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New and revised catch forecasts for two-sea-winter Atlantic salmon *(Salmo salar)* in Icelandic rivers[1]

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Summary

Linear and multiple regression analysis was used to develop and improve models to forecast catches of two-sea-winter (2SW) Atlantic salmon (*Salmo salar*) from 43 Icelandic rivers. Catches of 2SW salmon in a given year were forecast based upon yields of grilse (fish that remain one year at sea) the previous year and upon three sea-temperature variables from hydrographic stations in western and northern Iceland. Highly significant relations ($P < 0.01$) were found between grilse and 2SW salmon catches for 12 of 21 western rivers and 18 of 22 northern rivers. Nine of the 22 northern rivers had at least 60% of their variation in 2SW salmon catches explained by grilse catches the previous year. Because of collinearity between sea temperatures and grilse catches, little benefit was derived by adding sea temperature to the models based on grilse and 2SW salmon; in few rivers did the sea temperatures explain significant additional variation at $P < 0.05$.

Zusammenfassung

Neue und revidierte Ertragsvorhersagen für "two-sea-winter" Atlantische Lachse (Salmo salar) in isländischen Flüssen

Modelle zur Ertragsvorhersage von "two-sea-winter" (2SW) Atlantischen Lachsen *(Salmo salar)* wurden mit Hilfe linearer, multipler Regressionsanalyse für 43 isländische Flüsse entwickelt und verbessert. Bei "two-sea-winter" Lachsen handelt es sich um Tiere, die zwei Jahre im Meer verbrachten, bevor sie zum Laichen ins Süßwasser zurückkehrten. Die Jahreserträge an 2SW-Lachsen wurden vorhergesagt aus den Vorjahreserträgen an Grilse (Fische, die ein Jahr im Meer verbracht hatten). Zusätzlich wurden drei Variablen aus Temperaturen in See berücksichtigt, die auf Daten hydrographischer Stationen an der West- und Nordküste Islands basieren.

Für 12 von 21 westlichen Flüssen und für 18 von 22 nördlichen konnten statistisch sehr signifikante Beziehungen ($P < 0.01$) zwischen den Erträgen an Grilse und 2SW-Lachsen ermittelt werden. Bei 9 der 22 nördlichen Flüsse war jeweils mindestens 60% der Ertragsvariation für 2SW-Lachse durch die Grilse-Erträge im Vorjahr erklärt. Aufgrund der Kollinearität zwischen den See-Temperaturen und den Grilse-Erträgen war die Berücksichtigung der Temperaturvariablen in den Modellen von geringem Nutzen; für nur wenige Flüsse konnten die See-Temperaturen einen signifikanten zusätzlichen Varianzanteil erklären ($P < 0.05$).

Résumé

De nouveaux modèles ameliorés de prévision des rendements du saumon atlantique deux-mers-hiver (Salmo salar) de fleuves islandiques

Une analyse linéaire et de regression multiple a été utilisée pour développer et améliorer les modèles de prévision des rendements du saumon atlantique (2SW) deux-mers-hiver *(Salmo salar)* en provenance de 43 fleuves islandiques. Les rendements du saumon 2SW pendant une année ont été prévus basés sur le rendement de grilse (poissons restant en mer pendant un an) de l'année précédente, et sur trois variables de température de mer basés sur les donnés de stations hydrographiques en Islande de l'ouest et du nord.

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Des rapports très significatifs ($P < 0.05$) ont été trouvés entre les rendements du grilse et du saumon 2SW pour 12 sur 21 fleuves de l'ouest et 18 sur 22 fleuves du nord. Au moins 60% des variations des rendements du saumon 2SW dans neuf sur 22 fleuves du nord peuvent être expliqués par le rendement du grilse de l'année précédente. L'addition de la température de mer aux modèles basés sur le grilse et le saumon 2SW a été peu profitable à cause de la colinéarité entre la température de mer et les rendements du grilse; les températures de mer ont expliqué une variation significative additionnelle de $P < 0.05$ dans peu de fleuves.

Introduction

One successful method of forecasting catches of multi-sea-winter (MSW) Atlantic salmon *(Salmo salar)* has been to use the predicted catch and escapement of fish of the same smolt class that returned to the rivers the previous year or years. This age-structure method has had a long history with Atlantic salmon (Jacobsson and Johansen 1921) and has more recently been used successfully for Pacific salmons (*Oncorhynchus* sp.; Peterman 1982; U. S. General Accounting Office 1983). To successfully apply this method, reliable data or indices of abundance of different ages of salmon are needed.

Kristjánsson (1982) and Scarnecchia (1984b) have developed equations for a total of 15 Icelandic rivers to predict catches of two-sea-winter (2SW) Atlantic salmon from catches of grilse (fish that remain one year at sea) the previous year. In both cases, ages of salmon were determined upon the basis of weight-frequency distributions, and data from both sexes were combined before the separation into ages. Since those studies were completed, data from those 15 rivers and 28 other rivers have been analyzed separately by sex. Data from all 43 rivers have been summarized as a first step toward development of predictive models for all of Iceland's major and most of its minor salmon rivers that contain adequate numbers of MSW fish.

Scarnecchia (1984b) suggested that, to improve the accuracy of predictions from age-structure models, it might be useful to include environmental variables. Peterman (1985) concluded that similar annual variations in the ages of maturity among different Bristol Bay stocks of sockeye salmon *(Oncorhynchus nerka)* probably resulted from oceanic conditions during the early marine life of the fish. Recently, Scarnecchia et al. (1989a, b) have reported that higher grilse (yr x) to 2SW salmon (yr x+1) ratios on several northern and western Icelandic rivers are associated with higher spring sea temperatures in seas around Iceland. They suggested that these higher temperatures are associated with more productive conditions for growth of smolts (Scarnecchia 1984a) and that in warmer years, more smolts might mature as grilse rather than as 2SW fish. For Icelandic salmon, if oceanic conditions affect the grilse (yr x) to 2SW (yr x+1) salmon ratios, it might be useful to account for the variations in ages of returning salmon in these age-structure models.

Our objective in this paper is to develop new and improve existing predictions for catches of 2SW salmon from 43 different Icelandic rivers. For those 15 rivers for which models already exist (Kristjánsson 1982; Scarnecchia 1984b), data are re-analyzed with age-structure data calculated separately by sex. For the remaining rivers, models are developed and their reliability assessed. In addition, three sea-temperature variables are used as indicators of oceanic conditions in an attempt to account for unexplained variation in the age-structure models.

Materials and methods

Salmon data

For 43 rivers (Figure 1), age composition of returning salmon was based on actual counts of salmon caught by anglers. Most of these rivers support rod angling only (Gudjónsson 1978). Unfortunately, data on escapements are either unavailable or insufficient to be useful,

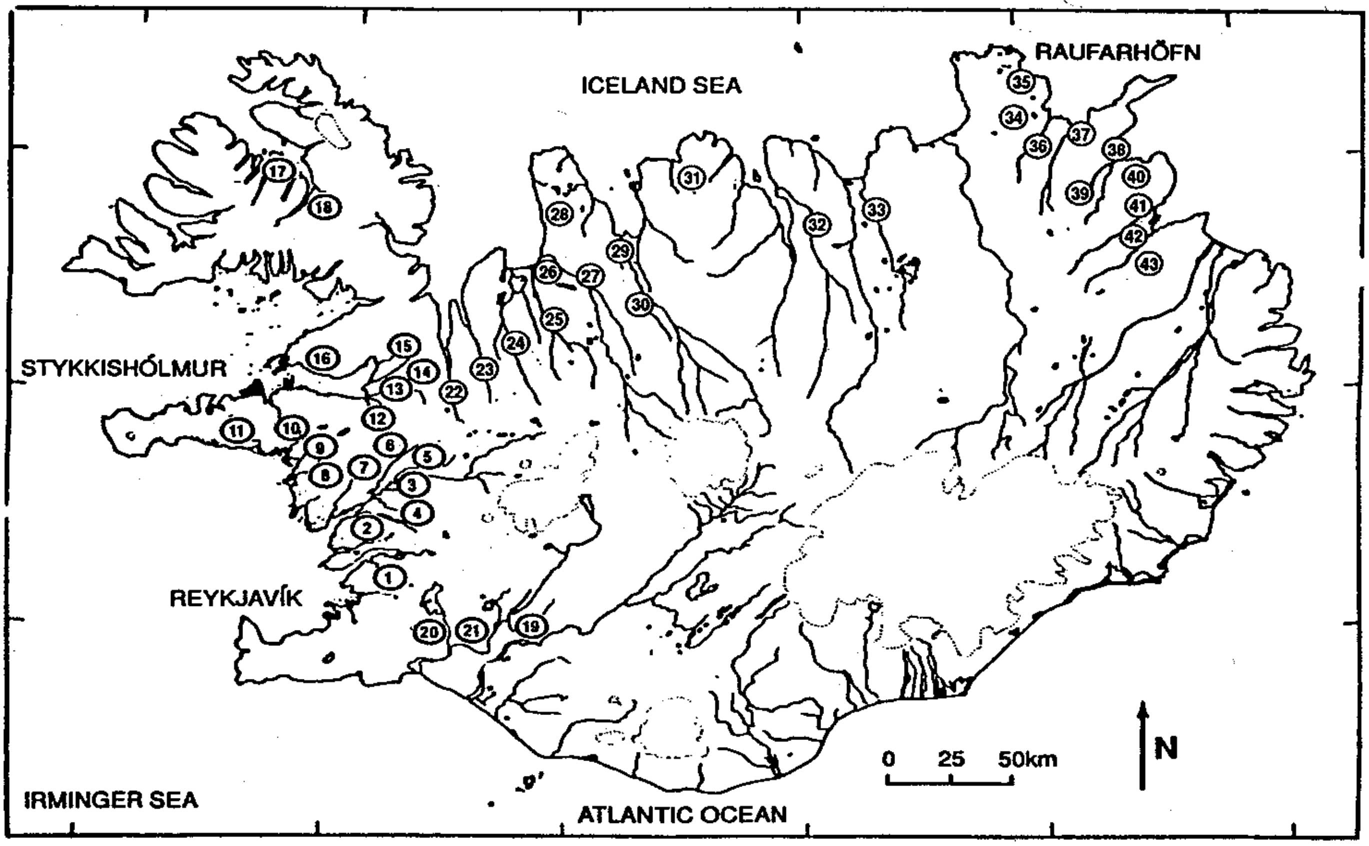

Fig. 1. Locations and rivers of Iceland mentioned in text. 1, Laxá í Kjós; 2, Laxá í Leirársveit; 3, Hvítá (Borgarfjördur); 4, Grímsá/Tunguá; 5, Thverá; 6, Nordurá; 7, Langá; 8, Álftá; 9, Hítará; 10, Haffjardará; 11, Straumfjardará; 12, Midá í Dölum; 13, Haukadalsá; 14, Laxá í Dölum; 15, Fáskrúd; 16, Flekkudalsá; 17, Laugardalsá; 18, Langadalsá; 19, Stóra-Laxá; 20, Sogid; 21, Ölfusá-Hvítá-Brúará (combined); 22, Hrútafjardará; 23, Midfjardará (Hunaflói); 24, Vídidalsá; 25, Vatnsdalsá; 26, Laxá á Ásum; 27, Blanda-Svartá; 28, Laxá-Ytri; 29, Saemundará; 30, Húseyjarkvísl; 31, Fljótaá; 32, Fnjóská; 33, Laxá í Adaldal; 34, Ormarsá; 35, Deildará; 36, Svalbardsá; 37, Sandá; 38, Hölkná; 39, Hafralónsá; 40, Midfjardará (Bakkaflóa); 41, Selá; 42, Vesturdalsá; 43, Hofsá

so all relations were based on catches (numbers of fish caught) rather than total abundance estimates (catch plus escapement). There is no significant fishery in the sea by Icelanders that would bias the catches (Ísaksson 1980), but long-standing net fisheries exist in the river Hvítá (Borgafjördur) and the Ölfusá-Hvítá-Brúará system that may bias age structures. Catches from several other rivers in Borgafjördur that flow into Hvítá may also be affected. A few other small traditional commercial fisheries have also existed at various times over the available time series. Their effects on the stocks are unknown.

The length of the angling seasons is limited by law (The Salmon, Trout and Char Fishing Act 1970), and the number of rods permitted is in general the same from year to year. In this paper, we assumed that catches were representative of abundance, at least over periods of adjacent years. In some rivers, incompletely reported data, known effort changes, substantially increasing catches associated with effort changes, or other biases such as fish ladders made it impossible to compare one year's data with that of a previous or succeeding year. Such years known to us were omitted before any analysis was done. The longest time series was 39 years (Table 1).

For the angling data, weight and sex of individual salmon had been recorded at the time of capture. For each year, the numbers of grilse and 2SW salmon caught were calculated

Table 1. **Regression equations and coefficients of determination for relations between grilse (G; yr x) and 2SW salmon catches (S; yr x+1) from 21 Icelandic west coast rivers**

River	Yrs investigated	Coefficient of determination	Equation
Laxá í Kjós	1949–50 1953–56 1959–82	0.33**	S = 157.0960 + 0.2029 (G)
Laxá í Leirársveit	1955–83	0.59**	S = 84.9519 + 0.2111 (G)
Hvítá (Borgarf)	1967–79 1982–84	0.26	S = 52.5533 + 0.1522 (G)
Grímsá	1972–84	0.33	S = 114.6079 + 0.1007 (G)
Thverá	1956–73 1976–82	0.60**	S = 165.9216 + 0.3820 (G)
Nordurá	1949–78 1981–84	0.45**	S = 170.6194 + 0.2994 (G)
Langá	1965–84	0.72**	S = 33.750 + 0.1345 (G)
Álftá	1965–84	0.39**	S = 8.6586 + 0.2719 (G)
Hítará	1961–62 1965–84	0.09	S = 65.7320 + 0.0969 (G)
Haffjardará	1969–84	0.30*	S = 113.5399 + 0.2562 (G)
Straumfjardará	1965–84	0.17	S = 81.3074 + 0.1588 (G)
Midá í Dölum	1970–78 1981–84	0.00	S = 45.6807 − 0.0132 (G)
Haukadalsá	1948–60 1963–84	0.64**	S = 37.8721 + 0.4146 (G)
Laxá í Dölum	1946–84	0.43**	S = 80.3979 + 0.3718 (G)
Fáskrúd	1949–84	0.30**	S = 40.8670 + 0.2701 (G)
Flekkudalsá	1961–82	0.34**	S = 25.6239 + 0.1326 (G)
Laugardalsá	1954–84	0.52**	S = 27.1326 + 0.3279 (G)
Langadalsá	1961–74 1978–84	0.78**	S = −15.1138 + 1.3247 (G)
Stóra Laxá	1974–78 1981–84	0.23	S = 112.4176 + 0.6998 (G)
Sogid	1975–84	0.41	S = 16.1782 + 0.2788 (G)
Ölfusá-Hvítá-Brúará	1964–84	0.04	S = 245.8388 + 0.0709 (G)

* = $P < 0.05$; ** = $P < 0.01$.

separately for each sex on the basis of weight-frequency distributions. This approach was used because of the observed sex-specific weight differences within stocks. Once fish had been classified by age separately according to sex, the sexes were combined for all further analyses. Overall, weights seemed to allow accurate classification for most stocks, but there was less overlap of modes in northern stocks (Nos. 22–43) than in western stocks (Nos. 1–21). Scale samples indicated that repeat spawners were present, and some were inadvertently classified as 2SW salmon and occasionally as grilse. Because scale data were unavailable for all but scattered instances, any repeat spawners classified as grilse or 2SW salmon by weight were included in these groups. Three-sea-winter salmon were scarce or absent, depending on the river, and were not included in the analyses.

Sea temperature data

Data on sea temperatures were obtained from Stykkishólmur, on Iceland's west coast, and Raufarhöfn, on the northeast coast, from the Icelandic National Weather Office. Monthly means were based on several, usually equally spaced, measurements per month. Three different temperature variables were used (Scarnecchia et al. 1989a, b). The first temperature variable (T1) was the sum of monthly mean temperatures from May to December (yr x–1), corresponding to the time period when the smolts would enter the sea and begin rapid growth until their first winter at sea. The second variable (T2) was the sum of mean monthly temperatures from May (yr x) to April (yr x+1), corresponding to the time from when grilse would be returning to the rivers to when 2SW salmon would be returning. The third variable (T3) was the mean April–May (yr x−1) temperature, which was used to indicate sea conditions in spring and early summer, just before the smolts would be entering the sea. PETERMAN (1985) suggested that ocean conditions during this last period, when the smolts are entering the sea, may be important in influencing age at maturity. Data from Stykkishólmur were analyzed in conjunction with catch data from the western rivers (Nos. 1–21), and data from Raufarhöfn were analyzed with data from the northern rivers (Nos. 22–43).

Less than 1 % of the monthly temperature values needed for the analyses were missing, and these values were estimated from the average of the 10 monthly means from surrounding years, five before and five after.

Statistical analyses

Simple linear and stepwise multiple regressions were used to identify the relations between catch of 2SW salmon (dependent variable) and grilse catch and sea temperature variables T1, T2, and T3 (independent variables). The regressions were of the Y on X predictive type rather than functional (RICKER 1973) inasmuch as the grilse were based on actual counts. In the stepwise analyses, grilse catches were forced into the model first, and temperature variables were then added in stepwise fashion. The criterion for entry of temperature variables into the model was $P < 0.20$. Because both sea temperatures and salmon catch time series tend to be autocorrelated, residuals of linear relations between variables entering the models were analyzed for autocorrelation with a Durbin-Watson statistic. Homogeneity of variance, linearity, and normality of residuals were also evaluated for each of the stepwise models.

Results

Two-sea-winter salmon catches (yr x+1) versus grilse catches (yr x).

Highly significant ($P < 0.01$) positive relations between grilse and 2SW salmon catches were found for 12 of 21 western rivers (Table 1) and 18 of 22 northern rivers (Table 2). Three additional (significant at $P < 0.05$) positive relations were also found, one in the west (Table 1) and two in the north (Table 2).

Among the western rivers, relations were generally closer for rivers with larger catches and more consistent reporting, such as Thverá (Figure 2a), Nordurá (Figure 2b), Langá, Langadalsá, Laugardalsá (Figure 2c), and Haukadalsá. Some western rivers with statistically insignificant ($P > 0.05$) relations such as Midá í Dölum, Hítará, and Straumfjardará, had poor catch statistics that were reported inconsistently and often not separated by sex. Other rivers such as Hvítá (Borgafjördur), Stóra-Laxá, Sogid, and the Ölfusá-Hvítá-Brúará system, are influenced by commercial fisheries, and the rod catch is small compared with commercial catch on these rivers. For these rivers, it is unlikely that meaningful predictive relations can be developed with this approach.

Relations for the northern rivers (Table 2) were generally much closer than for the western rivers. Nine of the 22 northern rivers had at least 60 % of their variation in 2SW salmon catches explained by grilse catches the previous year. In contrast, only four western rivers had relations this close. Even smaller northern rivers such as Fljótaá (Figure 2d), Fnjóská (Figure 2e), Sandá (Figure 2g), and Midfjardará (Bakkaflóa) (Figure 2h) showed close relations. The relation for the important river Laxá í Adaldal (Figure 2f) was highly significant ($P < 0.01$), but less close.

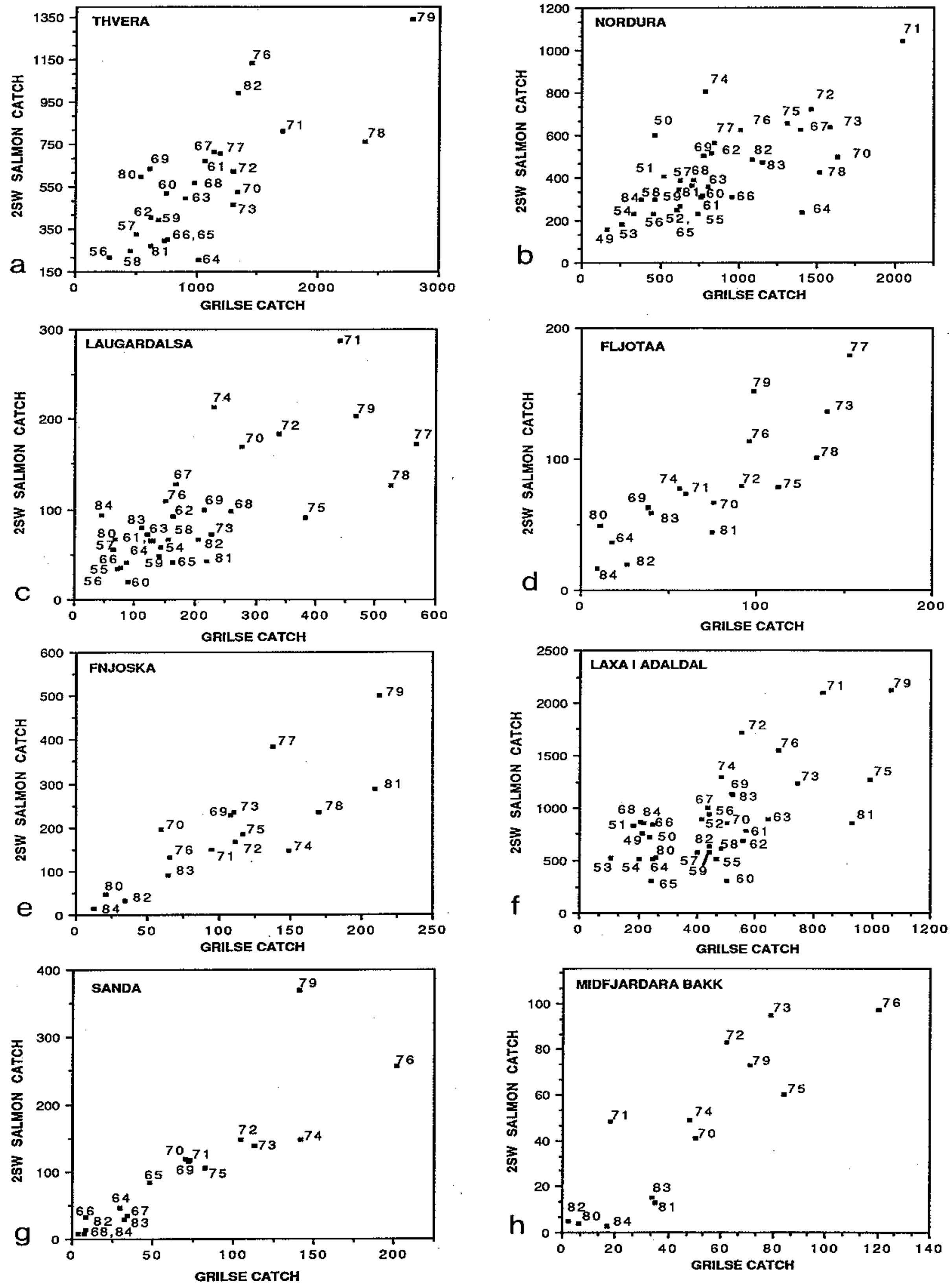

Fig. 2. Relation between grilse (yr x) and 2SW salmon (yr x+1) catches for a, Thverá; b, Nordurá; c, Laugardalsá; d, Fljótaá; e, Fnjóská; f, Laxá í Adaldal; g, Sandá; and h, Midfjardará (Bakkaflóa). Equations and coefficients of determination are in Tables 1 and 2

Table 2. **Regression equations and coefficients of determination for relations between grilse (G; yr x) and 2SW salmon catches (S; yr x+1) from 22 Icelandic north coast rivers**

River	Yrs investigated	Coefficient of determination	Equation
Hrútafjardará	1958–59 1962–68 1971–81	0.52**	S = 41.6199 + 0.5735 (G)
Midfjardará	1956–84	0.65**	S = 114.4203 + 0.7598 (G)
Vídidalsá	1961–75 1978–84	0.38**	S = 371.4113 + 0.4919 (G)
Vatnsdalsá	1961–84	0.64**	S = 175.8069 + 0.6345 (G)
Laxá á Ásum	1961–65 1968–84	0.46**	S = 55.7736 + 0.3217 (G)
Blanda-Svartá	1964–77 1980–84	0.22*	S = 440.5821 + 0.7504 (G)
Laxá-Ytri	1956–82	0.44**	S = 1.0229 + 0.7840 (G)
Saemundará	1967–68 1971–81	0.27	S = 39.7841 + 0.7232 (G)
Húseyjarkvísl	1970–84	0.54**	S = −10.2628 + 1.5622 (G)
Fljótaá	1964 1969–84	0.72**	S = 18.8622 + 0.8335 (G)
Fnjóská	1969–84	0.69**	S = 8.0920 + 1.729 (G)
Laxá í Adaldal	1949–76 1979–84	0.44**	S = 247.5823 + 1.3464 (G)
Ormarsá	1974–76 1979–84	0.36	S = 12.7242 + 0.6071 (G)
Deildará	1970–76 1979–84	0.41	S = 23.4080 + 0.5478 (G)
Svalbardsá	1969–76 1979–84	0.50**	S = 21.2163 + 1.0339 (G)
Sandá	1964–76 1979 1982–84	0.76**	S = 2.9838 + 1.4665 (G)
Hölkná	1971–76 1979–84	0.58**	S = −1.6898 + 1.6300 (G)
Hafralónsá	1971–76 1979–80 1983–84	0.59**	S = 25.8900 + 1.6674 (G)
Midfjardará (Bakkaflóa)	1970–76 1979–84	0.76**	S = 2.5354 + 0.8834 (G)
Selá	1955–66 1969–75 1979–84	0.62**	S = 15.0109 + 0.8654 (G)
Vesturdalsá	1956–69 1972–76 1979–84	0.83**	S = 19.7302 + 0.7170 (G)
Hofsá	1961–76 1979–84	0.71**	S = 51.2203 + 0.9289 (G)

* = $P < 0.05$; ** $P < 0.01$.

Do the sea temperature variables explain the residual variation in these relations?

Twelve of 21 western rivers had one or more temperature variables enter the models at $P < 0.20$. April–May temperature (T3) explained significant ($P < 0.05$) additional variation in catch of 2SW salmon for four western rivers: Haukadalsá (5 %), Laxá í Dölum (16 %), Fáskrúd (13 %), and Laugardalsá (9 %). May–December temperature (T1) explained significant additional variation in 2SW salmon catch for the western river Álftá. April–May and May–December temperatures entered the equations negatively, consistent with the hypothesis that grilse would be more abundant relative to salmon in years when seas were warmer and more productive for smolts. A second temperature variable entered the equations for several rivers. The remaining nine western rivers showed no benefits of the temperature variables.

Twelve of the 22 northern rivers had one or more temperature variables enter the models at $P < 0.20$, but few temperature variables explained significant ($P < 0.05$) additional variation in the catches of 2SW salmon. April–May temperature explained significant additional variation in only one river – Laxá á Ásum. May–December temperature explained significant additional variation in two other rivers – Blanda-Svartá and Hofsá, but the variable entered the model in the opposite direction from that hypothesized. A second variable entered the equations for several rivers. The frequency of the significant results was similar to that expected by chance. The remaining 10 northern rivers showed no benefits of the temperature variables. Equations including temperatures for all 43 rivers are available from the senior author.

On the basis of graphic printouts (interpreted by eye) of residuals from the stepwise models, seven of the 43 rivers showed indications of heteroscedasticity that might have called for methods to stabilize the variance. In only two of the 43 cases was a nonlinear model indicated, and in only two cases were residuals evidently not normally distributed. On the basis of the Durbin-Watson test, six rivers (four in the west and two in the north) had positively autocorrelated residuals, and results for two other rivers were inconclusive. Inasmuch as the frequencies of these problems were low, log transformations (Scarnecchia 1984b) of data sets or similar measures were not pursued in this study.

Discussion

The notably closer relations between grilse and salmon for the northern rivers than for the western rivers may have resulted from any of three (or more) factors. First, net fisheries in the Hvítá (Borgafjördur), and Ölfusá-Hvítá-Brúará systems undoubtedly altered the numbers of grilse and salmon available to rod anglers. Although Scarnecchia et al. (1989a, b) found no evidence that these net fisheries significantly reduced the percentage on 2SW salmon over time, the variable harvests between years probably altered the annual grilse to 2SW salmon relations.

Second, grilse and 2SW salmon were less easily distinguished on the basis of weight frequencies for western stocks than for northern stocks. More western fish probably were misclassified according to age, with a resultant loss of accuracy in the predictive models. The reason for the reduced distinguishability is not known, but we suspect that the western stocks may exhibit several variations in life histories and resultant variations in growth rate that do not fit our assumed simple classification. More research is needed on the life histories, based on more extensive scale samples than are now available. Scale samples would result in improved understanding of the ecology of Icelandic salmon and also result in more accurate age classification for western and northern stocks.

Third, the closer relations for the northern stocks may be a statistical result of their inherently greater variation in catches. From these stocks catches may vary more than tenfold between years, whereas catches from western stocks generally vary three- or fourfold between years. Preliminary studies indicate that annual catches vary most in the northeast, where the best predictive relations have been found.

Despite the need for improvements, we have presented several new relations for northern and western rivers that are strong enough for effective use in predicting catches of 2SW salmon. Highly significant relations between grilse catches and 2SW salmon catches for Thverá, Langá, Haukadalsá, Fljótaá, Fnjóská, Sandá, and Midfjardará (Bakkaflóa) will provide managers and Icelandic Fishing Associations with a tool for forecasting catches from these rivers. Seven of the 43 rivers showed heteroscedasticity problems (i. e. increasing

Table 3. **Correlation coefficients (r) between grilse catches and the three sea temperature variables for 22 northern Icelandic rivers.** Data are logged as outlined in methods section

River	Sea temperature variable		
	T1	T2	T3
Hrútafjardará	0.69**	−0.13	0.76**
Midfjardará	0.70**	0.20	0.59**
Vídidalsá	0.64**	−0.08	0.60**
Vatnsdalsá	0.61**	−0.15	0.52**
Laxá á Ásum	0.65**	0.28	0.55**
Blanda-Svartá	0.68**	−0.02	0.66**
Laxá-Ytri	0.16	−0.15	0.07
Saemundará	0.70**	0.56*	0.55*
Húseyjarkvísl	0.60*	0.14	0.34
Fljótaá	0.69**	0.18	0.43
Fnjóská	0.75**	−0.42	0.64**
Laxá í Adaldal	0.04	−0.18	0.06
Ormarsá	0.74**	0.23	0.46
Deildará	0.86**	0.03	0.81**
Svalbardsá	0.73**	0.35	0.62**
Sandá	0.76**	0.31	0.45*
Hölkná	0.72**	0.34	0.55*
Hafralónsá	0.74**	0.11	0.61*
Midfjardará (Bakk)	0.73**	0.24	0.57*
Selá	0.32	0.05	0.16
Vesturdalsá	0.50**	0.29	0.31
Hofsá	0.44*	0.41	0.28

* = P < 0.05; ** P = < 0.01.

variance for Y variate as X increased) that could perhaps be corrected by plotting the relations for the natural logarithm of grilse and salmon catches and thereby stabilizing the variance (Peterman 1982; Scarnecchia 1984b). Statistically appropriate model equations and improved predictions could result.

However, we found that, although catches of grilse could often be used as an effective predictor of 2SW salmon catches, there was little or no gain in predictive capability by adding sea-temperature variables to the model. Overall, sea temperatures significantly contributed to explaining variation in yields of 2SW salmon only about as frequently as would be expected by chance alone. This result differs substantially from the findings in Scarnecchia et al. (1989a, b), where sea temperatures (Mean April–May [yr x−1] and May–December (yr x−1)) were shown to be related to ratios of grilse (yr x) to salmon (yr x+1) for several northern and western rivers. The observed difference results from collinearity between mean April–May sea temperature (T3) and grilse catches, and a similar collinearity between May–December sea temperatures (T1) and grilse catches (Table 3). In the models used in Scarnecchia et al. (1989a, b), sea temperatures were plotted against the ratio of grilse (yr x) to salmon (yr x+1). However, in the present paper, sea temperatures were evaluated to explain variation in salmon catches *after* grilse catches had already explained much of the variation. In seeking to explain much of the variation in 2SW salmon catches with environmental variables, it could thus be better to use an environmental variable hypothesized to affect 2SW salmon catches but not correlated with grilse catches. Under present circumstances, a more effective approach is to forecast grilse catches one year in advance from sea temperatures the previous year, then use the actual grilse catch by itself to forecast 2SW salmon catch one year in advance. This approach will work particularly well for some of the northern rivers, where relations between sea temperatures and grilse (Scarnecchia 1984a) and grilse and 2SW salmon (Scarnecchia 1984b) are strongest.

The relations presented here are based on catches. We have thus assumed that catches reflect abundance of the stocks similarly between years and that minimal human modifications have occurred in the stocks. Human attempts at stock enhancement, through releases of smolts, stocking of parr, and other activities, are increasing on Icelandic rivers. As annual fishing patterns and stock characteristics change more rapidly, the relations presented above may break down. Ultimately, some indices of escapement should be obtained for at least selected Icelandic rivers so that predictions could be based on total abundance rather than catches. These rivers could then perhaps be used as "indicators" for forecasting catches from neighboring rivers.

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