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# In-season forecast for Atlantic salmon (*Salmo salar* L.) returning to Campbellton River in 1998

by

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## ABSTRACT

This document summarizes techniques used for in-season forecasts of Atlantic salmon returning to Campbellton River in 1998. Three techniques were examined: proportional, simple regression and regression with environmental correction. Data is limited to six years, 1993-98, of complete adult counts at a counting fence. The low degrees of freedom may have contributed to the high correlations. Regression with environmental correction gave the most accurate forecasts with a standard error of less than 10% of the forecasted value. While thermal habitat was used as an environmental variable in the regression model to good effect, there are other climate data that could also be used.

## RÉSUMÉ

Ce document résume les techniques utilisées pour les prévisions, en cours de saison, des remontes de saumon de l'Atlantique dans la rivière Campbellton en 1998. Trois techniques ont été examinées : proportionnelle, régression simple et régression avec correction environnementale. Les données sont limitées à six années, 1993-1998, de dénombrements complets d'adultes à une barrière de dénombrement. Les faibles degrés de liberté peuvent avoir contribué au niveau élevé de corrélation. La régression avec correction environnementale a donné les prévisions les plus exactes avec une marge d'erreur normale de moins de 10 % de la valeur prévue. Bien que la température de l'habitat ait été utilisée avec succès comme variable environnementale dans le modèle de régression, d'autres données climatiques pourraient être utilisées également.

## INTRODUCTION

In-season forecasts of Atlantic salmon returns to individual rivers have been provided to fisheries managers in Newfoundland since 1990. In-season forecasts are typically based on cumulative counts to a specific date to a counting facility adjusted in some way to predict or forecast the total count at the end of the season. There are several techniques for in-season forecasts, one of the simplest is to divide the current-year count by the proportion to the same date from other years or an average of data for other years. Another method is to generate in-season forecasts from regressions of counts to date versus total count to the end of the year (Dempson et al. 1998; Harvie & Amiro 1998). Other variables, such as those influencing run timing, can also be included in this approach as shown by Harvie & Amiro for climate data (1998). In-season forecasts are used by fisheries managers to make in-season adjustments to fishing plans in order to achieve management objectives based on maintaining some level of spawning escapement for conservation purposes. At the assessment meetings in 1998, it was decided to review the techniques used as well as their accuracy and precision in order to standardize and improve them. The purpose of this paper is to review methodology used to provide in-season forecasts and estimates of returns to the counting fence at Campbellton River.

## METHODS

Two techniques of forecasting in-season salmon returns are examined for Campbellton River salmon. The first technique, labelled the proportional technique, forecasts returns in a given year from the proportional distribution of returns in an average series of years applied to the current year count to the same date. The second technique examines regressions of count to date on end of season count to provide an in-season forecast of returns. Environmental parameters are examined for their potential in improving accuracy of the forecasts by inclusion in the regression technique. Data from 1998 are used as an example of how the techniques might be applied in a specific year.

### Sources of data

A counting fence for upstream migrating salmon has been operated every year since 1993 on Campbellton River (Downton & Reddin 1998). The counting fence and counting procedures carried out with an underwater video camera have been fully described in Downton & Reddin (1998). Since there have been no washouts or other problems that would result in incomplete counts and because there are no legal removals in the short distance from the counting fence to the sea, the counts described herein are considered an accurate measure of the total number of salmon entering Campbellton River exclusive of poaching. The daily count data was summed into standard weeks with the first week being that week which ends on June 7. This week was chosen so that forecasted returns would be as complete as possible for managers at the first of each week and would change annually.

In-season forecasts

In-season forecasts of small salmon returns to Campbellton River were generated from regressions of counts to date versus total count for the year, following an approach by Dempson et al. (1998). The count less an expectation of angling catches or other removals is then an estimate of spawning escapement which can be compared with the desired conservation requirements for the river or some other management goal. In total, five years of data (1993-97) were available. In-season dates chosen were the standard dates described above. In order for an in-season forecast to be useful to managers, the forecast must be provided in a timely fashion so that fisheries can be adjusted either upward or downward depending on the circumstances. The further into the season before making an in-season forecast the less useful any management action becomes because a higher proportion of removals by angling will have already taken place.

A retrospective analysis examining the predicted value versus the actual one was used to determine the accuracy of the forecasts. The 1998 data were not included directly in the regression analysis so as to provide an example of how the method works in the current year.

Environmental parameters

The accuracy and precision of any in-season forecast degrades due to variability in annual run timing. Variability in run timing is thought to be mainly under environmental control (Narayanan et al. 1995; Harvie & Amiro 1998). If run timing could be accurately predicted then more accurate forecasts could be made and then fisheries adjusted accordingly. Several authors have demonstrated that water temperature, presence of ice and amount can delay entry of salmon into freshwater (Reddin & Shearer 1987; Narayanan et al. 1995). Several environmental parameters have been examined for their usefulness in determining whether runs were going to be early or late (Drinkwater et al. 1998). One such parameter is thermal habitat, a measure of ocean suitability for salmon growth and survival in the northwest Atlantic (Reddin & Friedland 1993). The thermal habitat data used was the sum of monthly values for April and May. In order for the resulting forecast to be useful to fish management, I assumed that the chosen regression model must provide a forecast of end of season count at the earliest possible date while maintaining a standard error (bias) of the estimate of, at most, one-tenth of the 1993-98 average end of season count of small salmon (Harvie & Amiro 1998). For this analysis, the entire dataset including 1998 was used in the regressions. Even so there is only six years of data for model building and testing which may lead to overspecification of model parameters and artificially high coefficient of determinations.

## RESULTS

The daily run timing of small salmon to Campbellton River varies considerably from year to year as shown by the daily counts at the counting fence (Table 1 and Fig. 1). Variability in run timing is shown with up to an 11 day difference in the 25$^{th}$ percentile and a 12 day difference in the 75th percentile of small salmon returns to the counting fence (Fig. 2a). Median dates were later in 1994 and 1997 than in 1996 and 1998 which was the earliest on record. The length of the season also varies from year to year as shown by the magnitude of the difference between the 25th and 75th percentiles or the 10th and 90th percentiles. The 1997 run was the longest on record while the 1998 run was one of the shortest.

Smolt run timing is also variable with most of the variation occurring in the last three years (Fig. 2b). Variability of the smolt run is apparent with up to a 15 day difference in the 25th percentile and a 14 day difference in the 75th percentile. Median dates were later in 1997 and earliest in 1996 and 1998. The length of the run also varies from year to year as shown by the magnitude of the difference between the 25th and 75th and 10th and 90th percentiles. The 1996 run was the longest on record while the 1997 run was the shortest.

Survival data from smolt to adult is also available for Campbellton River salmon as both smolts and adult returning salmon are counted (Downton & Reddin 1998). Examination of the relationship between survival and adult run timing and smolt and adult run timing indicated that neither were significantly correlated at the 5% level of significance. For survival and adult run timing the correlation coefficient(Spearman r) was 0.39 with degrees of freedom (df) of 3 and for smolt and adult run timing the correlation coefficient (Spearman) was 0.79 with df of 4. This is a very short time series and it would be inappropriate to be overly conclusive as these results may change as a longer time series becomes available.

Figure 3 illustrates the sequential regressions of in-season counts to various dates with the corresponding total run for the year beginning with June 7 (week 1) and progressing to July 26 (week 8). The first week with a reasonable relationship between total count and in-season count is week 5 with an $R^2$ of 0.55 at which time 57% (range of 31% in 1994 and 72% in 1996) of the small salmon on average had entered the system. The next week which is week 6 (July 6-12) has a much improved $R^2$ of 0.90 which increases to 0.93 in week 7 and 0.99 in week 8. Therefore, it would appear possible to provide a fairly accurate in-season forecast for Campbellton River adult returns by July 5. Since about 60% of the run had entered the river by July 5 leaves enough time for fisheries managers to make changes to fishing plans if warranted.

Residuals from the sequential regressions indicate a trend to increasing negative residuals in the last few years for weeks 4, 5 and 6 (Fig. 4). For 1998, the forecast is about 1,250 fish higher in week 4 and almost 1,000 fish higher in week 5 than the actual values. The residual pattern also declines with time for week 6 but with lower residuals in recent years. For 1998, the forecast is about 150 fish higher than the actual value. For weeks 6 and 7, the residual pattern is erratic from year to year with no trend. For 1998, forecasts for week 7 are only 200 fish too high and about 70 in week 8.

If expressed as a percentage of the actual value then residuals for week 5 are the highest at about 30% declining to about 5% for week 6, 6% for week 7, and 3% for week 8 (Fig. 5). All were negative except those for week 8. The negative residuals indicate an over-forecast of returns suggesting that management decisions based on these forecasts might tend to forestall action when it was actually warranted.

Comparison of residuals from linear regression and proportional forecasts demonstrates that linear forecasts are more accurate than proportional forecasts (Fig. 6). Linear forecasts were consistently better than proportional for all weeks from week 1 to week 6. The residual pattern for the proportional method shows much large residuals in the warm years, viz. 1996 and 1998 than in the colder years viz. 1993-94 and 1997. This is not the case with the linear method which shows a pattern of increasing residuals with time and not an abrupt shift to higher residuals in 1998 only. Forecasts for 1998 returns are much better for the linear than the proportional method.

The addition of an environmental parameter into the regression technique also seems to improve the forecasted values. The coefficient of determination for weeks 1 to 6 regressions with no environmental parameter ranged from 0.02 to 0.90 and with an environmental parameter, in this case thermal habitat, range from 0.57 in week 2 to 0.99 in week 6. Also comparison of the predicted versus observed values indicates that under-forecasting is more common than over-forecasting returns (Fig. 7A). All regressions for weeks 1 to 6, averaged over the 1993-98 period, maintained a very acceptable standard error of the regression estimate (Fig. 7B). When expressed as a percent of the standard error of the forecasted value it was always less than 15%. A note of caution is required here due to the small sample size. The Campbellton River counting fence has only been operated for six years and additional data may alter the relationship between variables and hence the precision of the estimated number of salmon returns.

## DISCUSSION

In-season reviews of salmon abundance have been done annually in Newfoundland and Labrador since about 1990. In some cases, the reviews have resulted in alterations to fishing plans and openings or closures of angling in some rivers. An example of the alteration of fishing plans due to an in-season review occurred in 1997 in insular Newfoundland (O'Connell et al. 1998). It was shown during in-season review that many rivers were not going to achieve conservation requirements without some alteration to fishing plans to reduce potential catches. As a result most rivers were closed to angling in mid-July and remained that way to the end of the fishing season (O'Connell et al. 1998).

Although in-season reviews of fish abundance are common in several jurisdictions, little is available in the literature describing the techniques and accuracy of the results. A couple of exceptions are Dempson et al. (1998) and Harvie & Amiro (1998). Harvie & Amiro (1998) stated that in order to be useful to managers forecasted values should maintain a standard error of the estimate of, at most, 25% of average values. Forecasts shown herein for Campbellton River adult salmon returns after week 6 show standard errors that are consistently less than 15% of the estimates. Harvie & Amiro (1998) further demonstrated that inclusion of environmental parameters in the predictive relationship greatly improved the forecasts which was also the case for Campbellton River. In my paper, I have shown that:

- Regression technique performs better than proportional techniques;

- Inclusion of an environmental variable improves accuracy considerably;

- In-season reviews for other systems should consider testing the regression technique to see if it leads to improvement in forecasts. Similarly, inclusion of an environmental variable may also help to improve forecasts by acting as a predictor of run timing.

- Run timing variability if not accounted for will degrade forecasts in years with very early or late runs compared to average. While the forecasts may still work most of the time, inclusion of an environmental parameter in the regression may improve forecasts considerably.

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Table 1. Campbellton River upstream migration of adult salmon through the counting fence from 1993 to 1998.

| Date | 1993 Grilse | 1993 accum total | 1993 Large salmon | 1993 accum total | 1994 Grilse | 1994 accum total | 1994 Large salmon | 1994 accum total | 1995 Grilse | 1995 accum total | 1995 Large salmon | 1995 accum total | 1996 Grilse | 1996 accum total | 1996 Large salmon | 1996 accum total | 1997 Grilse | 1997 accum total | 1997 Large salmon | 1997 accum total | 1998 Grilse | 1998 accum total | 1998 Large salmon | 1998 accum total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 03-Jun | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 04-Jun | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 05-Jun | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 06-Jun | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 07-Jun | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 4 | 4 | 0 | 0 |
| 08-Jun | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 6 | 1 | 3 | 0 | 0 | 0 | 0 | 10 | 14 | 0 | 0 |
| 09-Jun | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 20 | 2 | 5 | 0 | 0 | 0 | 0 | 10 | 24 | 1 | 1 |
| 10-Jun | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 33 | 4 | 9 | 0 | 0 | 0 | 0 | 3 | 27 | 4 | 5 |
| 11-Jun | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 54 | 1 | 10 | 0 | 0 | 0 | 0 | 13 | 40 | 2 | 7 |
| 12-Jun | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28 | 82 | 5 | 15 | 0 | 0 | 0 | 0 | 11 | 51 | 0 | 7 |
| 13-Jun | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 35 | 117 | 6 | 21 | 0 | 0 | 0 | 0 | 6 | 57 | 9 | 16 |
| 14-Jun | 1 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 135 | 0 | 21 | 0 | 0 | 2 | 2 | 9 | 66 | 2 | 18 |
| 15-Jun | 4 | 9 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 114 | 249 | 5 | 26 | 3 | 3 | 2 | 4 | 31 | 97 | 2 | 20 |
| 16-Jun | 0 | 9 | 0 | 0 | 2 | 3 | 0 | 0 | 1 | 2 | 0 | 1 | 116 | 365 | 20 | 46 | 7 | 10 | 0 | 4 | 24 | 121 | 3 | 23 |
| 17-Jun | 5 | 14 | 0 | 0 | 0 | 3 | 0 | 0 | 2 | 4 | 1 | 2 | 73 | 438 | 5 | 51 | 6 | 16 | 2 | 6 | 62 | 183 | 2 | 25 |
| 18-Jun | 3 | 17 | 0 | 0 | 1 | 4 | 0 | 0 | 8 | 12 | 0 | 2 | 129 | 567 | 7 | 58 | 12 | 28 | 2 | 8 | 194 | 377 | 4 | 29 |
| 19-Jun | 8 | 25 | 0 | 0 | 10 | 14 | 4 | 4 | 6 | 18 | 1 | 3 | 37 | 604 | 1 | 59 | 15 | 43 | 1 | 9 | 257 | 634 | 11 | 40 |
| 20-Jun | 8 | 33 | 0 | 0 | 17 | 31 | 1 | 5 | 45 | 63 | 7 | 10 | 164 | 768 | 18 | 77 | 19 | 62 | 0 | 9 | 341 | 975 | 6 | 46 |
| 21-Jun | 24 | 57 | 0 | 0 | 9 | 40 | 0 | 5 | 89 | 152 | 7 | 17 | 85 | 853 | 4 | 81 | 63 | 125 | 4 | 13 | 457 | 1432 | 11 | 57 |
| 22-Jun | 20 | 77 | 3 | 3 | 29 | 69 | 3 | 8 | 31 | 183 | 1 | 18 | 81 | 934 | 15 | 96 | 38 | 163 | 2 | 15 | 294 | 1726 | 11 | 68 |
| 23-Jun | 50 | 127 | 0 | 3 | 28 | 97 | 3 | 11 | 58 | 241 | 5 | 23 | 94 | 1028 | 8 | 104 | 66 | 229 | 4 | 19 | 115 | 1841 | 9 | 77 |
| 24-Jun | 104 | 231 | 3 | 6 | 140 | 237 | 17 | 28 | 85 | 326 | 7 | 30 | 139 | 1167 | 4 | 108 | 104 | 333 | 3 | 22 | 155 | 1996 | 11 | 88 |
| 25-Jun | 103 | 334 | 0 | 6 | 119 | 356 | 7 | 35 | 103 | 429 | 9 | 39 | 150 | 1317 | 11 | 119 | 51 | 384 | 1 | 23 | 90 | 2086 | 5 | 93 |
| 26-Jun | 191 | 525 | 3 | 9 | 78 | 434 | 1 | 36 | 53 | 482 | 1 | 40 | 107 | 1424 | 6 | 125 | 27 | 411 | 1 | 24 | 82 | 2168 | 6 | 99 |
| 27-Jun | 44 | 569 | 0 | 9 | 92 | 526 | 1 | 37 | 248 | 730 | 9 | 49 | 43 | 1467 | 9 | 134 | 45 | 456 | 3 | 27 | 135 | 2303 | 0 | 99 |
| 28-Jun | 83 | 652 | 7 | 16 | 81 | 607 | 0 | 37 | 94 | 824 | 4 | 53 | 92 | 1559 | 6 | 140 | 106 | 562 | 5 | 32 | 83 | 2386 | 3 | 102 |
| 29-Jun | 172 | 824 | 12 | 28 | 71 | 678 | 0 | 37 | 119 | 943 | 3 | 56 | 66 | 1625 | 14 | 154 | 93 | 655 | 1 | 33 | 65 | 2451 | 11 | 113 |
| 30-Jun | 136 | 960 | 7 | 35 | 44 | 722 | 1 | 38 | 85 | 1028 | 1 | 57 | 166 | 1791 | 16 | 170 | 81 | 736 | 0 | 33 | 38 | 2489 | 6 | 119 |
| 01-Jul | 294 | 1254 | 11 | 46 | 40 | 762 | 1 | 39 | 165 | 1193 | 3 | 60 | 113 | 1904 | 35 | 205 | 47 | 783 | 1 | 34 | 32 | 2521 | 5 | 124 |
| 02-Jul | 279 | 1533 | 12 | 58 | 35 | 797 | 0 | 39 | 109 | 1302 | 4 | 64 | 149 | 2053 | 21 | 226 | 36 | 819 | 0 | 34 | 70 | 2591 | 1 | 125 |
| 03-Jul | 234 | 1767 | 5 | 63 | 10 | 807 | 0 | 39 | 71 | 1373 | 1 | 65 | 103 | 2156 | 26 | 252 | 68 | 887 | 0 | 34 | 14 | 2605 | 1 | 126 |
| 04-Jul | 200 | 1967 | 9 | 72 | 40 | 847 | 0 | 39 | 170 | 1543 | 3 | 68 | 84 | 2240 | 20 | 272 | 41 | 928 | 0 | 34 | 7 | 2612 | 5 | 131 |
| 05-Jul | 90 | 2057 | 1 | 73 | 50 | 897 | 1 | 40 | 103 | 1646 | 1 | 69 | 66 | 2306 | 26 | 298 | 35 | 963 | 0 | 34 | 7 | 2619 | 1 | 132 |
| 06-Jul | 285 | 2342 | 9 | 82 | 145 | 1042 | 7 | 47 | 104 | 1750 | 2 | 71 | 67 | 2373 | 19 | 317 | 43 | 1006 | 0 | 34 | 48 | 2667 | 2 | 134 |
| 07-Jul | 137 | 2479 | 3 | 85 | 343 | 1385 | 9 | 56 | 68 | 1818 | 1 | 72 | 115 | 2488 | 29 | 346 | 39 | 1045 | 1 | 35 | 41 | 2708 | 2 | 136 |
| 08-Jul | 126 | 2605 | 3 | 88 | 98 | 1483 | 5 | 61 | 68 | 1886 | 1 | 73 | 61 | 2549 | 20 | 366 | 22 | 1067 | 0 | 35 | 12 | 2720 | 25 | 161 |
| 09-Jul | 102 | 2707 | 3 | 91 | 88 | 1571 | 4 | 65 | 27 | 1913 | 1 | 74 | 31 | 2580 | 7 | 373 | 18 | 1085 | 2 | 37 | 33 | 2753 | 10 | 171 |
| 10-Jul | 165 | 2872 | 3 | 94 | 38 | 1609 | 2 | 67 | 40 | 1953 | 0 | 74 | 83 | 2663 | 11 | 384 | 11 | 1096 | 1 | 38 | 168 | 2921 | 1 | 172 |
| 11-Jul | 100 | 2972 | 2 | 96 | 66 | 1675 | 3 | 70 | 65 | 2018 | 0 | 74 | 52 | 2715 | 16 | 400 | 17 | 1113 | 1 | 39 | 41 | 2962 | 23 | 195 |
| 12-Jul | 99 | 3071 | 4 | 100 | 50 | 1725 | 3 | 73 | 76 | 2094 | 1 | 75 | 28 | 2743 | 13 | 413 | 16 | 1129 | 0 | 39 | 1 | 2963 | 107 | 302 |
| 13-Jul | 119 | 3190 | 5 | 105 | 41 | 1766 | 0 | 73 | 21 | 2115 | 0 | 75 | 21 | 2764 | 0 | 413 | 9 | 1138 | 1 | 40 | 8 | 2971 | 12 | 314 |
| 14-Jul | 69 | 3259 | 2 | 107 | 36 | 1802 | 2 | 75 | 37 | 2152 | 1 | 76 | 182 | 2946 | 53 | 466 | 7 | 1145 | 0 | 40 | 6 | 2977 | 0 | 314 |
| 15-Jul | 73 | 3332 | 6 | 113 | 34 | 1836 | 1 | 76 | 13 | 2165 | 1 | 77 | 42 | 2988 | 20 | 486 | 35 | 1180 | 14 | 54 | 9 | 2986 | 2 | 316 |
| 16-Jul | 1 | 3333 | 0 | 113 | 26 | 1862 | 3 | 79 | 75 | 2240 | 9 | 86 | 10 | 2998 | 7 | 493 | 11 | 1191 | 4 | 58 | 7 | 2993 | 1 | 317 |
| 17-Jul | 77 | 3410 | 3 | 116 | 41 | 1903 | 1 | 80 | 106 | 2346 | 12 | 98 | 14 | 3012 | 6 | 499 | 6 | 1197 | 0 | 58 | 1 | 2994 | 1 | 318 |
| 18-Jul | 106 | 3516 | 5 | 121 | 3 | 1906 | 0 | 80 | 77 | 2423 | 8 | 106 | 21 | 3033 | 11 | 510 | 5 | 1202 | 0 | 58 | 36 | 3030 | 5 | 323 |
| 19-Jul | 73 | 3589 | 2 | 123 | 6 | 1912 | 1 | 81 | 47 | 2470 | 1 | 107 | 19 | 3052 | 7 | 517 | 2 | 1204 | 1 | 59 | 15 | 3045 | 1 | 324 |
| 20-Jul | 36 | 3625 | 0 | 123 | 34 | 1946 | 1 | 82 | 43 | 2513 | 3 | 110 | 6 | 3058 | 4 | 521 | 4 | 1208 | 2 | 61 | 6 | 3051 | 5 | 329 |
| 21-Jul | 19 | 3644 | 0 | 123 | 53 | 1999 | 8 | 90 | 29 | 2542 | 1 | 111 | 5 | 3063 | 5 | 526 | 10 | 1218 | 2 | 63 | 13 | 3064 | 2 | 331 |
| 22-Jul | 28 | 3672 | 2 | 125 | 52 | 2051 | 5 | 95 | 17 | 2559 | 1 | 112 | 18 | 3081 | 6 | 532 | 4 | 1222 | 1 | 64 | 8 | 3072 | 2 | 333 |
| 23-Jul | 40 | 3712 | 3 | 128 | 150 | 2201 | 12 | 107 | 25 | 2584 | 1 | 113 | 4 | 3085 | 3 | 535 | 62 | 1284 | 7 | 71 | 10 | 3082 | 11 | 344 |
| 24-Jul | 39 | 3751 | 3 | 131 | 268 | 2469 | 18 | 125 | 41 | 2625 | 1 | 114 | 9 | 3094 | 1 | 536 | 55 | 1339 | 19 | 90 | 15 | 3097 | 4 | 348 |
| 25-Jul | 31 | 3782 | 1 | 132 | 53 | 2522 | 7 | 132 | 82 | 2707 | 15 | 129 | 12 | 3106 | 1 | 537 | 13 | 1352 | 5 | 95 | 28 | 3125 | 2 | 350 |
| 26-Jul | 14 | 3796 | 0 | 132 | 34 | 2556 | 4 | 136 | 54 | 2761 | 7 | 136 | 7 | 3113 | 0 | 537 | 34 | 1386 | 13 | 108 | 28 | 3153 | 6 | 356 |
| 27-Jul | 14 | 3810 | 0 | 132 | 15 | 2571 | 4 | 140 | 36 | 2797 | 6 | 142 | 13 | 3126 | 4 | 541 | 13 | 1399 | 5 | 113 | 12 | 3165 | 15 | 371 |
| 28-Jul | 12 | 3822 | 0 | 132 | 10 | 2581 | 0 | 140 | 41 | 2838 | 11 | 153 | 13 | 3139 | 4 | 545 | 1 | 1400 | 1 | 114 | 10 | 3175 | 3 | 374 |
| 29-Jul | 5 | 3827 | 0 | 132 | 8 | 2589 | 2 | 142 | 18 | 2856 | 4 | 157 | 11 | 3150 | 5 | 550 | 2 | 1402 | 1 | 115 | 9 | 3184 | 6 | 380 |
| 30-Jul | 6 | 3833 | 0 | 132 | 12 | 2601 | 1 | 143 | 10 | 2866 | 3 | 160 | 12 | 3162 | 2 | 552 | 6 | 1408 | 2 | 117 | 12 | 3196 | 4 | 384 |
| 31-Jul | 12 | 3845 | 0 | 132 | 7 | 2608 | 1 | 144 | 8 | 2874 | 1 | 161 | 4 | 3166 | 0 | 552 | 5 | 1413 | 4 | 121 | 8 | 3204 | 1 | 385 |
| 01-Aug | 8 | 3853 | 0 | 132 | 4 | 2612 | 1 | 145 | 13 | 2887 | 2 | 163 | 6 | 3172 | 1 | 553 | 1 | 1414 | 0 | 121 | 8 | 3212 | 1 | 386 |
| 02-Aug | 6 | 3859 | 1 | 133 | 41 | 2653 | 8 | 153 | 10 | 2897 | 4 | 167 | 7 | 3179 | 3 | 556 | 2 | 1416 | 0 | 121 | 0 | 3212 | 0 | 386 |
| 03-Aug | 8 | 3867 | 0 | 133 | 42 | 2695 | 7 | 160 | 24 | 2921 | 12 | 179 | 3 | 3182 | 0 | 556 | 1 | 1417 | 0 | 121 | 7 | 3219 | 0 | 386 |
| 04-Aug | 17 | 3884 | 0 | 133 | 6 | 2701 | 0 | 160 | 10 | 2931 | 1 | 180 | 3 | 3185 | 0 | 556 | 1 | 1418 | 1 | 122 | 0 | 3219 | 0 | 386 |
| 05-Aug | 2 | 3886 | 0 | 133 | 6 | 2707 | 0 | 160 | 3 | 2934 | 0 | 180 | 2 | 3187 | 0 | 556 | 2 | 1420 | 2 | 124 | 1 | 3220 | 1 | 387 |
| 06-Aug | 9 | 3895 | 0 | 133 | 32 | 2739 | 6 | 166 | 3 | 2937 | 1 | 181 | 1 | 3188 | 0 | 556 | 5 | 1425 | 6 | 130 | 4 | 3224 | 0 | 387 |
| 07-Aug | 11 | 3906 | 0 | 133 | 52 | 2791 | 7 | 173 | 14 | 2951 | 13 | 194 | 0 | 3188 | 0 | 556 | 3 | 1428 | 1 | 131 | 0 | 3224 | 1 | 388 |
| 08-Aug | 5 | 3911 | 1 | 134 | 6 | 2797 | 1 | 174 | 10 | 2961 | 9 | 203 | 2 | 3190 | 1 | 557 | 2 | 1430 | 0 | 131 | 3 | 3227 | 4 | 392 |
| 09-Aug | 14 | 3925 | 3 | 137 | 3 | 2800 | 0 | 174 | 4 | 2965 | 0 | 203 | 3 | 3193 | 0 | 557 | 2 | 1432 | 0 | 131 | 4 | 3231 | 1 | 393 |
| 10-Aug | 7 | 3932 | 0 | 137 | 6 | 2806 | 1 | 175 | 1 | 2966 | 0 | 203 | 2 | 3195 | 1 | 558 | 1 | 1433 | 0 | 131 | 1 | 3232 | 0 | 393 |
| 11-Aug | 4 | 3936 | 0 | 137 | 8 | 2814 | 2 | 177 | 6 | 2972 | 0 | 203 | 0 | 3195 | 0 | 558 | 0 | 1433 | 0 | 131 | 3 | 3235 | 2 | 395 |
| 12-Aug | 3 | 3939 | 0 | 137 | 7 | 2821 | 0 | 177 | 1 | 2973 | 0 | 203 | 2 | 3197 | 1 | 559 | 5 | 1438 | 1 | 132 | 4 | 3239 | 1 | 396 |
| 13-Aug | 7 | 3946 | 0 | 137 | 1 | 2822 | 1 | 178 | 2 | 2975 | 1 | 204 | 1 | 3198 | 0 | 559 | 54 | 1492 | 46 | 178 | 5 | 3244 | 1 | 397 |
| 14-Aug | 1 | 3947 | 0 | 137 | 2 | 2824 | 1 | 179 | 3 | 2978 | 4 | 208 | 1 | 3199 | 0 | 559 | 19 | 1511 | 7 | 185 | 2 | 3246 | 1 | 398 |
| 15-Aug | 8 | 3955 | 1 | 138 | 2 | 2826 | 0 | 179 | 27 | 3005 | 5 | 213 | 3 | 3202 | 0 | 559 | 14 | 1525 | 6 | 191 | 2 | 3248 | 0 | 398 |
| 16-Aug | 5 | 3960 | 1 | 139 | 4 | 2830 | 1 | 180 | 1 | 3006 | 0 | 213 | 2 | 3204 | 0 | 559 | 3 | 1528 | 2 | 193 | 4 | 3252 | 0 | 398 |
| 17-Aug | 3 | 3963 | 1 | 140 | 3 | 2833 | 0 | 180 | 4 | 3010 | 1 | 214 | 1 | 3205 | 0 | 559 | 21 | 1549 | 14 | 207 | 2 | 3254 | 0 | 398 |
| 18-Aug | 1 | 3964 | 0 | 140 | 1 | 2834 | 1 | 181 | 2 | 3012 | 0 | 214 | 3 | 3208 | 0 | 559 | 91 | 1640 | 23 | 230 | 2 | 3256 | 1 | 399 |
| 19-Aug | 0 | 3964 | 0 | 140 | 3 | 2837 | 3 | 184 | 1 | 3013 | 0 | 214 | 0 | 3208 | 1 | 560 | 56 | 1696 | 11 | 241 | 1 | 3257 | 0 | 399 |
| 20-Aug | 4 | 3968 | 0 | 140 | 3 | 2840 | 0 | 184 | 5 | 3018 | 0 | 214 | 0 | 3208 | 0 | 560 | 8 | 1704 | 0 | 241 | 1 | 3258 | 0 | 399 |
| 21-Aug | 3 | 3971 | 0 | 140 | 2 | 2842 | 0 | 184 | 2 | 3020 | 0 | 214 | 0 | 3208 | 0 | 560 | 3 | 1707 | 0 | 241 | 2 | 3260 | 0 | 399 |
| 22-Aug | 4 | 3975 | 1 | 141 | 1 | 2843 | 0 | 184 | 2 | 3022 | 1 | 215 | 0 | 3208 | 0 | 560 | 1 | 1708 | 0 | 241 | 1 | 3261 | 2 | 401 |
| 23-Aug | 3 | 3978 | 0 | 141 | 1 | 2844 | 0 | 184 | 6 | 3028 | 1 | 216 | 0 | 3208 | 0 | 560 | 5 | 1713 | 1 | 242 | 4 | 3265 | 0 | 401 |
| 24-Aug | 3 | 3981 | 0 | 141 | 2 | 2846 | 1 | 185 | 1 | 3029 | 2 | 218 | 0 | 3208 | 0 | 560 | 11 | 1724 | 9 | 251 | 2 | 3267 | 1 | 402 |
| 25-Aug | 0 | 3981 | 1 | 142 | 3 | 2849 | 0 | 185 | 2 | 3031 | 0 | 218 | 0 | 3208 | 0 | 560 | 2 | 1726 | 0 | 251 | 1 | 3268 | 0 | 402 |
| 26-Aug | 0 | 3981 | 0 | 142 | 1 | 2850 | 0 | 185 | 1 | 3032 | 0 | 218 | 0 | 3208 | 0 | 560 | 4 | 1730 | 1 | 252 | 1 | 3269 | 0 | 402 |
| 27-Aug | 3 | 3984 | 0 | 142 | 1 | 2851 | 1 | 186 | 3 | 3035 | 0 | 218 | 0 | 3208 | 0 | 560 | 27 | 1757 | 4 | 256 | 0 | 3269 | 0 | 402 |
| 28-Aug | 0 | 3984 | 0 | 142 | 0 | 2851 | 0 | 186 | 0 | 3035 | 0 | 218 | 0 | 3208 | 0 | 560 | 10 | 1767 | 1 | 257 | 0 | 3269 | 0 | 402 |
| 29-Aug | 1 | 3985 | 0 | 142 | 0 | 2851 | 0 | 186 | 0 | 3035 | 0 | 218 | 0 | 3208 | 0 | 560 | 2 | 1769 | 0 | 257 | 1 | 3270 | 0 | 402 |
| 30-Aug | 4 | 3989 | 0 | 142 | 1 | 2852 | 1 | 187 | 0 | 3035 | 0 | 218 | 0 | 3208 | 0 | 560 | 59 | 1828 | 31 | 288 | 0 | 3270 | 0 | 402 |
| 31-Aug | 1 | 3990 | 0 | 142 | 0 | 2852 | 0 | 187 | 0 | 3035 | 0 | 218 | 0 | 3208 | 0 | 560 | 122 | 1950 | 28 | 316 | 0 | 3270 | 0 | 402 |
| 01-Sep | 1 | 3991 | 0 | 142 | 0 | 2852 | 0 | 187 | 0 | 3035 | 0 | 218 | 0 | 3208 | 0 | 560 | 8 | 1958 | 0 | 316 | 3 | 3273 | 0 | 402 |
| 02-Sep | 2 | 3993 | 0 | 142 | 1 | 2853 | 1 | 188 | 0 | 3035 | 0 | 218 | 0 | 3208 | 0 | 560 | 2 | 1960 | 0 | 316 | 1 | 3274 | 0 | 402 |
| 03-Sep | 3 | 3996 | 1 | 143 | 0 | 2853 | 0 | 188 | 0 | 3035 | 0 | 218 | 0 | 3208 | 0 | 560 | 5 | 1965 | 1 | 317 | 0 | 3274 | 0 | 402 |
| 04-Sep | 2 | 3998 | 0 | 143 | 0 | 2853 | 0 | 188 | 0 | 3035 | 0 | 218 | 0 | 3208 | 0 | 560 | 4 | 1969 | 2 | 319 | 1 | 3275 | 0 | 402 |
| 05-Sep | 2 | 4000 | 2 | 145 | 0 | 2853 | 1 | 189 | 0 | 3035 | 0 | 218 | 0 | 3208 | 0 | 560 | 1 | 1970 | 1 | 320 | 0 | 3275 | 0 | 402 |
| 06-Sep | 0 | 4000 | 0 | 145 | 0 | 2853 | 0 | 189 | 0 | 3035 | 0 | 218 | 0 | 3208 | 0 | 560 | 2 | 1972 | 0 | 320 | 0 | 3275 | 0 | 402 |
| 07-Sep | 1 | 4001 | 0 | 145 | 1 | 2854 | 0 | 189 | 0 | 3035 | 0 | 218 | 0 | 3208 | 0 | 560 | 2 | 1974 | 1 | 321 | 0 | 3275 | 0 | 402 |
| 08-Sep | 0 | 4001 | 0 | 145 | 1 | 2855 | 0 | 189 | 0 | 3035 | 0 | 218 | 0 | 3208 | 0 | 560 | 1 | 1975 | 0 | 321 | 0 | 3275 | 0 | 402 |
| 09-Sep | 0 | 4001 | 0 | 145 | 0 | 2855 | 0 | 189 | 0 | 3035 | 0 | 218 | 0 | 3208 | 0 | 560 | 0 | 1975 | 0 | 321 | 0 | 3275 | 0 | 402 |
| 10-Sep | 0 | 4001 | 0 | 145 | 1 | 2856 | 1 | 190 | 0 | 3035 | 0 | 218 | 0 | 3208 | 0 | 560 | 0 | 1975 | 0 | 321 | 0 | 3275 | 0 | 402 |
| 11-Sep | 0 | 4001 | 0 | 145 | 0 | 2856 | 1 | 191 | 0 | 3035 | 0 | 218 | 0 | 3208 | 0 | 560 | 0 | 1975 | 0 | 321 | 0 | 3275 | 0 | 402 |
| 12-Sep | 0 | 4001 | 0 | 145 | 1 | 2857 | 0 | 191 | 0 | 3035 | 0 | 218 | 0 | 3208 | 0 | 560 | 0 | 1975 | 0 | 321 | 0 | 3275 | 0 | 402 |
| | 0 | 4001 | 0 | 145 | 0 | 2857 | 0 | 191 | 0 | 3035 | 0 | 218 | 0 | 3208 | 0 | 560 | 0 | 1975 | 0 | 321 | 0 | 3275 | 0 | 402 |
| Total | 4001 | | 145 | | 2857 | | 191 | | 3035 | | 218 | | 3208 | | 560 | | 1975 | | 321 | | 3275 | | 402 | |
| Overall Total | 4146 | | | | 3048 | | | | 3253 | | | | 3768 | | | | 2296 | | | | 3677 | | | |

Fig. 1. Daily upstream migrating salmon counts for Campbellton River, 1993-98.

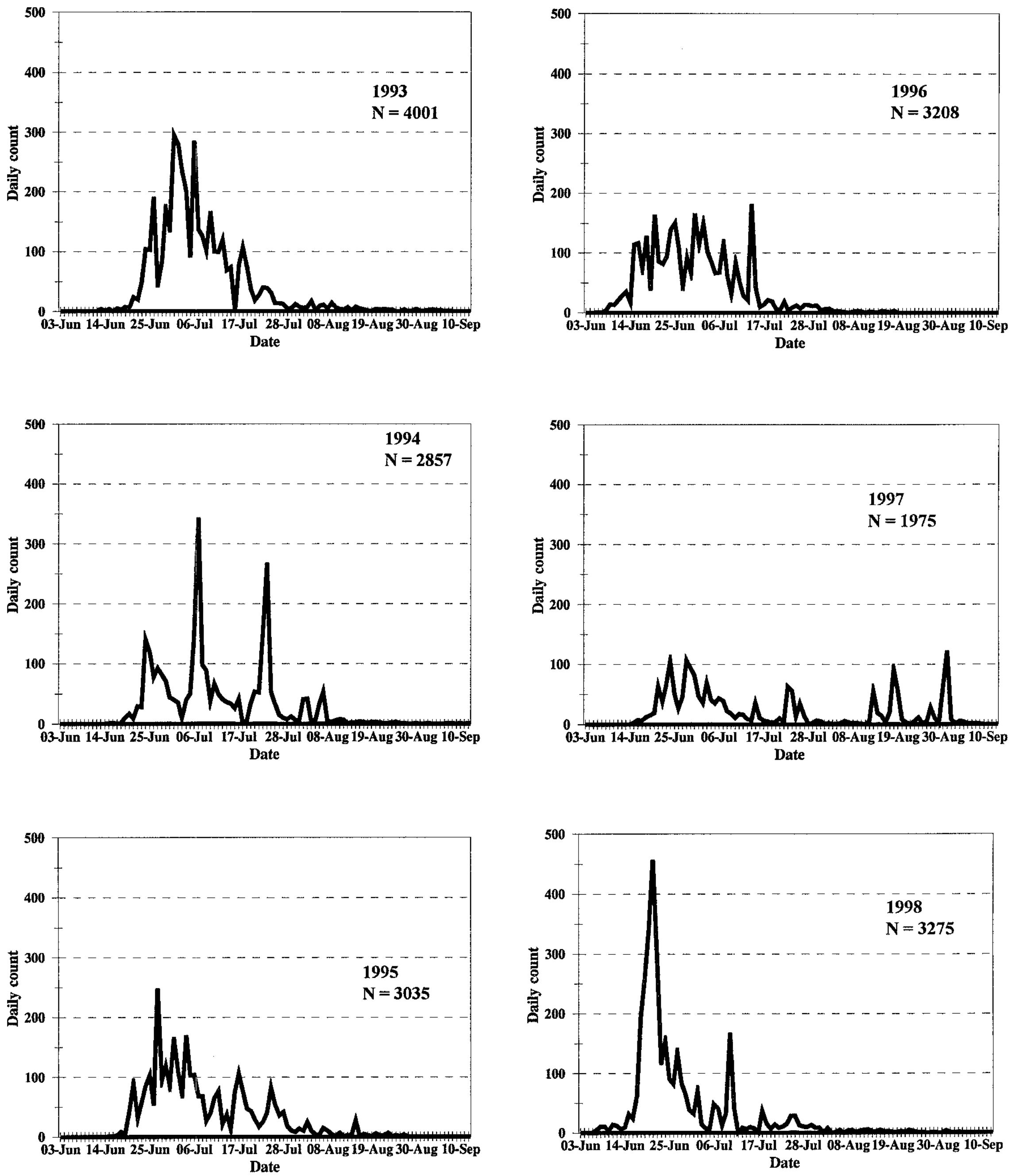

Fig. 2a. Annual variation in run timing for small salmon at Campbellton River, Nfld. Vertical lines represent the 10th and 90th percentiles of the day of the year of migration, the rectangle is the 25th and 75th percentiles, and the marker within the rectangle is the median run timing value.

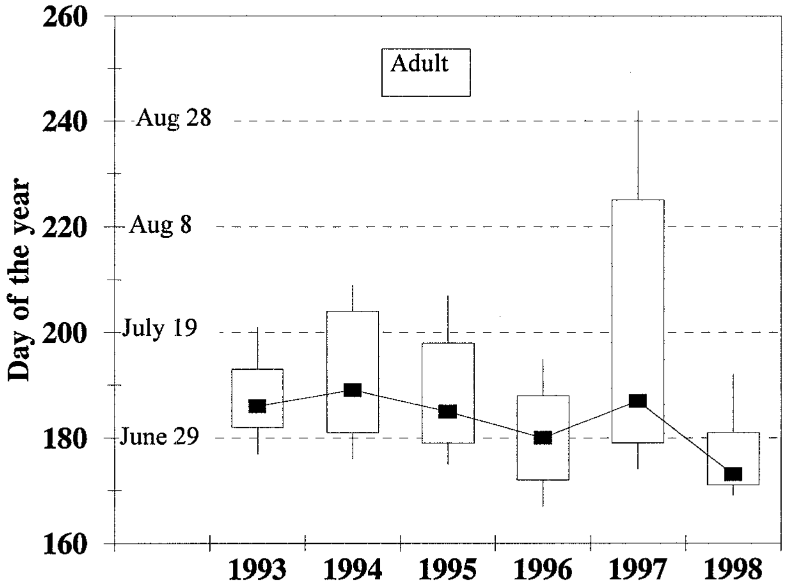


Fig. 2b. Annual variation in run timing for smolts at Campbellton River, Nfld. Vertical lines represent the 10th and 90th percentiles of the day of the year of migration, the rectangle is the 25th and 75th percentiles, and the marker within the rectangle is the median run timing value.

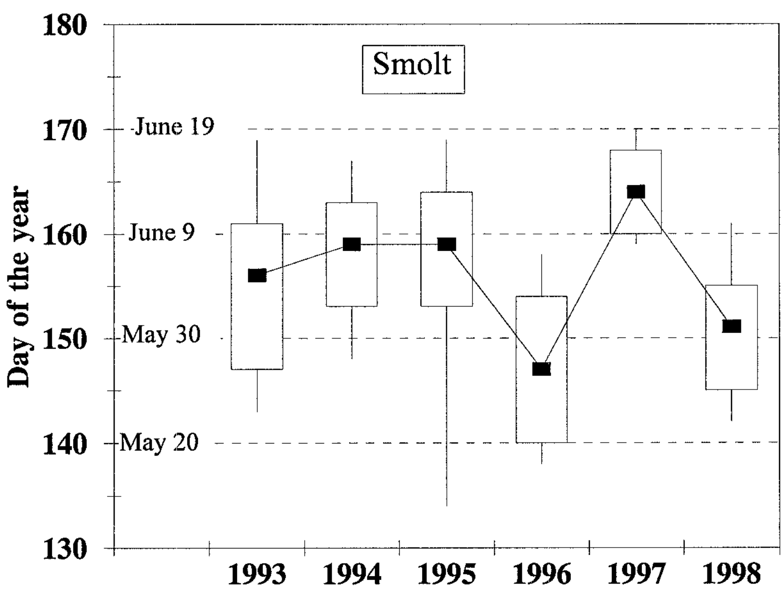

Fig 3. Relationships between count to end of season on count to the end of various weeks at Campbellton River, Newfoundland, 1993-97. 1998 value is shown for comparison.

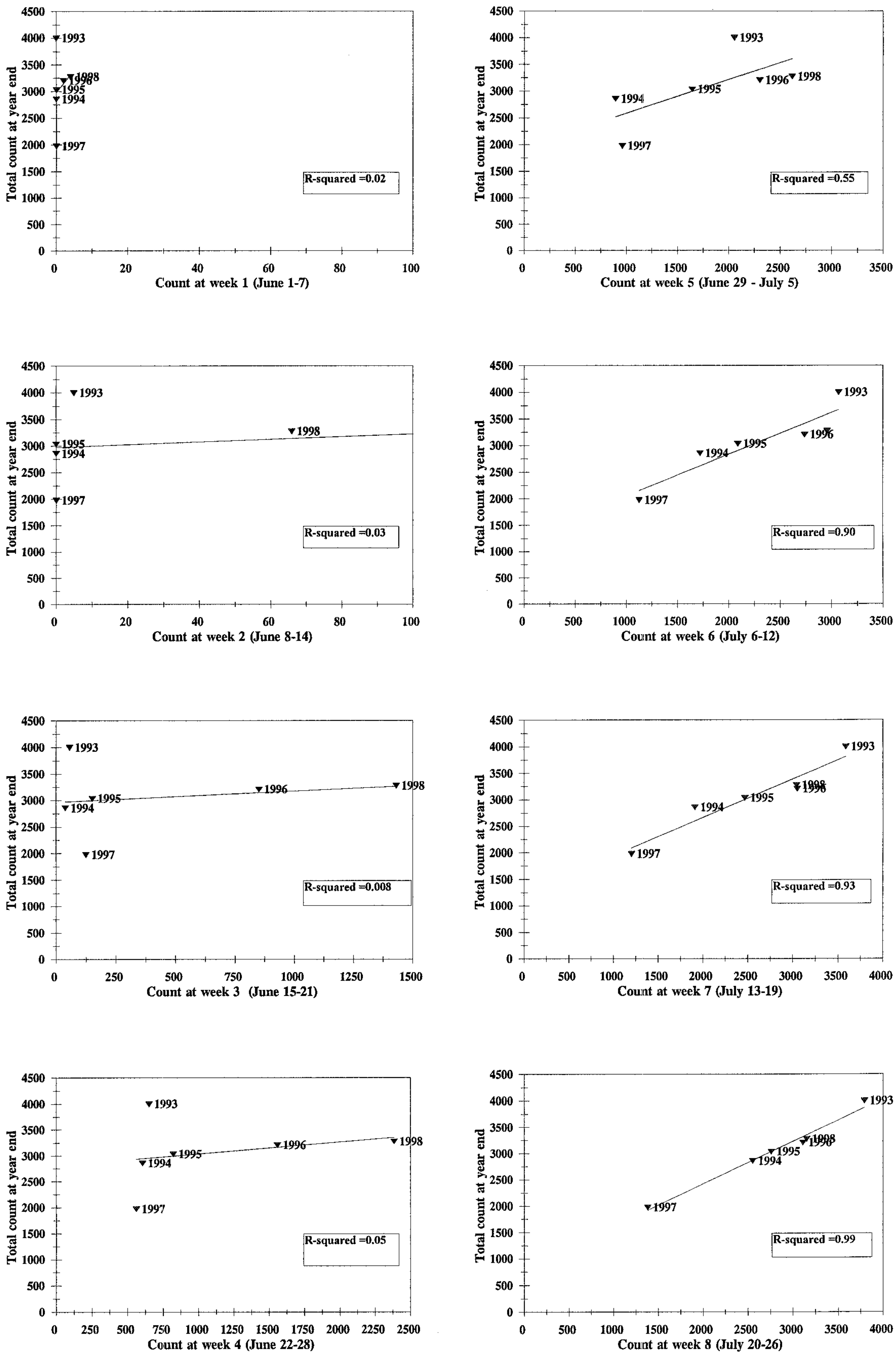

Fig 4. Residuals from regression of count to end of season on count to the end of the week.

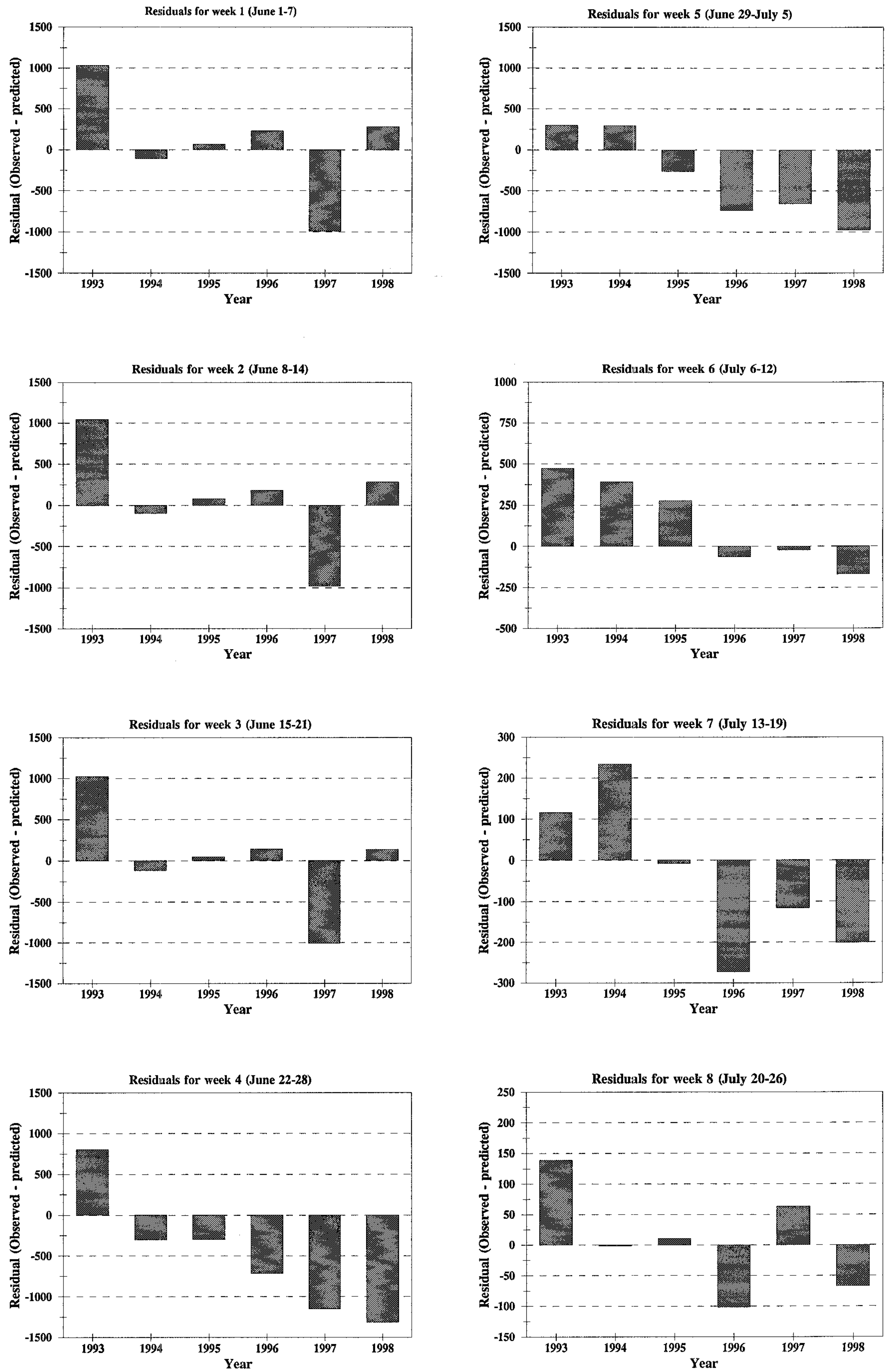

Fig 5. Comparison of the residual vs observed expressed as a percentage of the observed value.

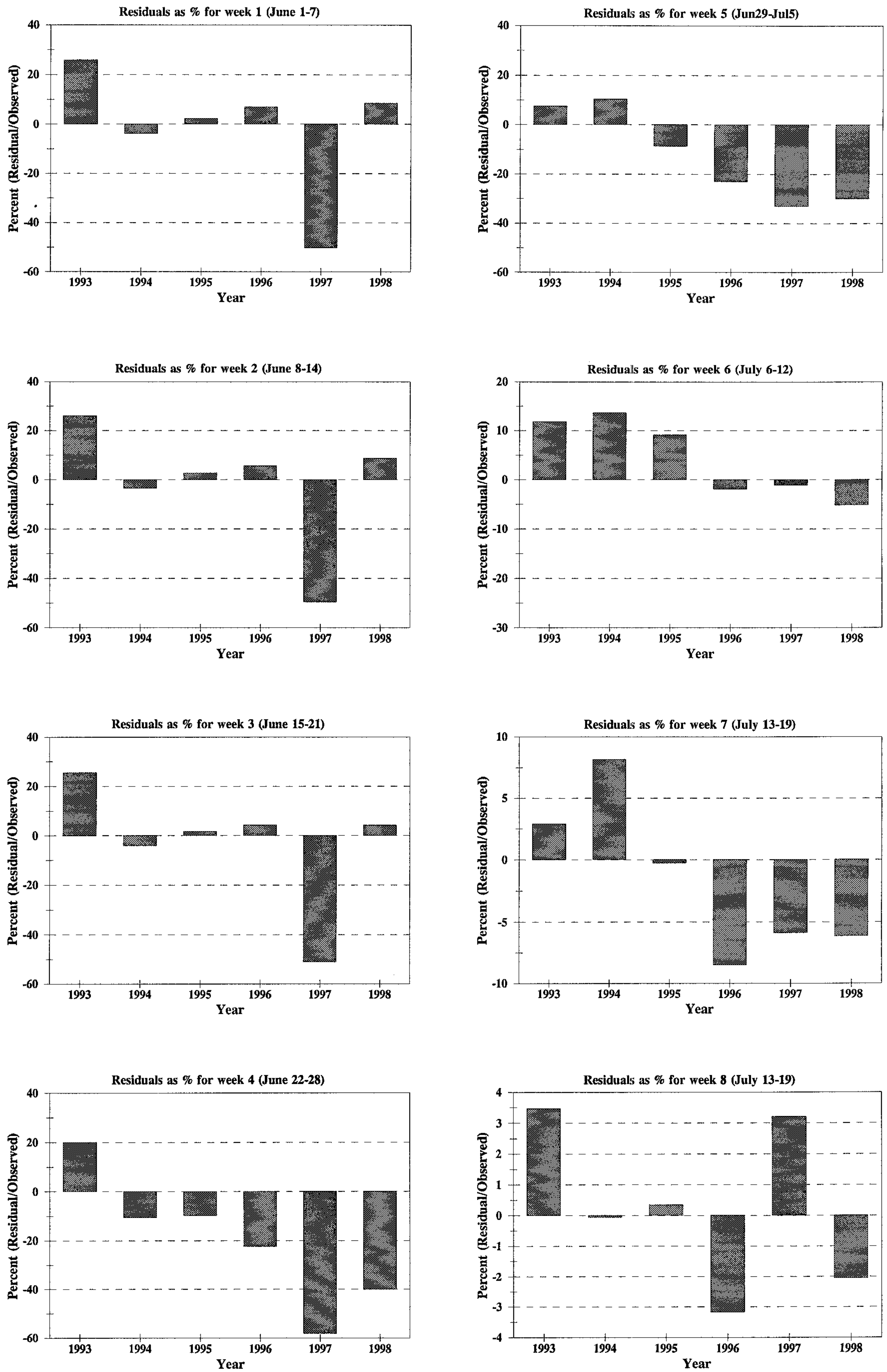

Fig. 6. Comparison of residual percents from forecasts based on linear (left side) and proportion (right side) methods for adults at Campbellton River, Nfld.

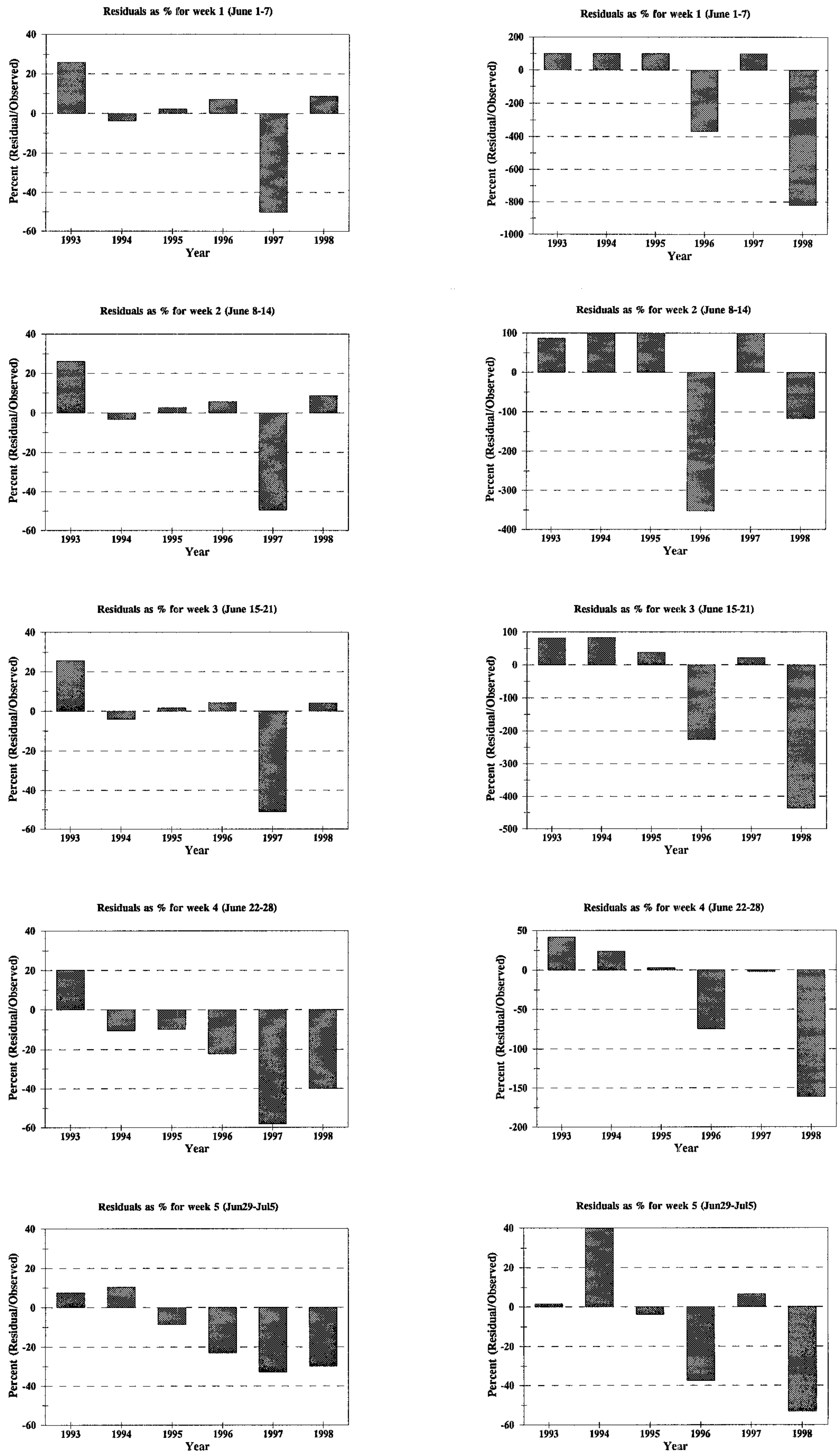

Fig. 7. A - is a comparison of end of season count on week 1 - 6 cumulative counts and thermal habitat. B - Average weekly (1993-98) standard error of the estimate in percent.