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Exploratory analysis of disparate survey indices of Greenland halibut (*Reinhardtius hippoglossoides*) in NAFO divisions 2+3KLMNO

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Abstract

Greenland halibut in NAFO divisions 2+3KLMNO has been monitored by a series of disparate surveys since the 1970s, none of which cover the entire stock area. Partial snapshots make it difficult to assess this stock. Apparent changes in catchability and, to a lesser degree, a change in survey protocol led to the exclusion of survey data collected prior to 1995 from the assessment of this stock. Two MSE processes were subsequently supported by extant Canadian and EU-Spain surveys. In this document, we revisit survey data collected prior to 1995 and review data from extant surveys, paying particular attention to coverage of the stock area. As has been noted in the past, biomass indices declined from the late 1980s to the early 1990s and, at the same time, indices of the larger and older component of the stock declined. This change may be related to a shift of the stock outside the survey area and/or an increase in mortality. Since then, indices have shown some signs of cyclic patterns, however, changes are not consistent across surveys and opposing patterns between the indices from the Newfoundland and Labrador shelf (2HJ3KLNO) and the Flemish Cap (3M) suggest potential distributional shifts. These observations may support minor revisions to existing operating models utilized in the ongoing Management Strategy Evaluation review process.

Introduction

Greenland halibut are a widely distributed and wide-ranging species (**Vihtakari et al., 2021**). The stock off Newfoundland and Labrador has been monitored by a series of disparate surveys conducted along NAFO divisions 2+3KLMNO, none of which cover the entire stock area. Rather, portions of the stock area are sampled at different times of year, precluding the calculation of a combined index of stratified abundance or biomass for the whole stock. Nevertheless, these data have been used to construct operating models for this stock to support two management strategy evaluation (MSE) processes.

The first MSE process was conducted in 2011 and, since then, the stock has been managed using a harvest control rule. The first rule (**NAFO, 2010**) was used from 2011-2016 and, following a second MSE process, a new rule has been applied since 2017 (**NAFO, 2017**). The current harvest control rule is based on five ongoing surveys, Canada Fall 2J3K, EU 3M 0-1400m, Canada Spring 3LNO, EU-Spain 3NO and Canada Fall 3LNO. While the stock was monitored by surveys predating 1995, the operating models developed for the

2017 MSE process were only informed by data from extant surveys. Useful information on the history of the stock and its population processes may therefore have been excluded. The upcoming review of the MSE for this stock presents a good opportunity to revisit these data. We therefore present a preliminary data review and discuss the potential utility of information from extant and legacy surveys.

Methods

Research Vessel Surveys

The surveys conducted by Canada and the EU follow a stratified random design with the survey area stratified by depth in each NAFO division. The number of survey sets allocated to each stratum is proportional to the area of that stratum, with at least two sets in each survey stratum. The Canadian surveys began in 1971, the EU survey of the Flemish Cap began in 1988, and the EU-Spain surveys of 3L and 3NO began in 1995. Subarea 2 + Div. 3K are sampled in the autumn by Canada, Div. 3LNO are sampled in autumn by Canada and in spring by Canada and EU-Spain, and Div 3M is sampled in summer by the EU. The Canadian series is marked by a sequence of expansions, and vessel and gear changes, changing from a Yankee to Engel trawl in 1977 and then from the Engel to Campelen trawl in 1995 (**McCallum and Walsh, 1996**). The EU survey was extended to cover depths down to 1400 m in 2004 (maximum depth covered prior to 2004 was 732 m). The sampling protocol (vessels, gear, strata, etc.) of these programs have been relatively consistent since 2004, and the most recent details on each can be found in in González-Troncoso et al. (**2022**), Garrido et al. (**2022**), Román-Marcote et al. (**2020**), and Rideout et al. (**2022**). Figure 1 shows the area covered by these surveys.

Survey Coverage

Given the number of changes to the spatial extent of the Canadian surveys, coverage of each strata for each period in the time series was evaluated. An overview of survey coverage by depth was obtained by tallying the number of years where two or more sets were sampled in strata across NAFO divisions 2+3KLNO. The proportion of years where each strata was sampled within each period was calculated to aid the identification of inconsistencies in each survey. Blocks of strata that were not consistently covered through each series should be excluded from stratified analyses as the objective is to obtain a standard and consistent index of the population. Coverage by region (NAFO divisions 2GH, 2J3K, and 3LNO) and series (Yankee, Engel, Cammpelen) are presented in Figure 2, and summarised below.

Division 2G has been inconsistently occupied and is no longer covered by Canadian surveys; given this sparse coverage, these data are not considered further for the assessment of 2+3KLMNO Greenland halibut. The rest of subarea 2 (Divisions 2HJ) and Division 3K have been more consistently covered. Prior to the Campelen era (1995 onwards), strata >750 m were rarely occupied and were therefore excluded from the analyses presented here. With the exception of inshore strata added in 1996, and some recent issues covering strata >750 m, most strata across 2HJ3K have been covered on an annual basis. Inshore strata were only consistently covered for a period of roughly 10 years and are no longer allocated in the surveys; these are therefore excluded from analyses of data from the Campelen era (1996-2021).

Spring and autumn surveys have been conducted by Canada in Divisions 3LNO since the 1970s. A Yankee then Engel trawl was used prior to 1996 and surveys typically covered only depths <400 m; consequently, we did not use data from these surveys in our analyses. After the introduction of the Campelen trawl in 1996, the survey was extended to at least 730 m, and strata up to 1500 m were included in some years in the fall. Additionally, beginning in 1996, inshore strata were included in the survey design. However, persistent coverage deficiencies of inshore and deep-water (>750 m) strata across Divisions 3LNO preclude the use of these data in the design-based analyses we use here.

Distribution

Changes in the distribution of the stock were visually assessed by extracting the number and weight (kg) of Greenland halibut sampled at each set from the fall surveys of 2J3K and 3LNO. These maps serve as a visual inspection of all available data from the Autumn surveys of 2J3K and 3LNO since 1996; data from deep and inshore strata were not excluded. Numbers were used to scale the size of set location points and each point was colour coded by the average weight of fish collected at each site (set weight/number).

Trends in Stock Size

Survey estimates of abundance and biomass, presented as mean numbers and weights per tow, were computed using standard stratified estimators. Approximate confidence intervals (95%) are provided for the stratified mean number and weight per tow; computational details can be found in Smith and Somerton (**1981**). Note that there are some instances when the lower confidence bounds of these indices are negative. This is a consequence of violating the distributional assumptions used to produce these confidence intervals. This result commonly arises when a limited number of large catches are taken by the survey.

Stratified estimates of abundance at length were obtained using length frequency samples collected at every set. For the age-disaggregated results, length stratified otoliths sampled in each region (e.g., 2J3K, 3LNO) were used to construct age-length keys. These keys are applied to length frequencies to obtain stratified estimates at age. Recent work (**Dwyer et al., 2013**; **Treble et al., 2008**) suggest that current aging techniques - reading of whole otoliths - likely underestimates the age of individuals of length > 60 cm. This corresponds to a whole otolith age of about 10 years old. Therefore the age-disaggregated results for fish older than 9 years old are likely to be biased, and multiple cohorts may be within the assigned ages; stratified estimates are therefore aggregated for ages 10+.

Dynamic Factor Analysis

To assess whether the various surveys display a common underlying trend, a Dynamic Factor Analysis (DFA) was preformed using the bayesdfa R package (**Ward et al., 2019**). A DFA attempts to extract common patterns by fitting two models, 1) a process component that describes the underlying and unobserved trend and 2) an observation process that connects survey trends to the unobserved process. Factor loadings estimated by the model can be used to assess the relationship between the underlying and observed trends. Independent DFAs were fit to standardized mean weight per tow indices from legacy and extant surveys. Independent DFAs were also fit to standardized mean number per tow indices for 3, 6, and 9 year old Greenland halibut. We did not attempt to combine the legacy and extant periods as not all surveys extended back to the 1970s. The bayesdfa package estimates this model using a Bayesian framework.

Results and Discussion

Distribution

The distribution of Greenland halibut in autumn across Divisions 2J3K and 3LNO is shown in Figures 3 and 4, respectively. Recall, that the distribution of Greenland halibut was considered for all strata. Numbers caught across the Newfoundland and Labrador shelf (2J3K) are consistently higher than numbers caught throughout the Grand Bank. In both regions, the heaviest fish are caught along the shelf edge, a pattern which is consistent with ontogenetic deepening where the average size of individuals increases with depth. This life history phenomenon is why it is critical that surveys cover deep water, as the oldest component of the population would otherwise be missed by the survey. It is for this reason that previous assessments of this stock did not utilize data collected in 3LNO prior to 1996 as depths >400 m were typically not covered and, consequently, the index was not considered representative of the exploitable component of the population (**Healey, 2013**). This may have been a necessary and logical choice when selecting data for calibrating extended survivor analyses (XSA), the approach previously used to assess this stock, as that model structure focuses on the exploitable component of the stock. However, current assessment tools may be able to use information from the Yankee and Engel-based surveys of 3LNO and those data may prove useful for tracking cohorts as they progress towards exploitable sizes.

It is also worth noting that there are some patterns in the distributional data that are artifacts of survey coverage. In several years between 1998 to 2013 there were large aggregations of Greenland halibut in several bays along the coast of Newfoundland; however, these aggregations are not visible from 2014 to 2021 simply because the inshore strata have not been surveyed. This inconsistency in the survey justifies the exclusion of the inshore strata from the stratified analyses as those observations introduce a false decline in the abundance of the population starting in 2014.

Trends in Stock Size

Biomass indices from the pre-1995 surveys, especially the Canada Autumn Engel 2J3K survey, indicated that the population declined in the late 1980s to the early 1990s (Figures 6 and 7). Subsequent surveys all indicated an increase in the population in the mid 1990s followed by a decrease in the early 2000s; however, the overall trend since then has been unclear (Figures 6 and 7). Some surveys suggest that the population increased around 2015 (e.g. EU 3M 0-1400 m) while others suggest a decrease (e.g., Canada Campelen Autum 2J3K). Given none of these surveys cover the entire stock area, these changes could represent distributional shifts.

Age and Size Composition

Trends in annual stratified mean number per tow at length and age are displayed across Figures 8 to 20. Focusing first on the earliest survey data, there is a clear shift in the length and age compositions of Greenland halibut across 2J3K and 3LNO, where the largest and oldest individuals fall out of the Engel indices through the late 1980s to the early 1990s (Figures 9 to 14 and 17 to 18). This change corresponds to a decline in the biomass indices observed at that time (Figures 6 and 7). A period of anomalous cold ocean conditions through this same period was associated with the shifts in the structure of the population and analyses presented by Wheeland and Morgan (**2020**) indicated that Greenland halibut shifted to deeper waters and moved farther south through this cooling period. Given these observations, the largest and oldest component of the population may have moved outside the survey area. This issue was interpreted as a catchability issue, and it introduced retrospective patterns in the XSA used to assess the stock in the early 2000s (**Darby et al., 2003**; **NAFO, 2003**). STACFIS therefore agreed to exclude the pre-1995 data from the XSA. However, it remains unclear whether the component of the population that moved outside the survey area remained in the population. This is not a trivial problem to solve as survey catchability is confounded with rates of natural mortality. Unlike other stocks - e.g., American Plaice in 3LNO (**L. Wheeland et al., 2021**), Atlantic cod in 2J3KL (**Cadigan, 2015**) - this hypothesis has not been tested. Given the widespread collapse of the broader demersal fish community in the early 1990s (**Atkinson, 1992**; **Dempsey et al., 2018**; **Pedersen et al., 2017**), it is plausible that natural mortality increased in the early 1990s. The alternative hypothesis that Greenland halibut left the survey area and survived in deeper waters or adjacent areas through the unfavorable cold water period. Whatever the case, such considerations are useful for developing operating model scenarios that might account for increases in natural mortality or climate-induced shifts in the distribution of the stock.

Patterns since the 1990s have shown some positive signals and there are signs of cohort tracking across most surveys. Indices at age across most surveys either started at high levels in the mid 1990s (ages 1-3), increased (ages 4-7), or were fairly stable (ages 8-10+; Figure 8). Heightened levels did not persist and declines were apparent across ages 1-10+ in the early 2000s. This corresponds to a decline in total biomass indices (Figure 7). Since the decline in the early 2000s, some ages showed a small rebound (ages 4-7) and the 10+ group displayed a gradual increase. In contrast to the total biomass index, patterns in indices at age since 2005 have been more consistent across surveys. Age-specific distributional shifts may be contributing to divergent patterns in total biomass indices, however, this requires further investigation.

Dynamic Factor Analysis

Results from Dynamic Factor Analyses highlight similar features in the data as described above. While there are some contradictory trends that introduce uncertainty in the overall trend estimate, most surveys indicate a decline in the stock from the late 1980s to early 1990s (Figure 21). Age disaggregated results indicate that this decline was more abrupt for ages 6 and 9 relative to age 3 (Figure 22). Results from the DFA fit to total biomass indices from surveys conducted since 1995 indicate that the stock has varied without trend, with some signs of a cyclic pattern with a five-year period. Given the uncertainty around the overall trend, it is sometimes not clear whether the population increased or decreased within a five-year window (e.g., 2014-2018; Figure 23). Interestingly, the EU-Spain survey indices display inverse trends from those from the Canadian indices through this period. This mirroring is not as obvious in age disaggregated results and the estimated trends from the DFA are similar across surveys; however, the fits to the 3M series are poor (Figure 24). Again, conflicting patterns may be related to distributional shifts in the stock. Complementary patterns across 2HJ3KLNO suggest that the stock is relatively homogeneous throughout this area and, given the Autumn survey covers this whole area a synoptic index is worth considering. It may be useful to build operating models informed by a combined index in lieu of independent indices for 2J3K and 3LNO. As far as the authors are aware, the splitting of these indices is a hold-over from a period when there was a desire to utilize an unbroken and long-term 2J3K series with Engel and Campelen data combined using conversion factors (**Brodie et al., 1998**). If nothing else, a swept area index of biomass from 2HJ3KLNO may be useful for comparisons with estimates of biomass from operating models using split indices.

Acknowledgements

These data sources would not exist without the extensive efforts of the scientific sampling teams, as well as the crews of the survey vessels from the EU, Spain, and Canada. Interpretation of otolith samples by age readers is gratefully acknowledged.

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Figures

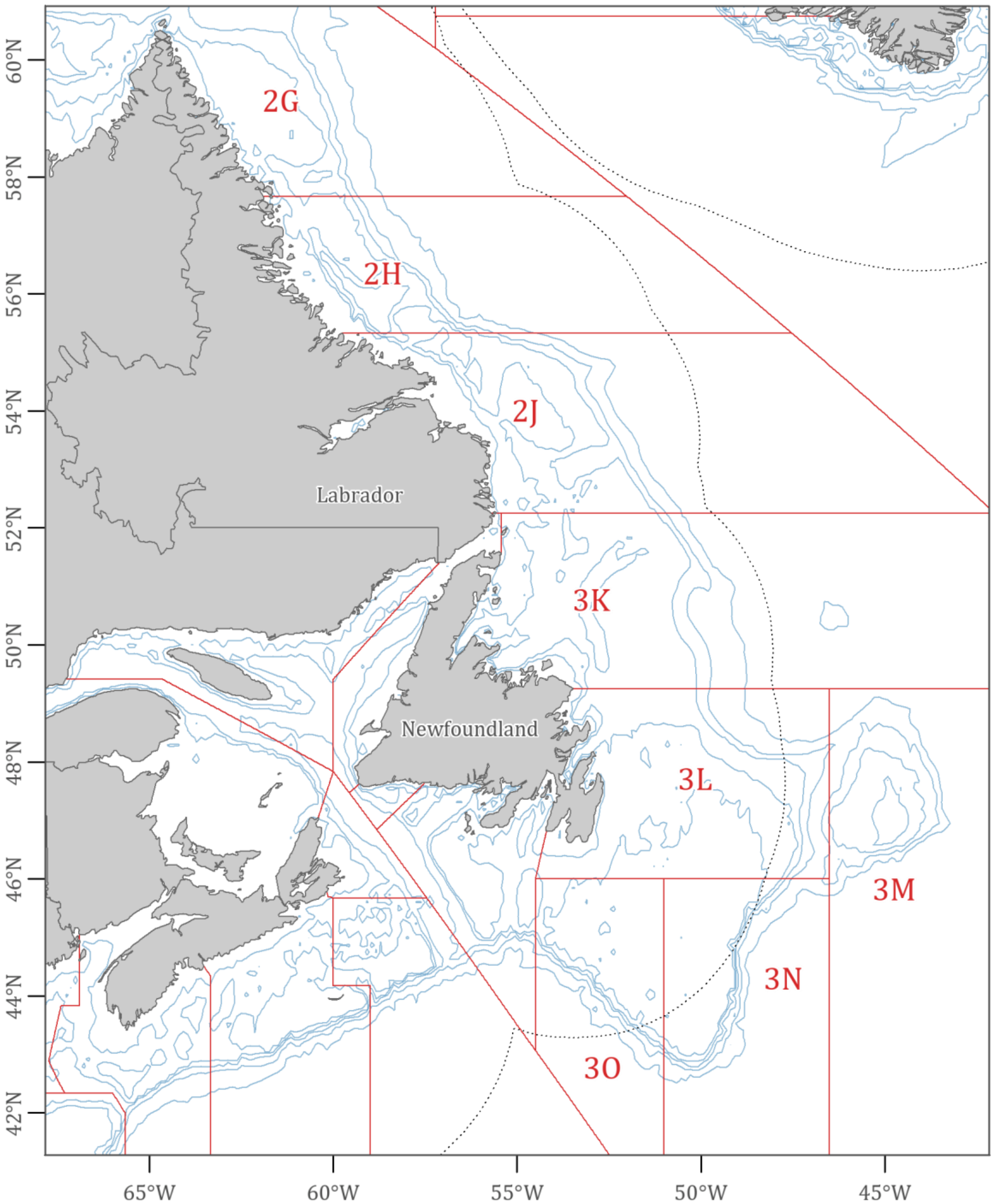

Figure 1. Map of stock area, with NAFO dividing lines, select isobaths (100, 200, 400, 1000, and 2000 m), and the EEZ boundary.

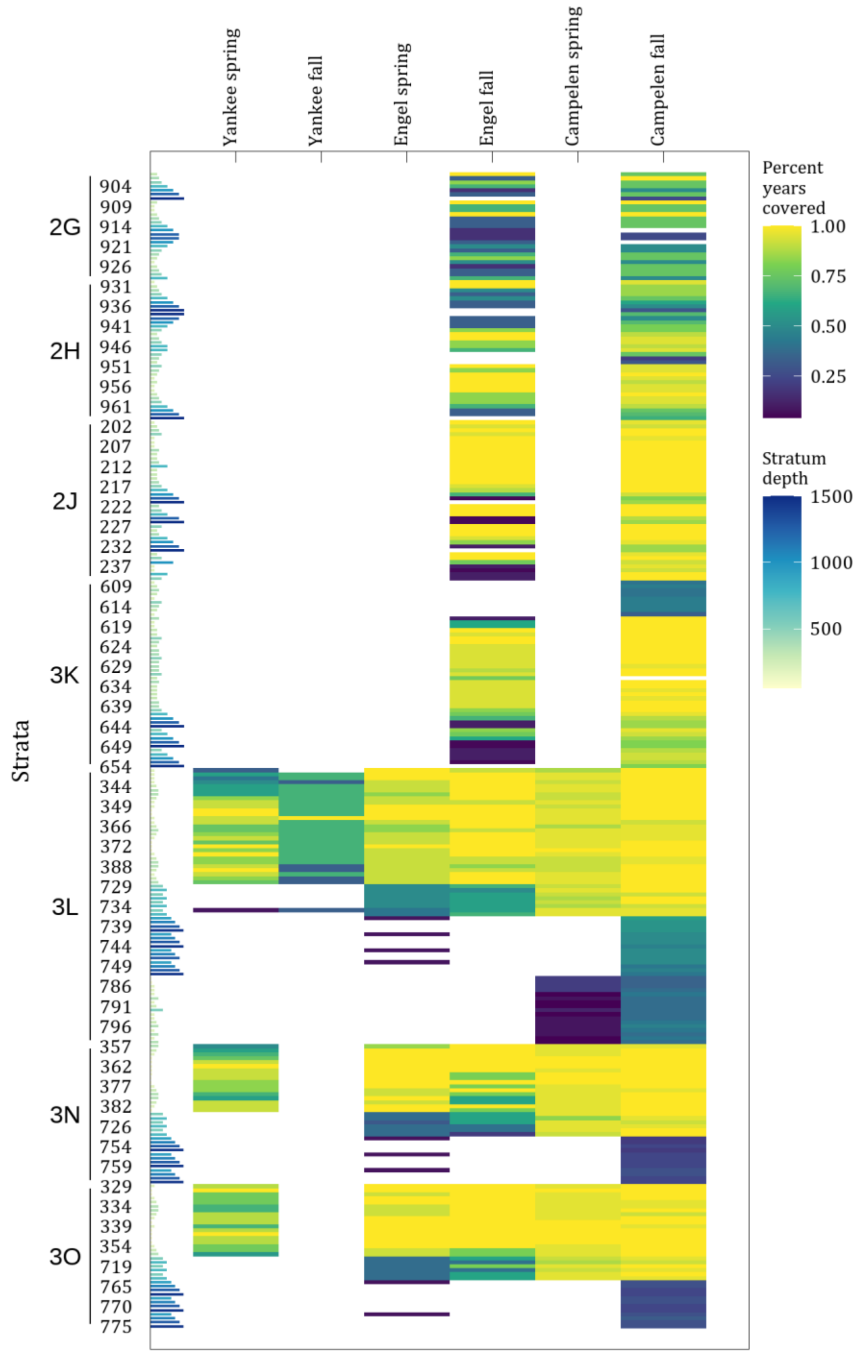

Figure 2. Heatmap of survey coverage for Spring and autumn Research Vesslel surveys conducted by Canada using Yankee, Engel, and Campelen trawls. Survey coverage is represented by the portion of years within each series where two or more sets were performed in each strata. Y-axis ticks length and colour is also scaled by maximum strata depth.

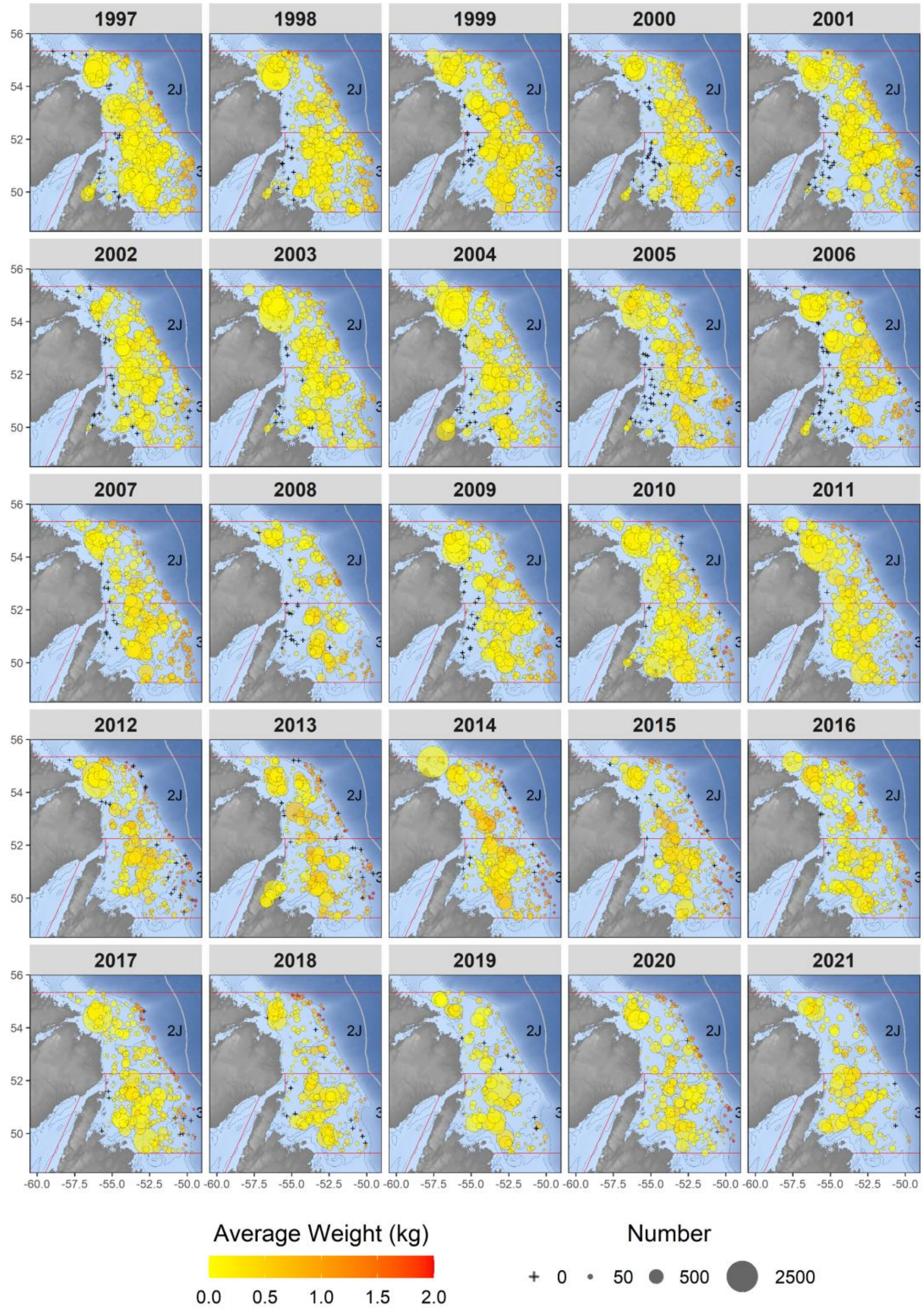

Figure 3. Distribution of Greenland halibut sampled in autumn across 2J3K from 1998-2021. Marker size is scaled by number and colours represent mean weight of halibut caught in each set (weight / number).

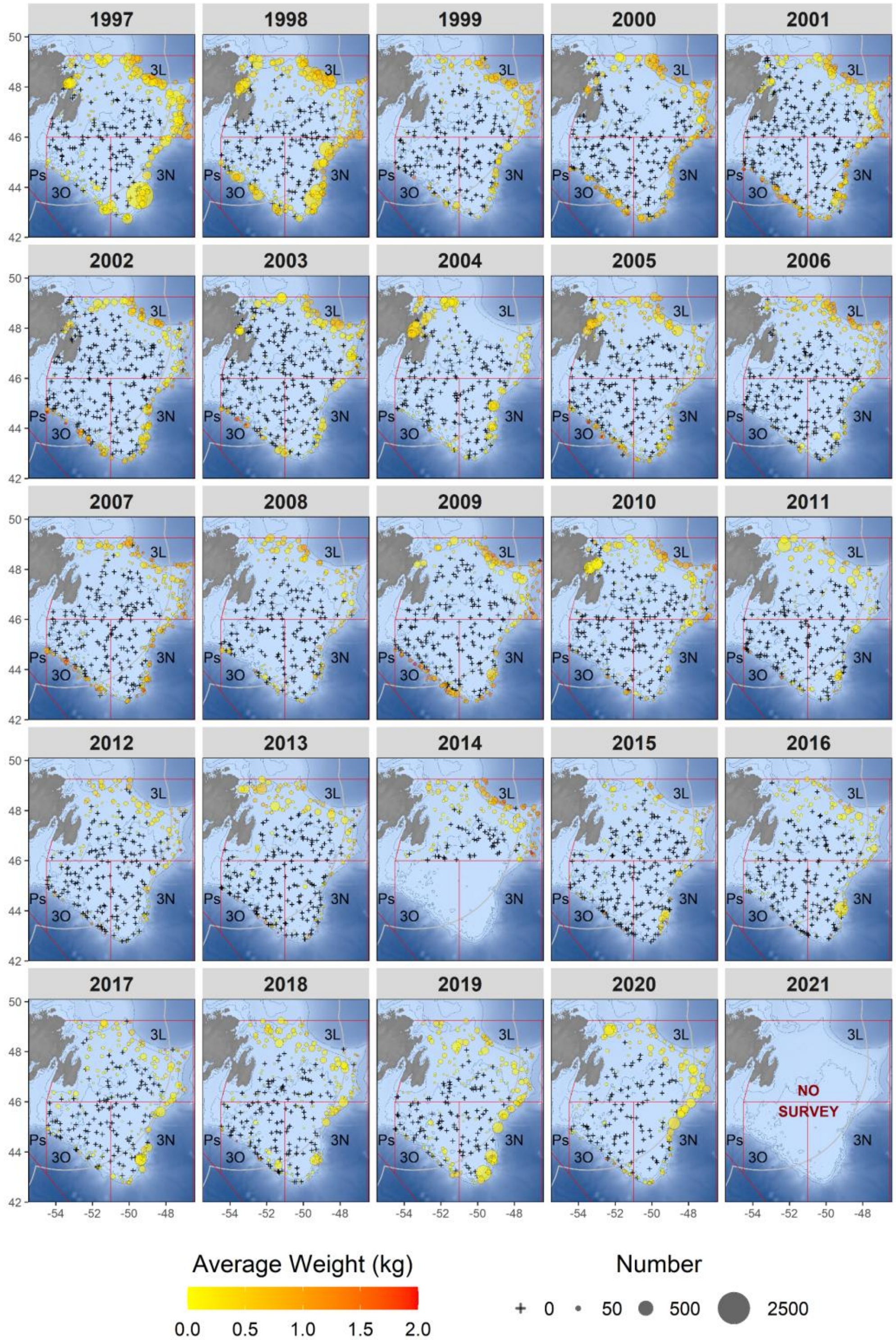

Figure 4. Distribution of Greenland halibut sampled in autumn across 3LNO from 1998-2021. Marker size is scaled by number and colours represent mean weight of halibut caught in each set (weight / number).

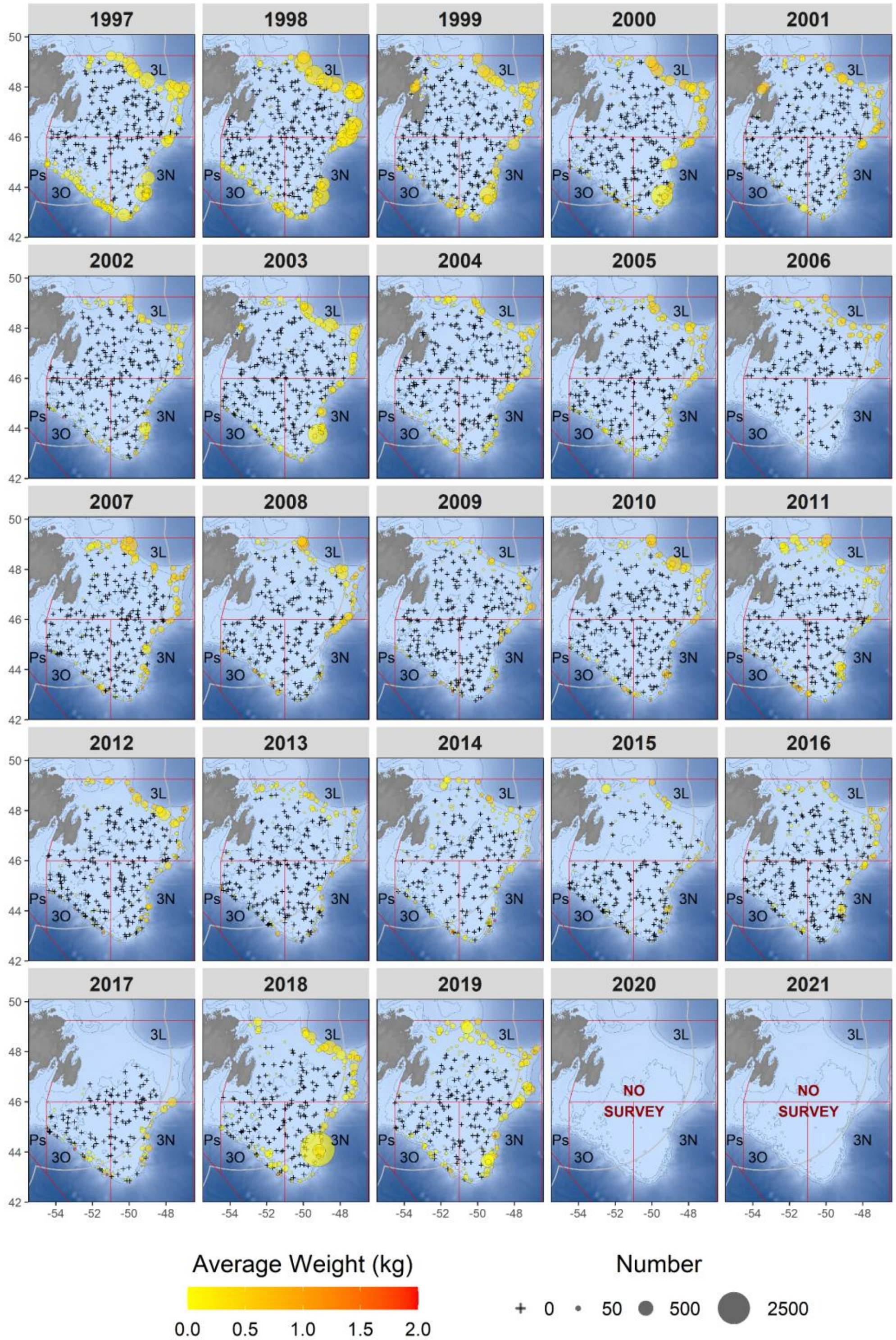

Figure 5. Distribution of Greenland halibut sampled in spring across 3LNO from 1998-2021. Marker size is scaled by number and colours represent mean weight of halibut caught in each set (weight / number).

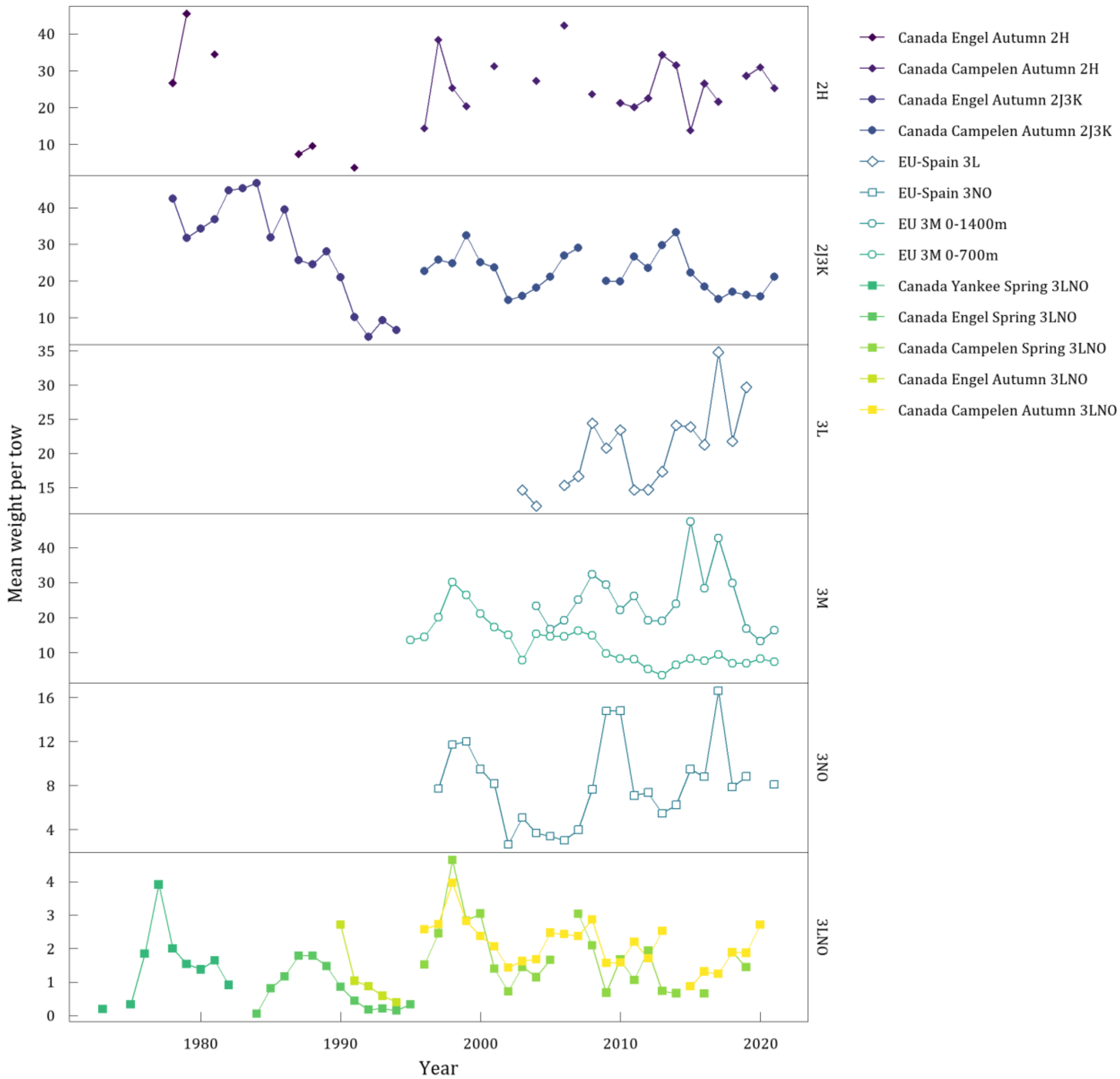

Figure 6. Biomass indices (mean weight (kg) per tow) from all surveys faceted by survey region.

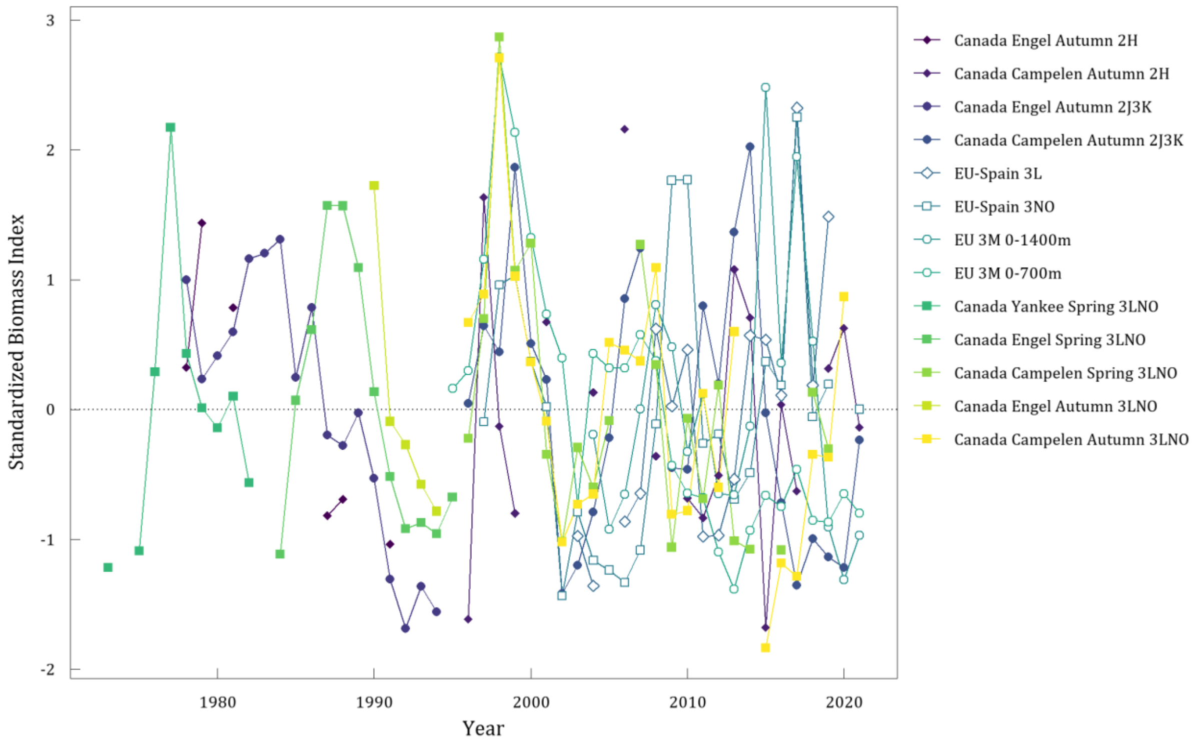

Figure 7. Standardized biomass indices from all surveys where each series is centered on its time-series mean (thin dotted line).

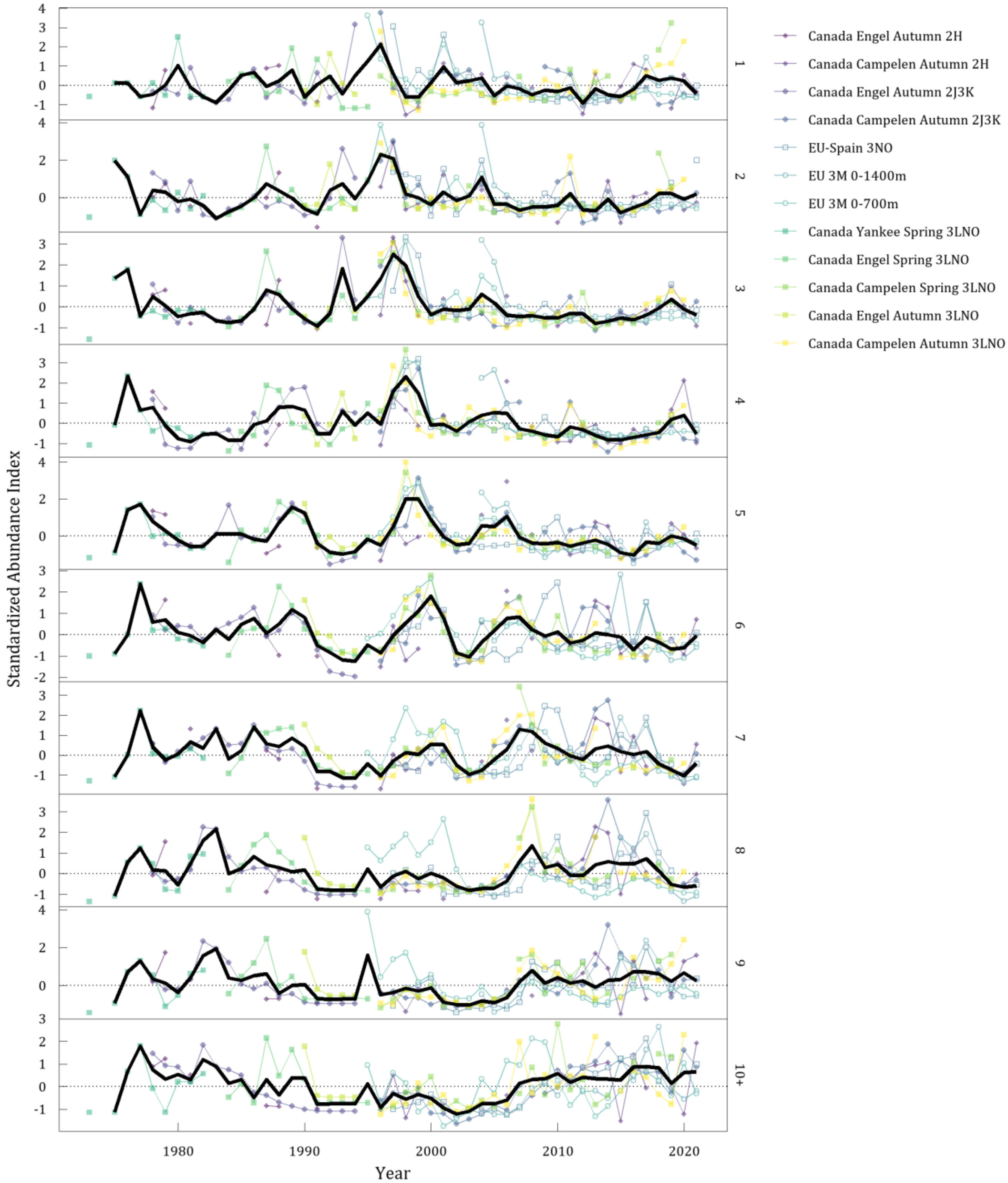

Figure 8. Standardized abundance indices at age from all surveys where each series is centered on its time-series mean (thin dotted line). Mean standard values are shown with a thick black line.

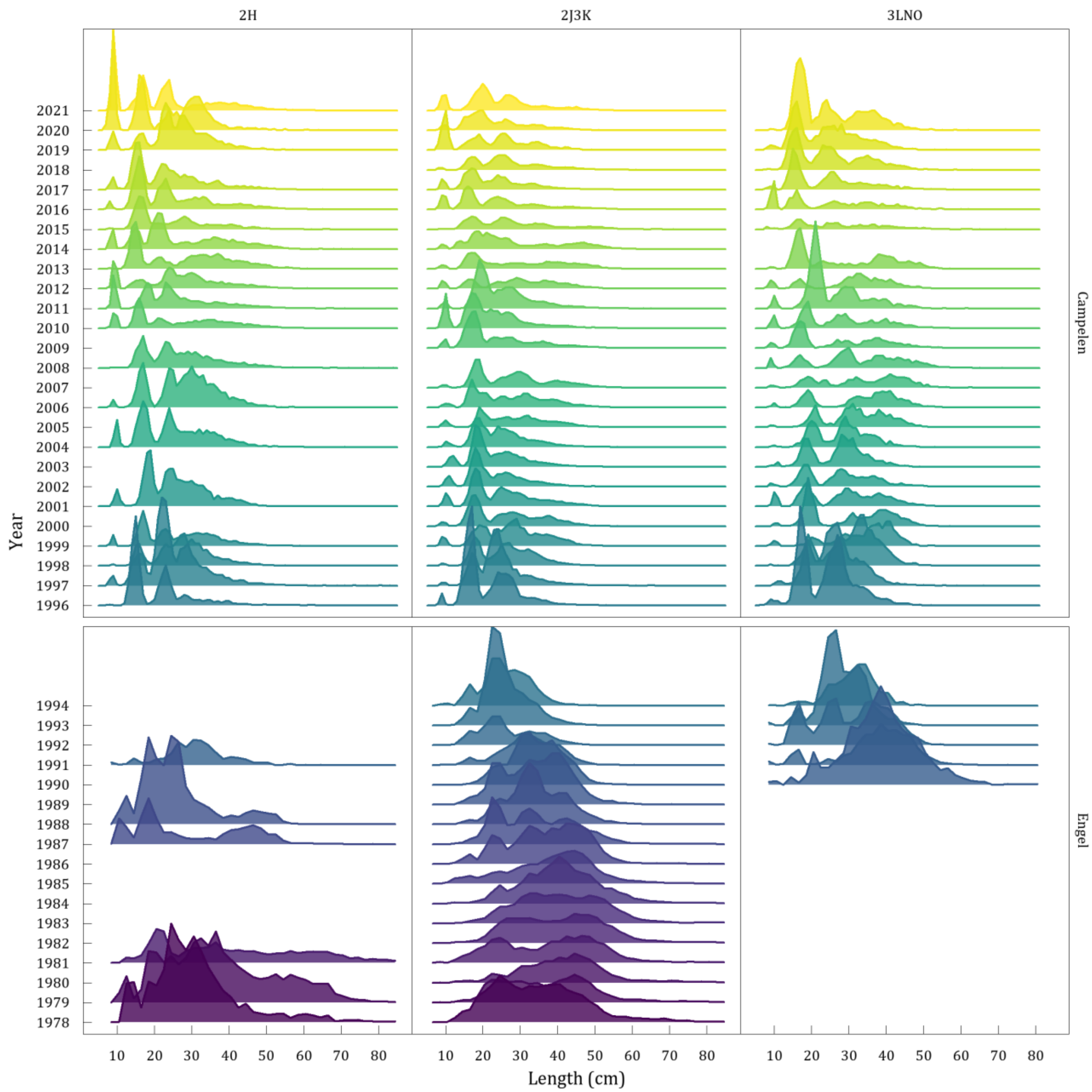

Figure 9. Survey length frequencies from the Canadian autumn research vessel survey for the Engel (middle) and Campelen (top) survey gear, for Greenland halibut. Note that comparisons should not be made across the survey protocols since all data are unconverted.

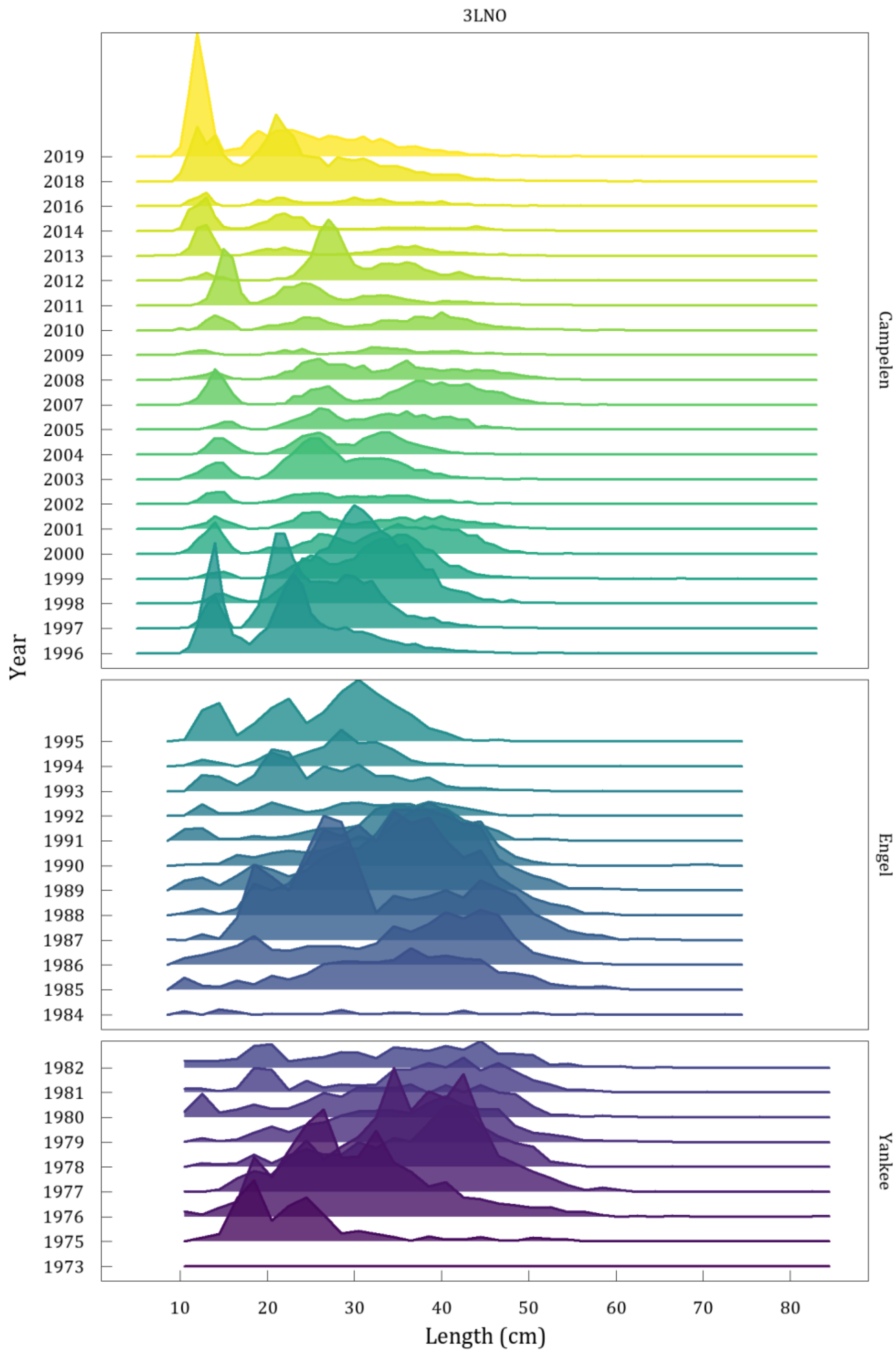

Figure 10. Survey length frequencies from the Canadian spring research vessel survey for the Yankee (bottom), Engel (middle) and Campelen (top) survey gear, for Greenland halibut. Note that comparisons should not be made across the survey protocols since all data are unconverted.

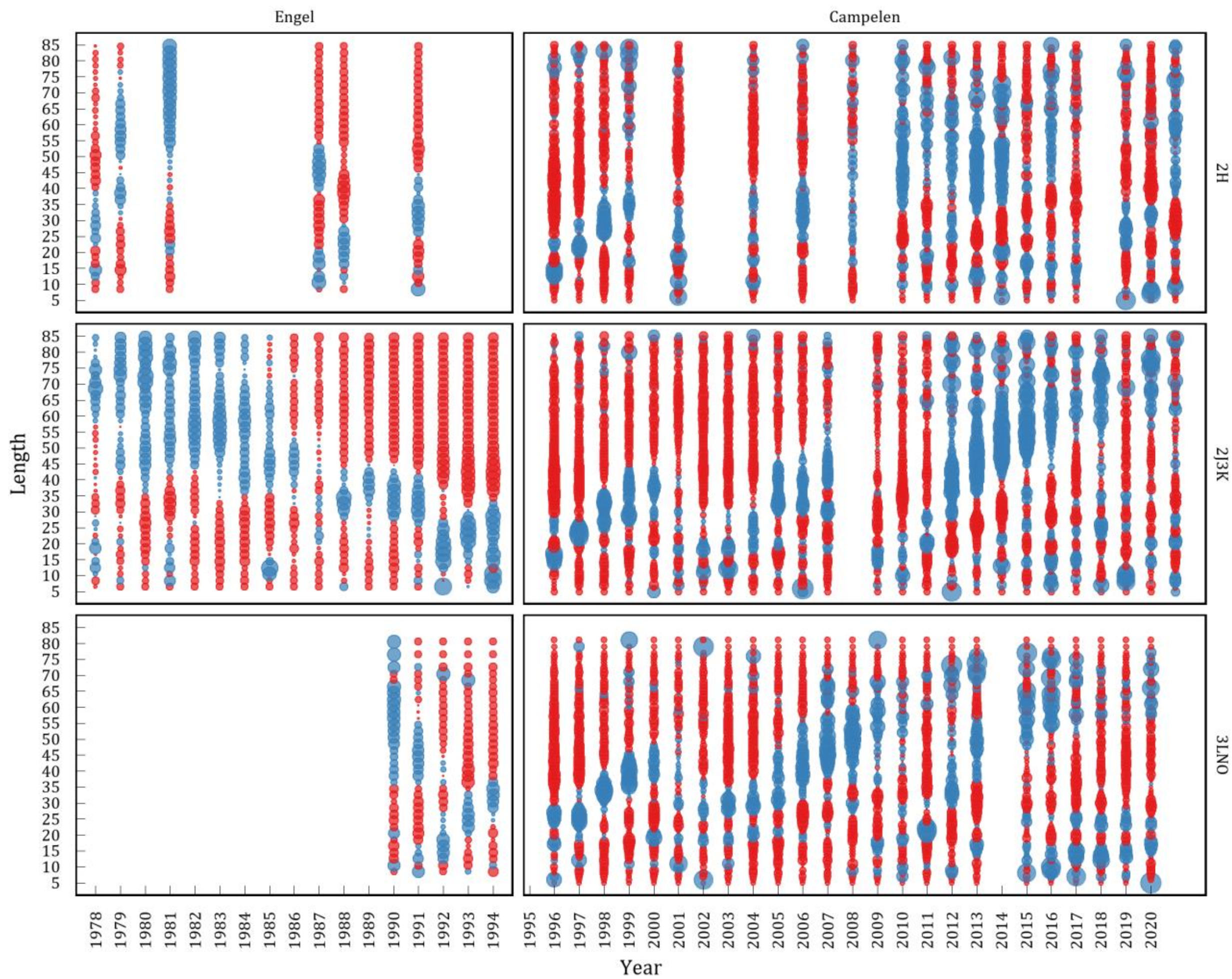

Figure 11. Standardized proportion at length (SPLY) plots from Canadian autumn research vessel surveys for Greenland halibut. The area of a bubble is proportional to the absolute value of the standardized proportion. Red is negative and blue is positive. Note data are unconverted and should not be compared across gear type.

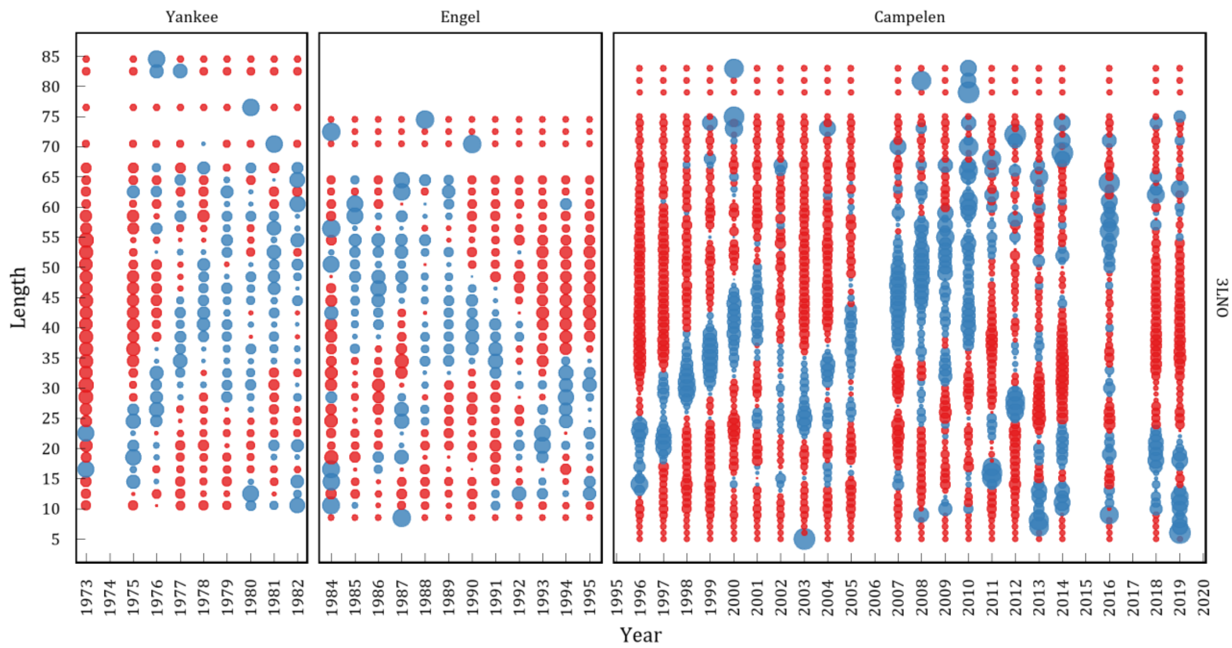

Figure 12. Standardized proportion at length (SPLY) plots from Canadian spring research vessel surveys for Greenland halibut. The area of a bubble is proportional to the absolute value of the standardized proportion. Red is negative and blue is positive. Note data are unconverted and should not be compared across gear type.

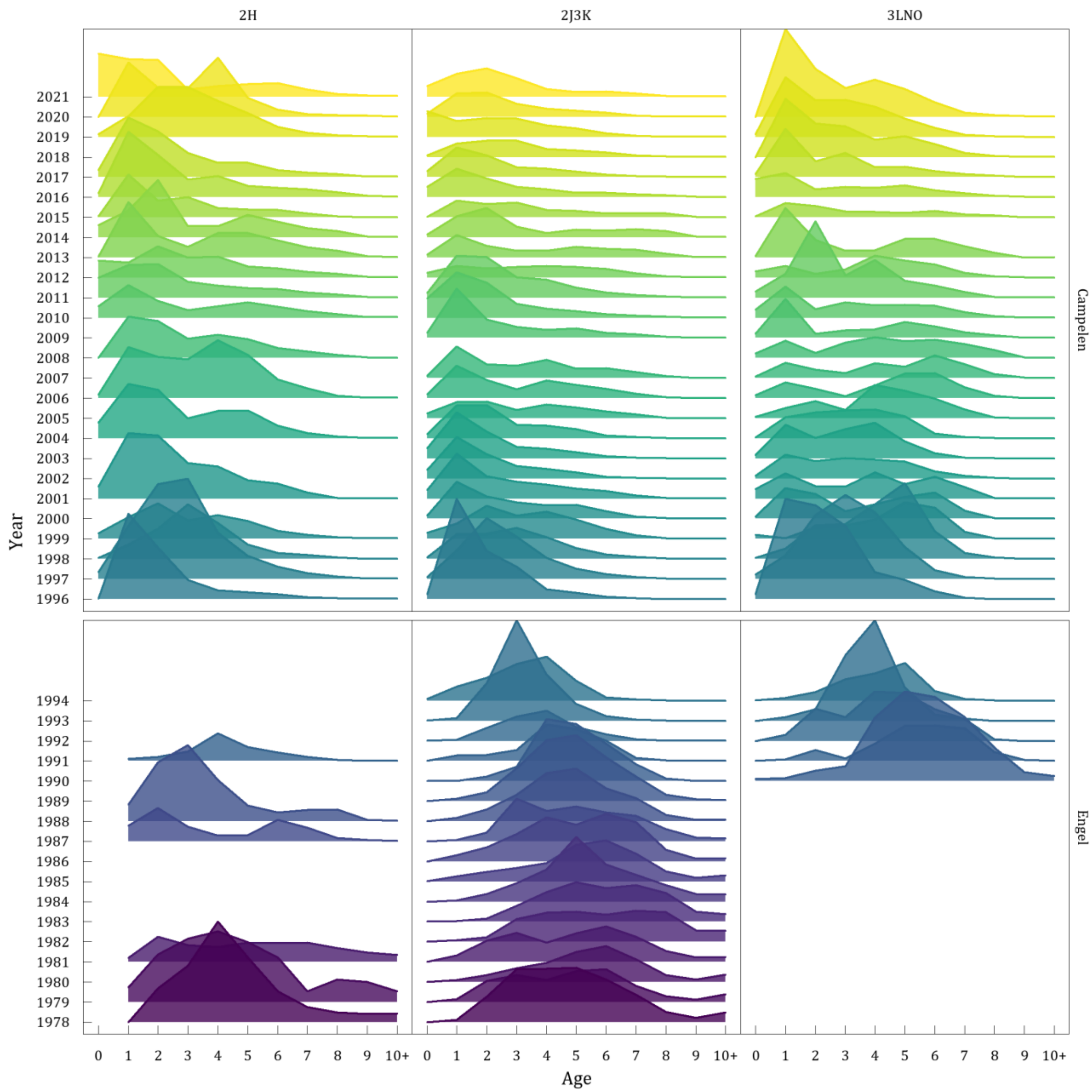

Figure 13. Survey age frequencies from the Canadian autumn research vessel survey for the Yankee (bottom), Engel (middle) and Campelen (top) survey gear, for Greenland halibut. Note that comparisons should not be made across the survey protocols since all data are unconverted.

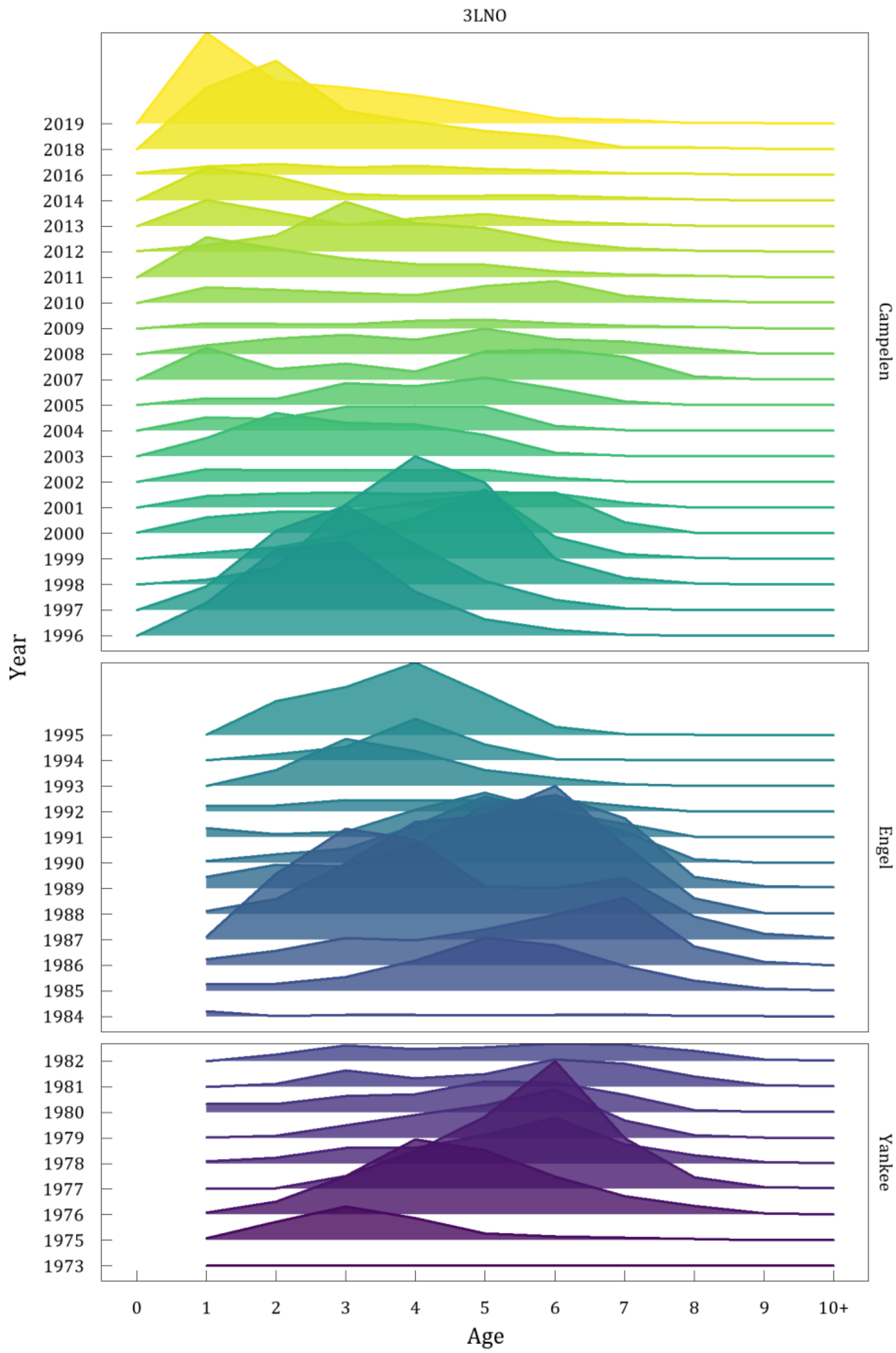

Figure 14. Survey age frequencies from the Canadian spring research vessel survey for the Yankee (bottom), Engel (middle) and Campelen (top) survey gear, for Greenland halibut. Note that comparisons should not be made across the survey protocols since all data are unconverted.

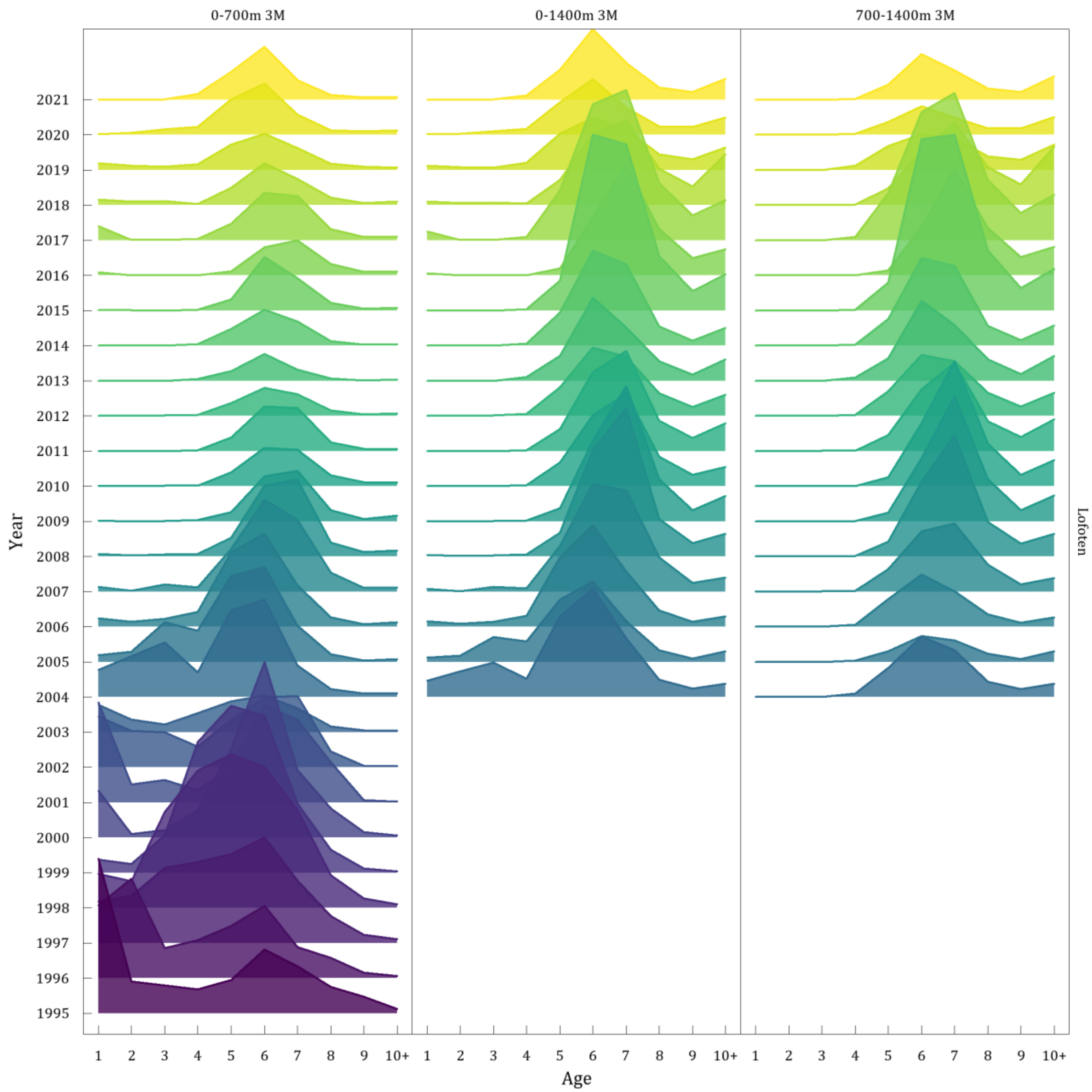

Figure 15. Survey age frequencies from the EU research vessel survey for the Lofoten survey gear for Greenland halibut, by depth.

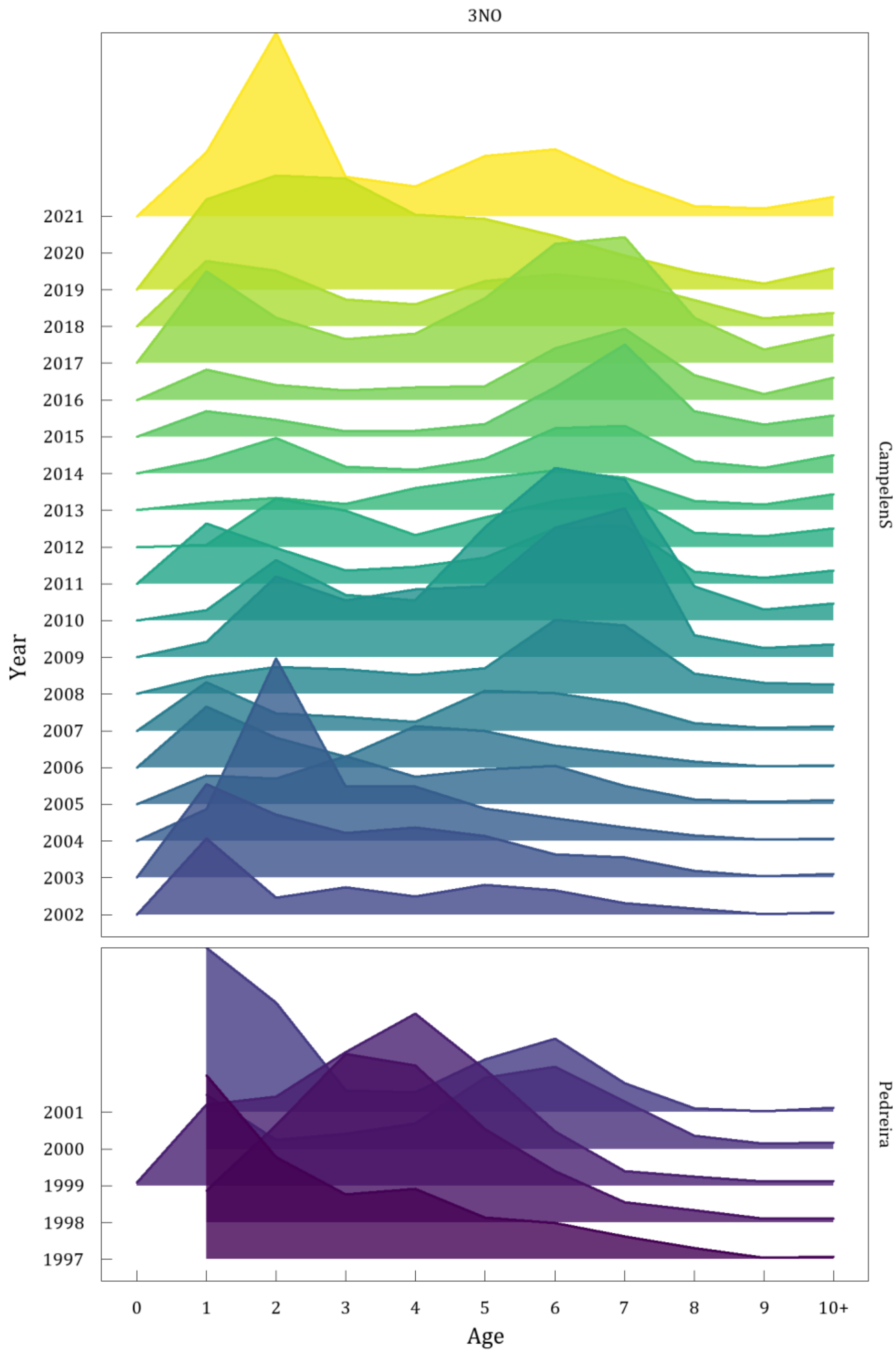

Figure 16. Survey age frequencies from the Spanish research vessel survey for the Padreira (bottom) and Campelen (top) survey gear for Greenland halibut. *I added the split by gear, but area these converted data?

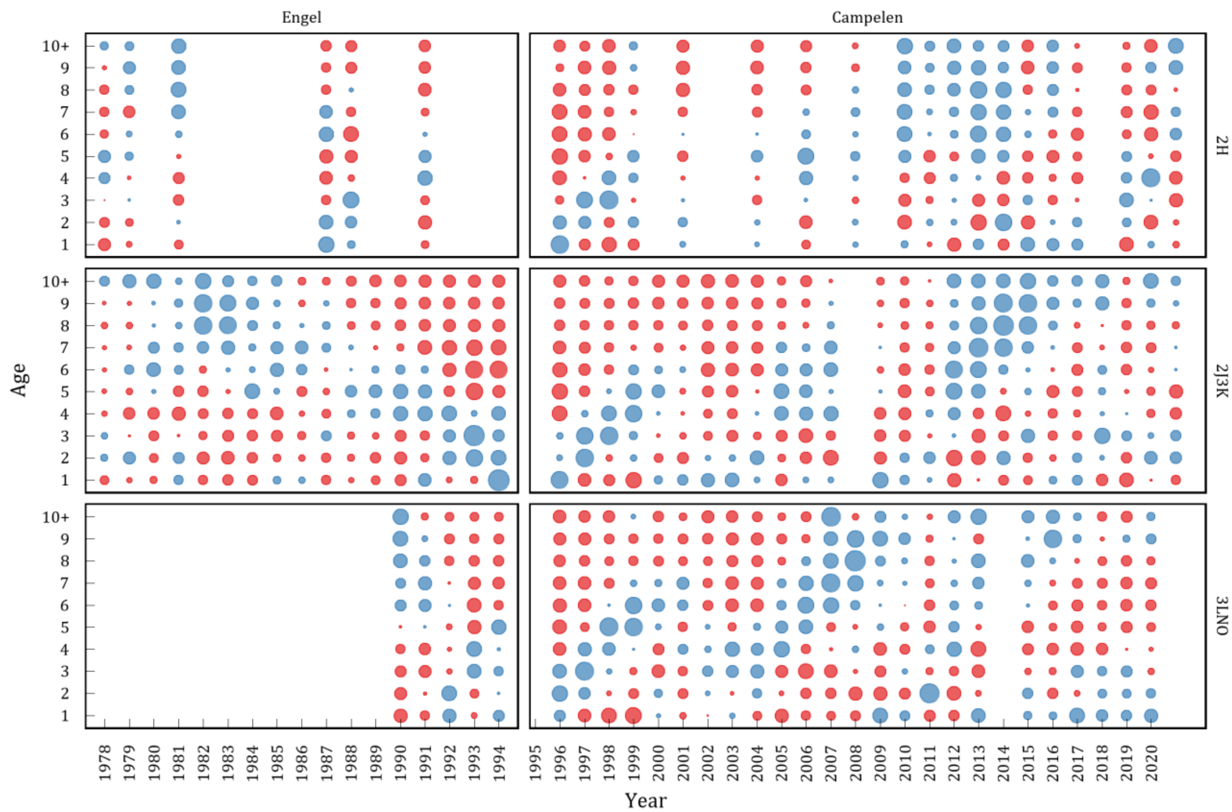

Figure 17. Standardized proportion at length (SPAY) plots from Canadian autumn research vessel surveys for Greenland halibut. The area of a bubble is proportional to the absolute value of the standardized proportion. Red is negative and blue is positive. Note data are unconverted and should not be compared across gear type.

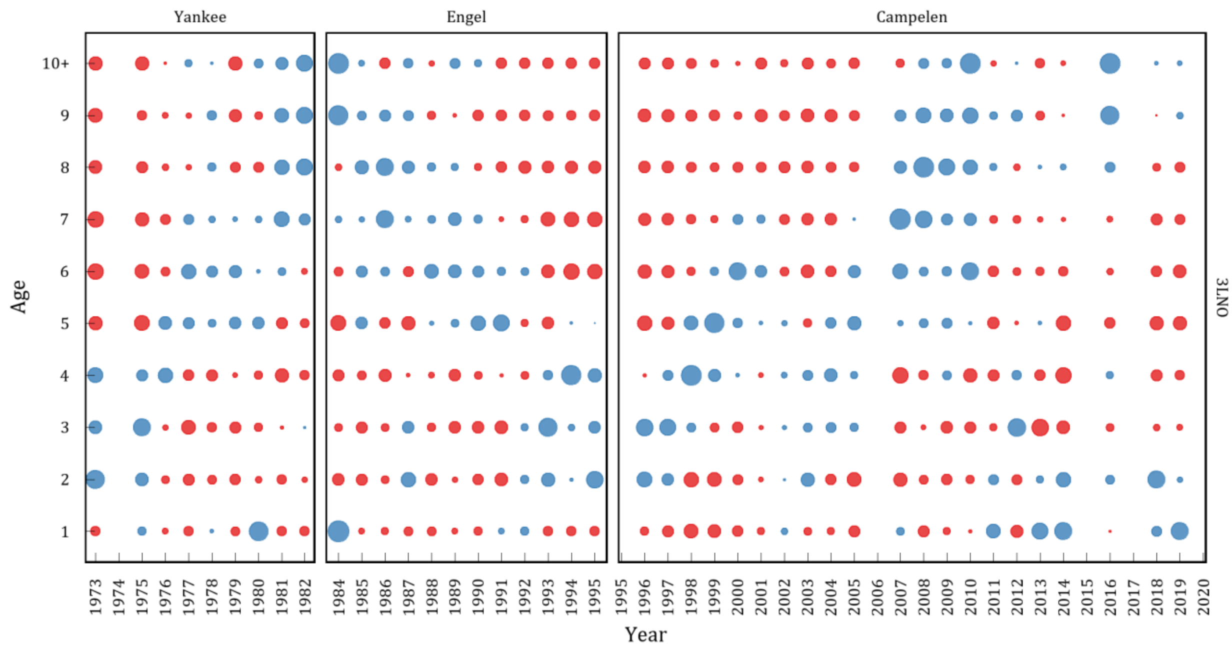

Figure 18. Standardized proportion at length (SPAY) plots from Canadian spring research vessel surveys for Greenland halibut. The area of a bubble is proportional to the absolute value of the standardized proportion. Red is negative and blue is positive. Note data are unconverted and should not be compared across gear type.

Figure 19. Standardized proportion at length (SPAY) plots from EU research vessel surveys for Greenland halibut. The area of a bubble is proportional to the absolute value of the standardized proportion. Red is negative and blue is positive.

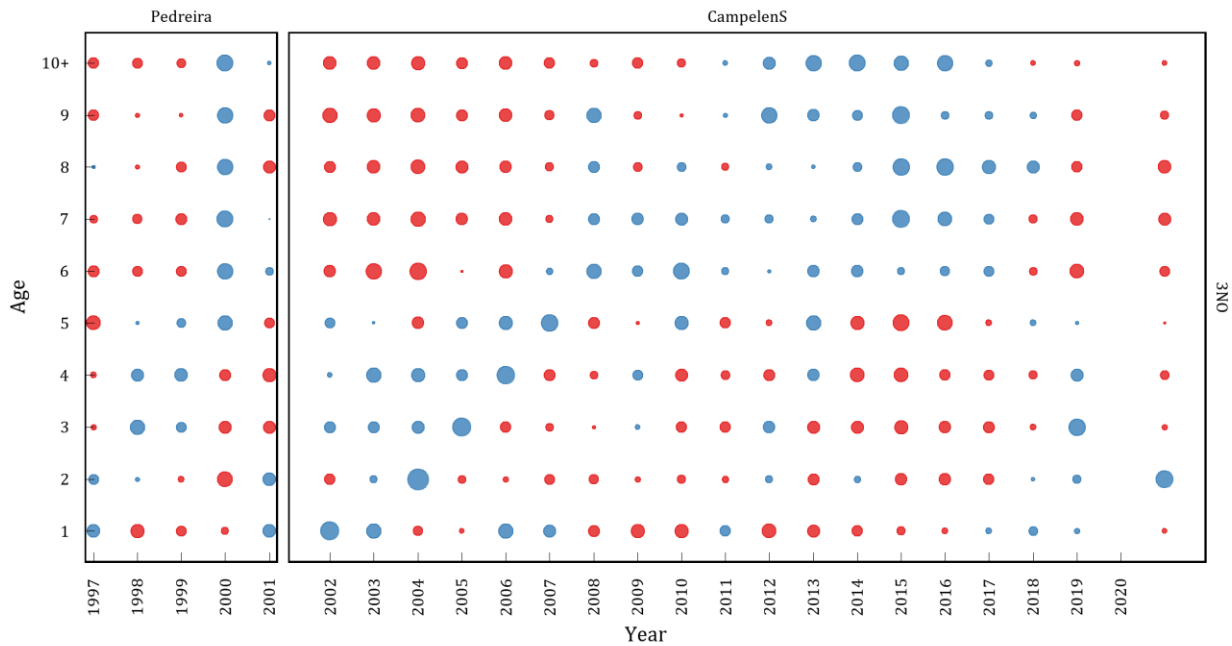

Figure 20. Standardized proportion at length (SPAY) plots from EU-Spain research vessel surveys for Greenland halibut. The area of a bubble is proportional to the absolute value of the standardized proportion. Red is negative and blue is positive. Note data are unconverted and should not be compared across gear type.

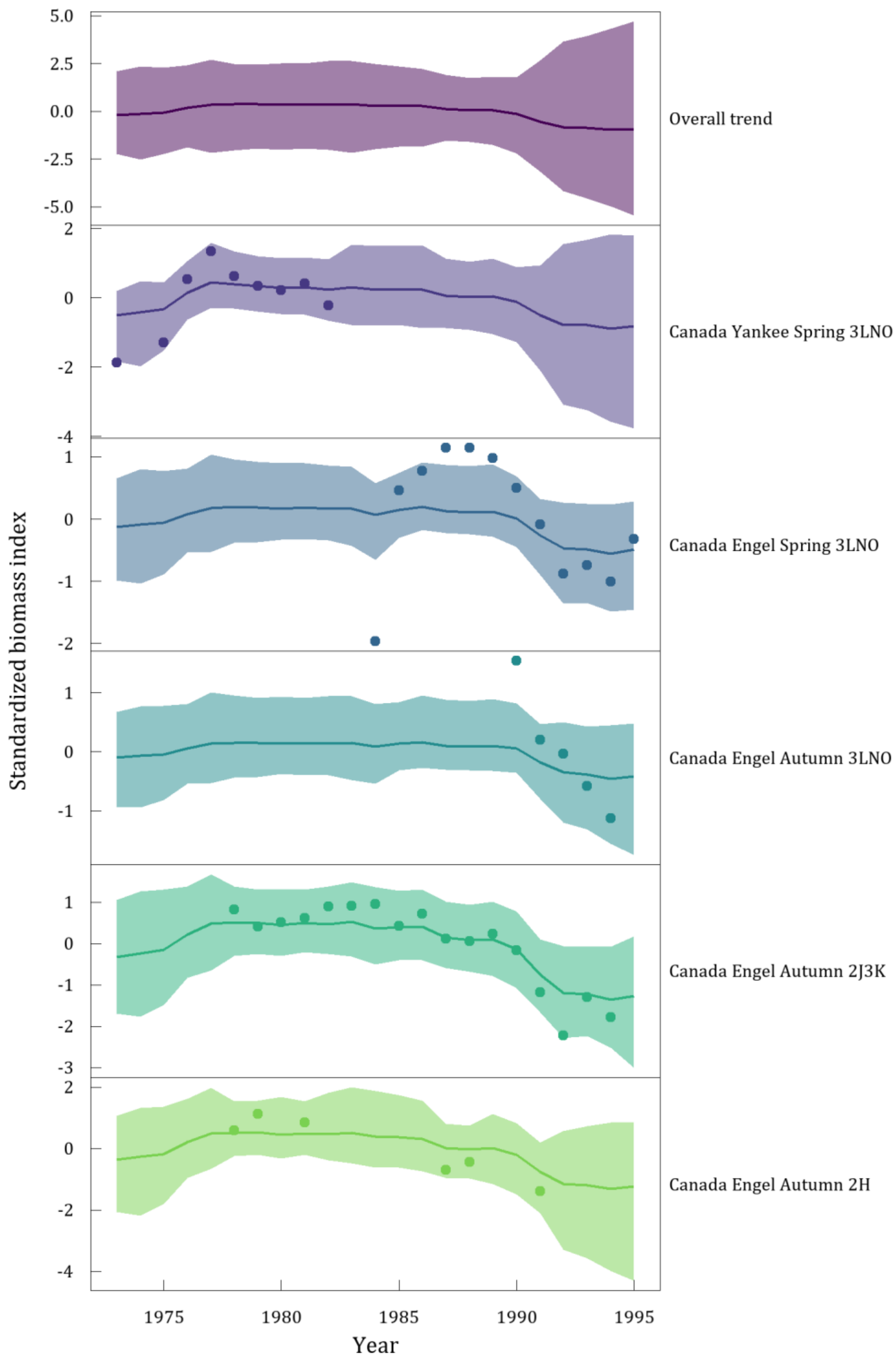

Figure 21. Standardized biomass indices (points) from all surveys conducted prior to 1995 with trends (lines) and 95% credible intervals (shaded area) from a Dynamic Factor Analysis.

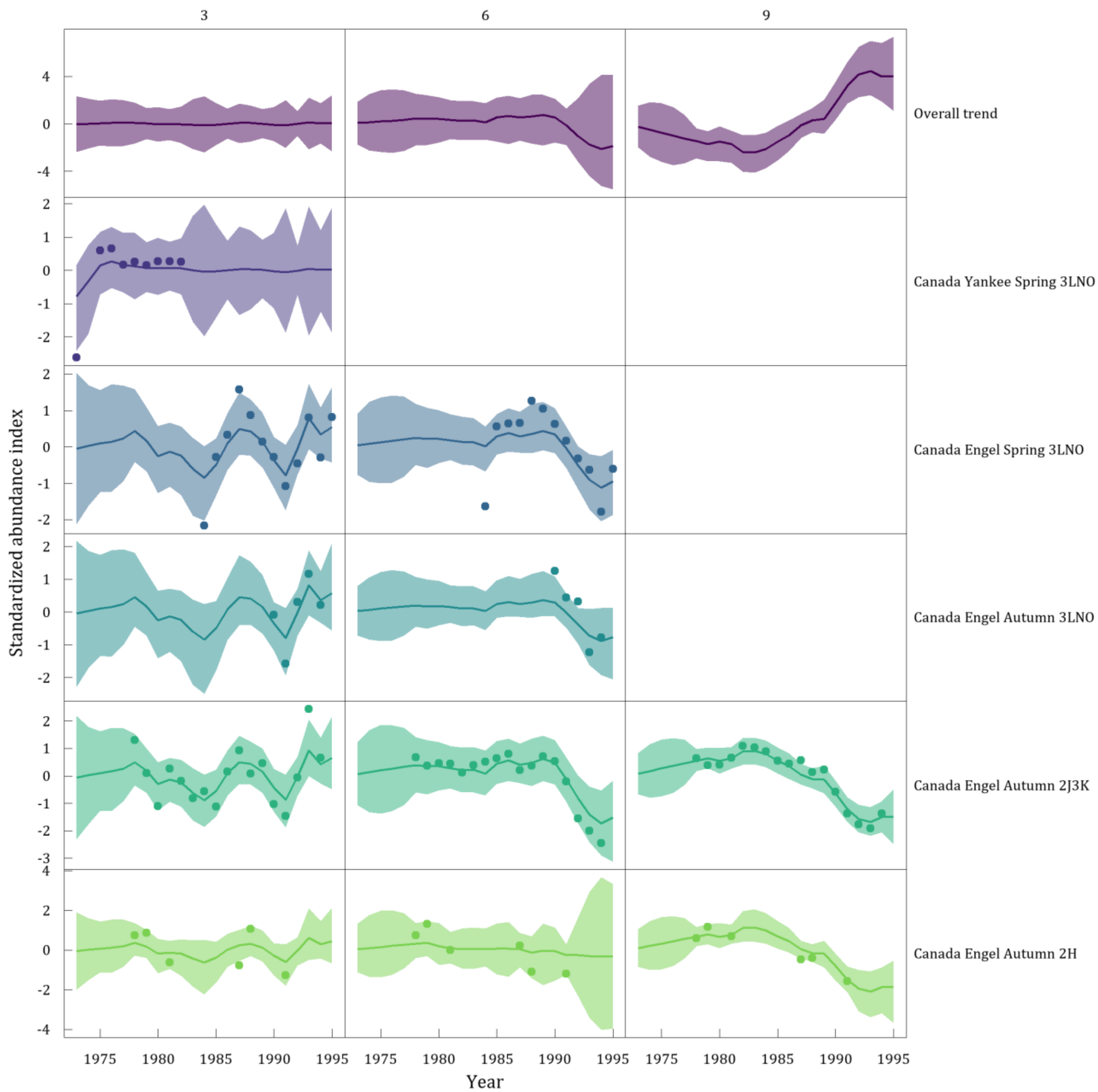

Figure 22. Standardized biomass indices at ages 3, 6, and 9 (points) from all surveys conducted prior to 1995 with trends (lines) and 95% credible intervals (shaded area) from a Dynamic Factor Analysis.

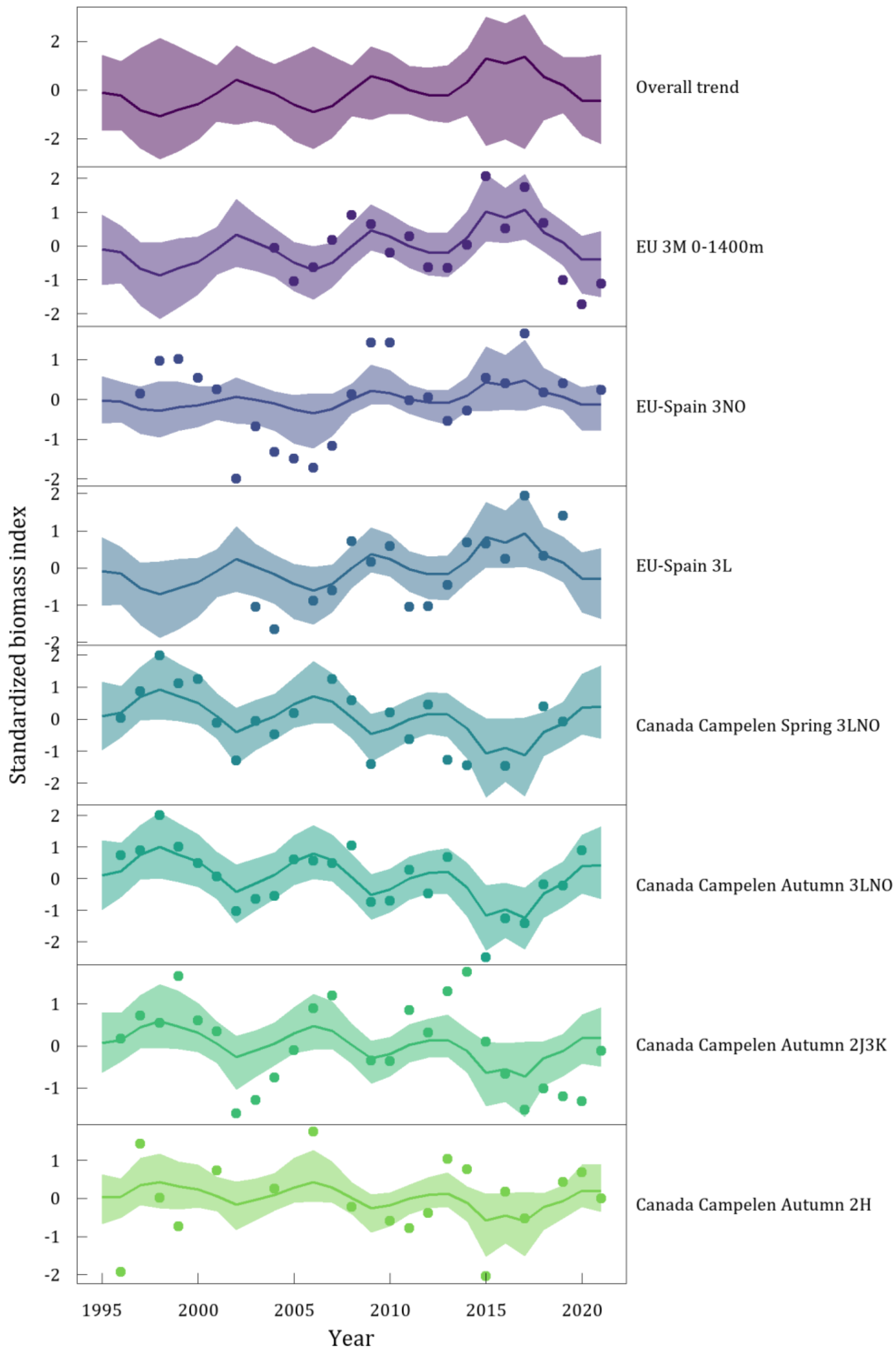

Figure 23. Standardized biomass indices (points) from all surveys conducted since 1995 with trends (lines) and 95% credible intervals (shaded area) from a Dynamic Factor Analysis.

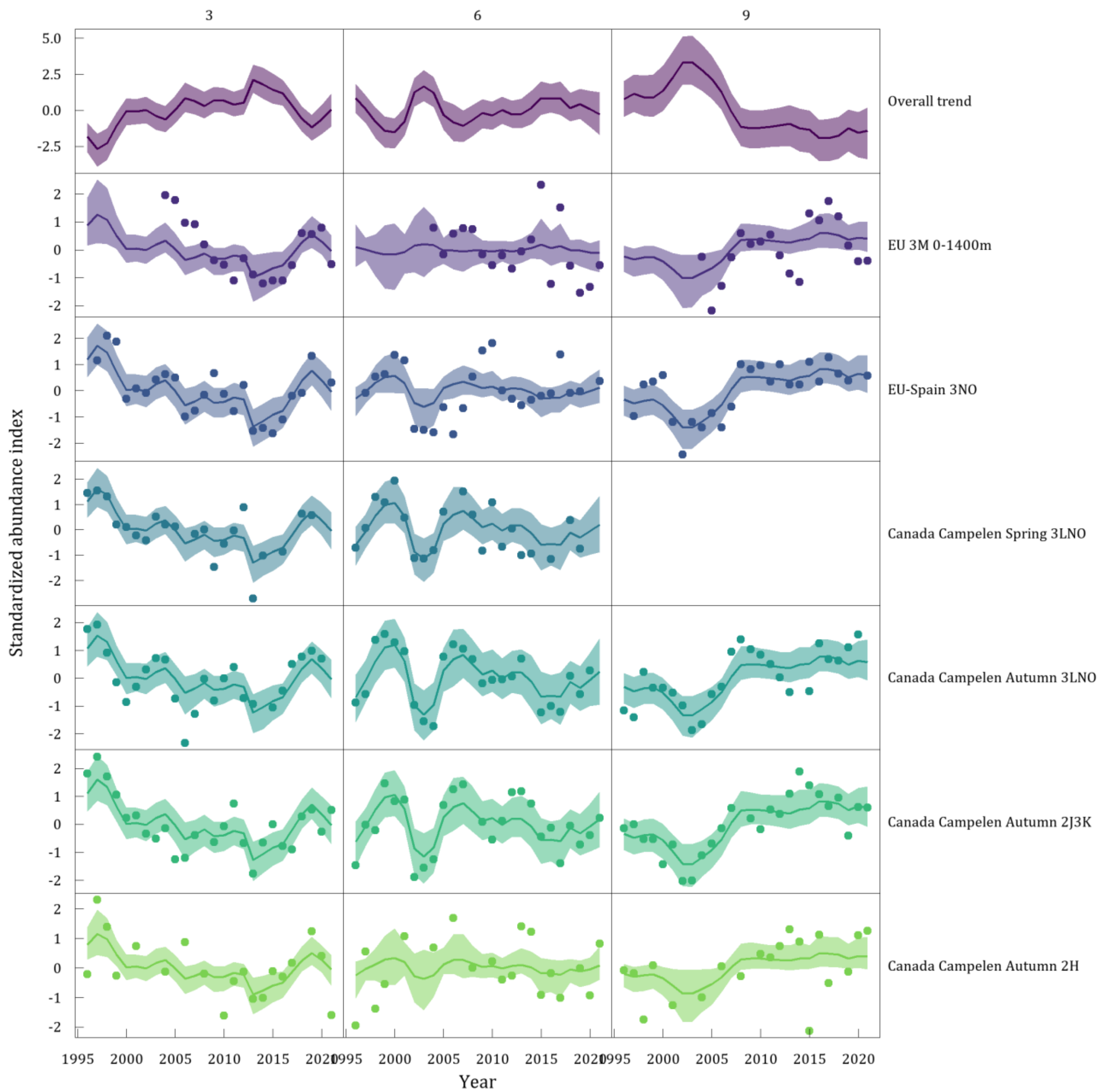

Figure 24. Standardized biomass indices at ages 3, 6, and 9 (points) from all surveys conducted since 1995 with trends (lines) and 95% credible intervals (shaded area) from a Dynamic Factor Analysis.

Colophon

This version of the document was generated on 2022-06-27 12:25:28 using the R markdown template for SCR documents from **NAFOdown**.

The computational environment that was used to generate this version is as follows:

```
#> - Session info ---------------------------------------------------------------
#>  setting  value
#>  version  R version 4.1.2 (2021-11-01)
#>  os       Windows 10 x64 (build 19042)
#>  system   x86_64, mingw32
#>  ui       RTerm
#>  language (EN)
#>  collate  English_United States.1252
#>  ctype    English_United States.1252
#>  tz       America/St_Johns
#>  date     2022-06-27
#>  pandoc   2.14.0.3 @ C:/Program Files/RStudio/bin/pandoc/ (via rmarkdown)
#>
#> - Packages -------------------------------------------------------------------
#>  ! package     * version  date (UTC) lib source
#>    assertthat    0.2.1    2019-03-21 [1] CRAN (R 4.1.2)
#>    backports     1.2.1    2020-12-09 [1] CRAN (R 4.1.1)
#>    base64enc     0.1-3    2015-07-28 [1] CRAN (R 4.1.0)
#>    bayesdfa    * 1.2.0    2021-09-28 [1] CRAN (R 4.1.3)
#>    bit           4.0.4    2020-08-04 [1] CRAN (R 4.1.1)
#>    bit64         4.0.5    2020-08-30 [1] CRAN (R 4.1.1)
#>    bmp           0.3      2017-09-11 [1] CRAN (R 4.1.3)
#>    bookdown      0.24     2021-09-02 [1] CRAN (R 4.1.1)
#>    broom         0.7.9    2021-07-27 [1] CRAN (R 4.1.1)
#>    cachem        1.0.6    2021-08-19 [1] CRAN (R 4.1.1)
#>    callr         3.7.0    2021-04-20 [1] CRAN (R 4.1.1)
#>    cli           3.1.0    2021-10-27 [1] CRAN (R 4.1.2)
#>    codetools     0.2-18   2020-11-04 [2] CRAN (R 4.1.2)
#>    colorspace    2.0-2    2021-06-24 [1] CRAN (R 4.1.1)
#>    crayon        1.4.1    2021-02-08 [1] CRAN (R 4.1.1)
#>    crosstalk     1.1.1    2021-01-12 [1] CRAN (R 4.1.1)
#>    data.table    1.14.0   2021-02-21 [1] CRAN (R 4.1.1)
#>    DBI           1.1.1    2021-01-15 [1] CRAN (R 4.1.1)
#>    desc          1.3.0    2021-03-05 [1] CRAN (R 4.1.1)
#>    devtools      2.4.3    2021-11-30 [1] CRAN (R 4.1.2)
#>    digest        0.6.29   2021-12-01 [1] CRAN (R 4.1.2)
#>    dplyr       * 1.0.7    2021-06-18 [1] CRAN (R 4.1.1)
#>    ellipsis      0.3.2    2021-04-29 [1] CRAN (R 4.1.1)
#>    evaluate      0.14     2019-05-28 [1] CRAN (R 4.1.1)
#>    fansi         0.5.0    2021-05-25 [1] CRAN (R 4.1.1)
#>    farver        2.1.0    2021-02-28 [1] CRAN (R 4.1.1)
#>    fastmap       1.1.0    2021-01-25 [1] CRAN (R 4.1.1)
#>    flextable     0.6.9    2021-10-07 [1] CRAN (R 4.1.0)
#>    fs            1.5.2    2021-12-08 [1] CRAN (R 4.1.2)
#>    gdtools       0.2.3    2021-01-06 [1] CRAN (R 4.1.1)
#>    generics      0.1.1    2021-10-25 [1] CRAN (R 4.1.2)
#>    ggplot2     * 3.3.5    2021-06-25 [1] CRAN (R 4.1.1)
#>    ggridges    * 0.5.3    2021-01-08 [1] CRAN (R 4.1.3)
```

```
#>   ggthemes      4.2.4      2021-01-20 [1] CRAN (R 4.1.3)
#>   ghalAssess  * 0.0.1.9000 2022-06-10 [1] local
#>   glue          1.4.2      2020-08-27 [1] CRAN (R 4.1.1)
#>   gridExtra     2.3        2017-09-09 [1] CRAN (R 4.1.1)
#>   gtable        0.3.0      2019-03-25 [1] CRAN (R 4.1.1)
#>   here        * 1.0.1      2020-12-13 [1] CRAN (R 4.1.1)
#>   highr         0.9        2021-04-16 [1] CRAN (R 4.1.1)
#>   htmltools     0.5.2      2021-08-25 [1] CRAN (R 4.1.1)
#>   htmlwidgets   1.5.4      2021-09-08 [1] CRAN (R 4.1.1)
#>   httr          1.4.2      2020-07-20 [1] CRAN (R 4.1.1)
#>   igraph        1.3.1      2022-04-20 [1] CRAN (R 4.1.3)
#>   imager      * 0.42.13    2022-03-07 [1] CRAN (R 4.1.3)
#>   inline        0.3.19     2021-05-31 [1] CRAN (R 4.1.2)
#>   jpeg          0.1-9      2021-07-24 [1] CRAN (R 4.1.1)
#>   jsonlite      1.7.3      2022-01-17 [1] CRAN (R 4.1.2)
#>   knitr         1.34       2021-09-09 [1] CRAN (R 4.1.1)
#>   labeling      0.4.2      2020-10-20 [1] CRAN (R 4.1.0)
#>   lattice       0.20-45    2021-09-22 [2] CRAN (R 4.1.2)
#>   lazyeval      0.2.2      2019-03-15 [1] CRAN (R 4.1.1)
#>   lifecycle     1.0.1      2021-09-24 [1] CRAN (R 4.1.3)
#>   loo           2.5.1      2022-03-24 [1] CRAN (R 4.1.3)
#>   magrittr    * 2.0.1      2020-11-17 [1] CRAN (R 4.1.1)
#>   Matrix        1.4-1      2022-03-23 [1] CRAN (R 4.1.3)
#>   matrixStats   0.61.0     2021-09-17 [1] CRAN (R 4.1.1)
#>   memoise       2.0.1      2021-11-26 [1] CRAN (R 4.1.2)
#>   mgcv          1.8-38     2021-10-06 [2] CRAN (R 4.1.2)
#>   munsell       0.5.0      2018-06-12 [1] CRAN (R 4.1.1)
#>   NAFOdown    * 0.0.1.9000 2022-06-13 [1] local
#>   nlme          3.1-153    2021-09-07 [2] CRAN (R 4.1.2)
#>   officer       0.4.0      2021-09-06 [1] CRAN (R 4.1.1)
#>   pillar        1.6.2      2021-07-29 [1] CRAN (R 4.1.1)
#>   pkgbuild      1.2.0      2020-12-15 [1] CRAN (R 4.1.1)
#>   pkgconfig     2.0.3      2019-09-22 [1] CRAN (R 4.1.1)
#>   pkgload       1.2.2      2021-09-11 [1] CRAN (R 4.1.0)
#>   plotly      * 4.10.0     2021-10-09 [1] CRAN (R 4.1.3)
#>   plyr          1.8.6      2020-03-03 [1] CRAN (R 4.1.1)
#>   png           0.1-7      2013-12-03 [1] CRAN (R 4.1.1)
#>   prettyunits   1.1.1      2020-01-24 [1] CRAN (R 4.1.1)
#>   processx      3.5.2      2021-04-30 [1] CRAN (R 4.1.1)
#>   ps            1.6.0      2021-02-28 [1] CRAN (R 4.1.1)
#>   purrr         0.3.4      2020-04-17 [1] CRAN (R 4.1.1)
#>   R6            2.5.1      2021-08-19 [1] CRAN (R 4.1.1)
#>   RColorBrewer  1.1-2      2014-12-07 [1] CRAN (R 4.1.0)
#>   Rcpp          1.0.7      2021-07-07 [1] CRAN (R 4.1.1)
#>   RcppEigen   * 0.3.3.9.1  2020-12-17 [1] CRAN (R 4.1.1)
#> D RcppParallel  5.1.5      2022-01-05 [1] CRAN (R 4.1.3)
#>   readbitmap    0.1.5      2018-06-27 [1] CRAN (R 4.1.3)
#>   remotes       2.4.0      2021-06-02 [1] CRAN (R 4.1.1)
#>   reshape       0.8.8      2018-10-23 [1] CRAN (R 4.1.1)
#>   rlang         1.0.2      2022-03-04 [1] CRAN (R 4.1.3)
#>   rmarkdown     2.11       2021-09-14 [1] CRAN (R 4.1.1)
#>   rprojroot     2.0.2      2020-11-15 [1] CRAN (R 4.1.1)
#>   rstan         2.21.5     2022-04-11 [1] CRAN (R 4.1.3)
#>   Rstrap      * 1.14.1     2022-06-07 [1] local
#>   rstudioapi    0.13       2020-11-12 [1] CRAN (R 4.1.1)
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#>   scales        1.1.1      2020-05-11 [1] CRAN (R 4.1.1)
#>   sessioninfo   1.2.2      2021-12-06 [1] CRAN (R 4.1.2)
#>   showtext      0.9-4      2021-08-14 [1] CRAN (R 4.1.1)
#>   showtextdb    3.0        2020-06-04 [1] CRAN (R 4.1.1)
#>   StanHeaders   2.21.0-7   2020-12-17 [1] CRAN (R 4.1.3)
#>   stringi       1.7.4      2021-08-25 [1] CRAN (R 4.1.1)
#>   stringr       1.4.0      2019-02-10 [1] CRAN (R 4.1.1)
#>   sysfonts      0.8.5      2021-08-09 [1] CRAN (R 4.1.1)
#>   systemfonts   1.0.3      2021-10-13 [1] CRAN (R 4.1.2)
#>   testthat      3.1.1      2021-12-03 [1] CRAN (R 4.1.2)
#>   tibble        3.1.4      2021-08-25 [1] CRAN (R 4.1.1)
#>   tidyr       * 1.1.3      2021-03-03 [1] CRAN (R 4.1.1)
#>   tidyselect    1.1.1      2021-04-30 [1] CRAN (R 4.1.1)
#>   tiff          0.1-11     2022-01-31 [1] CRAN (R 4.1.2)
#> D TMB         * 1.8.1      2022-03-23 [1] CRAN (R 4.1.3)
#>   tzdb          0.1.2      2021-07-20 [1] CRAN (R 4.1.1)
#>   usethis       2.0.1      2021-02-10 [1] CRAN (R 4.1.1)
#>   utf8          1.2.2      2021-07-24 [1] CRAN (R 4.1.1)
#>   uuid          0.1-4      2020-02-26 [1] CRAN (R 4.1.1)
#>   vctrs         0.3.8      2021-04-29 [1] CRAN (R 4.1.1)
#>   viridis       0.6.1      2021-05-11 [1] CRAN (R 4.1.1)
#>   viridisLite   0.4.0      2021-04-13 [1] CRAN (R 4.1.1)
#>   vroom         1.5.5      2021-09-14 [1] CRAN (R 4.1.0)
#>   withr         2.4.3      2021-11-30 [1] CRAN (R 4.1.2)
#>   xfun          0.26       2021-09-14 [1] CRAN (R 4.1.0)
#>   xml2          1.3.2      2020-04-23 [1] CRAN (R 4.1.1)
#>   yaml          2.2.1      2020-02-01 [1] CRAN (R 4.1.0)
#>   zip           2.2.0      2021-05-31 [1] CRAN (R 4.1.1)
#>
#> [1] C:/Users/RegularP/Documents/R/win-library/4.1
#> [2] C:/Program Files/R/R-4.1.2/library
#>
#> D -- DLL MD5 mismatch, broken installation.
#>
#> ------------------------------------------------------------------------------
```