Evaluating the need for future survey expansions in Areas 2A and 4A and proposed changes to the space-time modelling in 2017

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PURPOSE

To provide the Scientific Review Board (SRB) with preliminary results of an evaluation of the survey expansions in Areas 2A and 4A, and seek the SRB advice on potential further work.

BACKGROUND

At the 92nd Session of the IPHC Interim Meeting (IM092), the Commission made the following recommendation to the IPHC Secretariat:

> "*The Commission **RECOMMENDED** that the IPHC Staff develop an information paper associated with the survey expansion, which details the likely implications of periodic survey expansion on the stock assessment and apportionment, taking into consideration potential population variability of Pacific halibut in expansion areas which are infrequently surveyed. The paper shall be submitted for initial consideration at the Commission's Work Meeting in September 2017*." (IM092, para. 38)

This document provides a review of the effect survey expansions in Areas 2A and 4A have on estimates of the density index for each area, and considers the implications of these effects on the need for future survey expansions in these regulatory areas.

We also present proposed changes to the space-time modelling of survey data in 2017, and note some exploratory modelling work that is either planned or currently being undertaken.

INTRODUCTION

In most regulatory areas, the standard, annual setline survey grid is fished in waters within the 37-503 m (20-275 fm) depth range. Information from commercial fishery data and other fishery-independent sources showed the presence of halibut down to depths of 732 m (400 fm) and in waters shallower than 37m. Further, most regulatory areas had significant gaps in coverage within the standard 37-503 m depth range. The incomplete coverage of halibut habitat by the survey was likely to lead to biased estimates of the weight per unit effect (WPUE) and numbers per unit effort (NPUE) density indices used in the stock assessment modelling and for stock distribution estimation. For this reason, the IPHC has been undertaking a sequence of survey expansions since 2014 (following a 2011 pilot), with stations added to the standard grid to cover habitat not previously sampled in our survey. The expansions involve adding stations to one or two regulatory areas each year, and reverting to the standard grid for those areas in subsequent years.

Setline survey data, including data from the survey expansions to date, were used in the space-time modelling in 2016 (Webster 2017). This modelling replaced the previous empirical approach to estimating WPUE and NPUE with a model-based approach that takes advantage of the spatial and temporal dependence in the survey data to improve estimates of these density indices and provide reliable estimates of uncertainty.

Another advantage of the space-time modelling approach is that the effect of the expansions on estimates of density indices and their uncertainty can be investigated in a straightforward manner, by comparing the estimates we obtained with those we would have obtained in the absence of the data from the expansions. In order to undertake such an evaluation, we need an expansion to have already been carried out. Further, to help assess the need for future repeats of the expansion, it helps for some time to have elapsed since the expansion took place. For this reason, this report focuses on Areas 2A, which had survey expansions in 2011 and 2014, and Area 4A, expansion in 2014 (Webster et al. 2015).

In this report we compare the output of models fitted using all available setline survey data to those using subsets of the data that exclude groups of expansion stations. We compare the estimated posterior mean WPUE values from the reduced data sets to that of the full data, along with measures of uncertainty.

Survey expansions in Area 2A

This regulatory area is unique in having already had a full expansion of the survey grid down to 42°N in two years, 2011 and 2014 (Figs 1 and 2). A comparison of model output including and excluding the 2014 expansion data allows us to assess what is gained by having the expansion repeated after a three-year interval. The 2014 expansion also included additional stations between the latitudes of 39 and 42°N (northern California), which are considered separately as described below.

For our comparisons, the expansion stations were split into three geographic regions: coastal deep expansion (DE) and shallow expansion (SE) stations in Oregon and Washington (fished in 2011 and 2014); Salish Sea stations (2011 and 2014); and northern California stations (2014). In this way, we are able to examine the relative contribution of each component of the full expansion to improving estimates of density. Note that a subset of the full 2014 California expansion stations was fished in 2013. As this excluded deep and shallow stations, and stations between 39° and 40°, this is perhaps best considered as a pilot expansion into California and is not an expansion design that is likely to be repeated.

We fitted models to the full data set, along with seven subsets in the following order:

- Annually fished stations only (96 since 2011)
- Annually fished stations, plus 2011 DE/SE stations in OR and WA coastal waters
- Annually fished stations, plus 2011 and 2014 DE/SE stations in OR and WA coastal waters
- Annually fished stations, plus 2011 and 2014 DE/SE stations in OR and WA coastal waters, and 2011 Salish Sea stations
- Annually fished stations, plus 2011 and 2014 DE/SE stations in OR and WA coastal waters, and 2011 and 2014 Salish Sea stations
- Annually fished stations, plus 2011 and 2014 DE/SE stations in OR and WA coastal waters, 2011 and 2014 Salish Sea stations, and 2014 California stations
- All available data (also includes 2013 California expansion stations)

All model runs included data from 1998 to 2016, using the methods discussed in Webster (2017).

Survey expansions in Area 4A

The expansion in 2014 in Area 4A included additional stations along the Area 4A shelf edge, and the Aleutian Islands (Fig 3). The bulk of the shelf edge expansion stations are in relatively flat habitat that is likely more homogenous than the areas of incomplete annual survey covered in the Aleutian component of Area 4A. It is also surrounded by annually fished setline stations and NMFS trawl stations, with some of the latter actually located within the region that does not have annual coverage. Thus, we may expect that omitting shelf edge expansion stations to have a less significant effect on WPUE estimates than omitting stations along the Aleutian Islands. For this reason, we considered these regions separately in evaluating the effect of the 2014 expansion of estimates of WPUE. Thus, we fitted models to the following subsets of data and compared the output to that from the model with all setline stations:

- Annually fished stations
- Annually fished stations + 2014 shelf edge expansion stations
- Annually fished stations + 2014 Aleutian Islands expansion stations
- All available data

As with Area 2A above, model runs included data from 1998 to 2016, using the methods discussed in Webster (2017).

Results: Area 2A

Figure 4 shows the absolute relative difference in estimated mean WPUE (hence called the "relative error") for Area 2A between models using subset of the data and a model fit with all available data.

The model fitted to the smallest subset of data, the 96 annually fished stations off the WA and OR coasts, has very high relative error, being greater than 40% in all years. Areas like the Salish Sea, and particularly California, are distant from the annually fished stations, and estimated WPUE in these regions approaches the Area 2A mean, which is likely unrealistically high in most years in these regions. Also, the lack of data from deep and shallow waters means that WPUE estimates at these depths is informed by spatial proximity to stations in 20-275 fm waters through the spatial dependence model, leading again to over-estimates of WPUE (since the data generally show below-average WPUE outside of 20-275).

Adding the 2011 deep and shallow stations to the annually fished stations provided a substantial improvement, with relative error reducing to below 30% in most years. There is only a small further improvement in relative error from inclusion of the 2014 deep and shallow data. A similar improvement is observed when the 2011 Salish Sea data are included, with inclusion of the 2014 data having a minimal further effect on relative error. The remaining improvement comes from including the 2014 California data, which brings the relative error close to zero (showing that the 2013 California data have little effect on relative error).

Also of interest is the effect of the survey expansions on the precision of the mean WPUE estimate for Area 2A. Figure 5 shows the estimated sample coefficients of variation for the subset models listed above, along with the model that uses all available data. Inclusion of the

data from deep and shallow stations has, at best, modest effects on relative precision. A greater improvement is found when Salish Sea stations are added, but the greatest decrease comes with the addition of the California stations in 2014. Without the direct observations in California, estimates of WPUE in this region were very imprecise, and this imprecision contributed significantly to the variability in the overall estimates for Area 2A. We note that even with the full data set, CVs have been increasing since 2014, as time since the most recent survey expansion increases. Nevertheless, CVs remain at low levels, and it is not clear from the data in this figure what survey expansion frequency would be required to maintain precise estimates of mean WPUE. CVs came down after 2010, but this was only in part d

These results show that the 2011 expansion was on its own sufficient in reducing relative error due to lack of coverage in deep and shallow waters and the Salish Sea up to and including 2016, while the 2014 California expansion was also important for minimising relative error. Thus, the reduction in relative error from an expansion is maintained for several years after the expansion. Based on these results, the survey expansions in Area 2A may not need to be repeated more frequently than every six years. With increasing time, and in the absence of new model covariates (say, for region or latitude), we would still expect estimates in unsurveyed regions to approach the Area 2A mean, but it is clear from these results that this is something that occurs relatively slowly.

Results: Area 4A

The relative error in models fitted to subsets of the Area 4A data is shown in Figure 6. Compared to a model fitted to the annual fished stations only, addition of expansion stations along the Area 4A shelf edge in 2014 leads to small to modest reductions in relative error. A much larger gain comes from the expansion along the Aleutian Islands, which reduces relative error to below 10% in all years. There is some further benefit from including both components of the 2014 expansion (difference between green line and zero), but the Aleutian expansion was clearly the more important. Note also that the benefit from including expansion stations diminishes going back in time, due to the decreasing influence of the 2014 expansion data on estimates in coverages gaps as time from 2014 increases.

As with relative error, the expansion into the Aleutian Island had a much greater impact on the CV of mean WPUE than the shelf edge expansion (Figure 7). Since 2014, the CV has increased quickly, although based on years prior to 2014, we may expect the CV to stabilise at around 12-13% in the absence of repeats of the survey expansion stations in Area 4.

In conclusion, due to the presence of NMFS trawl stations near to and within the region of the Area 4A shelf edge without annual coverage, this region need only be surveyed infrequently by the setline survey. Regarding the Aleutian Islands, the largest coverage gap is in the western part of this region, where many stations have high WPUE, and includes stations in deep water and standard depths somewhat distant from annual fished stations. A solid argument could be made for fishing these stations frequently, while (to maintain costs if necessary) reducing coverage in the low-density part of Area 4A south-east of the Aleutian Islands.

Proposed changes to space-time modelling in 2017

What follows is a list of changes to the space-time modelling we propose for 2017.

1. Inclusion of setline survey data prior to 1998

While the current grid design for the setline survey was implemented in 1998, the bait used on IPHC surveys was only standardised to chum salmon in 1994. Prior to that, different baits were used in IPHC surveys, and because of the likely confounding of changes in bait type and changes in halibut density, we do not currently propose to use earlier survey data in our modelling. The inclusion of data from 1994-1997 will allow us to model density indices over a period that includes some of the highest survey catch rates in recent decades, providing a longer and more informative time series of WPUE and NPUE (numbers per unit effort). There are large coverage gaps in the 1994-1997 time period, and we expect this to be reflected in estimates of uncertainty (posterior standard deviations and credible intervals) that result from the modelling.

2. Calculation of total WPUE

Along with O32 WPUE and total NPUE, we intend to model total WPUE. This index is an alternative to O32 WPUE for use in computing biomass indices and estimating stock distribution, and may be of use in the management strategy evaluation modelling.

3. Inclusion of a latitude covariate in the model for Area 2A

The 2017 survey expansion will include additional stations in low-density areas as far south as 37.75°N (near San Francisco), in addition to a repeat of the 2014 California expansion stations down to 39°N. In the absence of suitable covariates, estimates of WPUE and NPUE far in time and space from the observed data will approach the mean for the entire regulatory area, which we would expect to be much higher than the true underlying density indices in most of California. To avoid this, we intend to include latitude in the space-time modelling of WPUE and NPUE, to account for the general decreasing halibut density from north to south. The availability of the 2017 expansion data will allow us to estimate the relationship of density with latitude to 37.75°N, and thereby improve model estimates down to this latitude in years in which the survey is not expanded that far south.

4. Updating with 2017 survey data

The data input updates will include all standard grid setline survey data, data from expansions in Areas 2A and 4B, the 2017 NMFS Bering Sea trawl survey data (including the expansion into the northern Bering Sea, data from the 2017 ADFG trawl survey in Norton Sound, and data from the 2017 NMFS sablefish longline survey.

5. Exploratory work

Some exploratory work has begun on including data from the IPHC's water column profilers into the space-time modelling. Profiler data from 2009-2013 are currently available in our

database, and we expect data up to 2016 to be added in coming months. This work will continue in coming months.

We will also investigate the use of covariates to account for exclusion of the setline survey from protected areas, in particular Marine Protected Areas (MPAs) and Rockfish Conservation Areas (RCAs) in regulatory Area 2B. It is likely that several setline survey stations will be omitted from the grid in Area 2B in 2017, and a number of 2018's planned expansion stations are also likely to fall within these conservation areas. If mean density is higher or lower than average within such areas, having a covariate for protected areas may improve model estimation of density indices within such areas in years in which our survey is excluded.

RECOMMENDATION/S

That the SRB **NOTE** paper IPHC-2017-SRB10-05 which provided a preliminary evaluation of the survey expansions in Areas 2A and 4A, and seeks the SRB advice on potential further work.

References

Webster, R. A., Dykstra, C. L., Henry, E., Soderlund, E. and Kong, T. 2015 Setline survey expansions in 2014 and use of sablefish longline survey data for a deep-water density index. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2015: 603-617.

Webster, R. A. 2017. Results of space-time modelling of survey WPUE and NPUE data. Int. Pac. Halibut Comm. Report of Assessment and Research Activities 2016: 241-257.

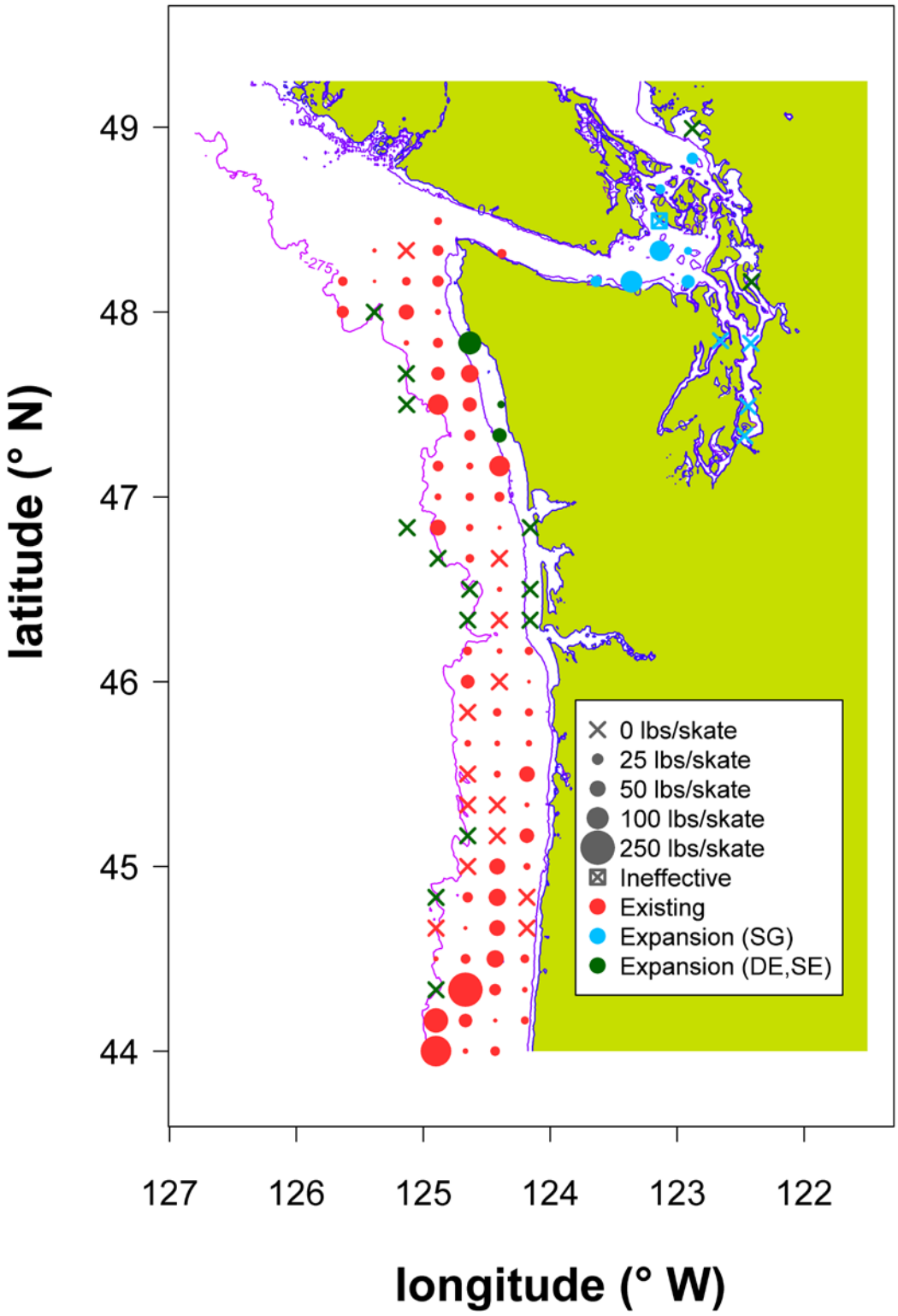

Figure 1 Map of O32 Pacific halibut WPUE by station in northern Area 2A in 2014

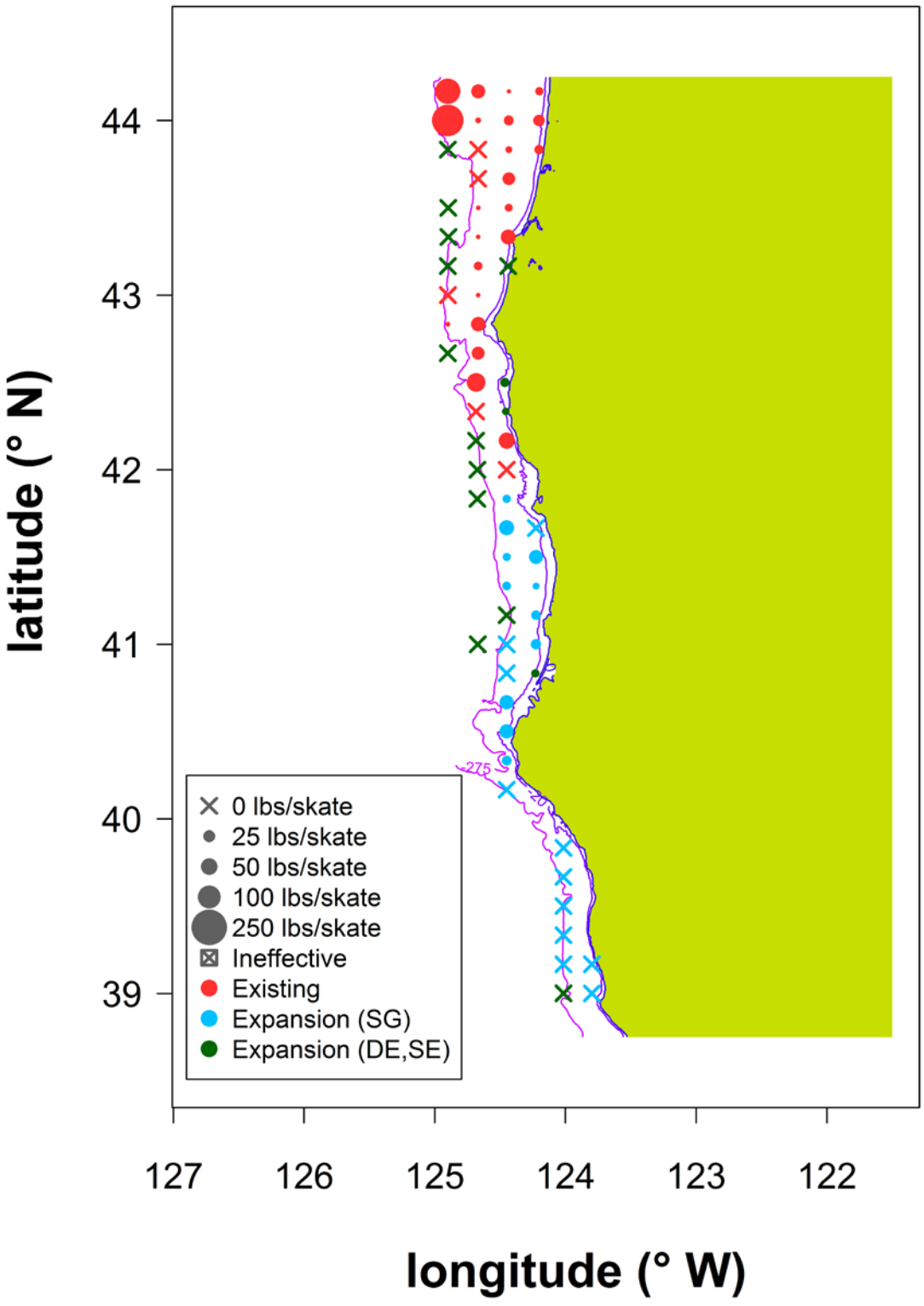

Figure 2 Map of O32 Pacific halibut WPUE by station in southern Area 2A in 2014.

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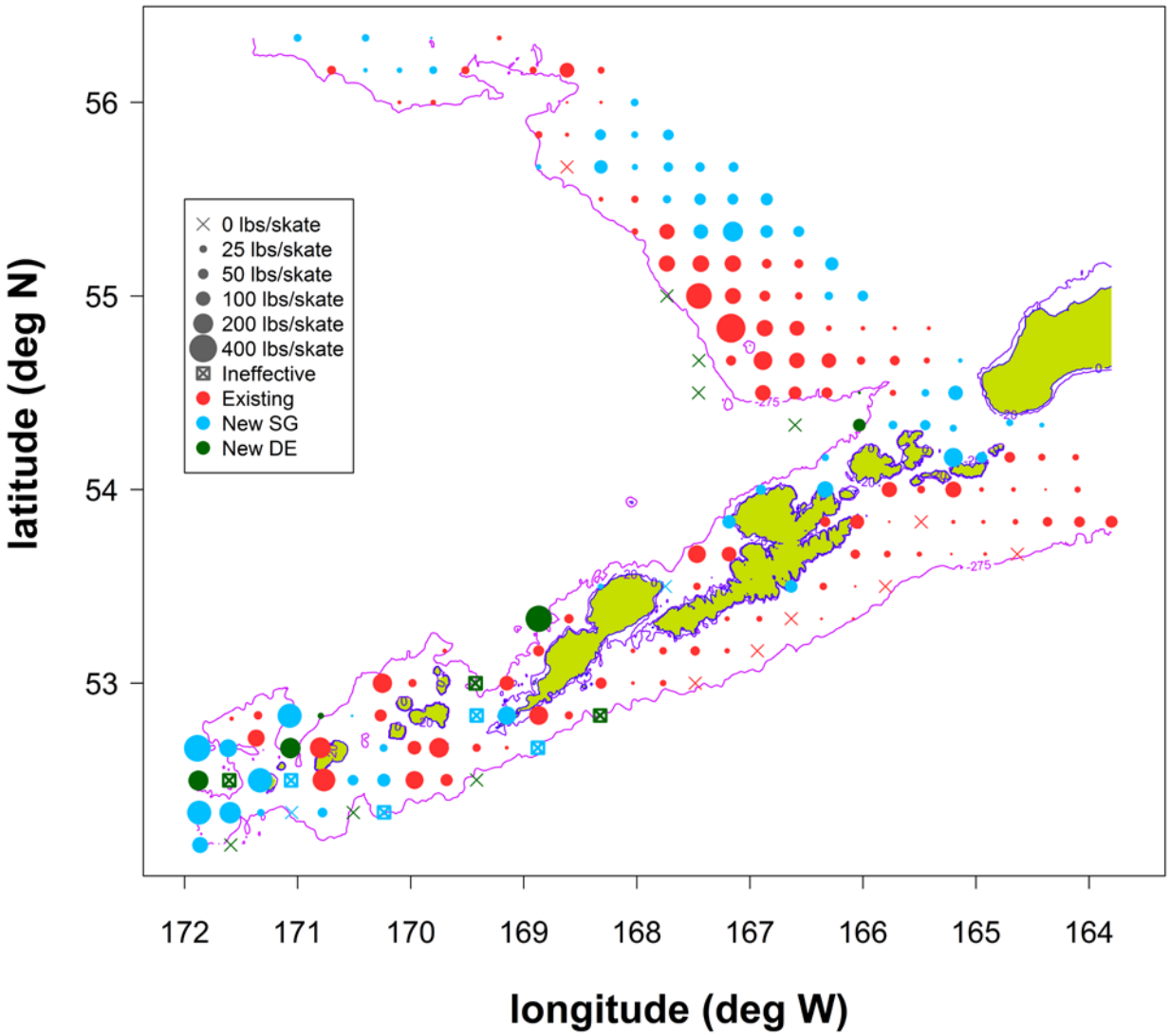

Figure 3 Map of O32 Pacific halibut WPUE by station in Area 4A in 2014.

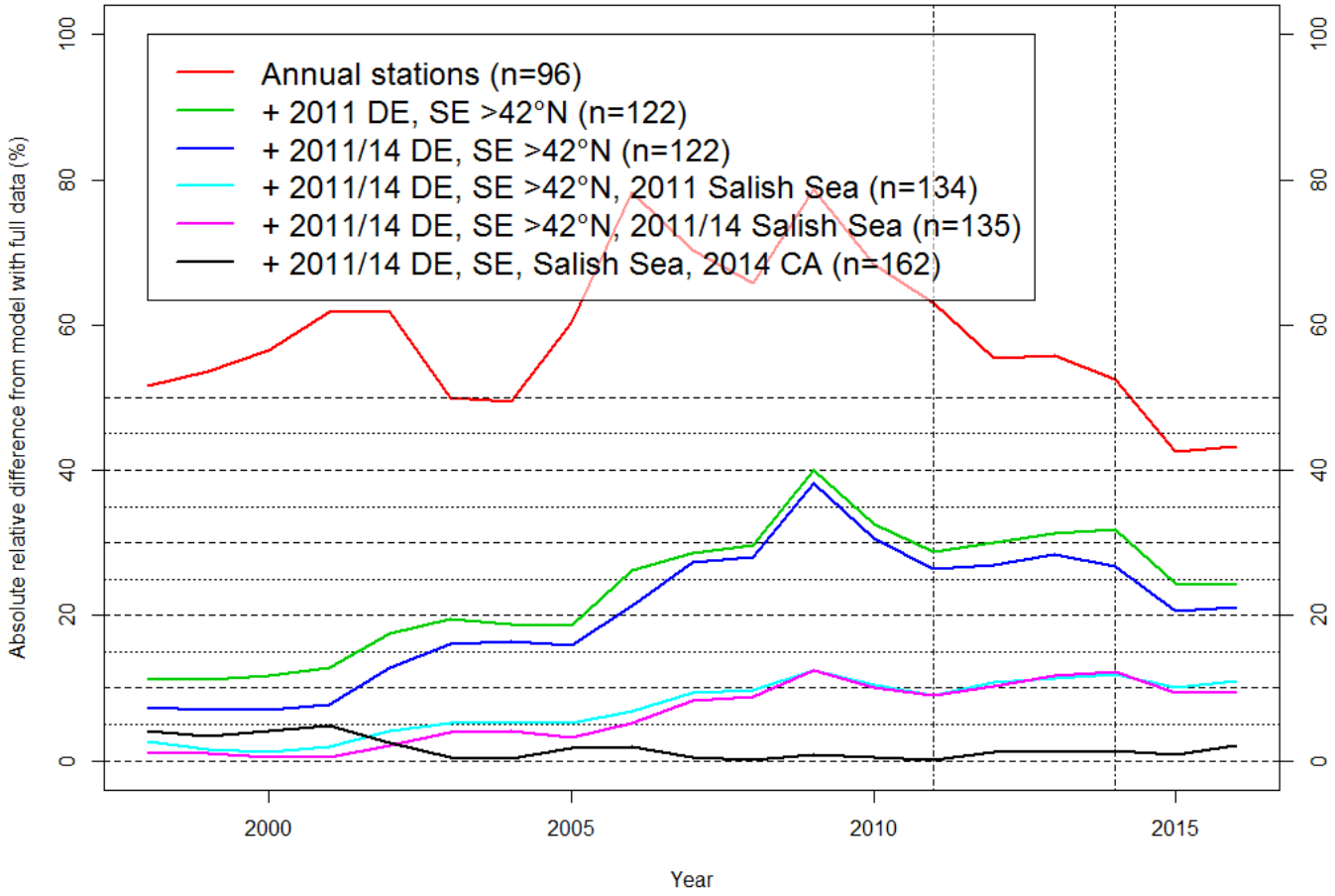

Figure 4 Absolute relative difference in estimated mean WPUE between models fitted to subsets of the Area 2A data, and the model using all available data. The vertical lines show the 2011 and 2014 survey expansion years in Area 2A.

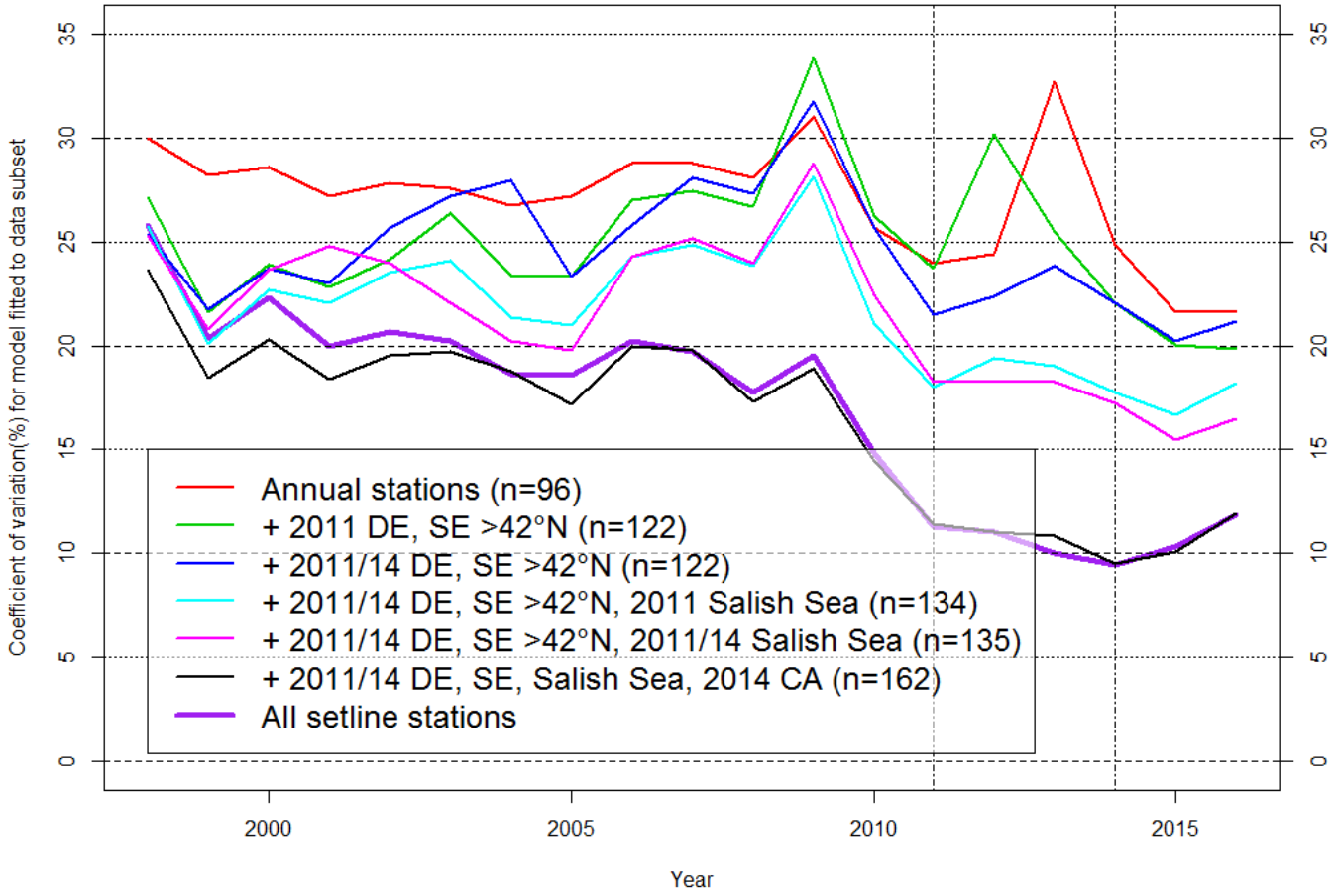

Figure 5 Coefficient of variation of estimated mean WPUE for models fitted to subsets of the Area 2A data and the model using all available data. The vertical lines show the 2011 and 2014 survey expansion years in Area 2A.

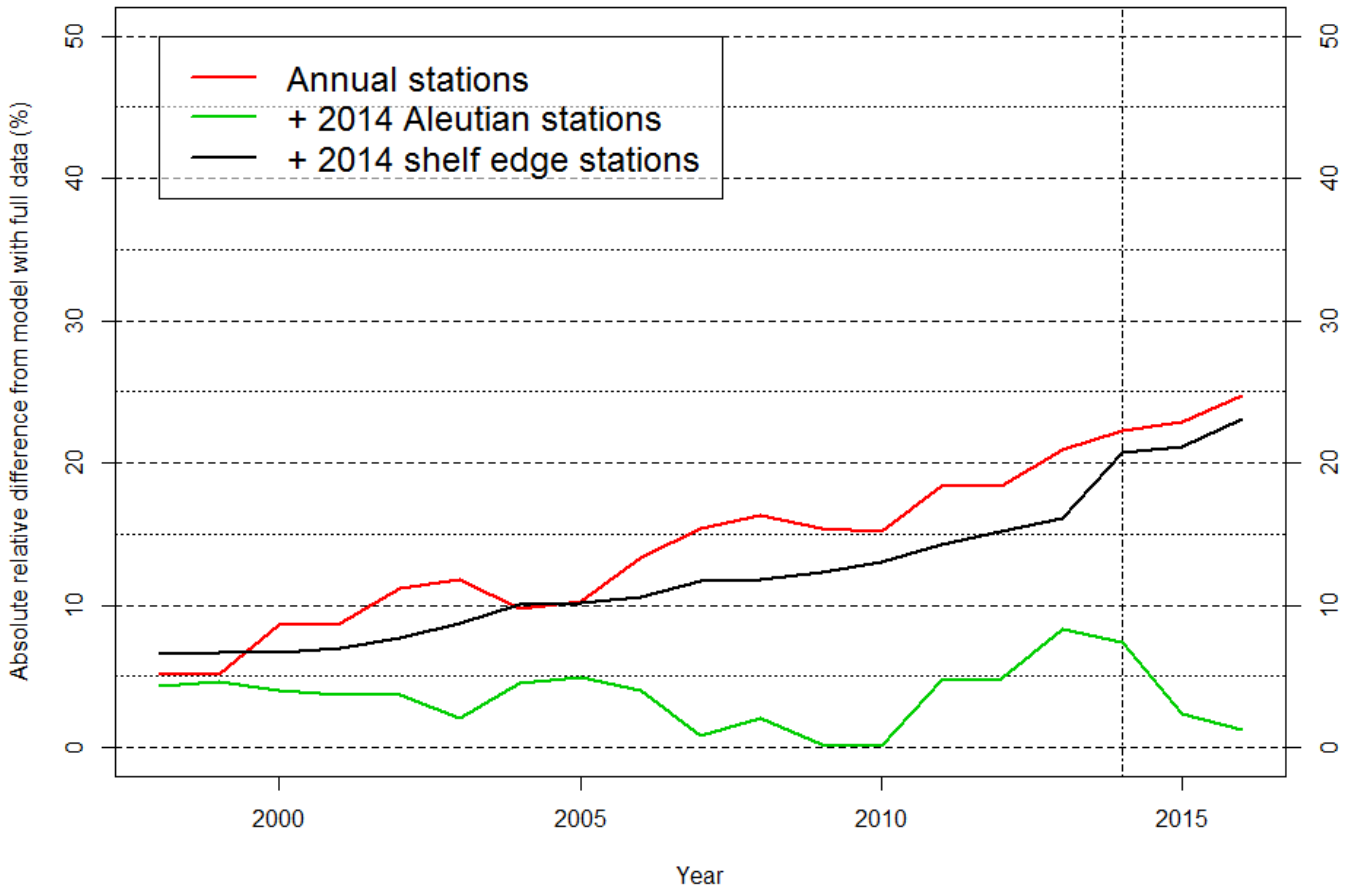

Figure 6 Absolute relative difference in estimated mean WPUE between models fitted to subsets of the Area 4A data, and the model using all available data. The vertical line shows 2014, the year of the Area 4A survey expansion.

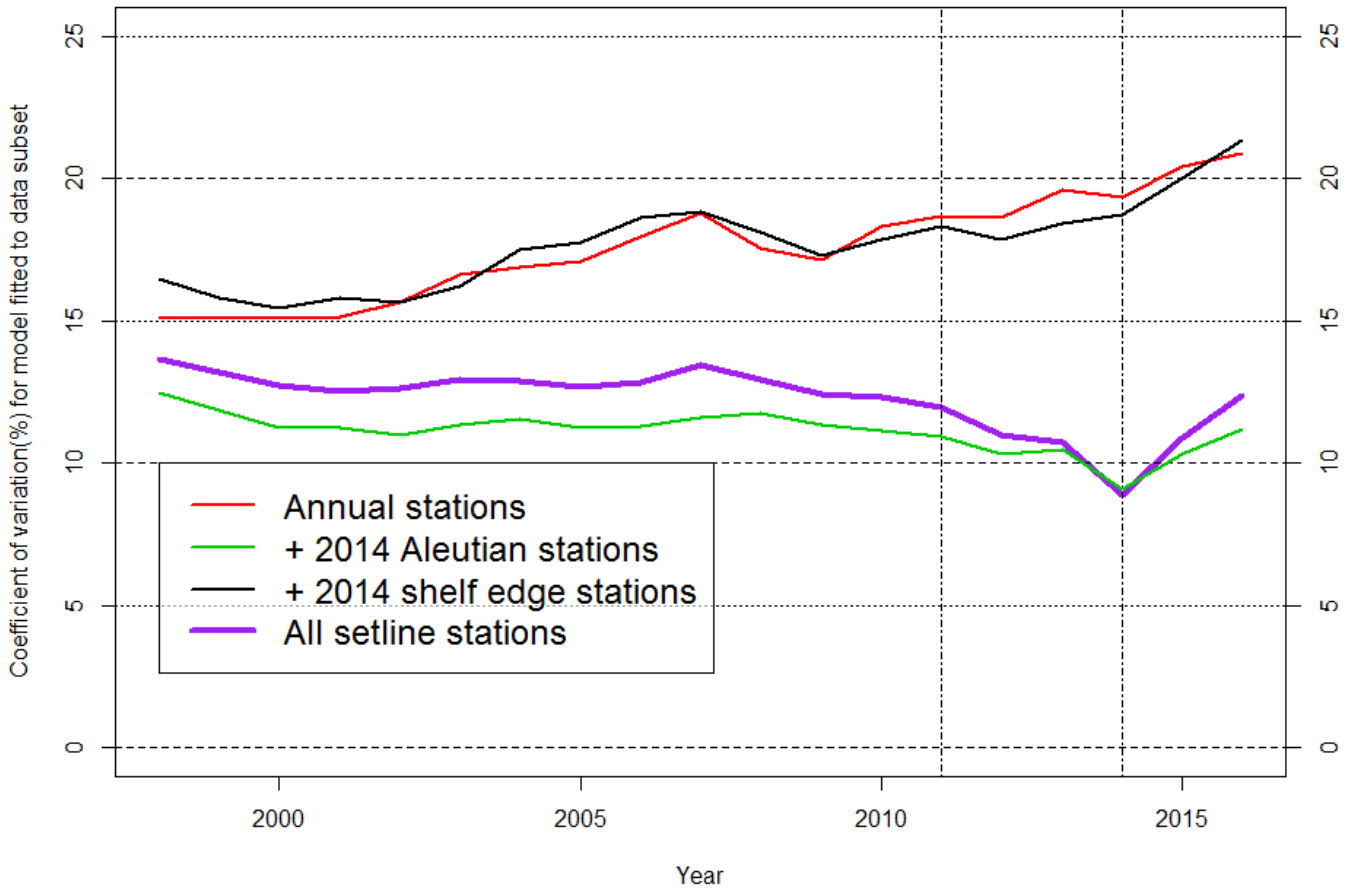

Figure 7 Coefficient of variation of estimated mean WPUE for models fitted to subsets of the Area 4A data and the model using all available data. The vertical line shows 2014, the year of the Area 4A survey expansion.