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# Inseason forecast model for 1SW salmon returning to the Saint John River, New Brunswick, in 1999

by

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**Abstract**

Inseason forecasts of wild and hatchery 1SW Atlantic salmon returning to Mactaquac Dam on the Saint John River, New Brunswick, have been estimated using simple linear regression models. The response variable has been cumulative proportion of the returns to date and, for wild 1SW salmon, the predictor variable has been average daily mean discharge. Since 1995, discharge has become a less significant predictor in the wild 1SW model and the seasonal distribution of hatchery 1SW arrival has changed, frequently resulting in overestimation of returns. A new model, regressing end-of-season returns on returns-to-date, for both wild and hatchery components at three dates, was evaluated for forecast accuracy in a retrospective examination and found to more accurately forecast end-of-season returns.

**Résumé**

Les prévisions en cours de saison des remontées de saumons de l'Atlantique sauvages et d'élevage unibermarins au barrage Mactaquac sur la rivière Saint-Jean, au Nouveau-Brunswick, ont été estimées par modèles simples de régression linéaire. La variable de réponse a été la proportion cumulative des remontées actualisées et, pour les saumons sauvages unibermarins, la variable prédictive a été l'écoulement quotidien moyen. Depuis 1995, l'écoulement est devenu une variable prédictive moins significative pour le modèle des saumons sauvages unibermarins et la distribution saisonnière des arrivées des unibermarins d'élevage s'est modifiée donnant souvent lieu à une surestimation des retours. Un nouveau modèle, de régression des remontées en fin de saison sur les remontées actualisées, appliqué aux éléments sauvage et d'élevage à trois dates particulières, a été évalué en ce qui a trait à l'exactitude des prévisions par examen rétrospectif et cela a permis d'obtenir une prévision plus juste des remontées de fin de saison.

**Background**

Inseason forecasts of 1SW Atlantic salmon returning to Mactaquac Dam on the Saint John River have been estimated using a simple linear regression of cumulative proportion of the run returning to date on the average daily mean discharge over the period July 2 to one day before the forecast date (Marshall and Cameron MS 1995). The model is of the form:

$$\text{Arcsine cumulative proportion to date} = \beta_0 + \beta_1 * \text{Average daily mean discharge} + \text{error}$$

A forecast equation was estimated for wild and hatchery 1SW salmon separately, for each of three dates: July 15, 22, and 29. Forecast equations estimated for wild 1SW salmon before 1995 indicated significant regression coefficients ($p<0.05$) for average daily mean discharge in the model, for each forecast date. Equations forecasting hatchery 1SW salmon returns over the same period were found to be not significantly dependent on discharge, so the model took the form:

$$\text{Arcsine cumulative proportion to date} = \beta_0 + \text{error} \qquad (1)$$

That is, the historical (1972 to forecast year-1) average arcsine cumulative proportion to date was used to estimate the forecast of hatchery 1SW salmon returns.

Starting in 1995, it was noted that the seasonal distribution of hatchery 1SW returns had changed. In addition, the regression coefficient for average daily mean discharge in the wild 1SW salmon model was no longer significant ($p>0.05$) for the July 15 forecast date. A model similar to the hatchery model (1) was used for this date. In 1997, none of the three forecast dates produced equations with significant regression coefficients for the independent variable, for either wild or hatchery 1SW returns. Model (1) was used to make all forecasts. However, this model often overestimated returns, particularly at medium to high values of returns-to-date.

In 1998, new potential forecast models were explored to determine whether a model could be found which produced more accurate estimates of returns, particularly at medium to high values of returns-to-date. Regression equation coefficients for the models, for each of wild and hatchery 1SW returns at each forecast date, were estimated by an iteratively reweighted least squares (IRLS) robust regression procedure (Neter *et al.* 1996) to reduce the influence of outliers. This examination produced the model:

$$\text{End of season returns} = \beta_0 + \beta_1 * \text{Returns to date} + \text{error} \qquad (2)$$

The 1998 returns-to-date values were very low for wild returns and very high for hatchery returns. At these values, model (2) would overestimate wild returns and model (1) would overestimate hatchery returns, particularly on July 15 and 22. Therefore, 1998 forecasts were made using model (1) for wild returns and model (2) for hatchery returns.

With the addition of the 1998 data point to the data set, models (1) and (2) became more similar in their forecasts of wild 1SW returns. The two models were compared to determine the one model which would best fit the data by providing more accurate estimates of returns. The same was examined for hatchery 1SW returns. For each of models (1) and (2), evaluations of forecast accuracy were made by estimating, for each of the years 1972 to 1998, a forecast returns value and comparing this to the actual returns value. The sum, over all years, of the squared differences between the actual and forecast returns was calculated to give an indication of the overall accuracy of forecasting with the two models.

**Results**

Regression coefficients and statistics were estimated for each of wild and hatchery 1SW returns at each forecast date (Figures 1-3). The discharge variable did not add significantly to any of the equations. The regression equations are:

Wild 1SW returns forecast from July 15

Model (1): Arcsine cumulative proportion returns to July 15 = 32.682
(n=27)

Model (2): End of season returns = 1229.701 + 2.375 * Returns to July 15
($R^2_{adj}$=0.646; p<0.001; n=27)

Wild 1SW returns forecast from July 22

Model (1): Arcsine cumulative proportion returns to July 22 = 45.452
(n=27)

Model (2): End of season returns = 526.736 + 1.646 * Returns to July 22
($R^2_{adj}$=0.858; p<0.001; n=27)

Wild 1SW returns forecast from July 29

Model (1): Arcsine cumulative proportion returns to July 29 = 54.305
(n=27)

Model (2): End of season returns = 90.826 + 1.441 * Returns to July 29
($R^2_{adj}$=0.954; p<0.001; n=27)

Hatchery 1SW returns forecast from July 15

Model (1): Arcsine cumulative proportion returns to July 15 = 24.816
(n=27)

Model (2): End of season returns = 1263.058 + 2.275 * Returns to July 15
($R^2_{adj}$=0.577; p<0.001; n=27)

Hatchery 1SW returns forecast from July 22

Model (1): Arcsine cumulative proportion returns to July 22 = 35.826
(n=27)

Model (2): End of season returns = 886.891 + 1.703 * Returns to July 22
($R^2_{adj}$=0.732; p<0.001; n=27)

Hatchery 1SW returns forecast from July 29

Model (1): Arcsine cumulative proportion returns to July 29 = 44.506
(n=27)

Model (2): End of season returns = 501.354 + 1.580 * Returns to July 29
($R^2_{adj}$=0.845; p<0.001; n=27)

The sum of squared differences between forecast returns and actual returns, for each of models (1) and (2), clearly indicates that model (2) more accurately forecasts returns of both wild and hatchery 1SW salmon, when only one model is used (Tables 1-2). Therefore, model (2) will be used to estimate 1999 forecasts of wild and hatchery 1SW salmon returns. The sum of squared differences for the July 29 forecast of wild returns indicated very little difference between the two models. For consistency, model (2) was chosen.

**References**

Marshall, T.L. and J.D. Cameron. MS 1995. Status of Atlantic salmon stocks of the Saint John River and southwest New Brunswick, 1994. DFO Atlantic Fisheries Res. Doc. 95/129.

Neter, J., M.H. Kutner, C.J. Nachtsheim, and W. Wasserman. 1996. Applied Linear Statistical Models. Fourth Edition. IRWIN, Inc., USA.

**Table 1**. End of season returns and forecast returns of wild 1SW salmon returning to Mactaquac Dam on the Saint John River, 1972 to 1998, for each of three forecast dates and two models.

| | Wild 1SW Returns | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Actual End of Season | Returns to Date | | | Forecast End of Season Returns | | | | | |
| | | | | | Model (1) | | | Model (2) | | |
| Year | Returns | July 15 | July 22 | July 29 | July 15 | July 22 | July 29 | July 15 | July 22 | July 29 |
| 1972 | 784 | 164 | 275 | 340 | 562 | 541 | 515 | 1619 | 979 | 581 |
| 1973 | 1854 | 511 | 1008 | 1272 | 1753 | 1985 | 1929 | 2443 | 2186 | 1924 |
| 1974 | 3389 | 522 | 1555 | 2208 | 1790 | 3062 | 3348 | 2469 | 3086 | 3273 |
| 1975 | 5725 | 2097 | 3364 | 4006 | 7192 | 6623 | 6074 | 6210 | 6064 | 5863 |
| 1976 | 6797 | 1477 | 2973 | 4186 | 5066 | 5854 | 6347 | 4738 | 5420 | 6123 |
| 1977 | 3506 | 1183 | 2084 | 2530 | 4057 | 4103 | 3836 | 4039 | 3957 | 3737 |
| 1978 | 1584 | 464 | 850 | 993 | 1591 | 1674 | 1506 | 2332 | 1926 | 1522 |
| 1979 | 6234 | 2770 | 3825 | 4365 | 9500 | 7531 | 6618 | 7808 | 6823 | 6381 |
| 1980 | 7555 | 1401 | 2406 | 4076 | 4805 | 4737 | 6180 | 4557 | 4487 | 5964 |
| 1981 | 4571 | 1619 | 2608 | 3301 | 5553 | 5135 | 5005 | 5075 | 4820 | 4848 |
| 1982 | 3931 | 1419 | 2033 | 2601 | 4867 | 4003 | 3944 | 4600 | 3873 | 3839 |
| 1983 | 3613 | 1010 | 1802 | 2459 | 3464 | 3548 | 3728 | 3628 | 3493 | 3634 |
| 1984 | 7353 | 463 | 1521 | 2595 | 1588 | 2995 | 3934 | 2329 | 3030 | 3830 |
| 1985 | 5331 | 487 | 1157 | 2403 | 1670 | 2278 | 3643 | 2386 | 2431 | 3554 |
| 1986 | 6347 | 2233 | 3215 | 4519 | 7658 | 6330 | 6851 | 6533 | 5819 | 6603 |
| 1987 | 5106 | 2200 | 3068 | 3675 | 7545 | 6041 | 5572 | 6455 | 5577 | 5387 |
| 1988 | 8062 | 2264 | 4711 | 5689 | 7765 | 9276 | 8625 | 6607 | 8281 | 8289 |
| 1989 | 8417 | 2855 | 5321 | 6308 | 9792 | 10477 | 9564 | 8010 | 9285 | 9181 |
| 1990 | 6486 | 2157 | 3390 | 4059 | 7398 | 6675 | 6154 | 6353 | 6107 | 5940 |
| 1991 | 5415 | 960 | 1794 | 2608 | 3292 | 3532 | 3954 | 3510 | 3480 | 3849 |
| 1992 | 5729 | 893 | 2236 | 3545 | 3063 | 4403 | 5375 | 3351 | 4207 | 5199 |
| 1993 | 2873 | 661 | 1283 | 2038 | 2267 | 2526 | 3090 | 2800 | 2639 | 3028 |
| 1994 | 2133 | 873 | 1476 | 1670 | 2994 | 2906 | 2532 | 3303 | 2956 | 2497 |
| 1995 | 2429 | 648 | 1227 | 1721 | 2222 | 2416 | 2609 | 2769 | 2546 | 2571 |
| 1996 | 1552 | 804 | 1065 | 1240 | 2757 | 2097 | 1880 | 3139 | 2280 | 1878 |
| 1997 | 380 | 211 | 279 | 299 | 724 | 549 | 453 | 1731 | 986 | 522 |
| 1998 | 476 | 198 | 310 | 370 | 679 | 610 | 561 | 1700 | 1037 | 624 |
| Sum of squared differences: | | | | | 99,655,057 | 53,500,470 | 22,127,013 | 74,060,337 | 48,969,418 | 22,931,755 |

**Table 2**. End of season returns and forecast returns of hatchery 1SW salmon returning to Mactaquac Dam on the Saint John River, 1972 to 1998, for each of three forecast dates and two models.

| | Hatchery 1SW Returns | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Actual End of Season | Returns to Date | | | Forecast End of Season Returns | | | | | |
| | | | | | Model (1) | | | Model (2) | | |
| Year | Returns | July 15 | July 22 | July 29 | July 15 | July 22 | July 29 | July 15 | July 22 | July 29 |
| 1972 | 246 | 21 | 48 | 66 | 119 | 140 | 134 | 1311 | 969 | 606 |
| 1973 | 1760 | 375 | 755 | 1013 | 2129 | 2204 | 2062 | 2116 | 2173 | 2102 |
| 1974 | 3700 | 275 | 1058 | 1603 | 1561 | 3088 | 3262 | 1889 | 2689 | 3034 |
| 1975 | 5335 | 1380 | 2455 | 2970 | 7834 | 7166 | 6044 | 4403 | 5068 | 5193 |
| 1976 | 7694 | 415 | 1101 | 2402 | 2356 | 3214 | 4888 | 2207 | 2762 | 4296 |
| 1977 | 6201 | 1571 | 3021 | 3828 | 8918 | 8818 | 7790 | 4837 | 6032 | 6548 |
| 1978 | 2556 | 407 | 858 | 1115 | 2310 | 2504 | 2269 | 2189 | 2348 | 2263 |
| 1979 | 3521 | 1000 | 1448 | 1745 | 5677 | 4226 | 3551 | 3538 | 3353 | 3258 |
| 1980 | 9759 | 1290 | 2204 | 3889 | 7323 | 6433 | 7915 | 4198 | 4641 | 6645 |
| 1981 | 3782 | 1004 | 1709 | 2247 | 5700 | 4988 | 4573 | 3547 | 3798 | 4051 |
| 1982 | 2292 | 310 | 505 | 800 | 1760 | 1474 | 1628 | 1968 | 1747 | 1765 |
| 1983 | 1230 | 207 | 362 | 575 | 1175 | 1057 | 1170 | 1734 | 1503 | 1410 |
| 1984 | 1304 | 72 | 205 | 400 | 409 | 598 | 814 | 1427 | 1236 | 1133 |
| 1985 | 1746 | 68 | 207 | 462 | 386 | 604 | 940 | 1418 | 1239 | 1231 |
| 1986 | 699 | 136 | 225 | 364 | 772 | 657 | 741 | 1572 | 1270 | 1076 |
| 1987 | 2894 | 760 | 1164 | 1496 | 4314 | 3397 | 3045 | 2992 | 2869 | 2865 |
| 1988 | 1129 | 266 | 518 | 692 | 1510 | 1512 | 1408 | 1868 | 1769 | 1594 |
| 1989 | 1170 | 157 | 420 | 571 | 891 | 1226 | 1162 | 1620 | 1602 | 1403 |
| 1990 | 1421 | 215 | 436 | 566 | 1221 | 1273 | 1152 | 1752 | 1630 | 1395 |
| 1991 | 2160 | 74 | 207 | 411 | 420 | 604 | 836 | 1431 | 1239 | 1151 |
| 1992 | 1935 | 109 | 406 | 850 | 619 | 1185 | 1730 | 1511 | 1578 | 1844 |
| 1993 | 1034 | 106 | 306 | 619 | 602 | 893 | 1260 | 1504 | 1408 | 1479 |
| 1994 | 1180 | 260 | 567 | 725 | 1476 | 1655 | 1475 | 1855 | 1853 | 1647 |
| 1995 | 2541 | 321 | 737 | 1236 | 1822 | 2151 | 2515 | 1993 | 2142 | 2454 |
| 1996 | 4603 | 1854 | 2346 | 2681 | 10525 | 6848 | 5456 | 5481 | 4883 | 4736 |
| 1997 | 2689 | 1390 | 1949 | 2267 | 7891 | 5689 | 4614 | 4425 | 4207 | 4082 |
| 1998 | 4413 | 2346 | 3278 | 3696 | 13318 | 9568 | 7522 | 6600 | 6470 | 6340 |
| Sum of squared differences: | | | | | 213,373,017 | 90,789,026 | 32,844,281 | 80,862,484 | 62,343,238 | 30,448,033 |

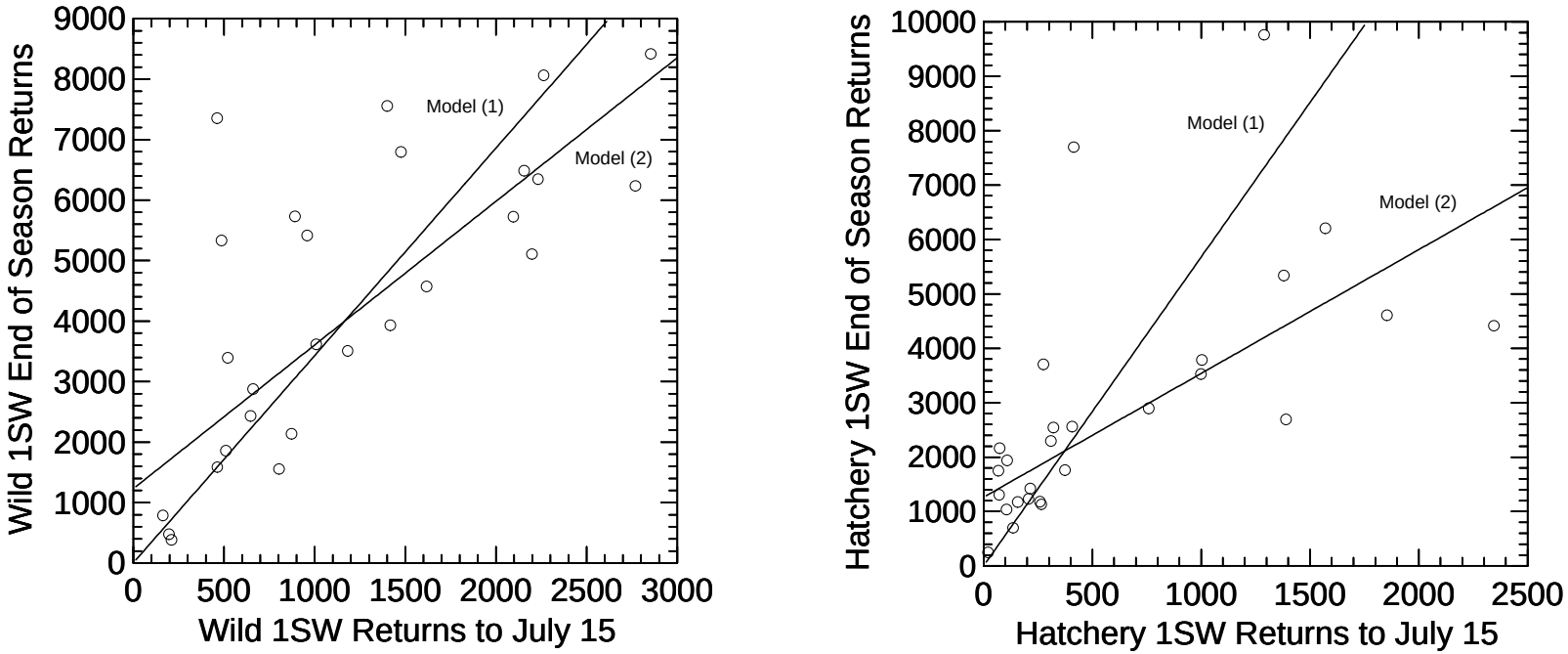


**Figure 1.** Plot of wild (left) and hatchery (right) 1SW end of season returns against returns to July 15, 1972 to 1998, on the Saint John River.

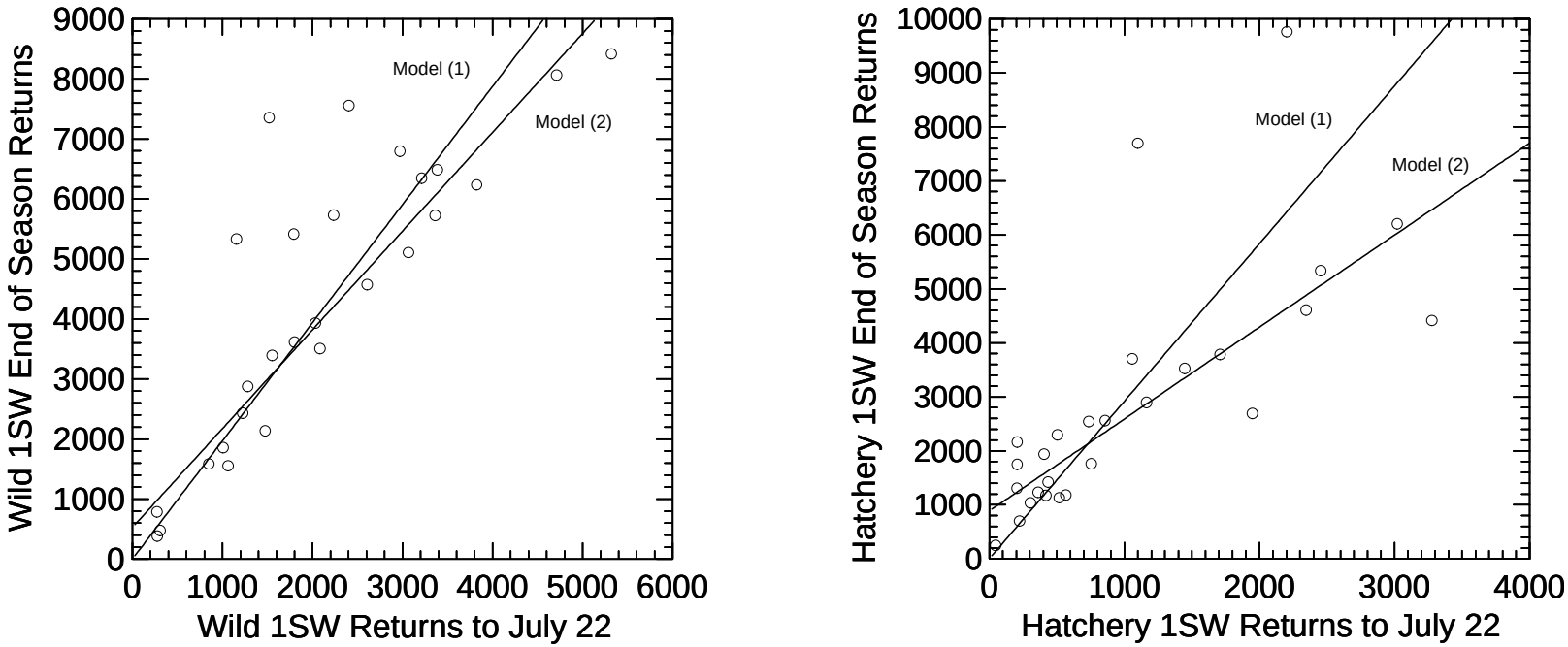


**Figure 2.** Plot of wild (left) and hatchery (right) 1SW end of season returns against returns to July 22, 1972 to 1998, on the Saint John River.

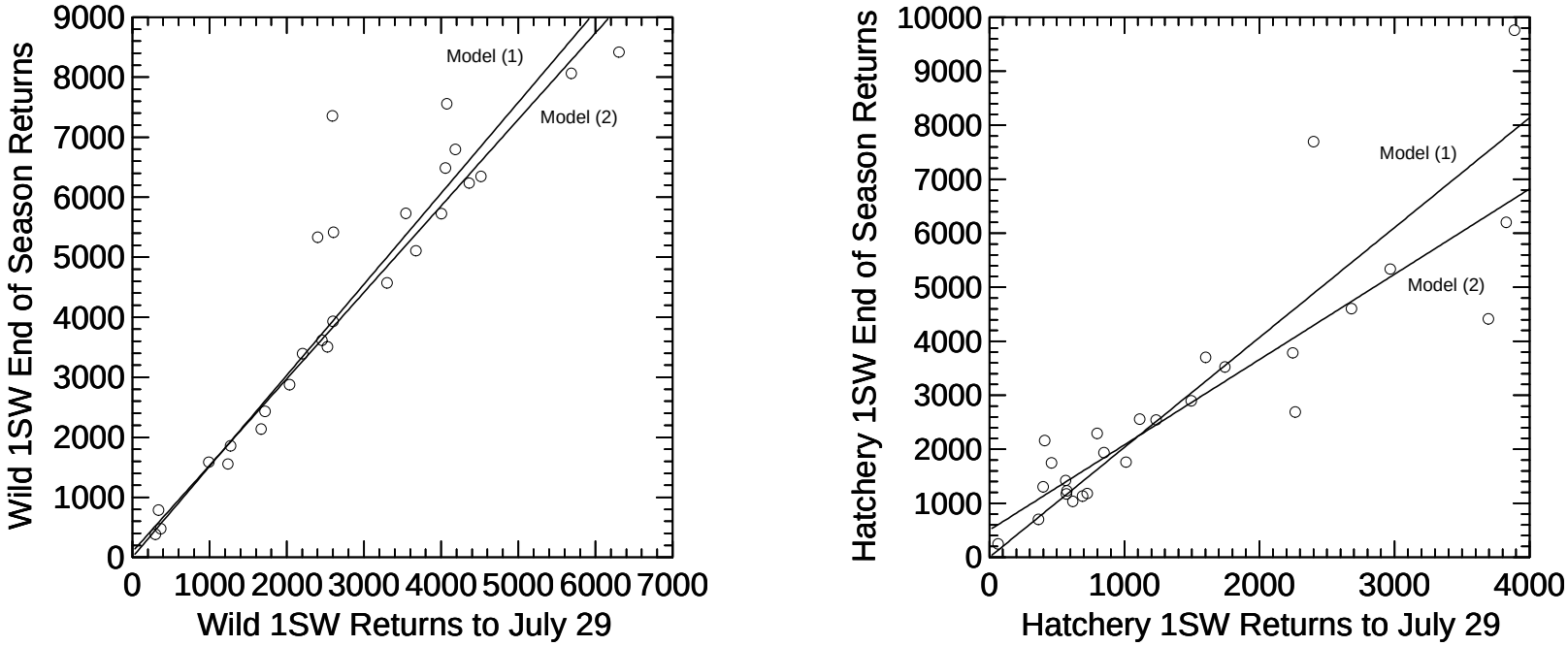


**Figure 3.** Plot of wild (left) and hatchery (right) 1SW end of season returns against returns to July 29, 1972 to 1998, on the Saint John River.