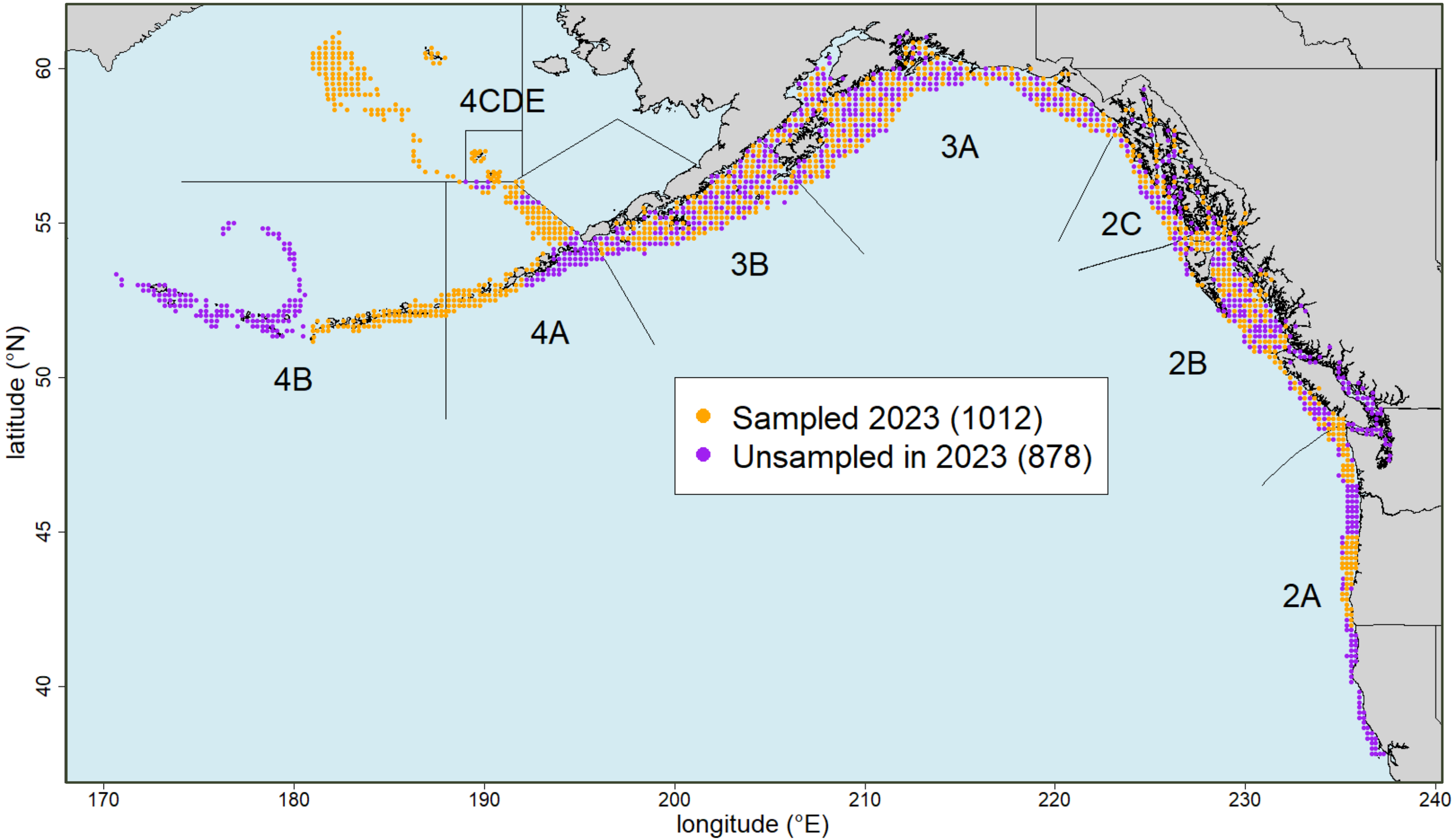
- At SRB018, the Secretariat presented proposed FISS designs for 2022-24 together with an evaluation of those designs.
- Based on the evaluation, it is expected that the proposed designs would lead to estimated indices of density that would meet bias and precision criteria.
- In their report (IPHC-2021-SRB018-R, paragraph 16) the SRB stated:

> *The SRB **ENDORSED** the final 2022 FISS design as presented in Fig. 2, and provisionally **ENDORSED** the 2023-24 designs (Figs. 3 and 4), recognizing that these will be reviewed again at subsequent SRB meetings.*

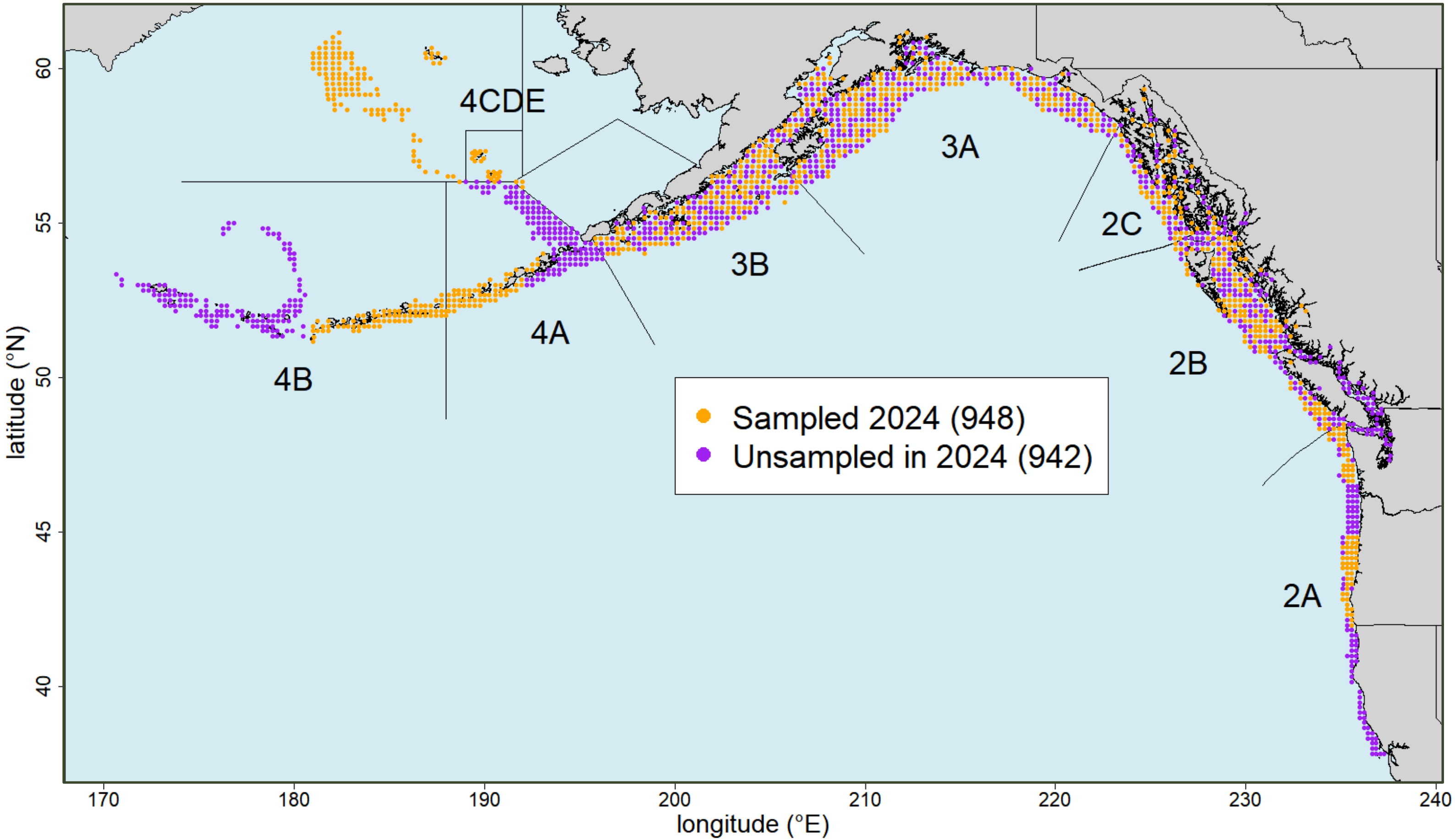
Proposed 2022 FISS design



Proposed 2023 FISS design



Proposed 2024 FISS design



Recommendation

That the Scientific Review Board:

1) **RECOMMEND** that the Commission note the SRB endorsement of the proposed 2022 design (Figure 1.1 of IPHC-2021-SRB019-05) and provisional endorsement of the proposed 2023-24 designs (Figures 1.2 and 1.3).

2. Modelling of IPHC length-weight data

- The IPHC and other agencies sampling Pacific halibut use a standard length-weight relationship to estimate Pacific halibut weight from length when direct weight measurements are not recorded.
- This relationship was estimated in 1926 from 454 fish captured in IPHC Regulatory Area 2B
- A review by Clark (1991) showed that the relationship still held up well
- In recent years there has been evidence that this historical relationship is biased, with weight being overestimated on average
  - Pacific halibut appear to have become thinner since the relationship was estimated

IPHC data sources

- Since 2015, the IPHC commercial sampling program has collected dockside weight data on Pacific halibut
- Since 2019, FISS charter vessels have been equipped with motion-compensated scales with the goal of weighing all captured Pacific halibut
- These data allow us to obtain contemporary estimates of the length-weight relationship, and examine variation in the relationship over time and space

Weight measures and conversion multipliers

Weight	Definition	Multiplier to convert to net weight	Notes
Round FISS (U32)	Head-on, not gutted, no ice and slime	0.75	
Gross (vessel weight)	Head-on, gutted, with ice and slime	0.8624	Assumes 10% head weight and 2% shrinkage, or 12% head, and 2% ice and slime
Dressed (vessel weight) FISS (O32)	Head-on, gutted, no ice and slime	0.88	Assumes 10% head weight and 2% shrinkage, or 12% head only
Gross (dock weight) Commercial (O32) FISS (some O32)	Head-on, gutted, with ice and slime	0.882 or 0.88	Assumes 10% head weight and 2% ice and slime; deductions either additive (10+2=12% in 2A and 2B) or multiplicative (1-0.9*0.98=0.118 or 11.8% in Alaska)
Dressed (dock weight) Commercial (O32)	Head-on, no ice and slime (washed)	0.9	Assumes 10% head weight
Net	Head-off, gutted, no ice and slime (washed)	1	

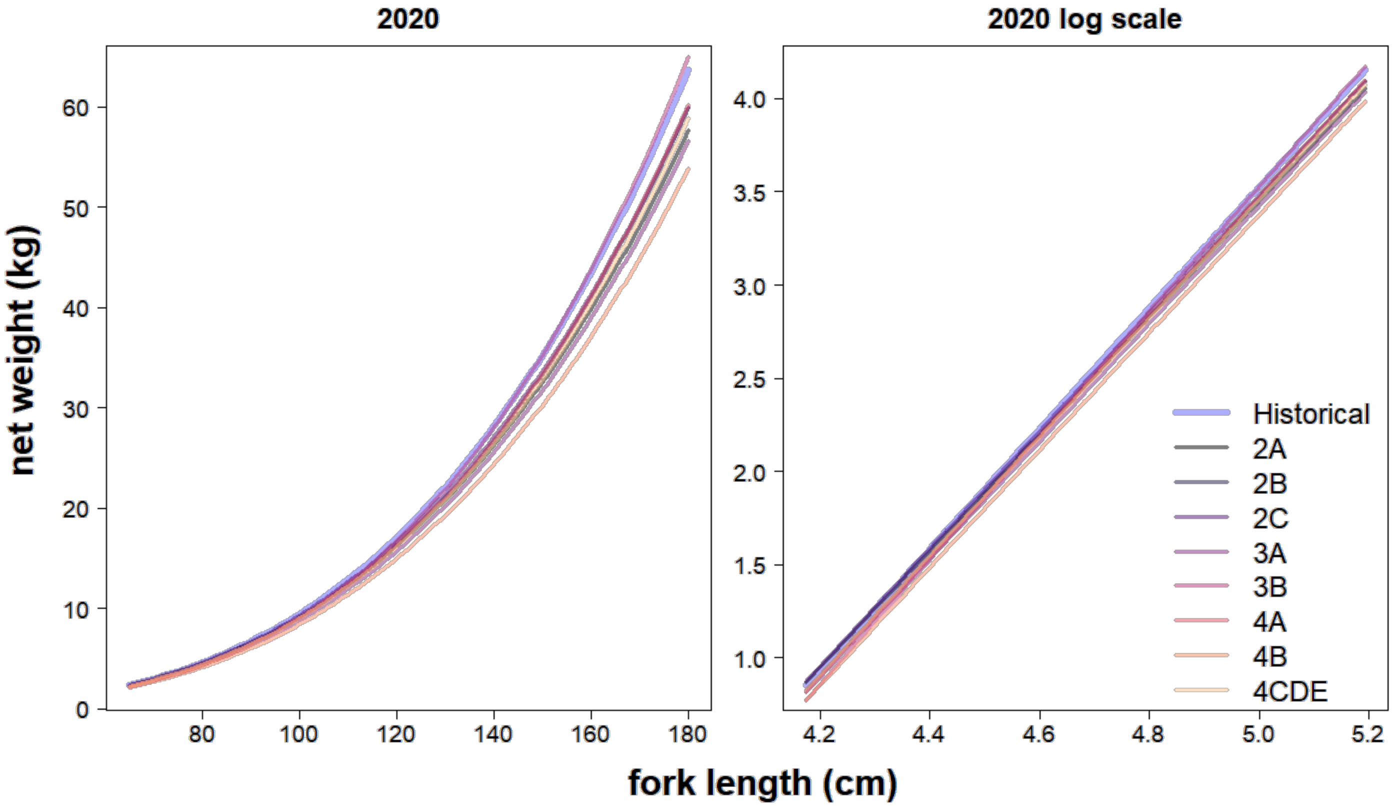
Commercial length-net weight

- We fitted linear models on the log scale to estimate the parameters of the length-net weight relationship from commercial sampling data:

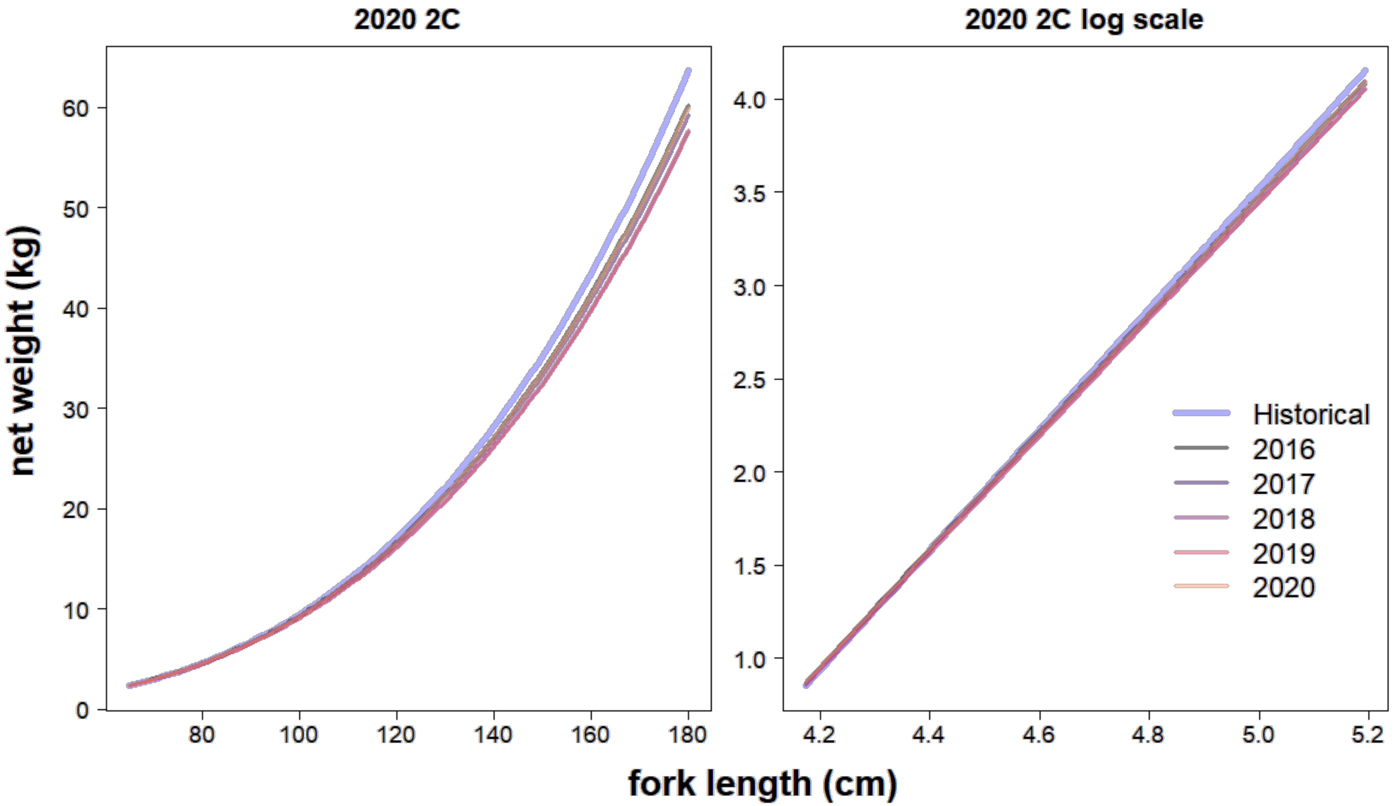
$$\log\left(W_i\right) = a + \beta \log\left(L_i\right) + \varepsilon_i$$

$$\varepsilon_i \sim N\left(0, \sigma^2\right)$$

Estimated length-net weight relationships by IPHC Regulatory Area, 2020 (commercial data)



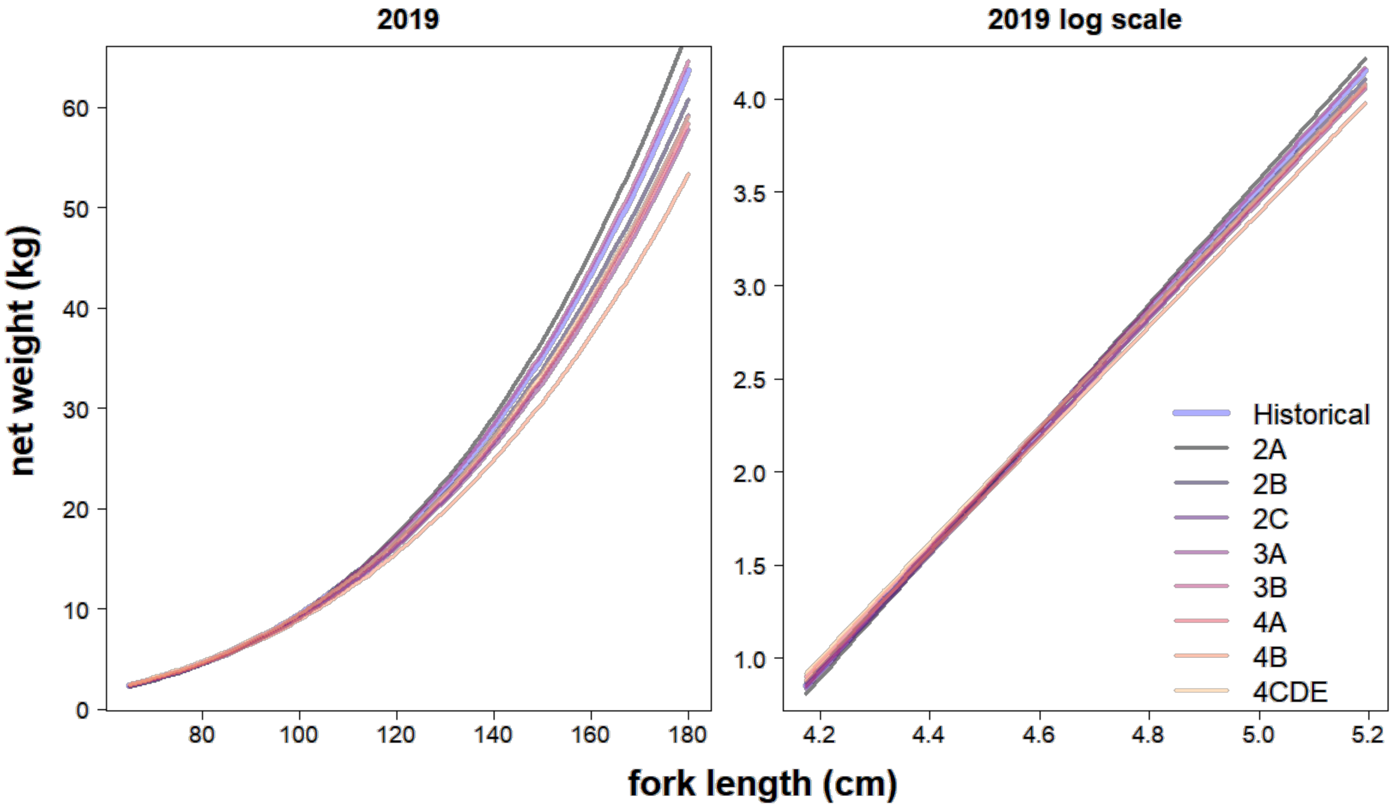
Estimated length-net weight relationships for IPHC Regulatory Area 2C by year (commercial data)



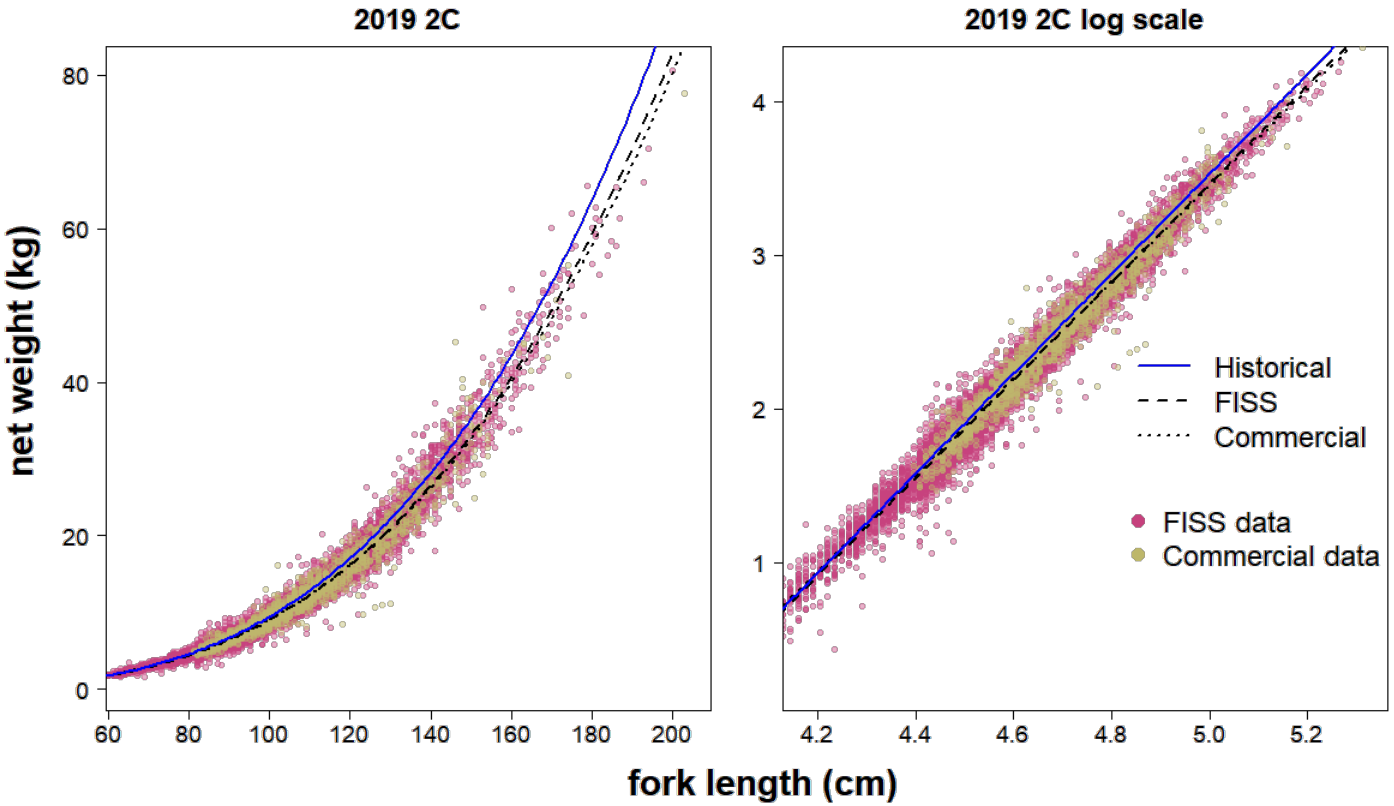
FISS length-net weight

- As with commercial data, linear models were fitted to estimated parameters of the length-net weight relationship
  - Data from two years to date only: little information on year-to-year variation
- U32 fish with both round and dressed weight recorded in 2019 were used to estimate a round-dressed weight relationship for use in subsequent years

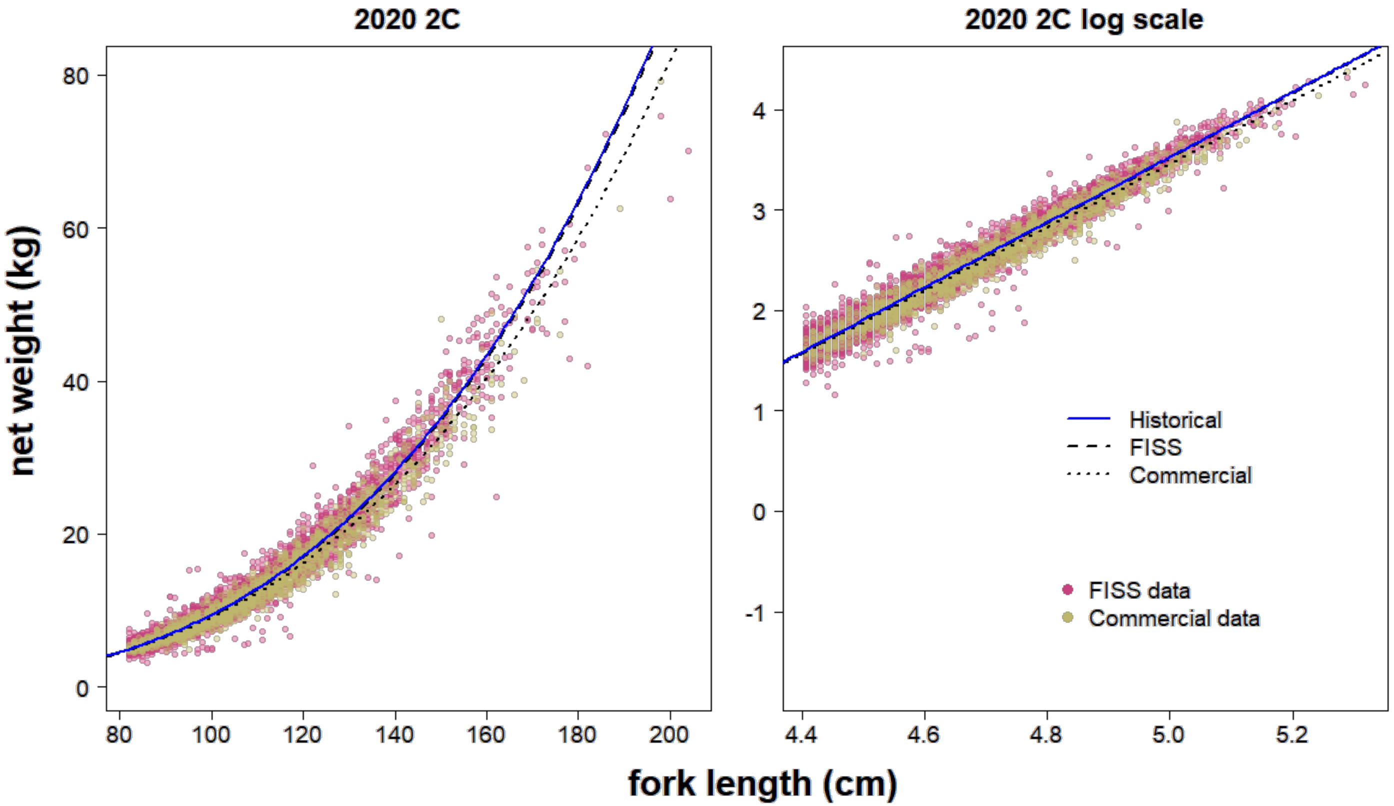
Estimated length-net weight relationships by IPHC Regulatory Area, 2019 (FISS data)



Comparison of commercial and FISS relationships, 2C in 2019



Comparison of commercial and FISS relationships, 2C in 2020



Comparison of commercial and FISS relationships

- Commercial data is collected throughout the fishing season (March-November) but is limited to fishing grounds
- FISS data is limited to the summer survey period, but is more spatially extensive within each sampled region
- We fitted two models to the combined commercial and FISS data:
  - Model 1: Fitting a single relationship to all data
  - Model 2: Allows parameters to differ between the two data sources
- Models fitted for 2019 and 2020 data only
  - 2020 FISS only sampled core areas, 2B, 2C, 3A and eastern 3B
- Compared predicted mean weights with observed mean weights to help understand potential for bias in model estimates

Comparison of commercial and FISS relationships

- Model 2 produced mean net weights within 1% of observed means of both commercial and FISS data for each year and IPHC Regulatory Area
- In almost all cases, Model 1 produced mean net weights within 2% of observed means
- The historical relationship had differences between predicted and observed means ranging from 1.1% to 10.7% for commercial data, and −1.7% to 5.5% for FISS data.

Discussion

- Using linear models fitted to contemporary data is likely to reduce bias in weight estimates relative to estimates from the historical relationship
- Model 1 is simpler and does not require users (e.g., other agency staff) to make a choice of which data source (commercial or FISS) most closely resembles their own
  - Estimated from combined data sources, so represents a blend of spatially extensive (FISS) and temporally extensive (commercial) samples: more generally applicable

Discussion

- All data had equal weight, so a source with larger sample sizes has more influence on model results
  - One option would be to equally weight commercial and FISS samples, i.e., apply lower relative weights to observations from the source with greater sample size
- Given apparent temporal stability (2016-20) and spatial variability, we recommend:
  - Providing curves to non-IPHC users estimated from (at least) three years' worth of combined data from commercial and FISS sources for each IPHC Regulatory Area (so 2019-21 at present)
  - Re-evaluating the relationships annually as additional years of data are collected and updating if necessary

Outstanding data needs

- At present we lack data to validate the assumed round to net weight conversion for O32 fish
  - We can obtain this be making two measurements (round and dressed) on a sample of O32 FISS fish
- We have no data to validate adjustment factors for ice and slime, despite collecting commercial weight samples since 2015

Recommendations

That the Scientific Review Board:

1) **NOTE** paper IPHC-2021-SRB019-05.2 that presents methods for revised the length-net weight relationships from FISS and commercial sampling data

2) **RECOMMEND** that the IPHC provide a revised length-net weight relationship for each IPHC Regulatory Area based on modelling of combined FISS and commercial sample data to be used for the calculation of all non-IPHC mortality estimates where individual weights cannot be collected, for 2021 and until further notice.

3. Review of IPHC hook competition standardization

- Since 2007, the IPHC has used the O32 WPUE index of density to estimate the distribution of the stock among IPHC Regulatory Areas
- Recognising that such indices are affected by variability catchability, adjustments to the WPUE index were devised to help account for catchability differences
- The most important of these is the hook competition standardization
  - One of only two standardizations still applied to the index (the other being for FISS timing relative to the fishery)

Standardisation for hook competition

- Gear saturation: catch rates decrease disproportionately to abundance as the sampling gear becomes fully occupied.
- Although it may be present for many types of sampling gear, for longline gear, as deployed by the IPHC, gear saturation may be considered via competition for the finite number of hooks deployed.
- The IPHC method for standardisation for hook competition was developed by Clark (2008), and is based on the number of baits removed on FISS sets, B_i, by predator species *i*.
- The Baranov catch equation was used to model the B_i after a time period, *T*:

$$B_i = B_0 \frac{F_i}{Z}\left(1 - e^{-ZT}\right)$$

F_i: Instantaneous rate of bait removal for predator *i*

B_0: Initial number of baits

Z: Sum of F_i over all predators

Standardisation for hook competition

- It follows that the expected catch of Pacific halibut (C_h), which is one of the bait predators, is given by

$$C_h = B_0 \frac{F_h}{Z}\left(1 - e^{-ZT}\right)$$

- Soak time is assumed to be of sufficient length that catches of all species are unaffected by the value of *T*, and we set *T*=1
- The standardized index is given by the estimator of F_h:

$$\hat{F}_h = \frac{C_h}{B_0}\log\left(\frac{B_0}{B_1}\right)\frac{B_0}{B_0 - B_1}$$

CPUE

Adjustment factor

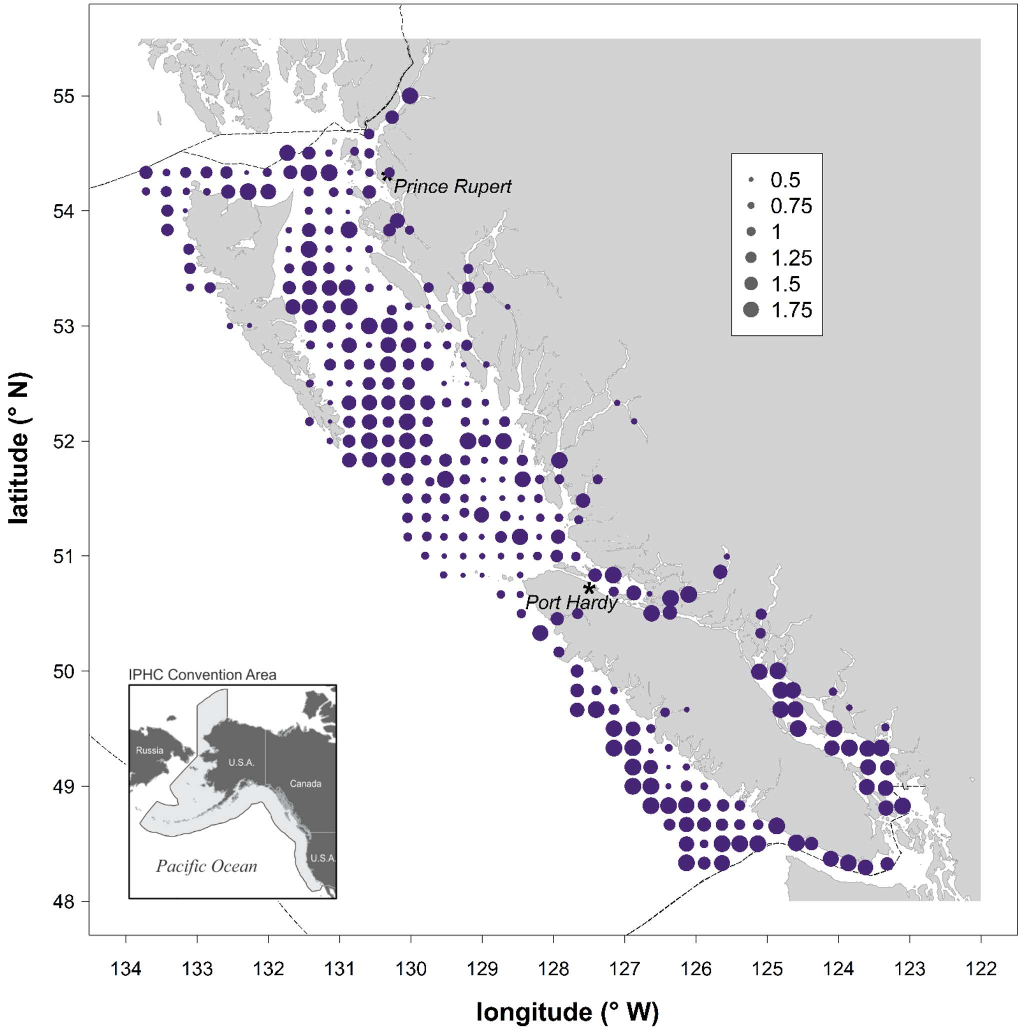
Final number of baits

Standardisation for hook competition

- The adjustment factors have a lower bound of one, so can only increase WPUE or NPUE
- To maintain indices on scale familiar to stakeholders, we divide by a scalar based on mean adjustment factor for 1998
- Other notes:
  - Mean adjustment factors can vary with year, allowing for changes in predator density with time
  - Missing baits on hauling attributed to escaped predators other than Pacific halibut
  - Adjustment is multiplicative, so zero catch rates of Pacific halibut remain as zeros after standardisation
  - Aggregating by area and year, generally 5-40% of baited hooks are returned with baits
- Method is mathematically the same as the multinomial exponential approach developed by Etienne et al. (2013).

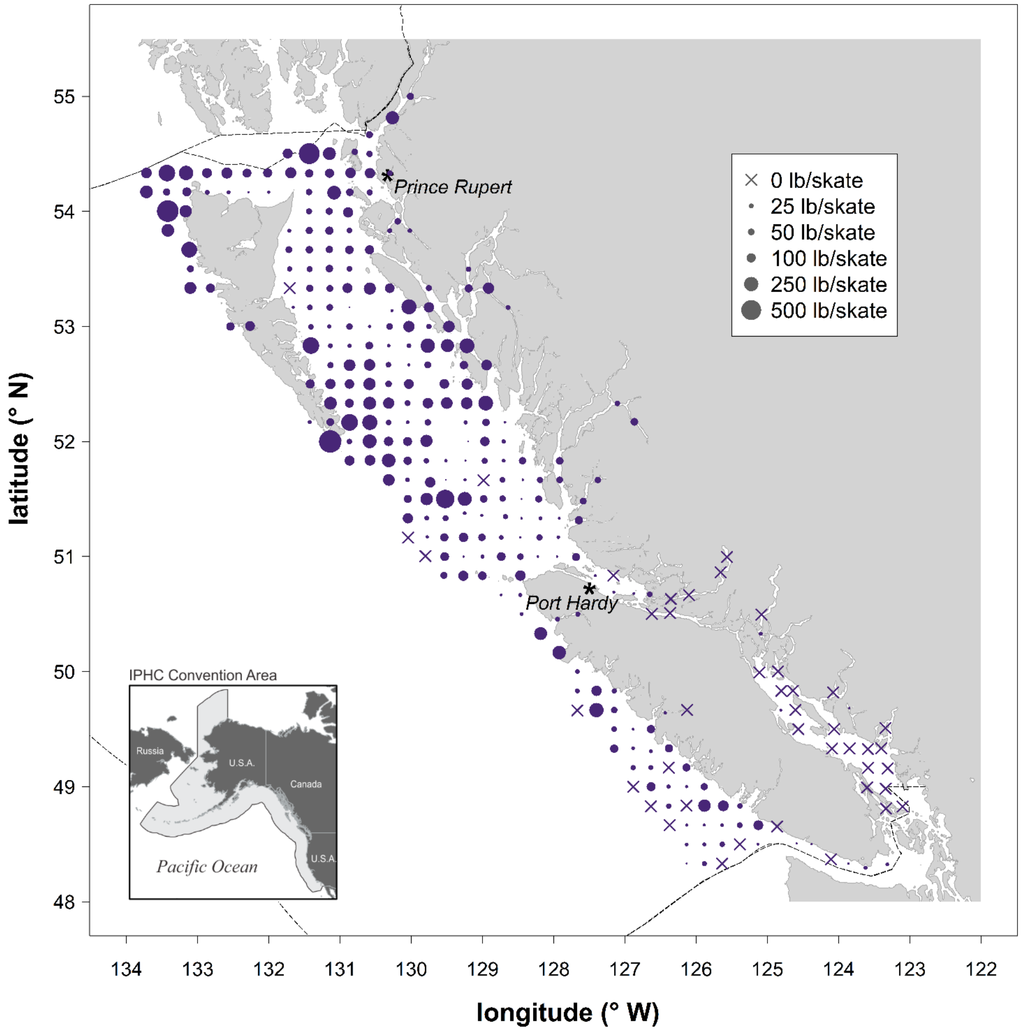
Example: 2B 2018

Adjustment factors by station



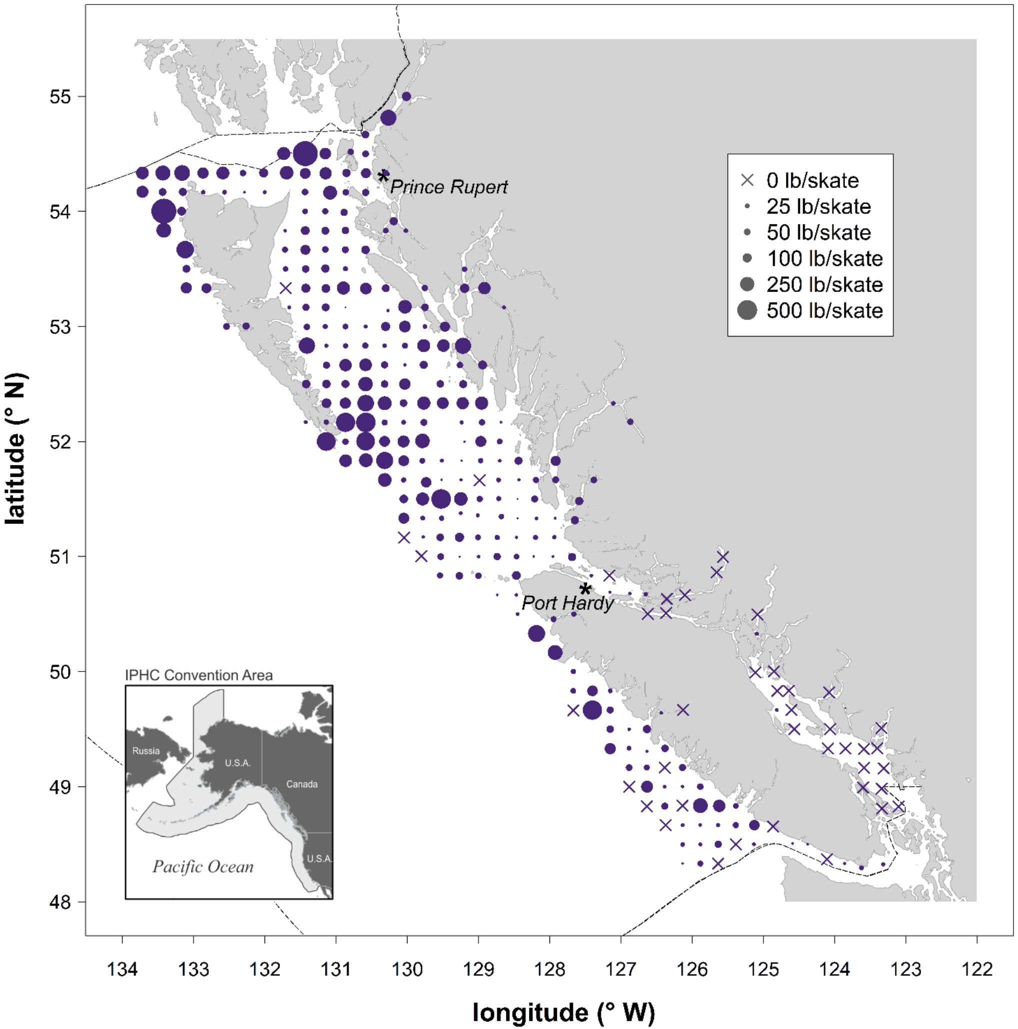
Example: 2B 2018

Unadjusted O32 WPUE



Example: 2B 2018

O32 WPUE standardized
for hook competition



IPHC hook timer studies

- Historical work on hook timers was intended to produce data on the rate of bait capture by Pacific halibut and competing species.
- The timers in use in those studies were not tripped most of the time:
  - It appears the timers were not sensitive to the capture of smaller fish or to smaller fish taking the bait without being captured
- The IPHC is currently collaborating on a study of standard and modified circle hooks that will use hook timers to record the capture time of different species.
  - Modern hook timers are expected to be more sensitive than those used in historical studies
  - It is therefore hoped that this study will yield data that will help inform the calculation of the hook competition standardisation.

Recommendation

That the Scientific Review Board:

1) **NOTE** paper IPHC-2021-SRB019-05.3 that presents an overview of the IPHC standardization for hook competition on FISS sets.

4. Accounting for the effects of whale depredation on the FISS

- The presence of sperm whales and orcas during the fishing and hauling of FISS sets can lead to such sets being designated as ineffective for the use in analyses due to the potential impact on recorded catch rates Pacific halibut of depredation
- The criteria for ineffectiveness, which were strengthened in 2019, are as follows:
  - Sperm whales: a sperm whale is spotted within 3 nmi of the boat while hauling gear
  - Orcas: a set has more than 1 lips-only Pacific halibut or a set has other observations of orca feeding on Pacific halibut
- These criteria were designed to minimize the potential for including biased data in the annual indices.

Accounting for the effects of whale depredation on the FISS

- Sperm whales have been found to depredate cryptically on the gear at large distances from the vessel, while orcas generally leave clear evidence of depredation or are observed in the act.
- Coastwide, from 2010-2020, 1.4-3.0% of all sets fished included sperm whales or orcas as a reason for ineffectiveness (see https://www.iphc.int/data/fiss-performance).
- However, the impacts can be greater for a given area and year.
  - IPHC Regulatory Area 3A has had up to 6% of sets affected by whales (mainly sperm whales);
  - IPHC Regulatory Area 4A is the area most affected by orca encounters, with over 10% of sets affected in some years, and 12% of sets during the 2014 FISS expansion (the only time some of these stations were fished prior to 2021)

Accounting for the effects of whale depredation on the FISS

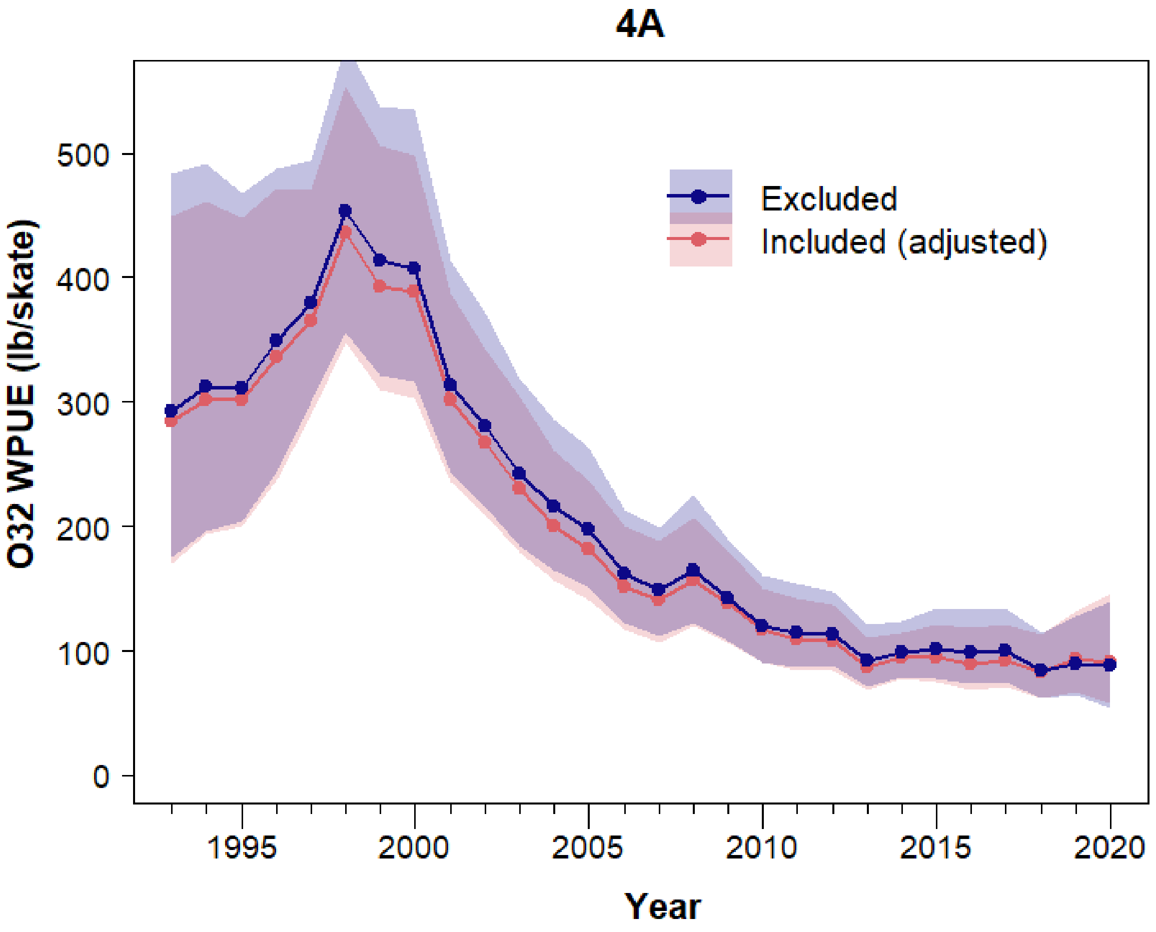
- We added covariates to the non-zero component of the space-time model to account for differences in catch rates between whale-affected sets and unaffected sets.
- Covariates were simple binary variables, taking the values zero or one:
  - 0 if set was effective
  - 1 if sperm whales and/or orcas were the reason for the set being marked as ineffective
- Prediction of WPUE or NPUE for time series estimation is done with this covariate set to zero for all sets.
- This allows us to include additional valuable data while accounting for the impact of these marine mammals on catch rates.

IPHC Regulatory Area 4A

- Area most affected by marine mammal interactions:
  - 139 orca-affected sets since 1993
  - 3 sperm whale-affected sets
  - In some years >10% of sets are affected by orcas
- Space-time model estimates that O32 WPUE on affected sets is 51% (95% CI: 43-60%) of unaffected sets.

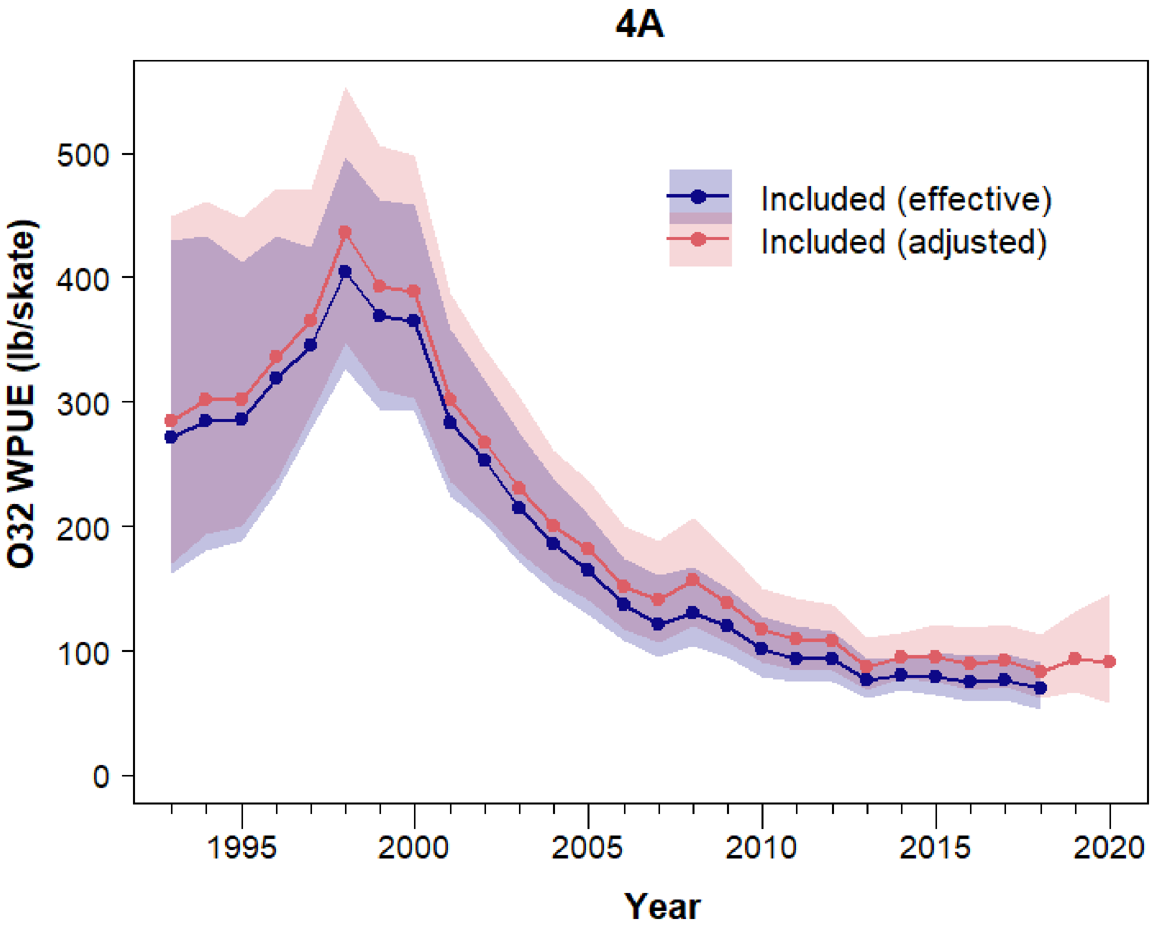
Comparison of estimated time series for O32 WPUE with and without whale-affected sets.

Inclusion of such sets while accounting for their effect on WPUE leads to some improvement in precision (narrow 95% CIs).



Many currently ineffective sets were included in analyses prior to 2019 when effectiveness criteria were tightened.

Model results show their exclusion was justified at the time, as failing to account for impact of orcas resulted in likely negative bias in time series estimates.



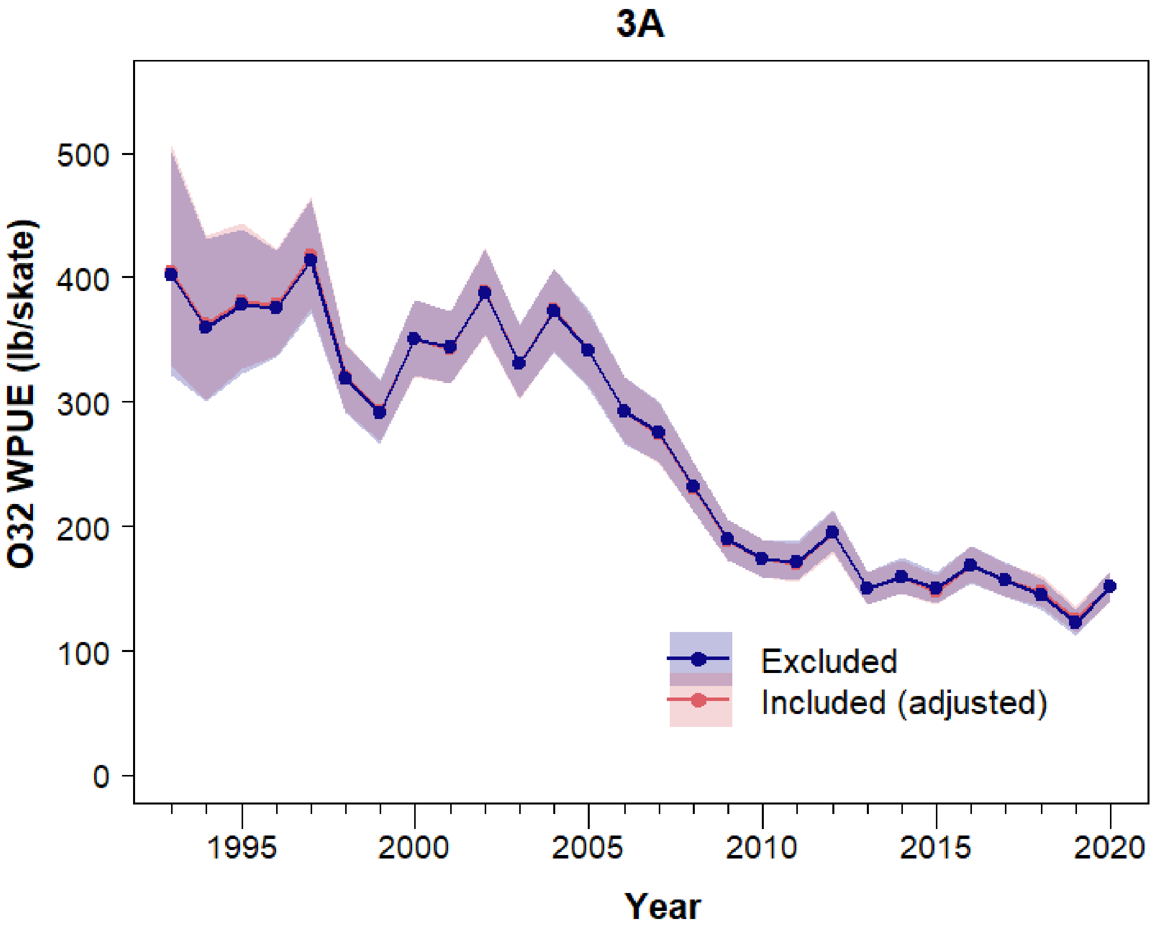
IPHC Regulatory Area 3A

- Area most affected by sperm whale interactions:
  - 116 sperm whale-affected sets since 1993
  - 29 orca-affected sets
  - 18 sets affected by both species
  - In some years >10% of sets are affected by orcas
- Space-time model estimates:
  - O32 WPUE on sperm whale-affected sets is 86% (95% CI: 75-99%) of unaffected sets
  - O32 WPUE on orca-affected sets is 84% (68-104%) of unaffected sets

Comparison of estimated time series for O32 WPUE with and without whale-affected sets.

Inclusion of such sets while accounting for their effect on WPUE leads to no apparent effect on estimates:

- Smaller proportion of affected sets than 4A
- Effect of marine mammals is much less



Discussion

- We propose that beginning in 2021, data from "ineffective" sperm whale and orca-affected sets be included in the modelling with appropriate covariates to account for differences in catch rates between affected and unaffected sets.
- In IPHC Regulatory Areas where such interactions are rare, precise estimation of whale covariate parameters will not be possible, and we can continue to omit such sets from the analyses with little loss of information.

Recommendation

That the Scientific Review Board:

1) **NOTE** paper IPHC-2021-SRB019-05.4 that presents an approach to accounting for the effects of whale interactions on FISS catch rates through the space-time modelling.

2) **RECOMMEND** that the Secretariat should apply such an approach going forwards.

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