NOT TO BE CITED WITHOUT PRIOR
REFERENCE TO THE AUTHOR(S)

Northwest Atlantic Fisheries Organization

Serial No. N7402 **NAFO SCR Doc. 23/015**

SCIENTIFIC COUNCIL MEETING – JUNE 2023

Exploring the effect of missing survey indices on TAC for Greenland halibut in NAFO Subarea 2 and Divisions 3KLMNO

N. Gullage[1], P.M. Regular[1], D. Varkey[1]

[1]Fisheries and Oceans Canada, Northwest Atlantic Fisheries Center, St. John's, Newfoundland and Labrador A1C 5X1, Canada

2023-06-03

Abstract

Total Allowable Catch (TAC) for Greenland Halibut in NAFO divisions 2+3KLMNO is defined by the average TACs from a slope-based harvest control rule (HCR) and a target-base HCR. Both HCRs are designed to ignore missing years in survey indices. However, exactly how missing survey indices affect final TAC results is not well understood. We recalculated TACs by excluding indices for different years and surveys to explore how missing survey indices impact the overall TAC calculation, as well as TACs from the slope and target based components of the HCR. Our results indicated that TACs did not depend on the year missing but rather the relative magnitude of the index or indices missing. We also noted that the slope-based HCR had a more significant impact on the TAC than the target-based rule, and the slope-based TAC was more varied because it relied on numerical approximations of slope whereas the target-based TAC was more robust because it was based on averages. Additionally, Canadian and European surveys propose opposing trends in TAC, and relying on one or the other may bias TAC to one extreme. We concluded missing data affected TAC when the variance between recent survey indices was already high, but average TAC for 2024 is not expected to deviate more than 10% from the TAC were 2022 Canadian indices available.

Introduction

The Harvest Control Rule (HCR) for Greenland Halibut in NAFO divisions 2+3KLMNO defines Total Allowable Catch (TAC) based on recent trends in survey abundance indices, which include the Canadian Spring 3LNO, Fall 3LNO and Fall 2J3K surveys, and the European (EU) Spain 3NO and 3M 0-1400m surveys (Figure 1). TAC is calculated as the average TAC of two separate HCRs: a slope-based rule and a target-base ruled (Annex I.F; NAFO 2023). The HCR is designed to ignore missing years in survey indices. However, exactly how missing survey indices affect TAC results is not well understood. Therefore, an empirical testing of the impacts of missing survey data on the TACs for prior years was conducted to understand these affects. The HCR is constructed as follows:

*Target based HCR (**t**)*

The target-based HCR is:

$$TAC_{y+1}^{target} = TAC_y\left(1 + \gamma(J_y - 1)\right) \qquad (1)$$

where TAC_y is the TAC recommended for year y, γ is the "response strength" tuning parameter, J_y is the weighted ratio between the current composite index and the target level for the mean weight per tow composite index from surveys (I_y^i) that are available to use for calculations for year *y*; four survey series are used, with i = 1, 2, 3, and 4 corresponding respectively to Canada Fall 2J3K, EU 3M 0-1400m, EU-Spain 3NO and Canada Fall 3LNO:

$$J_y = \sum_{i=1}^{4} \frac{1}{\sigma^2} \frac{J_{current}^i}{J_{target}^i} / \sum_{i=1}^{4} \frac{1}{\sigma^2} \qquad (2)$$

with $\left(\sigma^i\right)^2$ being the estimated variance for index *i* (estimated in the SCAA model fitting procedure),

$$J_{current,y}^i = \frac{1}{q} \sum_{y\prime=y-q}^{y-1} I_{y\prime}^i \qquad (3)$$

$$J_{target,y}^i = \frac{\alpha}{5} \sum_{y\prime=2011}^{2015} I_{y\prime}^i \qquad (4)$$

where α is a control/tuning parameter for the MP, and q indicates the period of years used to determine current status. Note the assumption that when a TAC is set in year *y* for year *y+1*, indices will not at that time yet be available for the current year *y*. Missing survey values are treated as missing in the calculation using the rule, as was done in the MSE. In such cases, q in Equation (3) is reduced accordingly.

*Slope based HCR (**s**)*

The slope harvest control rule (HCR) is:

$$TAC_{y+1}^{slope} = TAC_y\left[1 + \lambda_{up/down}\left(s_y - X\right)\right] \qquad (5)$$

where $\lambda_{up/down}$ and *X* are tuning parameters, s_y^i is a measure of the immediate past trend in the survey-based mean weight per tow indices, computed by linearly regressing $ln\left(I_y^i\right)$, vs year *y'* for *y'=y-5* to *y'=y-1*, for each of the four surveys considered, with:

$$s_y = \sum_{i=1}^{4} \frac{1}{\sigma^2} s_y^i / \sum_{i=1}^{4} \frac{1}{\sigma^2} \qquad (6)$$

with the standard error of the residuals of the observed compared to model-predicted logarithm of survey index *i* $\left(\sigma^i\right)$ as estimated in the SCAA base case operating model. Missing survey values are treated as missing in the calculation using the rule, as was done in the MSE. In such cases, the slope in Equation (6) is calculated from the available values within the last five years.

Average TAC

The average TAC is defined as:

$$TAC_{y+1} = \left(TAC_{y+1}^{target} + TAC_{y+1}^{slope}\right)/2 \qquad (7)$$

Finally, constraints on the maximum allowable annual change in TAC are applied, viz.:

$$TAC_{y+1} = \begin{cases} TAC_y(1-\Delta_{down}) & \text{if} \quad TAC_{y+1} < TAC_y(1-\Delta_{down}) \\ TAC_{y+1} & \text{if} \quad TAC_y(1-\Delta_{down}) \leq TAC_{y+1} \leq TAC_y\left(1+\Delta_{up}\right) \\ TAC_y\left(1+\Delta_{up}\right) & \text{if} \quad TAC_{y+1} > TAC_y\left(1+\Delta_{up}\right) \end{cases} \qquad (8)$$

Indices for 2022 Canadian surveys are unavailable (Table 1), which will make the 2024 TAC the first year since the current HCR has been implemented that three separate surveys will not available for the most recent year to be used to calculate TAC, and this will trigger the exceptional circumstances. Some prior years had missing survey indices, and empirical testing of the HCR indicated that the missing survey values had a relatively minor impact on the TAC calculations (**Regular, Butterworth, and Rademeyer 2023**). However, a deeper investigation was warranted given the limited survey data available for the 2024 TAC calculation.

Methods

A series of empirical testing was conducted to better understand the impact of each survey on TAC calculations. Specifically, TACs for years 2019-2022 were recalculated by removing indices for all years for each unique combination of available surveys (32 combinations) and compared to the realized TAC for those years. This facilitates the exploration of the effect of computing the TAC using only one survey series, and computing the TAC using specific survey groups. Note that some preliminary exploration was done on TAC changes by removing 1 to 3 years from specific surveys. However, trends were similar to those when all years were removed, but with a lesser magnitude, so results were considered redundant.

Additionally, to better understand the particular effect missing 2022 survey indices will have on TAC values for 2024, a secondary retrospective analysis was performed. TACs for years 2015-2023 were recalculated using the same relative missing indices that will be used for the 2024 TAC. For example, the prior target-based TAC for 2021 was calculated using survey indices for years 2017-2019 and is only missing the Canada Spring 3LNO survey, but the retrospective TAC was instead calculated using the pattern of available surveys for 2024 (see Table 2). Retrospective TACs were replicated for each year and compared to their respective realized TAC. Retrospective TACs using the 2024 TAC survey pattern are referred to hereafter as *2024-like*.

Results

TAC recalculations using specific surveys

To examine the effects of individual surveys on the TAC, we first focus on the TACs recalculated using only one survey (i.e., excluding all years from all surveys but one; Figure 2). Results for the

Canadian surveys suggested a positive percent change - and therefore overestimation - in TACs across years, and TAC trends for the EU surveys suggested a negative percent change - and therefore underestimation - in TACs computed using all surveys. However, changes in TAC using only the EU 3NO survey indices had high variability in time, ranging from about 24% in 2022 to about -18% in 2023. Nonetheless, percent changes in TAC over these years tended to decrease over time when using only the EU surveys, and increase over time when using only Canadian surveys. This can be seen more clearly when combining all Canadian surveys and European surveys indices separately (Figure 3). The Canadian Spring 3LNO survey indices had a variable impact on TAC in recent years, but these surveys have been dropped as of 2022 (**NAFO 2022**), and so their impact on the TAC was considered inconsequential (see also **Regular, Butterworth, and Rademeyer 2023**).

Excluding both the Spring and Fall 3LNO surveys from TAC calculations skewed TACs substantially, up to 10.8% in absolute difference (Figure 4). Excluding just the Canada Spring 3LNO survey had very little impact on TAC, only amounting to a 2.6% absolute difference (Figure 5).

Retrospective TACs using 2024 survey patterns

TACs were calculated for year 2015-2022 using the survey availability pattern that will be used to the 2024 TAC. The 2024-like slope-based TAC varies greatly from the realized TAC trends (Figure 6), while the target-based TAC remains within a few percentage difference of the realized values. The 2024-like target-based TAC follows closely to trends for the realized TAC values, but the slope-based TACs vary greatly from the trends in realized TAC for most years.

We investigated the differences between the 2024-like and realized average, slope-based, and target-based TACs. The change in the 2024-like TAC from the realized TAC years exceeds 1000t in some years (see Figures 7 & 8), but these changes are within a 10% deviation from their realized TACs (Figure 9). However, the slope-based TAC deviates from the realized TAC by about 15% in some years, while the target-based TAC is within a 3% of the realized TAC in any year.

The applied TAC is defined as the average of TACs from both HCRs, but to compare how much independent TACs vary, the difference between both was defined as a measure of disparity. The largest disparity between the realized slope- and target-based TACs was ~600t (2020), whereas the largest disparity between 2024-like slope- and target-based TACs was ~3000t (2019). This suggests that, despite average realized and 2024-like TACs potentially achieving similar values, missing surveys can increase the between-year variability of TACs markedly. To further elucidate this variability, the standard deviation in this disparity across years was calculated, and the 2024-like annual standard deviation (811t) was approximately double the realized annual standard deviation (395t).

Discussion

Further investigation was done into the inclusion of each unique combination of surveys and their resulting average TAC (see Table A.3). The limited number of years from which to sample made it difficult to extract much useful information, but trends in TAC similar to those described above were apparent in most cases.Overall, TAC was weighted more heavily by surveys with smaller uncertainties, namely the Fall 2J3K and EU 3M 0-1400m surveys, and excluding these surveys had the most dramatic effect on TAC. Removing particular years from TAC calculations only affects TAC inasmuch as removing particular indices (i.e. higher- or lower-than-average indices) shifts J_y or s_y. General trends from individual survey years differed little from the trends seen when excluding survey indices for all years.

The change in average TAC was mostly driven by changes in the slope-based TAC due to its high variability from missing indices. The slope-based rule is more complex than the target-based rule because the linear models are fit internally through optimizations and, as such, this component of the rule is likely more sensitive to data loss. We can eyeball how individual slopes may change based on the trend in indices across years if such changes are drastic. However, gaining further understanding of trends in the slope-based TACs based on indices alone would require *ad hoc* analyses.

The target-based rule, on the other hand, measures the ratio of a recent index average, $J_{current}$, to a fixed target index average, J_{target}. A ratio above 1 indicates a relative increase in TAC from that respective survey, and a ratio below 1 indicates a relative decrease from that respective survey. Although the exact effect of specific indices depends on its variance, we can deduce information on the expected TAC by the change in $J_{current}$ from one year to the next (see Figure 10).

The target-based TAC for some year *y* relies on survey indices for years y-2 to y-4, and TAC for some year y+1 relies on survey indices for years y-1 to y-3. The average value, $J_{current}$, used to define TAC between years y and y+1 will differ only by one year (year y-4 is dropped and year y-1 is added for year y+1 TAC). If the survey index for year y-1 is greater than the average (i.e. $J_{current}$) for the previous year, or more precisely if the survey index for year y-1 is greater that the index for year y-4, the new average will increase and TAC will increase with it. Consequently, missing surveys have little impact on the TAC because of this averaging. The average ignores missing indices, and were the index for some year y-1 to be missing, the new $J_{current}$ would simply be the average of years y-3 and y-2. If the new average were greater than the previous, it would have an increasing effect on TAC, and a lower average would have a decreasing effect on TAC. This is true for all surveys independently. Due to the weighting of each survey when calculating J_y (see Equation (2)), some surveys (notably Canada Fall 2J3K and EU 3M 0-1400m) will have more of an impact on the TAC. The general impact indices have on TAC can be understood by comparing values for $J_{current}$, but the exact effects on TAC can only be known from *ad hoc* analyses due to survey weights.

The retrospective analysis of a 2024-like TAC makes clear that the slope-based HCR is not only the driving factor for the average TAC used for the stock, but has a substantially higher variability than the target-based TAC and is far more sensitive to missing survey indices. It is also worth noting that the differences seen in the 2024-like change in average TAC (~8% change in TAC) are within the range tested under one of the MSE OMs (10% change in TAC; **NAFO 2017**; **Varkey et al. 2020**)). Furthermore, the missing Canadian surveys for 2022 are likely to bias TAC low compared to previous years with more survey indices available. As a result, the survey availability for the 2024 TAC may not be a conservation concern for upcoming management plans. Nonetheless, the relative impact the target- and slope-based HCRs have on average TAC, as well as the contrasting effect of Canadian and European survey indices, are important considerations to carry forward into the MSE review process.

Conclusion

Missing surveys can have a varied impact on the TAC, depending on which years and surveys are missing. Removing any year of individual surveys can have a drastic impact on TAC, especially for the higher-weighted surveys like the Fall 2J3K and EU 3M 0-1400m surveys. Canadian and European surveys have shown opposing annual trends in recent years, and TACs calculated from each exclusively were usually biased high or low with respect to the realized TAC. When replicating the missing survey patterns for the 2024 TAC, changes in prior TACs indicated substantial deviations from the realized slope-based TAC (~15%), but not for the target-based TAC (~3%), and the average TAC deviated by ~8% at most. The change in TAC was more severe when excluding all years for any particular survey than the 2024-like missing surveys. Although the 2024-like replicated TACs indicated that results for the 2024 average TAC are not expected to deviate drastically from a TAC were all surveys available, the target-based TAC alone provides a more stable value for TAC when several years are missing. Regardless of how TAC is calculated for 2024, the absence of 2022 Canadian surveys may provide a more conservative TAC compared to previous years in exchange for slightly reduced total catches.

References

NAFO. 2017. "Report of the NAFO Joint Commission-Scientific Council Working Group on Risk-Based Management Strategies (WG-RBMS) Meeting." *COM-SC Doc. 17-06* 17/06. **https://www.nafo.int/Portals/0/PDFs/COM-SC/2017/com-sc%20doc17-06.pdf**.

———. 2022. "Report of the Scientific Council, 03 -16 June 2022, Halifax, Nova Scotia." *NAFO SCS Doc* 22/18. **https://www.nafo.int/Portals/0/PDFs/sc/2022/scs22-18.pdf**.

———. 2023. "Conservation and Enforcement Measures 2023." *COM Doc. 23-01* 23/01. **https://www.nafo.int/Portals/0/PDFs/COM/2023/comdoc23-01.pdf**.

Regular, P. M., D. Butterworth, and R. Rademeyer. 2023. "Effect of missing values from the Canadian spring and fall surveys of NAFO Divisions 3LNO on the calculation of the TAC using the Greenland halibut HCR." *NAFO SCR Doc* 22/015. **https://www.nafo.int/Portals/0/PDFs/sc/2022/scr22-015.pdf**.

Varkey, D. A, P. M. Regular, R. Kumar, N. Gullage, M. J. Morgan, B. Healey, D. W. Ings, and K. Dwyer. 2020. "Review and revamp of the SSM-based Management Strategy Evaluation for Greenland halibut stock in NAFO Subarea 2 and Divisions 3KLMNO." *NAFO SCR Doc* 20/047. **https://www.nafo.int/Portals/0/PDFs/sc/2020/scr20-047REV.pdf**.

Tables

Table 1. Available surveys for recent years.

	2017	2018	2019	2020	2021	2022
Canada Fall 2J3K	✓	✓	✓	✓	✓	✕
Canada Fall 3LNO	✓	✓	✓	✓	✕	✕
EU 3M 0-1400m	✓	✓	✓	✓	✓	✓
Canada Spring 3LNO	✕	✓	✓	✕	✕	✕
EU-Spain 3NO	✓	✓	✓	✕	✓	✓

Table 2. Survey availability for 2024-like TAC replications for some year y.

	y-6	y-5	y-4	y-3	y-2
Canada Fall 2J3K	✓	✓	✓	✓	✕
Canada Fall 3LNO	✓	✓	✓	✕	✕
EU 3M 0-1400m	✓	✓	✓	✓	✓
Canada Spring 3LNO	✓	✓	✕	✕	✕
EU-Spain 3NO	✓	✓	✕	✓	✓

Figures

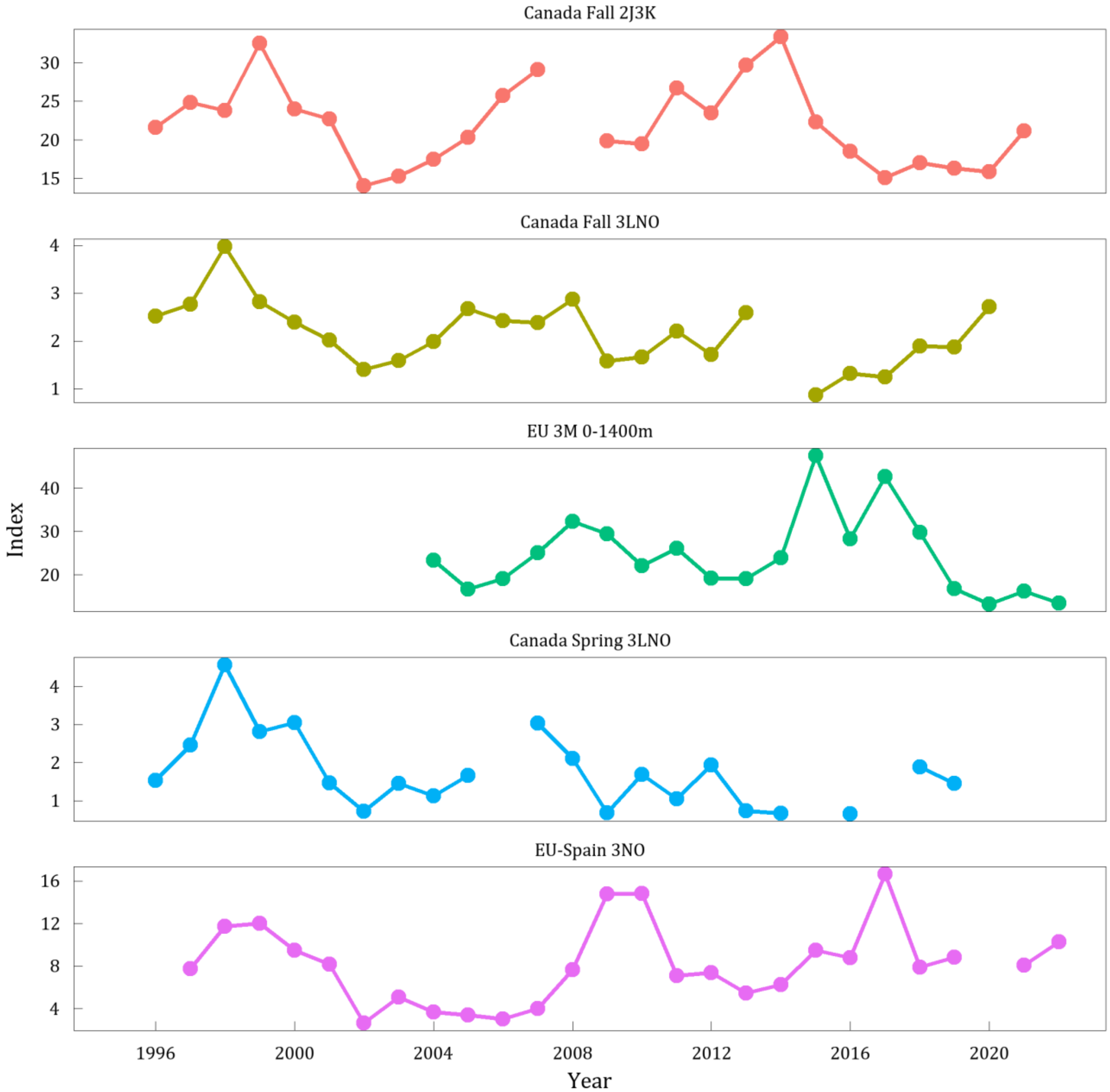

Figure 1. Greenland halibut annual survey indices utilized in the HCR.

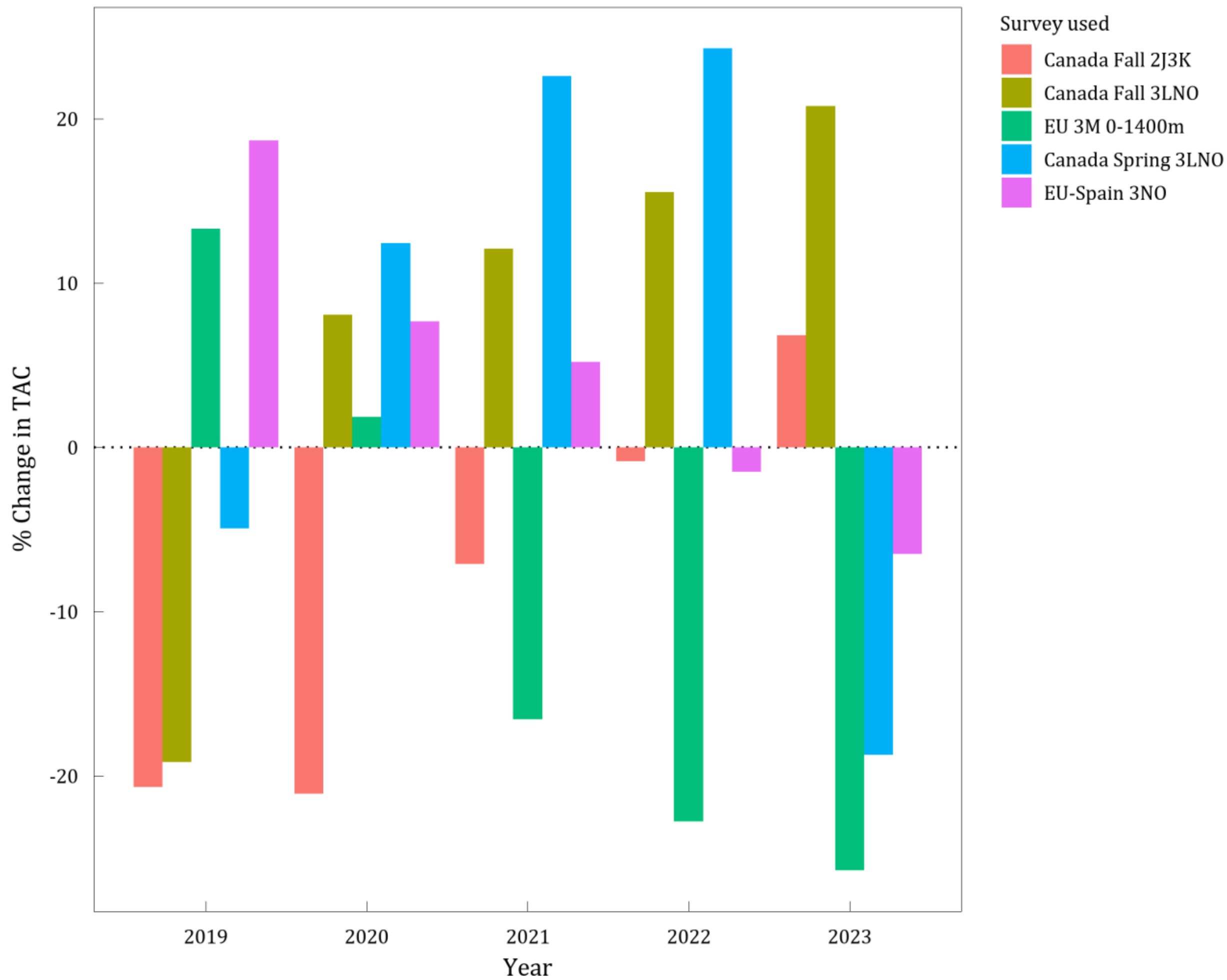

Figure 2. Percent change from the realized average TAC when computing the TAC using only one survey.

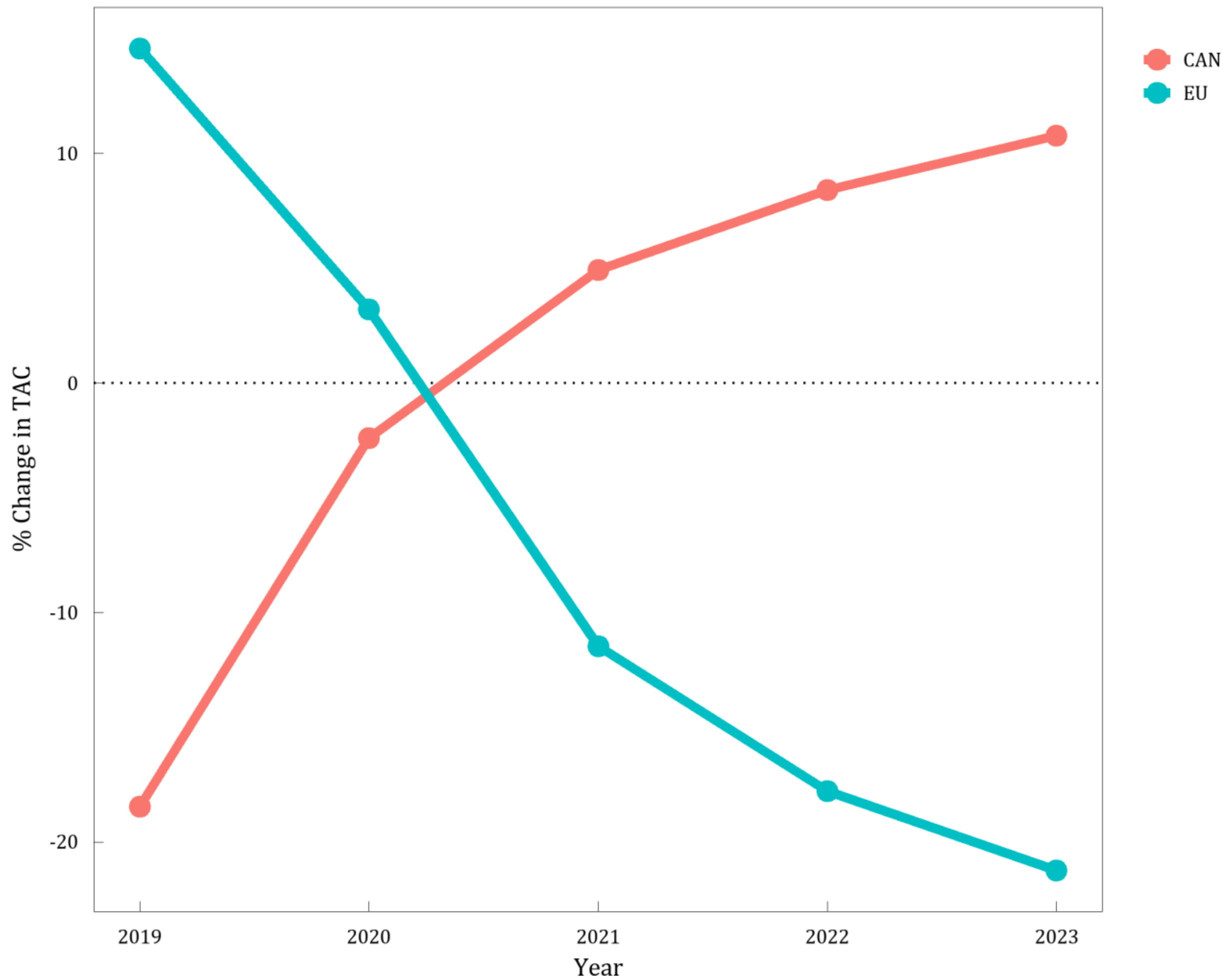

Figure 3. Percent change from the realized average TAC when computing the TAC using survey data the Canadian (Canada Fall 2J3K, Fall 3LNO, and Spring 3LNO; red) or EU surveys (EU 3M 0-1400m, and EU-Spain 3NO; blue).

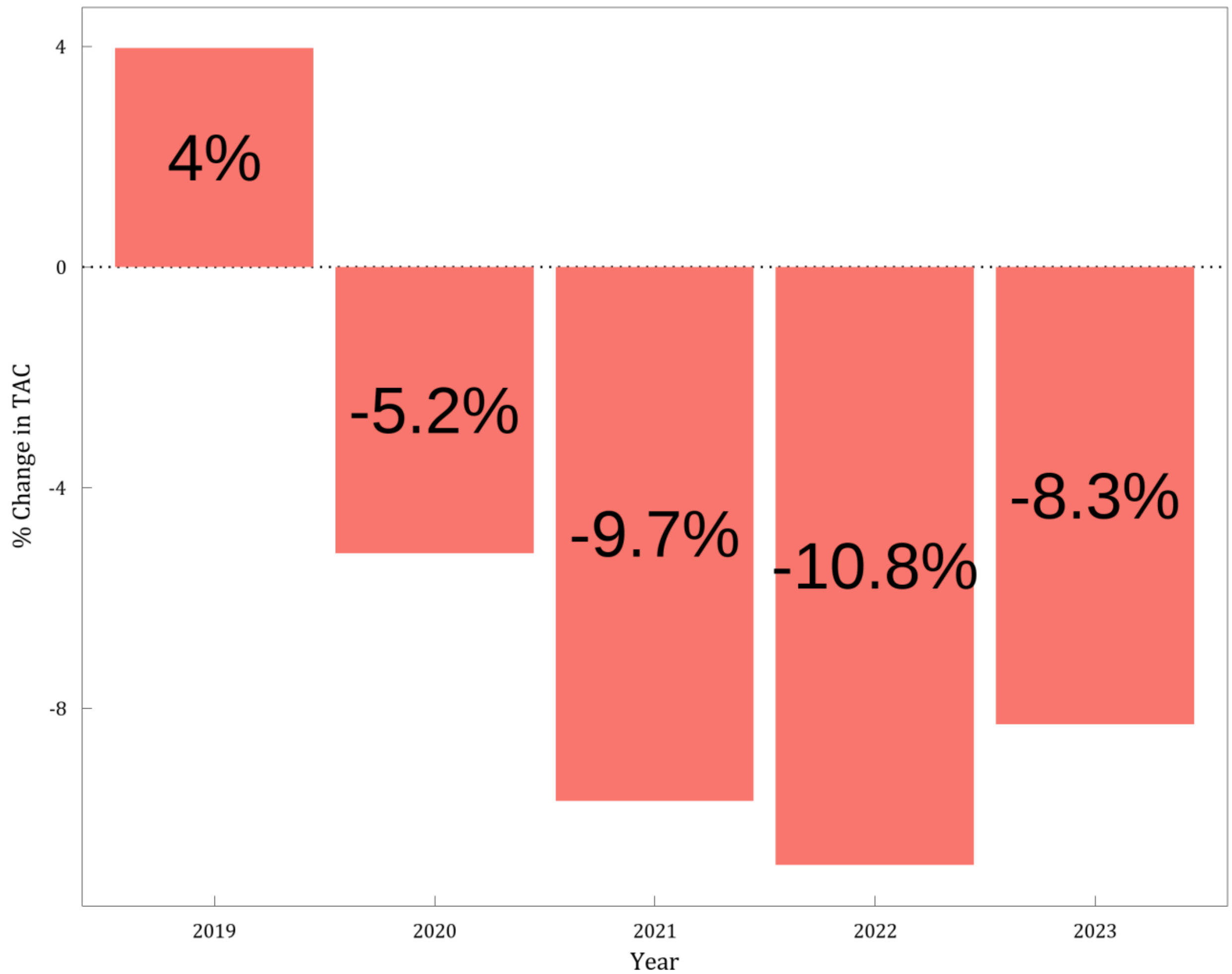

Figure 4. Percent change from the realized average TAC when computing the TAC without the Canadian Spring and Fall 3LNO survey indices for all years.

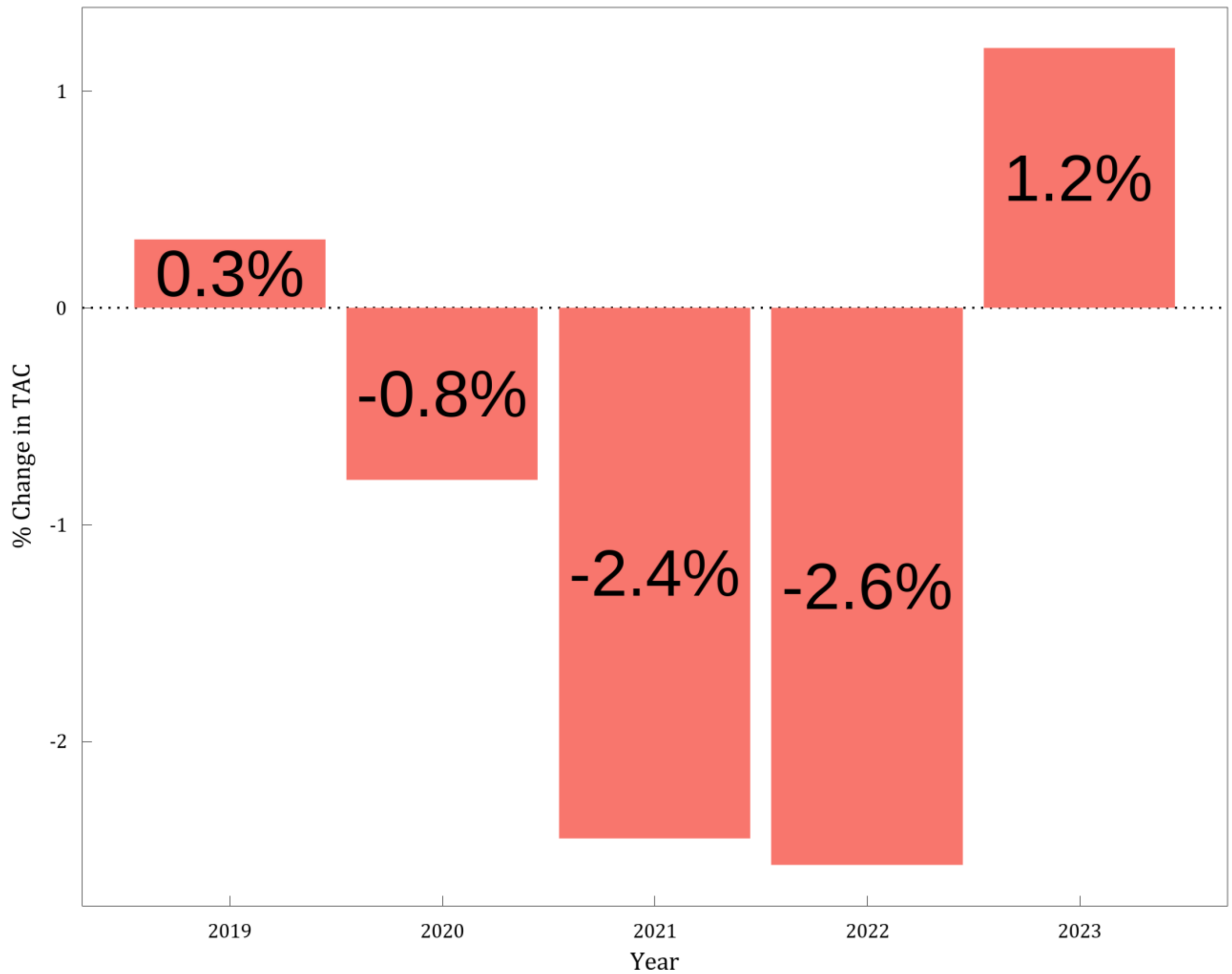

Figure 5. Percent change from the realized TAC when computing the TAC without the Canadian Spring 3LNO survey indices for all years.

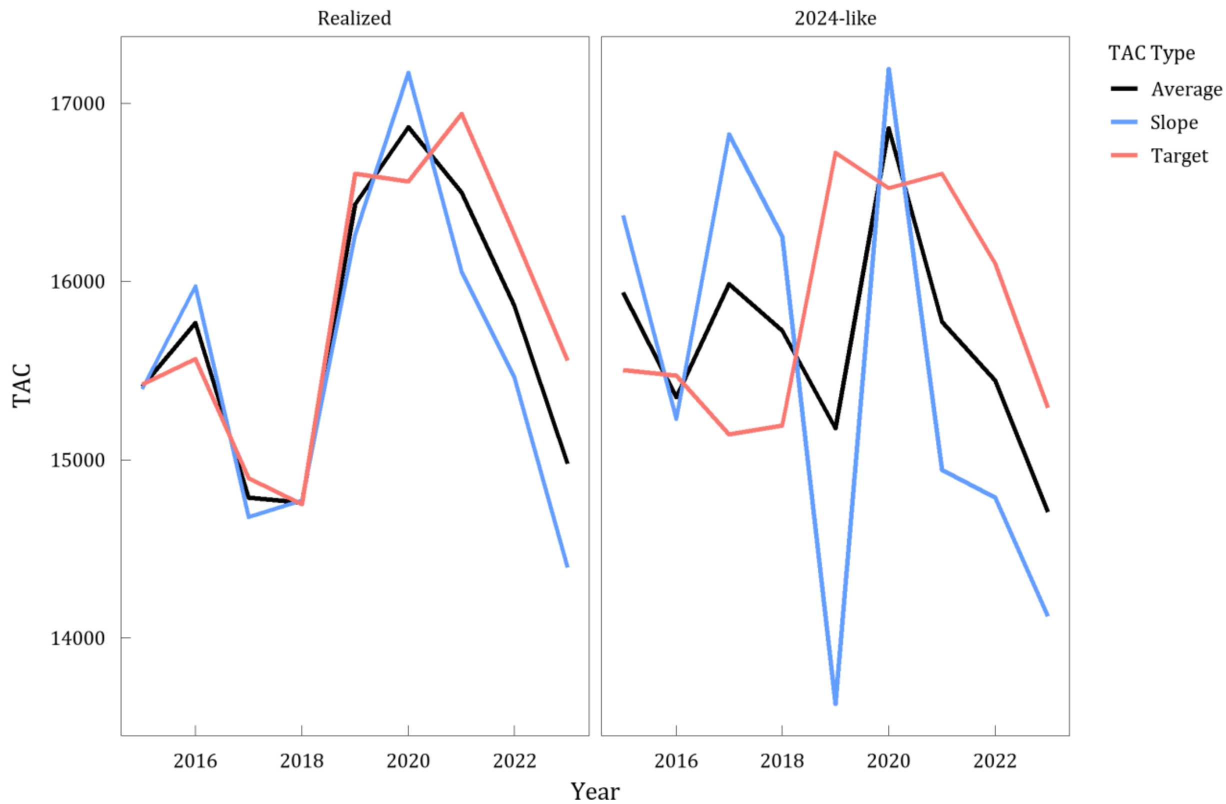

Figure 6. Realized TACs (left) and recalculated TACs using the missing survey pattern to be used for the 2024 TAC (right).

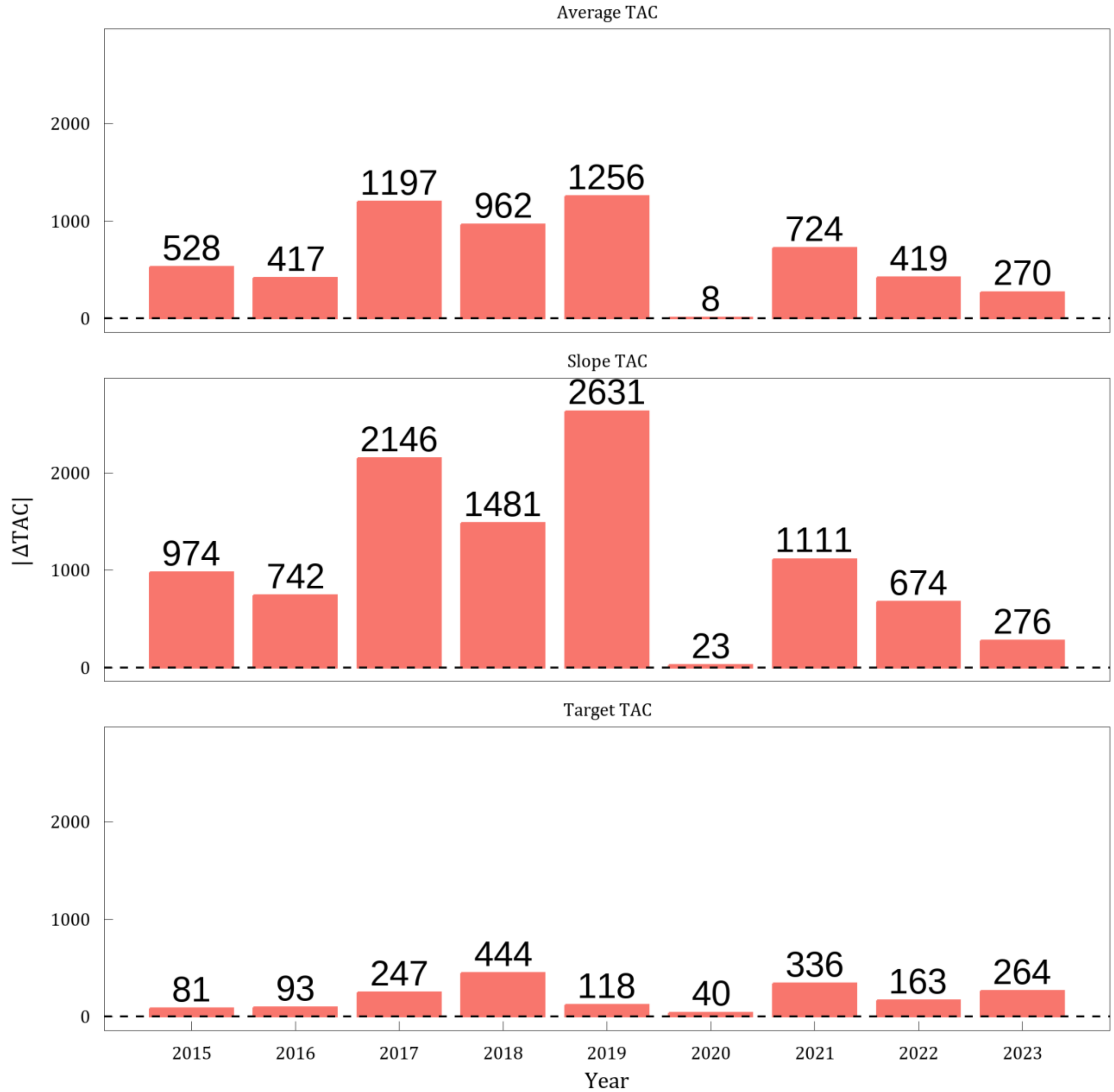

Figure 7. Absolute differences between the realized TACs and the 2024-like TACs for each HCR.

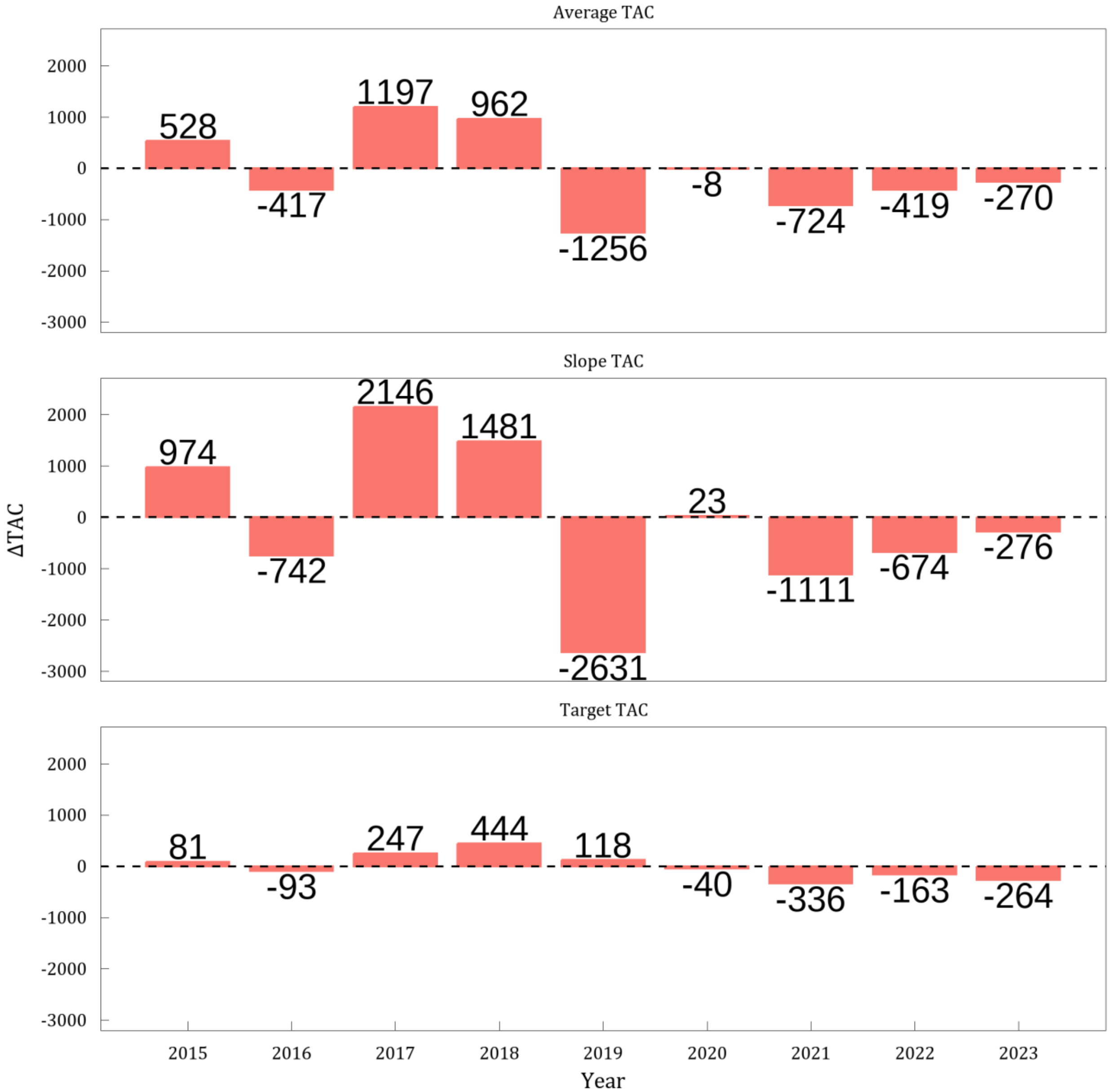

Figure 8. Exact differences between the realized TACs and the 2024-like TACs for each HCR.

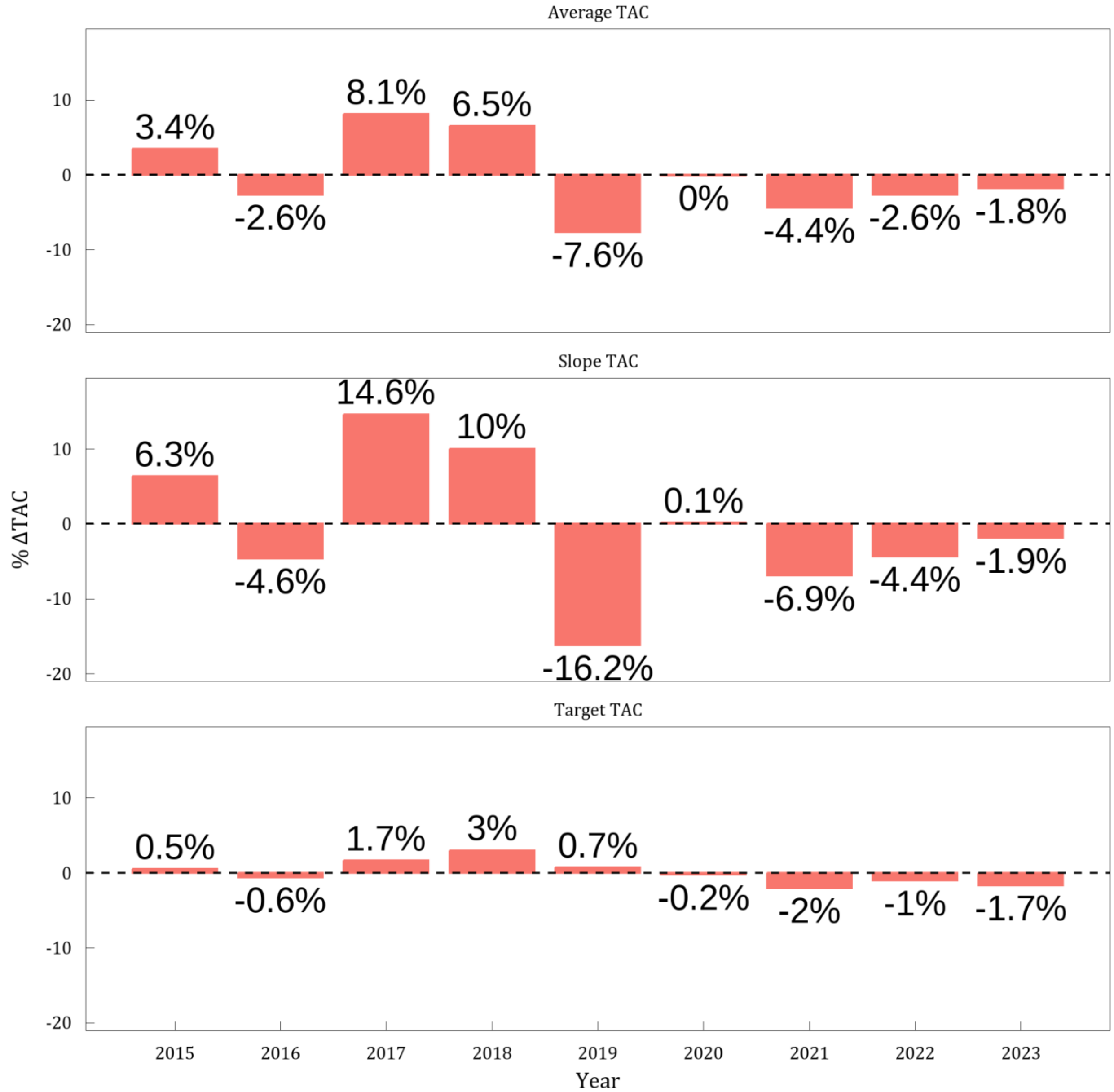

Figure 9. Relative (%) differences between the realized TACs and the 2024-like TACs for each HCR.

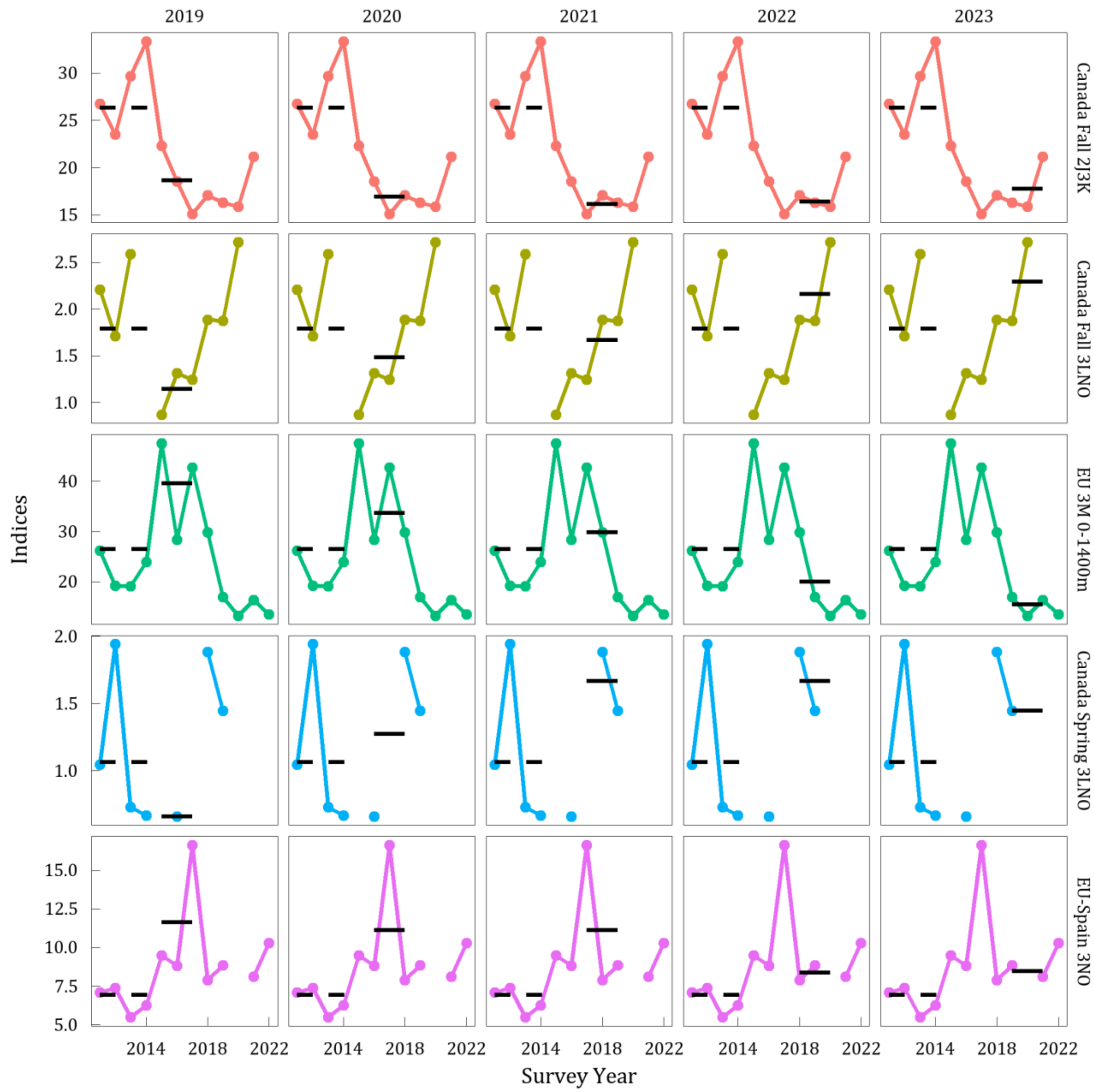

Figure 10. Values for $J_{current}$ (solid, black) and J_{target} (dashed, black) with respect to the survey indices from which they are calculated. Facet columns indicate for which year TAC is being calculated, where $J_{current}$ corresponds to the TAC for that year.

Appendix A

Table 3. Prior TAC recalculations from survey exclusions.

Year	TAC (t)	Canada Fall 2J3K?	EU 3M 0-1400m?	Canada Spring 3LNO?	EU-Spain 3NO?	Canada Fall 3LNO?
2019	13 037 (-20.7 %)	✗	✓	✓	✓	✓
2019	13 141 (-20 %)	✗	✓	✓	✓	✗
2019	13 285 (-19.2 %)	✓	✓	✓	✓	✗
2019	13 402 (-18.5 %)	✗	✓	✗	✓	✗
2019	13 471 (-18 %)	✗	✓	✗	✓	✓
2019	13 799 (-16 %)	✓	✓	✗	✓	✗
2019	14 535 (-11.6 %)	✗	✓	✓	✗	✗
2019	14 632 (-11 %)	✗	✓	✗	✗	✗
2019	15 205 (-7.5 %)	✗	✓	✓	✗	✓
2019	15 260 (-7.1 %)	✗	✓	✗	✗	✓
2019	15 623 (-4.9 %)	✓	✓	✗	✓	✓
2019	15 852 (-3.5 %)	✗	✗	✗	✓	✗
2019	15 868 (-3.4 %)	✗	✗	✓	✓	✗
2019	15 905 (-3.2 %)	✓	✓	✗	✗	✗
2019	15 959 (-2.9 %)	✓	✓	✓	✗	✗
2019	16 434 (0 %)	✗	✗	✗	✗	✗
2019	16 486 (0.3 %)	✗	✗	✓	✗	✗
2019	16 651 (1.3 %)	✗	✗	✗	✓	✓
2019	16 699 (1.6 %)	✗	✗	✓	✓	✓
2019	16 938 (3.1 %)	✓	✗	✗	✓	✗
2019	16 989 (3.4 %)	✗	✗	✗	✗	✓
2019	17 061 (3.8 %)	✓	✗	✓	✓	✗
2019	17 086 (4 %)	✗	✗	✓	✗	✓
2019	17 304 (5.3 %)	✓	✗	✗	✗	✗
2019	17 443 (6.1 %)	✓	✗	✓	✗	✗
2019	18 124 (10.3 %)	✓	✓	✗	✗	✓
2019	18 189 (10.7 %)	✓	✗	✗	✓	✓
2019	18 459 (12.3 %)	✓	✗	✗	✗	✓
2019	18 623 (13.3 %)	✓	✗	✓	✓	✓

Year	TAC (t)	Canada Fall 2J3K?	EU 3M 0-1400m?	Canada Spring 3LNO?	EU-Spain 3NO?	Canada Fall 3LNO?
2019	18 829 (14.6 %)	✓	✗	✓	✗	✓
2019	19 506 (18.7 %)	✓	✓	✓	✗	✓
2020	13 312 (-21.1 %)	✗	✓	✓	✓	✓
2020	14 628 (-13.3 %)	✗	✓	✗	✓	✓
2020	14 754 (-12.5 %)	✗	✓	✓	✗	✓
2020	15 502 (-8.1 %)	✗	✗	✓	✓	✓
2020	15 594 (-7.5 %)	✗	✓	✗	✗	✓
2020	15 992 (-5.2 %)	✗	✗	✓	✗	✓
2020	15 998 (-5.1 %)	✗	✗	✗	✓	✓
2020	16 166 (-4.2 %)	✗	✓	✓	✓	✗
2020	16 387 (-2.8 %)	✗	✗	✗	✗	✓
2020	16 463 (-2.4 %)	✗	✓	✗	✓	✗
2020	16 495 (-2.2 %)	✗	✓	✓	✗	✗
2020	16 563 (-1.8 %)	✗	✗	✓	✓	✗
2020	16 715 (-0.9 %)	✗	✓	✗	✗	✗
2020	16 723 (-0.9 %)	✗	✗	✗	✓	✗
2020	16 733 (-0.8 %)	✗	✗	✓	✗	✗
2020	16 867 (0 %)	✗	✗	✗	✗	✗
2020	17 178 (1.8 %)	✓	✗	✓	✓	✓
2020	17 408 (3.2 %)	✓	✗	✓	✗	✓
2020	17 454 (3.5 %)	✓	✗	✗	✓	✓
2020	17 593 (4.3 %)	✓	✗	✓	✓	✗
2020	17 599 (4.3 %)	✓	✗	✗	✗	✓
2020	17 681 (4.8 %)	✓	✗	✓	✗	✗
2020	17 730 (5.1 %)	✓	✗	✗	✓	✗
2020	17 791 (5.5 %)	✓	✗	✗	✗	✗
2020	18 161 (7.7 %)	✓	✓	✓	✗	✓
2020	18 207 (7.9 %)	✓	✓	✓	✗	✗
2020	18 229 (8.1 %)	✓	✓	✓	✓	✗
2020	18 329 (8.7 %)	✓	✓	✗	✗	✗
2020	18 390 (9 %)	✓	✓	✗	✓	✗
2020	18 461 (9.5 %)	✓	✓	✗	✗	✓

Year	TAC (t)	Canada Fall 2J3K?	EU 3M 0-1400m?	Canada Spring 3LNO?	EU-Spain 3NO?	Canada Fall 3LNO?
2020	18 961 (12.4 %)	✓	✓	✗	✓	✓
2021	13 768 (-16.5 %)	✓	✗	✓	✓	✓
2021	14 511 (-12 %)	✗	✗	✓	✓	✓
2021	14 607 (-11.5 %)	✓	✗	✓	✗	✓
2021	14 902 (-9.7 %)	✗	✗	✓	✗	✓
2021	15 171 (-8 %)	✓	✗	✗	✓	✓
2021	15 238 (-7.6 %)	✗	✗	✗	✓	✓
2021	15 325 (-7.1 %)	✗	✓	✓	✓	✓
2021	15 507 (-6 %)	✗	✗	✗	✗	✓
2021	15 619 (-5.3 %)	✓	✗	✗	✗	✓
2021	15 835 (-4 %)	✗	✓	✓	✗	✓
2021	15 944 (-3.4 %)	✗	✗	✓	✓	✗
2021	16 094 (-2.4 %)	✗	✗	✓	✗	✗
2021	16 285 (-1.3 %)	✓	✗	✓	✓	✗
2021	16 403 (-0.6 %)	✗	✗	✗	✓	✗
2021	16 452 (-0.3 %)	✓	✗	✓	✗	✗
2021	16 498 (0 %)	✗	✗	✗	✗	✗
2021	16 581 (0.5 %)	✗	✓	✗	✓	✓
2021	16 750 (1.5 %)	✗	✓	✗	✗	✓
2021	16 938 (2.7 %)	✓	✗	✗	✓	✗
2021	16 969 (2.9 %)	✗	✓	✓	✓	✗
2021	16 997 (3 %)	✓	✗	✗	✗	✗
2021	17 059 (3.4 %)	✗	✓	✓	✗	✗
2021	17 311 (4.9 %)	✗	✓	✗	✓	✗
2021	17 343 (5.1 %)	✗	✓	✗	✗	✗
2021	17 354 (5.2 %)	✓	✓	✓	✗	✓
2021	18 182 (10.2 %)	✓	✓	✓	✗	✗
2021	18 490 (12.1 %)	✓	✓	✓	✓	✗
2021	18 511 (12.2 %)	✓	✓	✗	✗	✗
2021	18 538 (12.4 %)	✓	✓	✗	✗	✓
2021	18 871 (14.4 %)	✓	✓	✗	✓	✗
2021	20 226 (22.6 %)	✓	✓	✗	✓	✓

Year	TAC (t)	Canada Fall 2J3K?	EU 3M 0-1400m?	Canada Spring 3LNO?	EU-Spain 3NO?	Canada Fall 3LNO?
2022	12 251 (-22.8 %)	✓	✗	✓	✓	✓
2022	13 041 (-17.8 %)	✓	✗	✓	✗	✓
2022	13 800 (-13 %)	✓	✗	✗	✓	✓
2022	13 908 (-12.3 %)	✗	✗	✓	✓	✓
2022	14 145 (-10.8 %)	✗	✗	✓	✗	✓
2022	14 175 (-10.6 %)	✓	✗	✗	✗	✓
2022	14 638 (-7.7 %)	✗	✗	✗	✓	✓
2022	14 764 (-6.9 %)	✗	✗	✗	✗	✓
2022	15 274 (-3.7 %)	✓	✗	✓	✓	✗
2022	15 329 (-3.4 %)	✓	✗	✓	✗	✗
2022	15 435 (-2.7 %)	✗	✗	✓	✓	✗
2022	15 456 (-2.6 %)	✗	✗	✓	✗	✗
2022	15 627 (-1.5 %)	✓	✓	✓	✗	✓
2022	15 702 (-1 %)	✗	✓	✓	✗	✓
2022	15 728 (-0.9 %)	✗	✓	✓	✓	✓
2022	15 864 (0 %)	✗	✗	✗	✗	✗
2022	15 890 (0.2 %)	✗	✗	✗	✓	✗
2022	15 922 (0.4 %)	✓	✗	✗	✗	✗
2022	15 971 (0.7 %)	✓	✗	✗	✓	✗
2022	16 450 (3.7 %)	✗	✓	✗	✗	✓
2022	16 523 (4.2 %)	✗	✓	✗	✓	✓
2022	16 785 (5.8 %)	✗	✓	✓	✗	✗
2022	16 902 (6.5 %)	✗	✓	✓	✓	✗
2022	17 047 (7.5 %)	✗	✓	✗	✗	✗
2022	17 197 (8.4 %)	✗	✓	✗	✓	✗
2022	17 513 (10.4 %)	✓	✓	✗	✗	✓
2022	17 647 (11.2 %)	✓	✓	✓	✗	✗
2022	17 980 (13.3 %)	✓	✓	✗	✗	✗
2022	18 330 (15.5 %)	✓	✓	✓	✓	✗
2022	18 634 (17.5 %)	✓	✓	✗	✓	✗
2022	19 715 (24.3 %)	✓	✓	✗	✓	✓
2023	11 121 (-25.7 %)	✓	✗	✓	✓	✓

Year	TAC (t)	Canada Fall 2J3K?	EU 3M 0-1400m?	Canada Spring 3LNO?	EU-Spain 3NO?	Canada Fall 3LNO?
2023	11 284 (-24.7 %)	✓	✗	✗	✓	✓
2023	11 796 (-21.2 %)	✓	✗	✓	✗	✓
2023	11 842 (-20.9 %)	✓	✗	✗	✗	✓
2023	12 175 (-18.7 %)	✓	✓	✗	✓	✓
2023	13 318 (-11.1 %)	✓	✓	✗	✗	✓
2023	13 560 (-9.5 %)	✗	✗	✗	✓	✓
2023	13 617 (-9.1 %)	✗	✗	✗	✗	✓
2023	13 693 (-8.6 %)	✗	✗	✓	✓	✓
2023	13 736 (-8.3 %)	✗	✗	✓	✗	✓
2023	14 005 (-6.5 %)	✓	✓	✓	✗	✓
2023	14 321 (-4.4 %)	✓	✗	✗	✗	✗
2023	14 374 (-4 %)	✓	✗	✗	✓	✗
2023	14 523 (-3 %)	✓	✗	✓	✗	✗
2023	14 618 (-2.4 %)	✓	✗	✓	✓	✗
2023	14 977 (0 %)	✗	✗	✗	✗	✗
2023	15 085 (0.7 %)	✗	✗	✗	✓	✗
2023	15 156 (1.2 %)	✗	✗	✓	✗	✗
2023	15 293 (2.1 %)	✗	✗	✓	✓	✗
2023	15 399 (2.8 %)	✗	✓	✗	✗	✓
2023	15 700 (4.8 %)	✗	✓	✗	✓	✓
2023	15 763 (5.2 %)	✗	✓	✓	✗	✓
2023	15 996 (6.8 %)	✗	✓	✓	✓	✓
2023	16 365 (9.3 %)	✗	✓	✗	✗	✗
2023	16 574 (10.7 %)	✗	✓	✓	✗	✗
2023	16 592 (10.8 %)	✗	✓	✗	✓	✗
2023	16 659 (11.2 %)	✓	✓	✗	✗	✗
2023	16 869 (12.6 %)	✗	✓	✓	✓	✗
2023	17 124 (14.3 %)	✓	✓	✓	✗	✗
2023	17 241 (15.1 %)	✓	✓	✗	✓	✗
2023	18 088 (20.8 %)	✓	✓	✓	✓	✗

```
#> caption [antonum off]: abc
```

Colophon

This version of the document was generated on 2023-06-03 08:05:57 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 4.2.2 (2022-10-31 ucrt)
#>  os       Windows 10 x64 (build 19044)
#>  system   x86_64, mingw32
#>  ui       RTerm
#>  language (EN)
#>  collate  English_United States.utf8
#>  ctype    English_United States.utf8
#>  tz       America/St_Johns
#>  date     2023-06-03
#>  pandoc   2.19.2 @ C:/Program Files/RStudio/resources/app/bin/quart
o/bin/tools/ (via rmarkdown)
#>
#> ─ Packages ───────────────────────────────────────────────────────────
───────────
#>  package           * version    date (UTC) lib source
#>  askpass             1.1        2019-01-13 [1] CRAN (R 4.2.2)
#>  backports           1.4.1      2021-12-13 [1] CRAN (R 4.2.0)
#>  bookdown            0.33       2023-03-06 [1] CRAN (R 4.2.2)
#>  broom               1.0.4      2023-03-11 [1] CRAN (R 4.2.3)
#>  cachem              1.0.7      2023-02-24 [1] CRAN (R 4.2.2)
#>  callr               3.7.3      2022-11-02 [1] CRAN (R 4.2.2)
#>  cli                 3.6.0      2023-01-09 [1] CRAN (R 4.2.2)
#>  colorspace          2.1-0      2023-01-23 [1] CRAN (R 4.2.2)
#>  crayon              1.5.2      2022-09-29 [1] CRAN (R 4.2.2)
#>  crul                1.3        2022-09-03 [1] CRAN (R 4.2.2)
#>  curl                5.0.0      2023-01-12 [1] CRAN (R 4.2.2)
#>  data.table          1.14.8     2023-02-17 [1] CRAN (R 4.2.2)
#>  devtools            2.4.5      2022-10-11 [1] CRAN (R 4.2.2)
#>  digest              0.6.31     2022-12-11 [1] CRAN (R 4.2.2)
#>  dplyr             * 1.1.1      2023-03-22 [1] CRAN (R 4.2.3)
#>  ellipsis            0.3.2      2021-04-29 [1] CRAN (R 4.2.2)
#>  equatags            0.2.0      2022-06-13 [1] CRAN (R 4.2.3)
#>  evaluate            0.20       2023-01-17 [1] CRAN (R 4.2.2)
#>  fansi               1.0.4      2023-01-22 [1] CRAN (R 4.2.2)
#>  farver              2.1.1      2022-07-06 [1] CRAN (R 4.2.2)
#>  fastmap             1.1.1      2023-02-24 [1] CRAN (R 4.2.2)
#>  flextable         * 0.9.1      2023-04-02 [1] CRAN (R 4.2.3)
#>  fontBitstreamVera   0.1.1      2017-02-01 [1] CRAN (R 4.2.0)
#>  fontLiberation      0.1.0      2016-10-15 [1] CRAN (R 4.2.0)
#>  fontquiver          0.2.1      2017-02-01 [1] CRAN (R 4.2.2)
#>  fs                  1.6.1      2023-02-06 [1] CRAN (R 4.2.2)
#>  gdtools             0.3.3      2023-03-27 [1] CRAN (R 4.2.3)
```

```
#>  generics             0.1.3      2022-07-05 [1] CRAN (R 4.2.2)
#>  gfonts               0.2.0      2023-01-08 [1] CRAN (R 4.2.2)
#>  ggplot2            * 3.4.2      2023-04-03 [1] CRAN (R 4.2.2)
#>  ggridges             0.5.4      2022-09-26 [1] CRAN (R 4.2.2)
#>  ggthemes             4.2.4      2021-01-20 [1] CRAN (R 4.2.2)
#>  ghalAssess         * 0.0.1.9000 2023-06-02 [1] local
#>  glue                 1.6.2      2022-02-24 [1] CRAN (R 4.2.2)
#>  gtable               0.3.3      2023-03-21 [1] CRAN (R 4.2.3)
#>  here               * 1.0.1      2020-12-13 [1] CRAN (R 4.2.2)
#>  highr                0.10       2022-12-22 [1] CRAN (R 4.2.2)
#>  htmltools            0.5.5      2023-03-23 [1] CRAN (R 4.2.3)
#>  htmlwidgets          1.6.2      2023-03-17 [1] CRAN (R 4.2.3)
#>  httpcode             0.3.0      2020-04-10 [1] CRAN (R 4.2.2)
#>  httpuv               1.6.9      2023-02-14 [1] CRAN (R 4.2.2)
#>  jsonlite             1.8.4      2022-12-06 [1] CRAN (R 4.2.2)
#>  katex                1.4.1      2022-11-28 [1] CRAN (R 4.2.3)
#>  knitr                1.42       2023-01-25 [1] CRAN (R 4.2.2)
#>  labeling             0.4.2      2020-10-20 [1] CRAN (R 4.2.0)
#>  later                1.3.0      2021-08-18 [1] CRAN (R 4.2.2)
#>  lattice              0.20-45    2021-09-22 [2] CRAN (R 4.2.2)
#>  lifecycle            1.0.3      2022-10-07 [1] CRAN (R 4.2.2)
#>  magrittr             2.0.3      2022-03-30 [1] CRAN (R 4.2.2)
#>  Matrix               1.5-4      2023-04-04 [1] CRAN (R 4.2.2)
#>  memoise              2.0.1      2021-11-26 [1] CRAN (R 4.2.2)
#>  mime                 0.12       2021-09-28 [1] CRAN (R 4.2.0)
#>  miniUI               0.1.1.1    2018-05-18 [1] CRAN (R 4.2.2)
#>  munsell              0.5.0      2018-06-12 [1] CRAN (R 4.2.2)
#>  NAFOdown           * 0.0.1.9000 2023-05-30 [1] local
#>  officer            * 0.6.2      2023-03-28 [1] CRAN (R 4.2.3)
#>  openssl              2.0.6      2023-03-09 [1] CRAN (R 4.2.3)
#>  pillar               1.9.0      2023-03-22 [1] CRAN (R 4.2.3)
#>  pkgbuild             1.4.0      2022-11-27 [1] CRAN (R 4.2.2)
#>  pkgconfig            2.0.3      2019-09-22 [1] CRAN (R 4.2.2)
#>  pkgload              1.3.2      2022-11-16 [1] CRAN (R 4.2.2)
#>  prettyunits          1.1.1      2020-01-24 [1] CRAN (R 4.2.2)
#>  processx             3.8.0      2022-10-26 [1] CRAN (R 4.2.2)
#>  profvis              0.3.7      2020-11-02 [1] CRAN (R 4.2.2)
#>  promises             1.2.0.1    2021-02-11 [1] CRAN (R 4.2.2)
#>  ps                   1.7.4      2023-04-02 [1] CRAN (R 4.2.2)
#>  purrr                1.0.1      2023-01-10 [1] CRAN (R 4.2.2)
#>  R6                   2.5.1      2021-08-19 [1] CRAN (R 4.2.2)
#>  ragg                 1.2.5      2023-01-12 [1] CRAN (R 4.2.2)
#>  Rcpp                 1.0.10     2023-01-22 [1] CRAN (R 4.2.2)
#>  RcppEigen          * 0.3.3.9.3  2022-11-05 [1] CRAN (R 4.2.2)
#>  remotes              2.4.2      2021-11-30 [1] CRAN (R 4.2.2)
#>  rlang                1.1.0      2023-03-14 [1] CRAN (R 4.2.3)
#>  rmarkdown            2.21       2023-03-26 [1] CRAN (R 4.2.3)
#>  rprojroot            2.0.3      2022-04-02 [1] CRAN (R 4.2.2)
#>  rstudioapi           0.14       2022-08-22 [1] CRAN (R 4.2.2)
#>  scales               1.2.1      2022-08-20 [1] CRAN (R 4.2.2)
#>  sessioninfo          1.2.2      2021-12-06 [1] CRAN (R 4.2.2)
#>  shiny                1.7.4      2022-12-15 [1] CRAN (R 4.2.2)
```

```
#>  showtext            0.9-5      2022-02-09 [1] CRAN (R 4.2.2)
#>  showtextdb          3.0        2020-06-04 [1] CRAN (R 4.2.2)
#>  stringi             1.7.12     2023-01-11 [1] CRAN (R 4.2.2)
#>  stringr             1.5.0      2022-12-02 [1] CRAN (R 4.2.2)
#>  sysfonts            0.8.8      2022-03-13 [1] CRAN (R 4.2.2)
#>  systemfonts         1.0.4      2022-02-11 [1] CRAN (R 4.2.2)
#>  textshaping         0.3.6      2021-10-13 [1] CRAN (R 4.2.2)
#>  tibble            * 3.2.1      2023-03-20 [1] CRAN (R 4.2.3)
#>  tidyr             * 1.3.0      2023-01-24 [1] CRAN (R 4.2.2)
#>  tidyselect          1.2.0      2022-10-10 [1] CRAN (R 4.2.2)
#>  TMB               * 1.9.4      2023-04-18 [1] CRAN (R 4.2.2)
#>  urlchecker          1.0.1      2021-11-30 [1] CRAN (R 4.2.2)
#>  usethis             2.1.6      2022-05-25 [1] CRAN (R 4.2.2)
#>  utf8                1.2.3      2023-01-31 [1] CRAN (R 4.2.2)
#>  uuid                1.1-0      2022-04-19 [1] CRAN (R 4.2.0)
#>  V8                  4.3.0      2023-04-08 [1] CRAN (R 4.2.3)
#>  vctrs               0.6.1      2023-03-22 [1] CRAN (R 4.2.3)
#>  withr               2.5.0      2022-03-03 [1] CRAN (R 4.2.2)
#>  xfun                0.38       2023-03-24 [1] CRAN (R 4.2.3)
#>  xml2                1.3.3      2021-11-30 [1] CRAN (R 4.2.2)
#>  xslt                1.4.4      2023-02-21 [1] CRAN (R 4.2.3)
#>  xtable              1.8-4      2019-04-21 [1] CRAN (R 4.2.2)
#>  yaml                2.3.7      2023-01-23 [1] CRAN (R 4.2.2)
#>  zip                 2.2.2      2022-10-26 [1] CRAN (R 4.2.2)
#>
#>  [1] C:/Users/RegularP/AppData/Local/R/win-library/4.2
#>  [2] C:/Program Files/R/R-4.2.2/library
#>
#> ────────────────────────────────────────────────────────────────────
───────────
```