Methods for spatial survey modelling - program of work for 2019

PREPARED BY: IPHC SECRETARIAT (R. WEBSTER; 24 MAY 2019)

PURPOSE

To propose methods for assessing options for a rationalised IPHC fishery-independent setline survey (FISS or "setline survey") following completion of the planned setline survey expansions in 2019.

BACKGROUND/INTRODUCTION

The IPHC has been undertaking a series of setline survey expansions, beginning with a 2011 pilot in IPHC Regulatory Area 2A, and continuing from 2014-19 as follows:

- 2014: Regulatory Areas 2A and 4A
- 2015: Regulatory Area 4CDE eastern Bering Sea flats
- 2016: Regulatory Area 4CDE shelf edge
- 2017: Regulatory Areas 2A and 4B
- 2018: Regulatory Areas 2B and 2C
- 2019: Regulatory Areas 3A and 3B

The purpose of the expansion program has been to fill in the often large gaps in the annually-fished setline survey to build a complete picture of Pacific halibut density throughout its range, and thereby reduce bias and improve precision in density indices and other quantities computed from the setline survey data.

With the planned expansions due for completion in 2019, the intention is to use our improved understanding of the Pacific halibut distribution to re-design the annual setline survey. As a result, it is likely that stations that were previously fished annually may require less frequent fishing, while it may be preferable to annually fish some expansion stations that have been surveyed just once to date. This report proposes criteria and methods for evaluating such a survey rationalisation, and uses Regulatory Area 4B as an example to demonstrate the application of our proposed approach. We envision the rationalisation as an ongoing process: as new data become available each year and relative costs change with time, future designs choices will be re-evaluated and modified to adapt to changing data needs.

Methods

The overall goal of the setline survey rationalisation is to maintain or enhance data quality (precision and bias) subject to the cost constraints of the FISS budget. Here we propose some precision targets, discuss an approach for reducing the chance of large biases, and note the importance of considering costs in any redesign.

Precision targets

At present, the IPHC Secretariat has an informal goal of maintaining a coefficient of variation (CV) of no more than 15% for mean WPUE for each IPHC Regulatory Area. Including all expansion data to date, this goal has been achieved in all areas from 2011, the year of the first pilot expansion (Table 1), except Regulatory Area 4B in 2011 and 2012 for O32 WPUE, and Regulatory Area 4A in 2018 (all sizes WPUE).

Table 1. Range of coefficients of variation for O32 and all sizes WPUE from 2011-18 by Regulatory Area.

Reg Area	O32 WPUE (2011-18)				All sizes WPUE (2011-18)			
	Lowest CV (%)	Year	Highest CV (%)	Year	Lowest CV (%)	Year	Highest CV (%)	Year
2A	9.9	2017*	11.7	2018	9.4	2014*	11.9	2018
2B	5.6	2018*	6.7	2012	5.8	2018*	6.7	2011
2C	5.6	2018*	6.3	2012	5.7	2018*	6.5	2011
3A	11.1	2016	12.0	2018	9.0	2016	9.7	2018
3B	10.3	2012	12.7	2015	9.3	2018	10.1	2015
4A	8.3	2014*	14.7	2018	9.3	2014*	16.3	2018
4B	9.5	2017*	16.1	2012	8.5	2017*	15.3	2012
4CDE	9.0	2017#	10.0	2013	5.2	2015*	5.9	2018

* Year of setline survey expansion in Reg Area. # Year of trawl survey expansion in Reg Area 4CDE.

Considering Biological Regions, CVs for WPUE in Region 2 were below 5% in all years from 2011 (Table 2), while we expect CVs to be reduced to similar levels in Region 3 following the 2019 expansion. Region 4 CVs for WPUE were below 10%, while the smallest region, Region 4B, has some years with CVs above 15% as noted previously. For all sizes NPUE (Table 3), CVs were above 10% in Region 3 only – again, we expect a reduction below 10% following the 2019 expansion. Based on this information, constraining the setline survey design to produce CVs of 10% or less for Regions 2-4 and 15% for Region 4B should allow for some reduced survey effort in the former regions, while maintaining low uncertainty in Region 4B.

Table 2. Range of coefficients of variation for O32 and all sizes WPUE from 2011-18 by Biological Region.

Region	WPUE (2011-18)				All sizes WPUE (2011-18)			
	Lowest CV (%)	Year	Highest CV (%)	Year	Lowest CV (%)	Year	Highest CV (%)	Year
2	3.8	2018*	4.4	2012	3.9	2018*	4.3	2013
3	8.7	2011	10.0	2018	6.9	2016	7.7	2018
4	7.2	2014*	8.1	2018	4.9	2014*	6.8	2018
4B	9.5	2017*	16.1	2012	8.5	2017*	15.3	2012

* Year of FISS expansion in at least part of the Region.

Table 3. Range of coefficients of variation for all sizes NPUE from 2011-18 by Biological Region.

Region	All sizes NPUE (2011-18)			
	Lowest CV (%)	Year	Highest CV (%)	Year
2	4.2	2018*	5.1	2012
3	12.5	2011	14.0	2017
4	4.6	2014*	6.3	2018
4B	9.0	2017*	17.0	2012

* Year of FISS expansion in at least part of the Region.

Finally, the CV of coastwide, all sizes NPUE (used in the stock assessment) is estimated to be from 6-10% for all years of estimation from 1993 to 2018, and can be expected to be reduced further following the 2019 expansions in Regulatory Areas 3A and 3B. This suggests a target of 10% for the CV of this index will ensure that uncertainty is maintained at a low level for this key stock assessment input.

In summary, in order to maintain the quality of the estimates used for the assessment, and for estimating stock distribution, we propose that a rationalised survey should be designed to meet the following precision targets:

- CVs below 15% for O32 and all sizes WPUE for all Regulatory Areas
- CVs below 10% for O32 WPUE, all sizes WPUE, and all sizes NPUE for Regions 2, 3 and 4
- CVs below 15% for O32 WPUE, all sizes WPUE, and all sizes NPUE for Region 4B
- CVs below 10% for the coastwide, all sizes NPUE index

Reducing the potential for bias

With these targets set, we can proceed to using the space-time modelling to evaluate different survey designs by IPHC Regulatory Area and Biological Region. However, sampling a subset of stations in any area or region brings with it the potential for bias, when trends in the unsurveyed portion of a management unit (Regulatory Area or Region) differ from the surveyed portion. To reduce the potential for bias, we also looked at how frequently part of an area or region (called a “subarea” here) should be surveyed in order to reduce the likelihood of appreciable bias. For this, we propose a threshold of a 10% absolute change in biomass share: how quickly can a subarea’s share of a Regulatory Area or Region’s biomass change by at least 10%? By sampling each subarea frequently enough to keep down the chance of its share changing by more than 10% between successive surveys of the subarea, we reduce the potential for appreciable bias in the Regulatory Area or Region’s indices as a whole.

Cost constraints

While there are financial benefits to sampling low-density waters less frequently, reduced sampling frequency in high-density waters will result in a loss of income generated from fish sales. Thus, there are constraints on the how the survey design can be modified in a given year. Consideration of the effect of survey operating costs and cost recovery will be part of the final analysis, and is likely to constrain options for reducing annual effort in high-density Regulatory Areas and limit the frequency of surveys in remote, low density regions. Any decisions on future survey designs must account for the relative costs of design options, and be subject to overall budget limitations.

Analytical methods

We propose examining the effect of subsampling a management unit on precision as follows:

- Identify subareas within each management unit and select priorities for future sampling
- Generate simulated data for all survey stations based on the output from the most recent space-time modelling
- Fit space-time models to the 1993-2018 observed data augmented with 1 to 3 additional years of data, where the design over those three years reflects the sampling priorities identified above

Extending the modelling beyond three years is not considered worthwhile, as we expect further evaluation undertaken following collection of data during the 1-3 year time period to influence design choice to subsequent years.

Ideally, a full simulation study with many replicate data sets would be used, but this is impractical for the computationally time-consuming spatio-temporal modelling. Instead, "simulated" sample data sets for the future years will be taken from the 2000 posterior samples from the most recent year's modelling (i.e. 2018 for now). Each year's simulated data will have to be added and modelled sequentially, as subsequent data can improve the precision of prior years' estimates, meaning the terminal year is often the least precise (given a consistent design). If time allows, the process can be repeated with several simulated data sets to ensure consistency in results, although with large enough sample sizes (number of stations) in each year, we would expect even a single fit to be informative.

Example: IPHC Regulatory Area 4B

Regulatory Area 4B was chosen as an example for discussion as it is a relatively small area (and so models are quite quick to run), can be divided into fairly distinct subareas based on the 2017 expansion results, and is likely to benefit from a redesign as it has a high potential for exceeding CV targets and is costly to survey. We began by dividing Regulatory Area 4B into three subareas based on the results of the 2017 expanded survey (Figure 1):

1. West of Kiska Is. At present, a relatively low density subarea, but one that previously had much higher densities of Pacific halibut. (57 stations)
2. East of Kiska Is, and west of Amchitka Pass, including Bowers Ridge. Also at present a low density subarea, but one largely unsurveyed before 2017. (73 stations)
3. East of Amchitka Pass. Currently, a subarea of relatively high density and stability, although with higher density in the past. (73 stations)

In recent years, the bulk of the 4B stock (70-80%, Table 4) is estimated to have been in Subarea 3. With standard deviations typically increasing with the mean for this type of data, focusing survey effort on this subarea in future surveys may succeed in maintaining target CVs, while reducing net cost. However, Subarea 1's share of the biomass can also change by relatively large amounts over short time frames, with changes of over 10% in its share of the 4B biomass frequently occurring over as little as 3-4 years (Table 5). This also should be accounted for in a three-year design plan.

We augmented the 1993-2018 data with simulated data sets for 2019-22. For 2019, the planned setline survey design was used, while the following designs were considered for subsequent years:

- 2019: Planned survey fished (standard 89-station 4B survey)
- 2020: Only Subarea 3 fished (73 stations)
- 2021: Only Subarea 3 fished (73 stations)
- 2022a: Only Subarea 3 fished (73 stations)
- 2022b: Only Subarea 1 fished (57 stations)
- 2022c: Subareas 1 and 2 fished (130 stations)

The three options for 2022 allow either a continuation of Subarea 3 only (2022a), Subarea 1 only to reduce the chance of bias due to changes in density in Subarea 1 over the three years since 2019 (2022b), and a third option (2022c) in case 2022b leads to CVs above the 15% target. The third option is also precautionary in that while there is apparent stability in Subarea 2's share of the biomass (Tables 4 and 5), most of Subarea 2 has been surveyed just once, in the 2017 expansion. Therefore, this stability can be at least partly attributed to a lack of data reducing the potential for rapid change in its biomass share. As a precautionary approach, a more frequent survey for Subarea 2 than implied by the estimates in Table 2 could be implemented initially, with further evaluation once more data are available.

Table 4. Estimated share of biomass (%) in each subarea of Regulatory Area 4B by year.

Subarea	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
1	34	35	36	37	38	35	30	26	26	20	18	18	20
2	26	26	25	25	24	21	19	22	21	23	23	22	23
3	40	39	39	39	38	45	50	52	53	57	59	60	57
Subarea	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
1	25	26	29	30	22	22	17	12	9	9	9	11	15
2	20	17	16	16	16	17	18	18	16	14	12	10	11
3	55	57	55	54	63	61	65	70	75	77	79	78	74

Table 5. For each year, the number of years until at least a 10% absolute change in estimated biomass share is observed.

Subarea	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
1	9	8	7	4	3	4	3	13	12	7	5	4	4
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
Subarea	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
1	7	6	4	3	4	3	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–	–	–	–	–	–
3	6	6	4	3	4	3	3	–	–	–	–	–	–

Table 6 presents the estimated CVs for each of the space-time model inputs listed above for 2020-22, along with those from the 2018 model fit to observed 1993-2018 data only. The three fits based on surveying only Subarea 3 in 2020-22 (rows 3, 4 and 5 of Table 6) all lead to CVs below the 15% target. However, surveying only Subarea 1 instead of Subarea 3 in 2022 was insufficient to meet the target, with a CV of 17.0% estimated in 2022. Adding Subarea 2 brought the 2022 CV down to 14.2%, now below the target.

The next step would be to calculate the relative costs of each option. Fishing both Subareas 1 and 2 in 2022 would be an expensive survey, with likely high vessel charter costs together with low catches offsetting those costs. It may be desirable to explore other options for 2022, such as pairing Subareas 1 and 3, and fishing Subarea 2 (probably together with Subarea 3) in a later year. Relative costs of different options for this example have yet to be discussed with relevant staff at the time of writing.

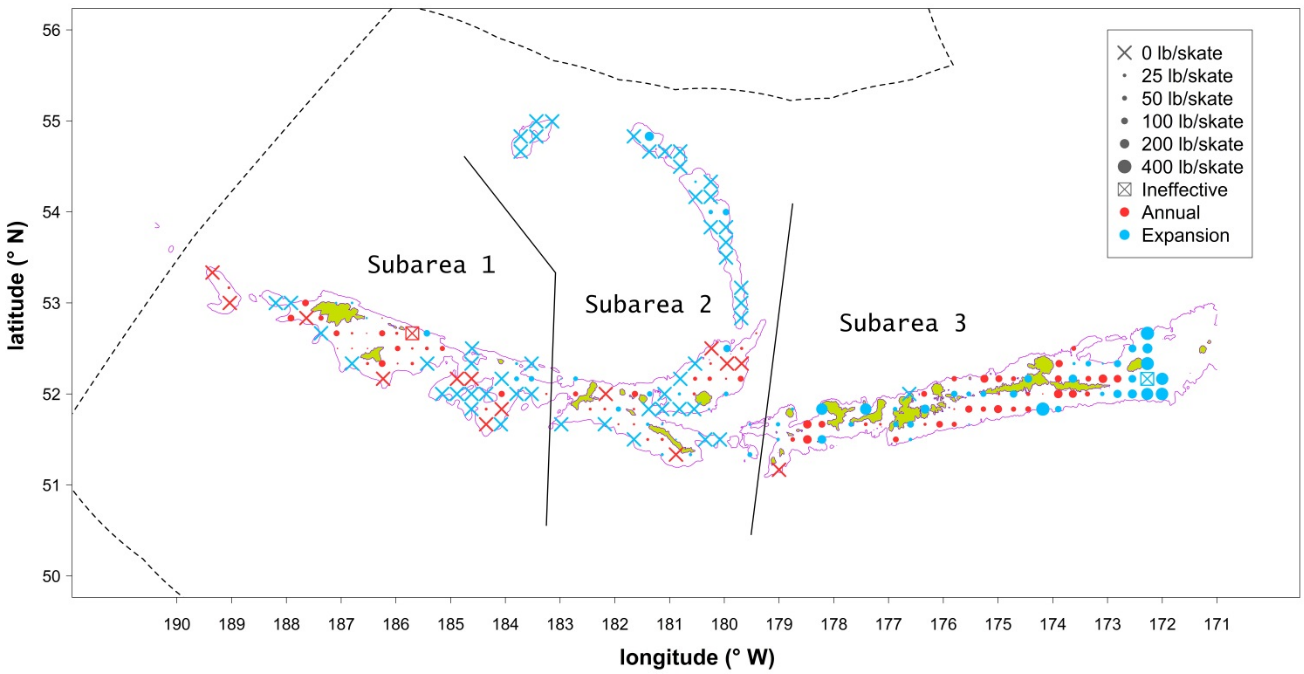

Figure 1. Map of 2017 the FISS expansion design in IPHC Regulatory Area 4B showing the subareas used in the analysis.