Space-time modelling of IPHC fishery-independent setline survey WPUE and NPUE data

PREPARED BY: IPHC SECRETARIAT (R. WEBSTER; 12 JANUARY 2017)

PURPOSE

To provide the Commission with an opportunity to consider the results and implications of the space-time modelling of survey data which is used to produce regulatory-area estimates of mean weight-per-unit-effort (WPUE) and numbers-per-unit-effort (NPUE) for Pacific halibut from 1998-2016, with corresponding estimates of uncertainty.

BACKGROUND

The International Pacific Halibut Commission (IPHC)'s fishery-independent setline survey (setline survey) provides data used to compute indices of Pacific halibut density for use in monitoring stock trends, apportioning biomass, and as an important input in the stock assessment. Biomass apportionment among regulatory areas is based on the annual mean weight-per-unit effort (WPUE) for each area, computed as the average of WPUE of O32 (greater than or equal to 32" or 81.3cm in length) halibut caught at each station in an area (Webster and Stewart 2017). Mean numbers-per-unit-effort (NPUE) is used to index the trend in halibut density in the stock assessment models (Stewart and Hicks 2017). Until this year, both indices were computed as the simple arithmetic mean of station-level WPUE or NPUE for each area, with various adjustment scalars applied to the means to account for incomplete setline survey coverage in some regions in some years. Further adjustments to the WPUE index were made to account for different levels of competition with halibut for baits in each regulatory area, and the variability in the timing of the setline survey relative to the total harvest. In this work, we call this direct data-based approach to estimating density indices the "empirical method".

Webster (2016a) outlined an improved approach to estimating density indices which makes use of additional information within the setline survey catch data, along with auxiliary information collected on the survey (such as station depth). Specifically, improvements in estimation are made by fitting models to the data that account for spatial and temporal dependence, which make use of the degree to which the halibut distribution is patchy (has regions of high and low density), and that those patches tend to persist with time. For example, if WPUE is high at a particular location, it is more likely to be high at nearby locations, and at the same location in previous and subsequent years. Therefore, we not only have information about density at a location and time from a direct observation, but from other data recorded nearby in space and time. Similarly, such an approach also allows estimation of a density index at a location with no data (e.g., a location between stations, a station with an ineffective set, or a region not surveyed annually). Further improvements can come from careful selection of a covariate model for density.

While the primary data source in both the present modelling approach, and the previous empirical method, is the IPHC setline survey, this is complemented by the use of data from several other fishery-independent surveys. For the Bering Sea, data from annual National Marine Fisheries Service (NMFS) trawl surveys (Lauth and Nichol 2013) and the approximately triennial Alaska Department of Fish and Game (ADFG) surveys (Soong and Hamazaki 2012) in Norton Sound are also included in our calculations. For the modelling, a region-wide calibration curve and scaling (Webster et al. 2016) are applied to station-level NMFS trawl survey data to produce WPUE and NPUE values at each NMFS station on the same scale as the IPHC setline survey indices. The ADFG Norton Sound trawl survey data are in the form of station-level catch-per-unit-effort data, and these are converted to station-level WPUE and NPUE indices using scale factors computed from the mean calibrated WPUE and NPUE values from the 2010 NMFS trawl survey stations in Norton Sound. In regulatory areas yet to have an expanded setline survey into deeper waters (Areas 2B, 2C, 3A and 3B), scaled station-level data from the NMFS sablefish longline survey were included in the modelling.

Prior to 2016, the WPUE series used for apportionment included two standardisations to account for competition for baits among Pacific halibut and other species, and for the timing of the setline survey relative to the total Pacific halibut harvest. Both were applied to each regulatory area's WPUE mean value, and not to the WPUE of individual stations. With the support of the Scientific Review Board (Cox et al. 2017), the competition standardisation was changed to apply to each station's WPUE and NPUE, rather than the mean indices for each regulatory area. The survey timing adjustment is still calculated at the regulatory area-level, but with some changes in the method of calculation from past years (see Webster 2017). The standardisations were not previously applied to NPUE series used in the stock assessment, but for the space-time modelling, both indices had the standardisations applied for consistency.

In presenting the results, new estimates of the indices are compared with estimates based on methods used previously. The special case of Area 4CDE is discussed separately due to the relatively complex data compilation process it requires. Finally, revised biomass apportionment estimates are compared with estimates from the previous empirical method.

A detailed description of the methodology used, and the results, is provided in Chapter 3.5 '*Results of space-time modelling of IPHC fishery-independent setline survey WPUE and NPUE data'* of the IPHC Report of Assessment and Research Activities (2016): http://iphc.int/library/raras/485-rara2016.html.

RESULTS

Figure 1 shows the mean O32 WPUE time series from the space-time modelling, compared with the time series obtained using previous, empirical methods. Note that the empirical method uses hook standardisations applied at the regulatory area-level, and that due to the different ways the hook standardisation was scaled for the two methods (see above), we may expect differences between the two time series in terms of the absolute value of WPUE. Of greatest interest here is how the trends in the time series compare, and in general the trends follow each other very closely. Even though the empirical method uses a 75:20:5 weighting on the three most recent years (greatest weighting on current year), the space-time modelling's accounting for temporal dependence often leads to a smoother time series. This is most clear in Area 2, and in Area 2A in particular. For Area 2A, the large spikes in the empirical time series were due to years with very high values of the hook competition adjustment factor; the change to station-level adjustments has helped smooth out these otherwise anomalous spikes in the series (the reason for this is discussed below).

The space-time modelling also paints a more realistic picture of uncertainty in the WPUE time series by accounting for spatial and temporal dependence in the data. The confidence intervals for the empirical method assume observations at all stations within an area are completely independent, which the space-time modelling demonstrates is not true: when spatial dependence is present, the effective sample size will be less than the number of survey stations, leading to the standard deviation of the mean to be underestimated. Also unlike the empirical method, the space-time modelling incorporates variability among stations in the hook standardisation. Finally, by predicting WPUE at unobserved locations, a further source of variability is accounted for in the space-time modelling, one that is ignored by the empirical method. It is no surprise, therefore, that in most cases, the credible intervals of the space-time estimates are wider than the approximate confidence intervals from the empirical method. A clear exception to this is Area 2A, where the new space-time modelling makes use of the strong underlying spatial and temporal dependence to estimate indices that appear much more precise than those previously estimated.

Due to the relatively complex compilation of data sources required for use in the space-time modelling, and the large gaps in coverage in most years, the results for Area 4CDE are of particular interest. Figure 2 breaks down the WPUE into four components: the region covered by the annual setline survey along the continental shelf edge, the two clusters of setline survey stations around the Bering Sea islands of St Matthew and the Pribilof Islands (Area 4C islands) and the large shallow region not covered by the IPHC setline survey. Shaded regions show uncertainty in the estimates of each component. Figure 3 shows a map of predicted WPUE for 2016 at each station location used in compiling the overall index (together with 15 stations shallower than 10 fm, or 18 m, mainly in Norton Sound, not used in the index), and the corresponding standard deviations. With large coverage gaps in the northern Bering Sea, we are interested in how well the model is predicting WPUE in this region in the absence of direct observations. The NMFS 2010 trawl survey caught almost no halibut in much of this area, with the higher catch rates occurring at the stations closest to shore in the east, and in Norton Sound. Indeed, the 2016 estimates are very consistent with that. Use of a space-time model that includes both depth and distance from the shelf edge as covariates has led to sensible predictions of WPUE, even in areas which lacked any survey coverage in 2016.

Estimated biomass proportions for the start of 2017from the space-time modelling are shown in Figure 4, alongside estimates from the empirical method. There is generally good agreement between estimates from the two methods, and indeed 95% intervals for the model-based estimates overlap the empirical estimates for every area. The largest absolute differences between the two methods occur in Areas 2B, 2C and 4B. For Area 2A, the difference is also relatively large (2.22% of coastwide biomass for space-time method, vs 2.62% for empirical method), although small in absolute terms. In Area 2B, prediction of WPUE in the shallow waters of Dogfish Bank and the unsurveyed Strait of Georgia (influenced by low WPUE in the adjacent waters of the Salish Sea in Area 2A) contributed to lower WPUE estimates relative to other areas compared to estimates obtained by the empirical method, which had assumed WPUE in those regions was the same as WPUE measured elsewhere in Area 2B. In Areas 2A, 2C and 4B, the change to a station-based hook adjustment, instead of one computed at the regulatory area level, was a major reason for the apportionment changes, as accounting for local effects of competition for baits changed the overall effect of this standardisation in these areas.

DISCUSSION

The space-time modelling approach to estimating mean WPUE and NPUE time series has several important advantages over the previous empirical method. More information in the data is used, specifically information on spatial and temporal dependence, and auxiliary information from covariates can be incorporated into the modelling to further improve estimates. Estimates for regions without survey coverage can be included without making possibly unreasonable assumptions about the relationship of density in such regions with density elsewhere in an area. Estimation of uncertainty is greatly improved, by estimating uncertainty in regions without data, allowing for variation among stations in the adjustment factors calculated for the hook competition standardisation, and by no longer incorrectly assuming that stations are sampled independently. On a practical level, the space-time modelling approach simplifies calculations by dispensing with the complex and ad hoc set of adjustments for incomplete spatial coverage previously employed.

In calculating the competition standardisations, the previous approach of aggregating competition data across an area led to competition adjustment factors that were most greatly influenced by stations with low levels of competition. With station-level adjustments, each station’s influence on an area’s overall WPUE now depends on both its level of competition and its WPUE. This means that the new approach provides an improvement over the old method by accounting for local effects of competition, e.g., if an area has low levels of competition where WPUE is highest, the overall effect of the standardisation will be a small increase in an area’s WPUE, whereas high competition at stations with high WPUE will lead to a larger positive adjustment to overall WPUE.

Improvements in the data are expected in coming years. Setline survey expansions in Areas 4B (2017), 2B and 2C (2018) and 3A and 3B (2019) are planned, and NMFS has proposed a repeat of the 2010 northern Bering Sea trawl survey in 2017. The ADFG Norton Sound trawl survey is also due to take place in 2017, which should allow us to improve the calibration of this survey with the NMFS trawl survey stations in Norton Sound. As the planned setline survey expansion nears completion, it is important for us to evaluate the need for repeats of the expansions in the future. The space-timing modelling is the perfect tool for this, as through modelling we can study the effect of new data on overall WPUE estimates and on estimates of their precision.

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RECOMMENDATION/S

That the Commission **NOTE** paper IPHC-2017-AM093-05 which provided the Commission with an opportunity to consider the results and implications of the space-time modelling of survey data which is used to produce regulatory-area estimates of mean weight-per-unit-effort (WPUE) and numbers-per-unit-effort (NPUE) for Pacific halibut from 1998-2016, with corresponding estimates of uncertainty.

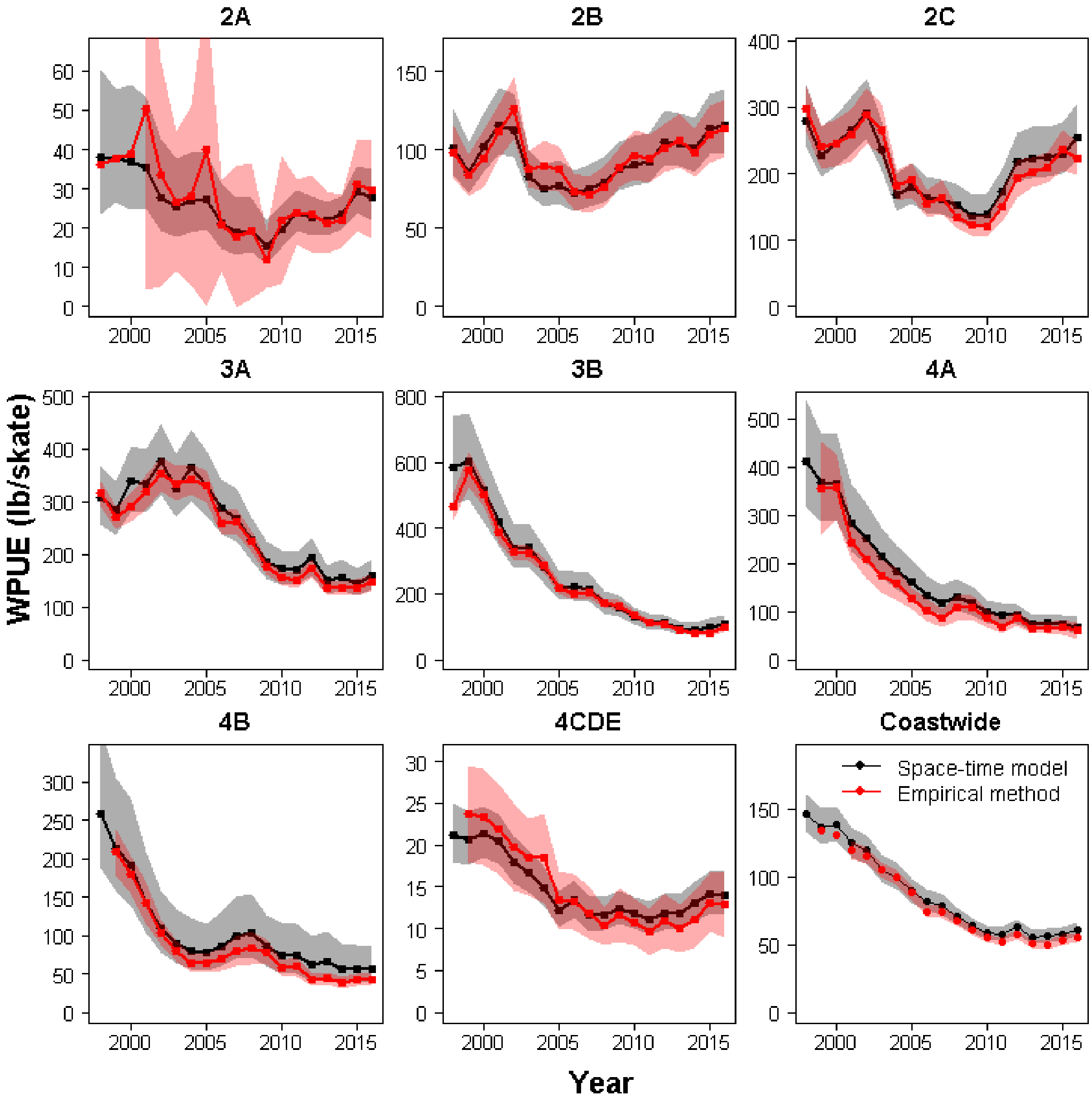

Figure 1. Comparison of estimated WPUE time series with the series calculated from space-time model predictions ("Space-time model") and from observed data with adjustment factors applied ("Empirical method"). For space-time model results, the gray shaded region represents the 95% posterior credible interval, while for the empirical method, the red shaded region shows an approximate 95% confidence interval.

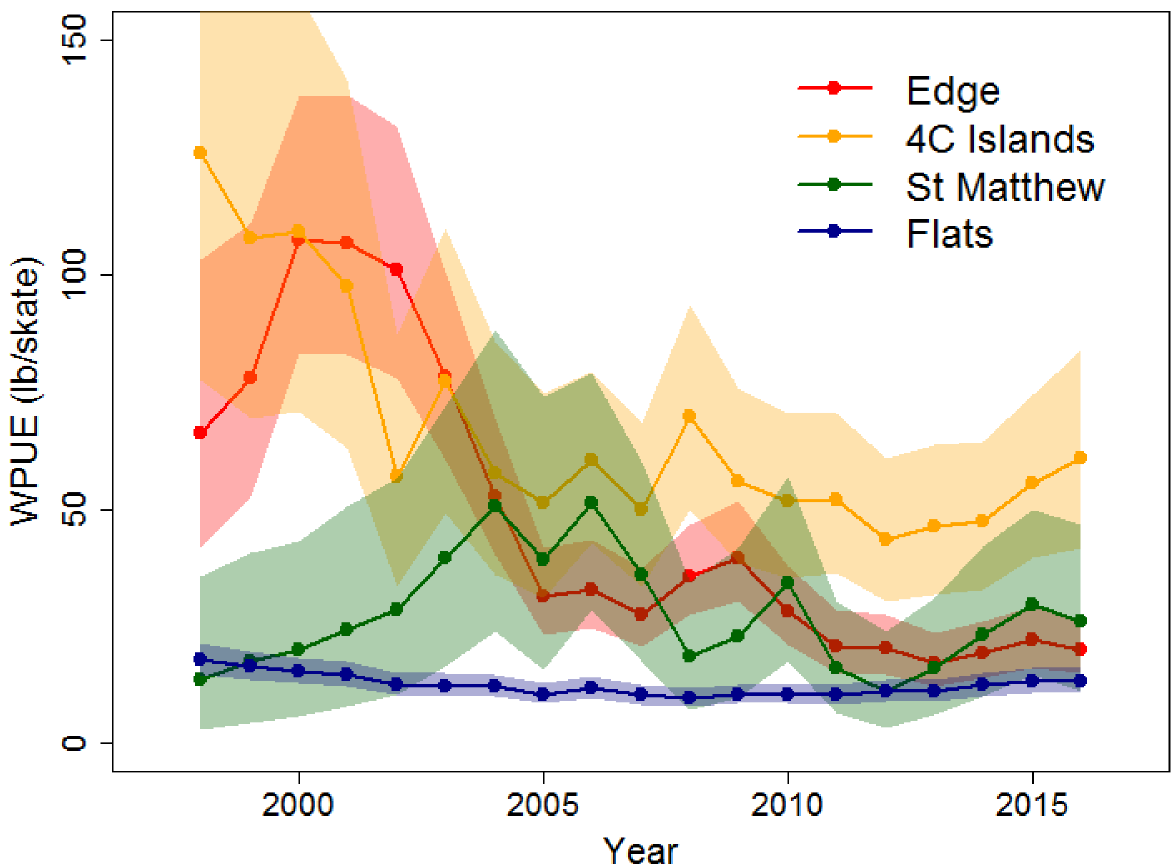

Figure 2. Comparison of estimated WPUE time series calculated from space-time model predictions for components of Area 4CDE. The shaded regions represent 95% posterior credible intervals.

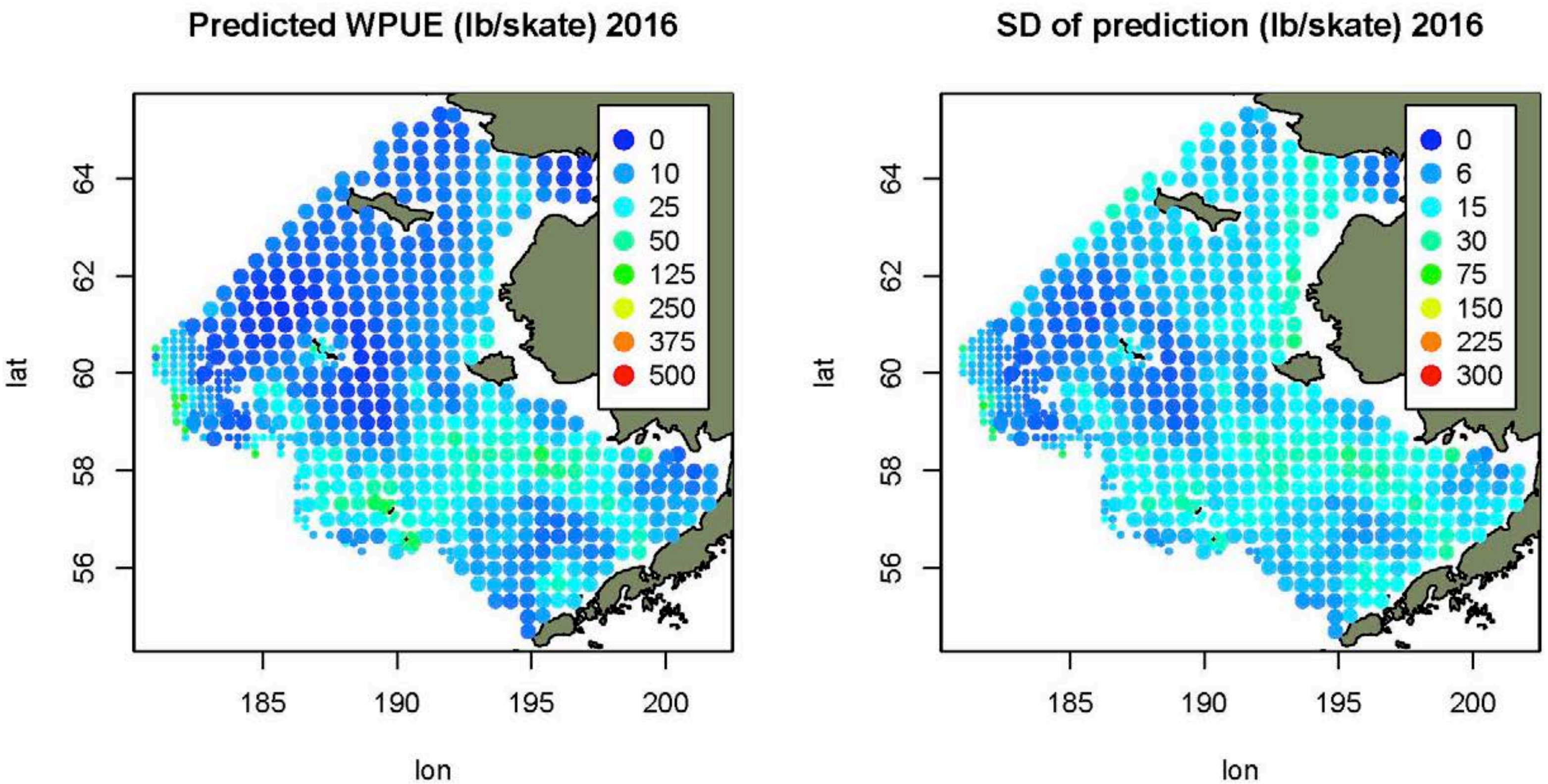

Figure 3. Predicted station WPUE in Area 4CDE in 2016, and corresponding standard deviations. Small circles represent the locations of IPHC fishery-independent setline survey stations, while large circles are NMFS trawl survey stations on the standard 20 nmi (37 km) grid.

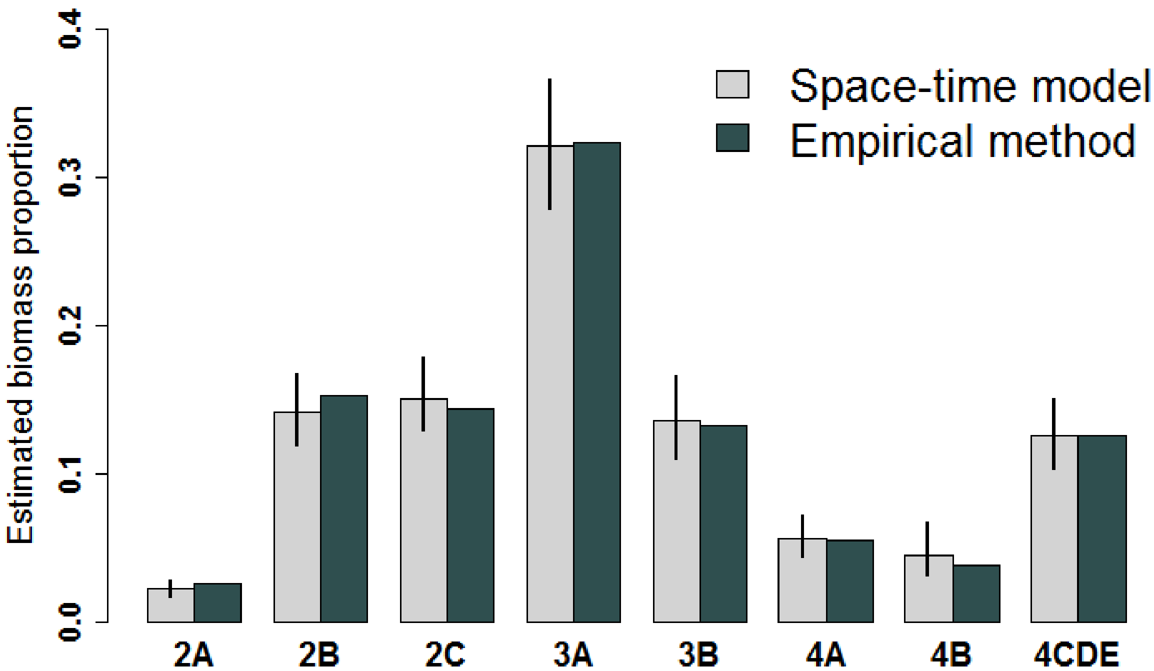

Figure 4. Posterior means of apportionment estimates (estimated biomass proportions) for the start of 2017 by area from the space-time modelling, compared with estimates from the empirical method used previously. The vertical bars represent 95% posterior credible intervals for the space-time model estimates.