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Inter-annual and Inter-river Variability in Fecundity in Atlantic Salmon (*Salmo salar* L.) in Newfoundland Region Rivers

by

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Abstract

Fecundity is an important parameter used in the calculation of Atlantic salmon egg depositions for rivers in the Newfoundland Region. It is usually derived from ovaries collected in the recreational fishery during summer. The process involved in fecundity determinations is time consuming and expensive. From this perspective, it would be desirable to know the extent on inter-annual and inter-river variability in fecundity and the risk involved in using default values as a means of reducing cost. Annual fecundity data were available for one river in Labrador and nine rivers in insular Newfoundland. Most rivers showed significant annual variability in relative fecundity expressed in terms of weight (egg/kg) and length (eggs/cm) and there were significant differences among rivers as well. There was also a suggestion that there are regional differences in fecundity, for instance between northeast coast rivers and south coast rivers. Fecundity for repeat spawning grilse tended to be higher than for virgin grilse and significantly so for some rivers. Given the magnitude of the differences observed within and among rivers, in order to minimize the risk of error in the calculation of egg depositions, the use of defaults should be avoided.

Résumé

L'un des paramètres importants utilisés dans le calcul de la ponte d'oeufs de saumon de l'Atlantique dans les rivières de la région de Terre-Neuve est celui de la fécondité. Elle est calculée habituellement en fonction des ovaires recueillis pendant l'été dans le cadre de la pêche récréative. La détermination de la fécondité prend du temps et coûte cher. C'est pourquoi il serait souhaitable de connaître l'ampleur de la variabilité de la fécondité à l'intérieur d'une même année et dans une même rivière de même que le risque inhérent à l'utilisation de valeurs par défaut dans le but de réduire les coûts. Il a été possible d'obtenir des données sur la fécondité annuelle dans une rivière du Labrador et dans neuf rivières du plateau continental insulaire de Terre-Neuve. La variabilité annuelle de la fécondité relative exprimée en termes de poids (oeufs/kg) et de longueur (oeufs/cm) était considérable dans la plupart des rivières. De plus, les écarts étaient importants d'une rivière à une autre. Par ailleurs, certaines personnes croient que la fécondité varie suivant les régions, par exemple des rivières de la côte nord-est aux rivières de la côte sud. Certaines tendances montrent que la fécondité est plus marquée chez les saumons ayant déjà frayé que chez le saumon qui fraie pour la première fois. C'est tout particulièrement le cas dans certaines rivières. Compte tenu de l'ampleur des écarts observés au sein d'une même rivière et d'une rivière à une autre, il faudrait éviter d'avoir recours à des valeurs par défaut, afin de minimiser le risque d'erreurs dans les calculs de la ponte.

Introduction

Where possible, all biological parameter values used in the calculation of egg deposition for Atlantic salmon should be provided annually and on a river-specific basis. The use of defaults in the absence of such information results in uncertainty around conclusions drawn about the status of stocks in relation to conservation egg deposition and spawner requirements.

Fecundity is one of the most important parameters used in the calculation of Atlantic salmon egg depositions (O'Connell and Dempson 1995; Dempson and Furey MS 1996; O'Connell *et al.* MS 1996; Reddin *et al.* MS 1996) for rivers in the Newfoundland Region. Fecundity is usually determined from ovaries collected in the recreational fishery, which occurs from mid-June to early September each year, with most of the catch typically being taken in July-early August. The collection and processing of ovaries and counting of eggs on an annual basis is costly and very time consuming. From the perspective of reducing cost, it would be desirable to know the extent of inter-annual and inter-river variability in fecundity, which could provide some idea of the risk involved in using defaults. This is examined for small salmon (< 63 cm in fork length) for one river in Labrador and nine rivers in insular Newfoundland.

Materials and Methods

A map showing the locations of the rivers studied and the Salmon Fishing Areas (SFAs) in which they are found is provided in Fig. 1. Sand Hill River is located in Labrador and the remainder in insular Newfoundland.

Eggs were collected in the recreational fishery and stored in Gilson's fluid until ovarian tissue had broken down, after which time they were transferred to 10% formalin. Eggs were counted directly. All fish were measured for fork length (cm) and whole weight (kg) and scales removed for ageing and life-history analysis.

Individual regressions of number of eggs on fork length (both variables ln transformed) typically displayed wide scatter, were not significant ($P > 0.05$) in some instances, and had low r^2 values. Also, there were wide differences in sample sizes. This precluded the use of a general linear model for comparisons among years and rivers using fecundity with length as a covariate, such as employed by Winters *et al.* (1993). Therefore, non-parametric comparisons [Wilcoxon two-sample test (Z) or Kruskal-Wallis (K) test for more than two groups] were performed on individual values of relative fecundity (number of eggs per kg of body weight and number of eggs per cm of body length) using the NPAR1WAY procedure of SAS (SAS Institute 1985). Mean number of eggs per kg or cm and associated 95% confidence limits were estimated using the ratio estimator techniques of Cochran (1977).

Results

Relationships between fecundity and fork length in general were weak and whether regressions were examined on a yearly basis or with years combined for a given river, in many cases they were not significant and r^2 values were low (Figs. 2-10). Considerable extremes in yearly r^2 values were noted for nearly all rivers. For example, values ranged from 0.0030 in 1995 to 0.2127 in 1994 for Sand Hill River (Fig. 2); 0.0162 in 1993 to 0.2170 in 1994 for Campbellton River (Fig. 4); 0.0000 in 1989 to 0.3489 in 1992 for Gander River (Fig. 5). Sample sizes for the regressions and all other analyses are provided in Table 1.

Mean number of eggs per female, mean weight, mean length, and associated upper and lower 95% confidence limits for years separately and combined for each river are presented in Table 1. For relative fecundity in terms of weight (Table 2, Fig. 11), differences among years were significant for all rivers except Exploits River, Campbellton River, Middle Brook, and Northeast River, Placentia (Table 3). In terms of length (Table 2, Fig. 12), differences among years were significant in all cases. Trends in fecundity for both the weight and length designations tended to track each other reasonably well across years for all rivers. It should be cautioned that sample sizes were small (< 20) in many instances and this should be taken into consideration when interpreting trends. Gander River, Biscay Bay River, Northeast River, Placentia, and Conne River possessed the longest time series and had reasonably large sample sizes. Gander River fecundity increased from a low in 1985 to a peak in 1988 and declined (less pronouced in the case of eggs/cm) from that point until 1993. Biscay Bay River fecundity values between 1984 and 1988 followed a somewhat dome shape with 1984 having the lowest values. Values for Northeast River, Placentia were relatively flat in terms of weight while in terms of length there was a slight increasing trend with the widest difference being observed between 1985 (lowest) and 1988 (highest). There was a substantial decline in fecundity from 1988 to 1992 for Conne River.

Comparing fecundity in terms of weight (Table 2, Fig. 13) and length (Table 2, Fig. 14) among rivers each year, there were significant differences in all cases except for the weight designation in 1994 (Table 4). Caution regarding the interpretation of data with respect to small sample sizes applies here also. The years 1984, 1985, and 1986 had reasonably good sample sizes for all rivers except Terra Nova River in 1986. In these years there was a tendency for rivers on the northeast and east coasts (Indian River, Exploits River, Middle Brook, and Terra Nova River) to have lower fecundity values than observed for south coast rivers (Biscay Bay River, Northeast River, Placentia, and Conne River). When data are combined for all years (Fig. 15), the tendency for fecundity in terms of length to be higher for south coast rivers than for notheast and east coast rivers is maintained; however, fecundity for Sand Hill River in Labrador was close to the high value recorded for Northeast River, Placentia, insular Newfoundland. In terms of weight, except for Campbellton River, the same trend as observed for eggs/cm applies to Newfoundland but the value for Sand Hill River falls within the range for northeastern and eastern Newfoundland. The differences among rivers for years combined were significant for both fecundity designations (Table 4).

Figs. 16 and 17 compare fecundity-length relationships of repeat spawning grilse with those of virgin grilse, with all data combined in each life-history group, for Gander River, Middle Brook, Terra Nova River, and Biscay Bay River. These were the only rivers with sufficient sample sizes in the repeat spawners group to permit such an analysis. Both groups displayed wide scatter and r^2 values were low. Fecundity in terms of weight and length is compared between the two groups in Table 5 and Fig. 18. In terms of length, fecundity was higher for repeat spawners for all rivers and significantly so for three of the rivers with the larger repeat spawner sample sizes (Gander River: $Z = 2.10$, $P = 0.0356$; Middle Brook: $Z = 2.54$, $P = 0.0111$; Biscay Bay River: $Z = 4.84$, $P = 0.0001$). With respect to weight, fecundity for repeat spawners was higher in 6 out of 8 cases and was significant for Biscay Bay River only ($Z = 3.02$, $P = 0.0025$).

Discussion

There was significant geographical and temporal variation in fecundity in nearly all instances. The Kruskal-Wallis non-parametric test was sufficient to detect significant differences overall, but since sample sizes were unequal, there is not an appropriate multiple comparisons test (Zar 1974) that could be applied to determine which years (or rivers) were significantly different from each other. Some indication of the magnitude of the differences can obtained by examining the degree of overlap in 95% confidence limits, although caution has to be exercised using this approach and it should not be intended as a substitute for multiple comparisons tests (Zar 1974). For rivers with longer time series, except for Northeast River, Placentia, there is evidence that there can be substantial annual variation in fecundity from the average situation and in some cases there are indications of ascending or descending trends. On a geographic basis, in terms of length, there is an indication that southern rivers are different from northeast and east coast rivers in Newfoundland while the single Labrador river is closer to southern Newfoundland rivers. The demarcations are not as disinct in terms of weight but the tendency for southern rivers to be higher overall remains more or less intact and Labrador is similar to northeast and eastern Newfoundland.

From a stock assessment perspective, the results of this analysis indicate that there is an inherent risk in using information for a single year as characteristic of a given river (and also in using the mean to some degree, depending on the year) and in extrapolating values from one river to another, even though for the latter there appears to be some regional similarities. The problem in extrapolating from one river to another is compounded by the potential annual variability within each river. There is evidence that fecundity for repeat spawning grilse is higher than for virgin grilse. Annual variability in the realtive proportions of these life-history groups will add another element of uncertainty. The above analyses were conducted on ovaries collected in the recreational fishery in the summer, when eggs were in early stages of development, and therefore fecundity values should be regarded as potential. There is evidence that the number of eggs actually laid can be reduced from the number potentially available for ripening as a result of a process called follicular atresia, which can occur to varying degrees in Newfoundland (O'Connell and Dempson MS 1997). It is concluded that if one wishes to minimize risk in calculating egg deposition as far as fecundity is concerned, then every effort should be made to obtain egg counts on an annual basis for each river.

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Table 1. Mean number of eggs per female, mean length (cm) and mean weight (kg) for each river for years separately and combined. N = no. of spawners; UCL and LCL are the upper and lower 95% confidence limits.

River	Year	N	$\bar{X}$ eggs per female	UCL	LCL	$\bar{X}$ length (cm)	UCL	LCL	$\bar{X}$ weight (kg)	UCL	LCL
Sand Hill River	1994	58	4279	4462	4096	55.6	56.3	55	1.89	1.97	1.81
	1995	38	3089	3356	2822	56.1	56.8	55.5	1.93	2.01	1.85
	Years combined	96	3808	3999	3617	55.8	56.3	55.4	1.91	1.96	1.85
Indian River	1984	78	2604	2791	2417	49.5	50.3	48.6	1.44	1.53	1.36
	1985	154	2663	2772	2555	50.7	51	50.4	1.56	1.59	1.53
	Years combined	232	2643	2738	2548	50.3	50.6	49.9	1.52	1.56	1.48
Exploits River	1985	145	2802	2914	2690	53.4	53.9	52.9	1.48	1.52	1.43
	1986	39	2985	3263	2707	52.8	54.1	51.5	1.44	1.53	1.35
	Years combined	184	2841	2946	2736	53.3	53.8	52.8	1.47	1.51	1.43
Campbellton River	1993	45	3163	3315	3010	52.5	53.2	51.8	1.49	1.56	1.43
	1994	20	3415	3739	3091	52.4	53.9	51	1.55	1.68	1.42
	1995	12	2885	3478	2291	51.8	54.2	49.3	1.45	1.66	1.24
	Years combined	78	3178	3324	3032	52.4	53	51.8	1.51	1.56	1.45
Gander River	1984	60	2730	2875	2585	50.9	52.0	49.9	1.51	1.60	1.41
	1985	73	2461	2606	2316	50.9	51.8	50.1	1.62	1.70	1.53
	1986	34	2868	3085	2652	52.9	53.9	51.9	1.73	1.84	1.63
	1987	13	2800	3167	2433	50.4	52.3	48.6	1.55	1.77	1.32
	1988	31	3186	3481	2891	51.9	53.2	50.6	1.58	1.70	1.46
	1989	29	3176	3508	2844	53.8	55.1	52.5	1.60	1.73	1.46
	1990	128	3097	3245	2950	53.3	54.1	52.5	1.78	1.86	1.70
	1992	77	3235	3395	3075	54.0	54.9	53.0	1.77	1.87	1.66
	1993	25	3227	3587	2867	55.7	56.8	54.5	1.97	2.12	1.82
	Years combined	470	2967	3038	2896	52.7	53.1	52.3	1.69	1.73	1.66
Middle Brook	1984	102	2789	2940	2639	49.8	50.7	48.9	1.47	1.55	1.39
	1985	84	3025	3157	2893	50.2	51.1	49.3	1.52	1.59	1.44
	1986	36	3145	3401	2889	52.4	54.0	50.8	1.61	1.76	1.46
	1987	5	2981	3651	2312	50.8	54.1	47.4	1.38	1.83	0.93
	1988	10	2869	3198	2539	49.6	51.3	47.9	1.27	1.44	1.10
	1990	10	3338	3758	2917	53.5	54.9	52	1.76	1.92	1.60
	1993	31	3718	4059	3376	52.9	54.5	51.3	1.73	1.89	1.57
	Years combined	278	3036	3127	2945	50.7	51.3	50.2	1.53	1.58	1.49
Terra Nova River	1984	46	2700	2908	2492	50.4	51.5	49.2	1.58	1.67	1.49
	1985	7	3029	3751	2307	50.6	53.3	48	1.40	1.64	1.16
	1986	15	2213	2774	1653	52.2	54.3	50.2	1.57	1.78	1.36
	1987	3	4568	6379	2756	56.0	66.8	45.2	1.97	2.91	1.03
	1990	5	3878	5470	2286	51.0	56.6	45.4	1.70	2.19	1.21
	1993	8	3005	3549	2460	53.6	57.7	49.6	1.68	2.04	1.31
	Years combined	84	2806	3009	2604	51.3	52.2	50.4	1.59	1.67	1.52
Biscay Bay River	1984	72	3049	3263	2836	51.6	52.5	50.7	1.63	1.73	1.52
	1985	81	3613	3827	3400	52.7	53.4	52.1	1.65	1.70	1.59
	1986	114	3761	3910	3613	53.4	54.0	52.7	1.76	1.82	1.69
	1987	26	3465	3819	3111	52.1	53.8	50.5	1.63	1.78	1.47
	1988	75	3165	3397	2932	52.5	53.4	51.6	1.63	1.70	1.56
	1994	5	3920	4201	3639	56.3	57.4	55.2	1.95	2.30	1.60
	Years combined	373	3453	3549	3357	52.7	53.0	52.3	1.68	1.71	1.64
Northeast River	1984	21	3543	3764	3321	52.2	53.3	51.2	1.52	1.60	1.43
	1985	39	3374	3658	3091	51.9	52.9	50.9	1.53	1.60	1.46
	1986	45	3752	3940	3565	53.5	54.2	52.8	1.64	1.72	1.57
	1988	34	4050	4326	3774	52.8	54.0	51.6	1.64	1.73	1.54
	1990	41	3868	4143	3593	54.5	55.3	53.7	1.55	1.64	1.46
	1993	5	3967	4958	2977	52.6	55.7	49.5	1.85	2.34	1.36
	Years combined	186	3735	3848	3622	53.1	53.5	52.6	1.59	1.62	1.55
Conne River	1986	102	3494	3628	3360	50.9	51.3	50.4	1.48	1.52	1.43
	1987	136	3424	3531	3317	51.1	51.5	50.7	1.45	1.49	1.41
	1988	85	3196	3319	3074	50.2	50.7	49.6	1.35	1.40	1.30
	1990	93	2245	2364	2127	51.1	51.5	50.7	1.45	1.49	1.42
	1991	22	2772	3322	2221	51.7	52.6	50.8	1.35	1.42	1.29
	1992	21	1768	1995	1542	50.6	51.5	49.6	1.38	1.50	1.27
	Years combined	459	3052	3130	2974	50.9	51.1	50.7	1.43	1.45	1.41

Table 2. Relative fecundity (RF) in terms of fork length (eggs/cm) and whole weight (eggs/kg) for each river by years separately and combined. N = no. of spawners; FL = fork length; WW = whole weight; UCL and LCL are the upper and lower 95% confidence limits.

River	Year	N	RF(FL)	UCL	LCL	RF(WW)	UCL	LCL
Sand Hill River	1994	58	76.9	79.9	73.9	2262	2354	2171
	1995	38	55.0	59.8	50.3	1601	1739	1464
	Years combined	96	68.2	71.6	64.8	1998	2098	1897
Indian River	1984	78	52.6	56.1	49.2	1808	1929	1686
	1985	154	52.5	54.6	50.5	1708	1779	1638
	Years combined	232	52.6	54.3	50.8	1740	1802	1679
Exploits River	1985	145	52.5	54.5	50.4	1899	1982	1815
	1986	39	56.5	61.5	51.5	2074	2273	1875
	Years combined	184	53.3	55.3	51.4	1935	2013	1857
Campbellton River	1993	45	60.2	63.1	57.3	2118	2242	1993
	1994	20	65.2	70.7	59.7	2197	2396	1998
	1995	12	55.7	66.2	45.2	1988	2248	1728
	Years combined	78	60.7	63.3	58.0	2111	2205	2016
Gander River	1984	60	53.6	56.1	51.1	1811	1925	1697
	1985	73	48.3	50.8	45.8	1524	1609	1438
	1986	34	54.2	58.0	50.4	1656	1796	1516
	1987	13	55.6	61.4	49.7	1811	2006	1616
	1988	31	61.4	66.4	56.4	2020	2174	1865
	1989	29	59.0	65.3	52.8	1989	2246	1733
	1990	128	58.1	60.7	55.4	1739	1839	1639
	1992	77	59.9	62.4	57.4	1831	1918	1744
	1993	25	58.0	64.0	51.9	1638	1809	1467
	Years combined	470	56.3	57.5	55.1	1752	1797	1708
Middle Brook	1984	102	56.0	58.6	53.4	1896	1999	1793
	1985	84	60.3	62.7	57.9	1993	2092	1894
	1986	36	60.0	64.6	55.4	1955	2165	1745
	1987	5	58.7	68.3	49.1	2160	2409	1912
	1988	10	57.8	64.0	51.6	2259	2570	1947
	1990	10	62.4	69.1	55.7	1896	2096	1697
	1993	31	70.3	76.5	64.1	2150	2365	1936
	Years combined	278	59.8	61.4	58.3	1980	2042	1919
Terra Nova River	1984	46	53.6	57.2	50.0	1709	1837	1580
	1985	7	59.8	73.4	46.2	2163	2532	1795
	1986	15	42.4	53.0	31.8	1410	1727	1093
	1987	3	81.6	105.1	58.0	2323	3112	1533
	1990	5	76.0	105.4	46.7	2281	3380	1183
	1993	8	56.0	63.2	48.9	1794	1957	1631
	Years combined	84	54.7	58.4	51.1	1761	1876	1646
Biscay Bay River	1984	72	59.1	63.0	55.2	1874	1998	1751
	1985	81	68.5	72.2	64.8	2194	2312	2077
	1986	114	70.5	72.9	68.1	2141	2224	2059
	1987	26	66.4	72.4	60.5	2130	2371	1889
	1988	75	60.3	64.2	56.3	1940	2057	1824
	1994	5	69.6	73.7	65.6	2007	2300	1714
	Years combined	373	65.6	67.2	63.9	2060	2112	2008
Northeast River	1984	21	67.8	71.9	63.7	2332	2500	2165
	1985	39	65.0	70.4	59.7	2205	2394	2016
	1986	45	70.1	73.4	66.8	2282	2391	2173
	1988	34	76.7	81.8	71.6	2472	2663	2281
	1990	41	71.0	75.7	66.3	2500	2686	2314
	1993	5	75.4	92.7	58.2	2144	2943	1346
	Years combined	186	70.4	72.4	68.4	2352	2426	2278
Conne River	1986	102	68.7	71.1	66.3	2367	2451	2282
	1987	136	67.0	69.1	65.0	2364	2462	2266
	1988	85	63.7	65.8	61.5	2366	2464	2269
	1990	93	44.0	46.1	41.8	1545	1621	1468
	1991	22	53.6	63.9	43.3	2046	2435	1658
	1992	21	35.0	39.3	30.7	1278	1423	1134
	Years combined	459	60.0	61.5	58.5	2134	2190	2078

Table 3. Results of statistical comparisons by year for fecundity in terms of weight and length for each river.

River	Years compared	Relative fecundity			
		Eggs/kg		Eggs/cm	
		Z/K	P	Z/K	P
Sand Hill River	1994-95	-6.75	0.0001	-6.53	0.0001
Indian River	1984-85	1.95	0.0510	0.77	0.7727
Exploits River	1985-86	1.64	0.1019	1.92	0.0544
Campbellton River	1992-95	4.10	0.2506	5.13	0.1628
Gander River	1984-90, 1992-93	53.08	0.0001	52.86	0.0001
Middle Brook	1984-88, 1990, 1993	7.26	0.2978	25.30	0.0003
Terra Nova River	1984-87, 1990, 1993	19.24	0.0017	18.94	0.0020
Biscay Bay River	1984-88, 1994	21.31	0.0007	41.94	0.0001
Northeast River, Plac.	1984-88, 1990, 1993	10.69	0.0984	12.43	0.0531
Conne River	1986-88, 1990-92	185.28	0.0001	200.25	0.0001

Table 4. Results of statistical comparisons by river for fecundity in terms of weight and length for each year.

Year	Rivers compared	Relative fecundity			
		Eggs/kg		Eggs/cm	
		Z/K	P	Z/K	P
1984	2,3,5,6,7,8,9	26.97	0.0001	33.02	0.0001
1985	2,3,5,6,7,8,9	112.34	0.0001	128.11	0.0001
1986	3,5,6,7,8,9,10	71.61	0.0001	81.14	0.0001
1987	5,6,7,8,9,10	18.85	0.0021	20.01	0.0012
1988	5,6,8,9,10	46.40	0.0001	36.21	0.0001
1990	5,6,7,9,10	80.12	0.0001	99.53	0.0001
1992	4,5,10	28.95	0.0001	42.15	0.0001
1993	4,5,6,7,9	22.67	0.0001	16.12	0.0029
1994	1,4,8	2.61	0.2711	15.38	0.0005
1995	1,4	2.35	0.0187	-0.03	0.9728
Years combined	1,2,3,4,5,6,7,8,9,10	268.02	0.0001	313.03	0.0001

1 - Sand Hill River; 2 - Indian River; 3 - Exploits River; 4 - Campbellton River; 5 - Gander River; 6-Middle Brook; 7 - Terra Nova River; 8 - Biscay Bay River; 9 - Northeast River, Plac.; 10 - Conne River.

Table 5. Relative fecundity (RF) in terms of fork length (eggs/cm) and whole weight (eggs/kg) compared between repeat spawning grilse and virgin grilse with data combined by year for each river. N = no. of specimens; FL = fork length; WW = whole weight; UCL and LCL are the upper and lower 95% confidence limits.

River	Grilse	N	RF(FL)	UCL	LCL	RF(WW)	UCL	LCL
Indian River	Repeat spawners	12	65.8	77.4	54.3	1786	2048	1524
	Virgin	213	51.7	53.5	50.0	1735	1800	1669
Exploits River	Repeat spawners	4	60.8	90.7	30.9	1930	3190	669
	Virgin	178	53.2	55.1	51.2	1935	2013	1856
Campbellton River	Repeat spawners	5	69.0	92.5	45.5	2270	2698	1843
	Virgin	69	59.9	62.5	57.2	2098	2200	1995
Gander River	Repeat spawners	19	64.0	72.5	55.6	1952	2229	1675
	Virgin	433	56.0	57.2	54.7	1738	1784	1693
Middle Brook	Repeat spawners	25	67.3	74.4	60.3	1950	2190	1710
	Virgin	249	58.9	60.5	57.3	1982	2046	1919
Terra Nova River	Repeat spawners	16	56.9	71.2	42.6	1774	2216	1332
	Virgin	65	53.5	56.7	50.2	1749	1852	1647
Biscay Bay River	Repeat spawners	67	74.6	79.4	69.8	2220	2371	2070
	Virgin	293	63.1	64.7	61.5	2008	2061	1955
Northeast River	Repeat spawners	8	79.8	103.0	56.6	2614	3537	1691
	Virgin	178	69.9	71.8	68.0	2339	2408	2270

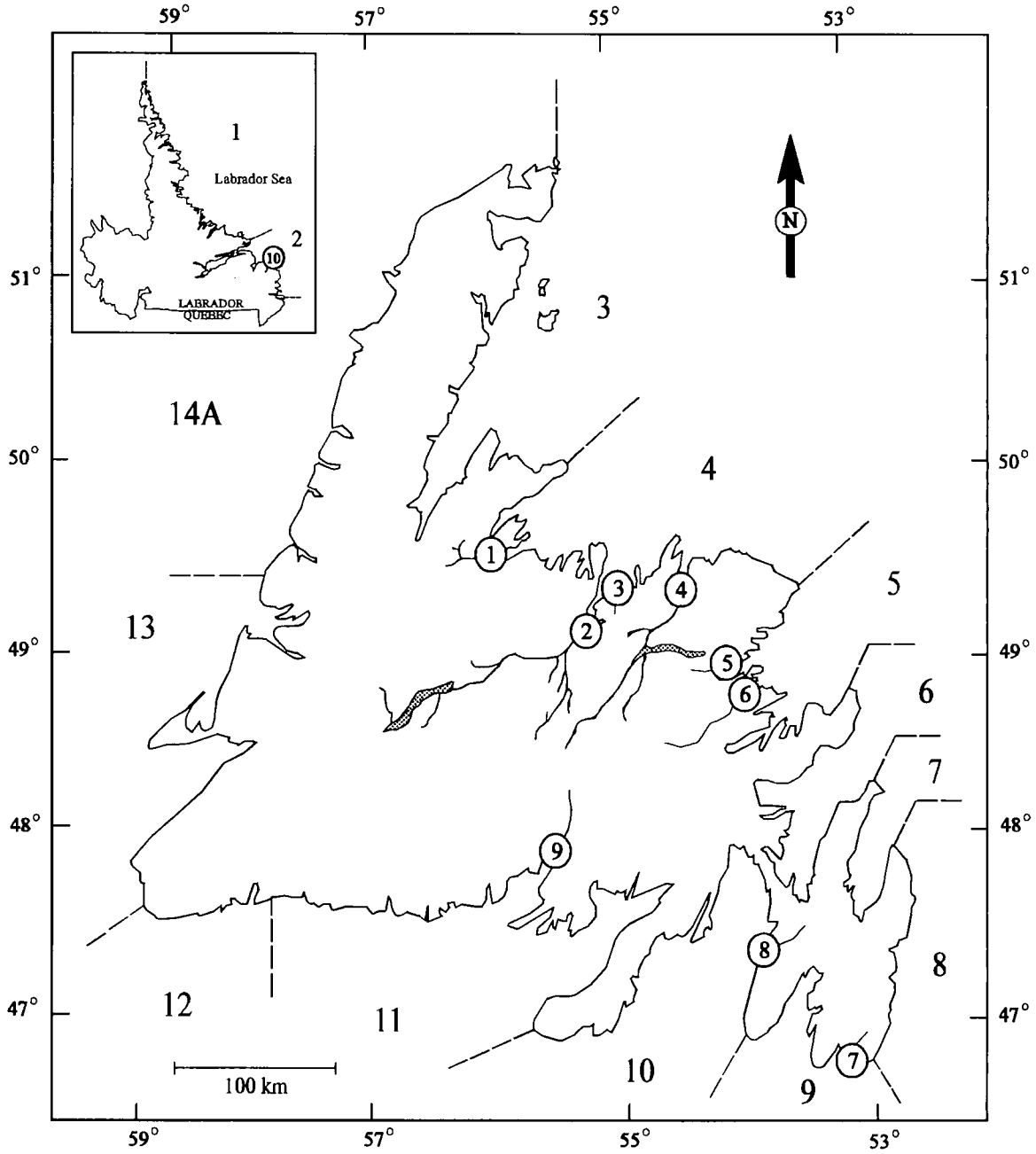


Fig 1. Map showing the Salmon Fishing Areas of Newfoundland and Labrador and the location of the ten rivers mentioned in the text: (1) Indian River; (2) Exploits River; (3) Campbellton River; (4) Gander River; (5) Middle Brook; (6) Terra Nova River; (7) Biscay Bay River; (8) Northeast River; (9) Conne River; (10) Sand Hill River.

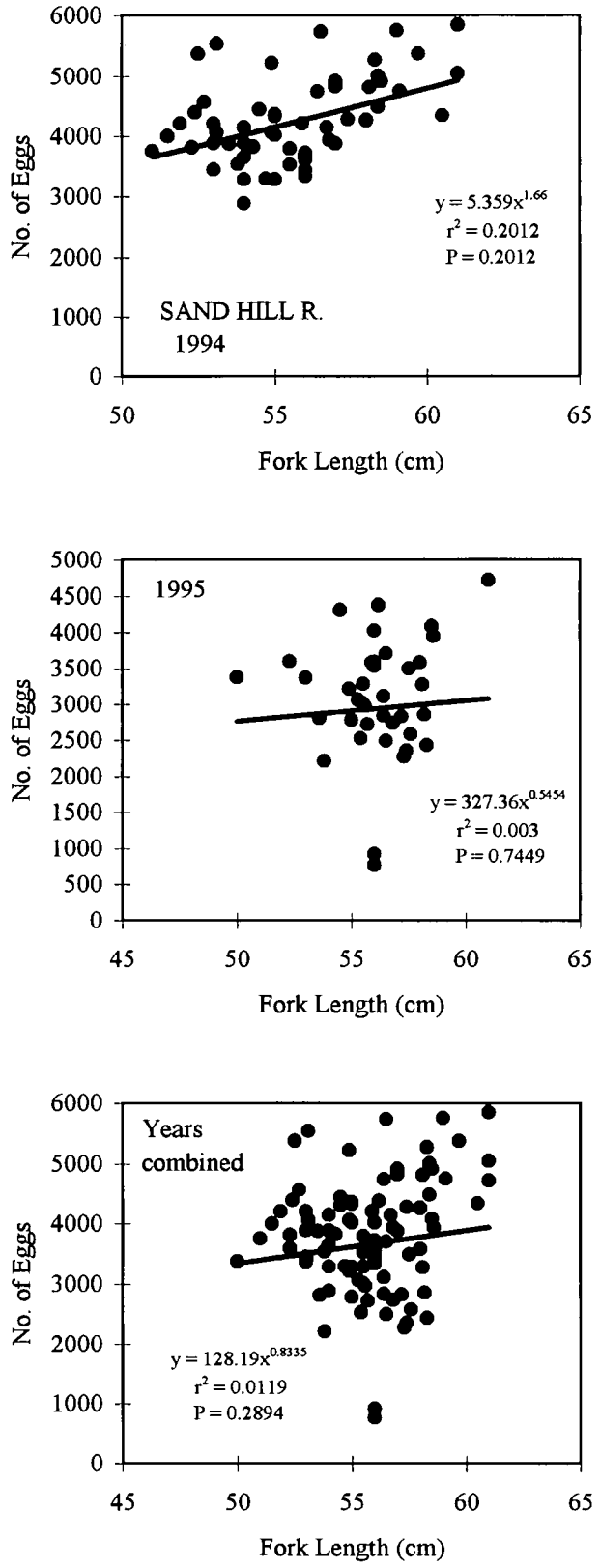


Fig. 2. Fecundity-length relationships for Sand Hill River (SFA 2), Labrador.

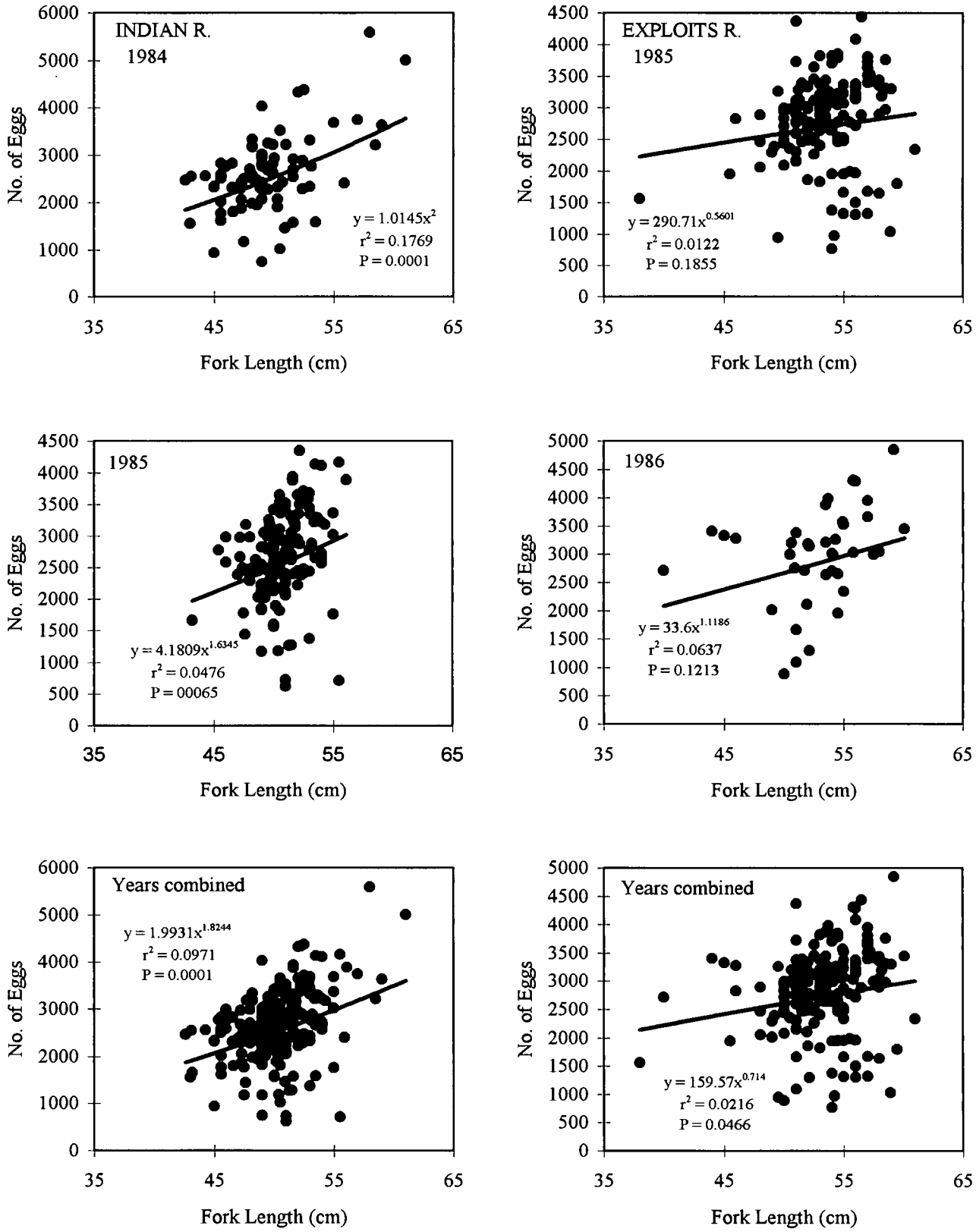


Fig. 3. Fecundity-length relationships for Indian River and Exploits River, Notre Dame Bay (SFA 4), Newfoundland.

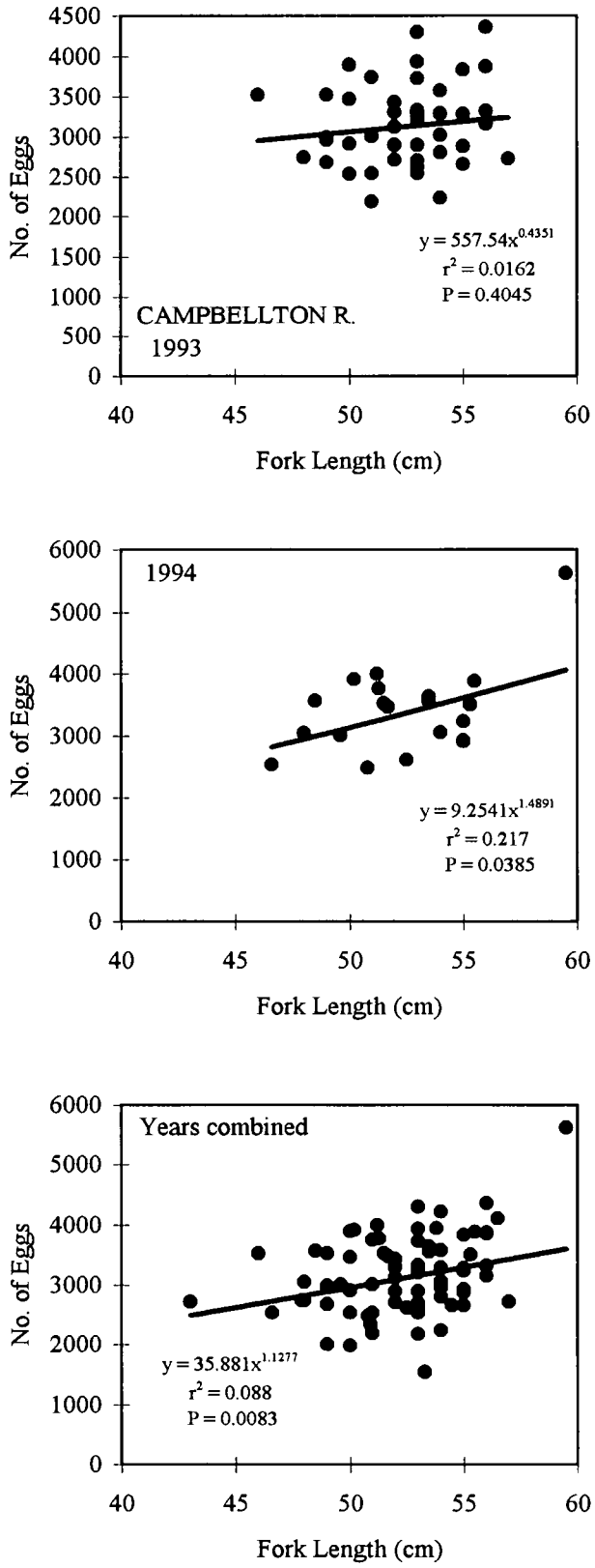


Fig. 4. Fecundity-length relationships for Campbellton River, Notre Dame Bay (SFA 4), Newfoundland.

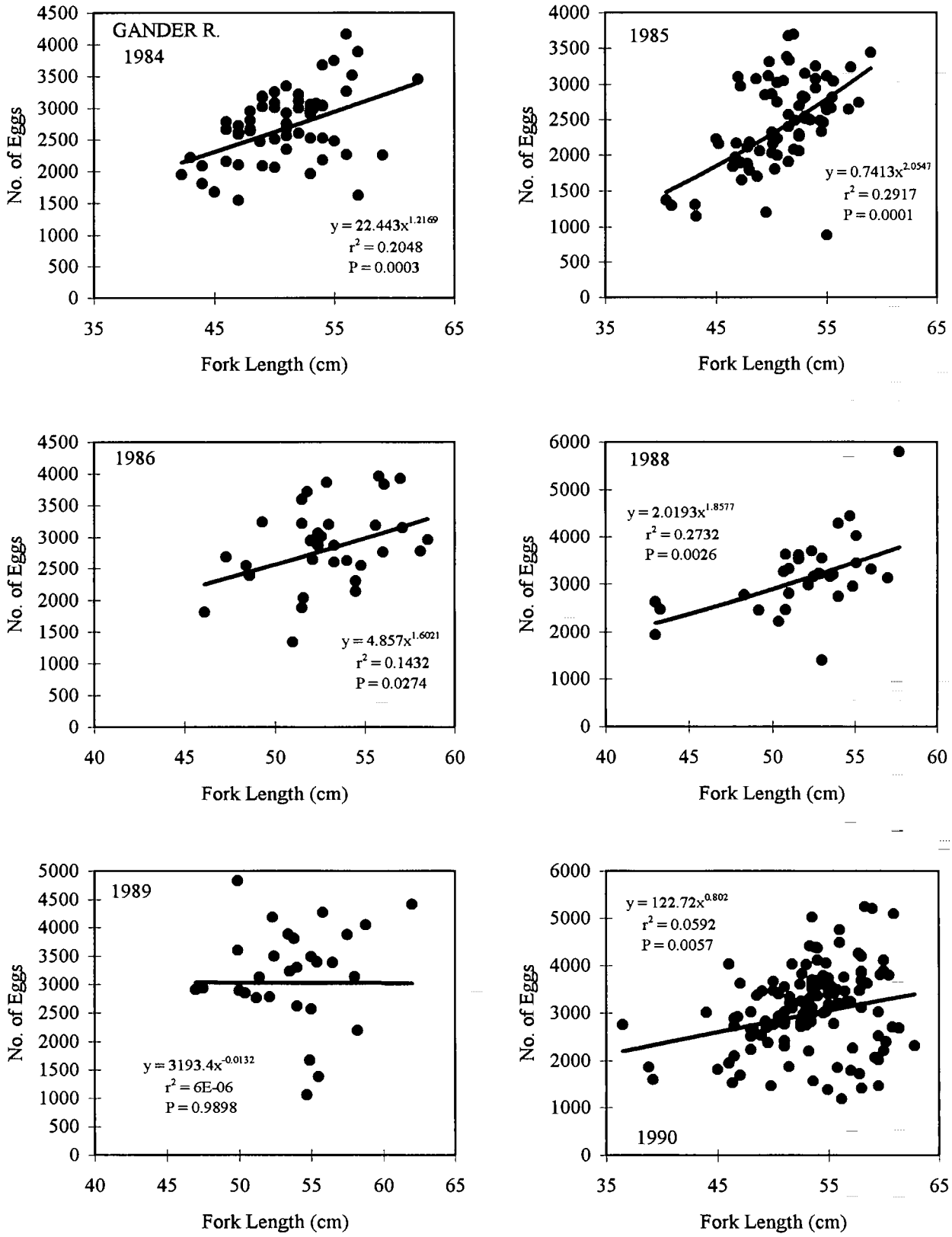


Fig. 5. Fecundity-length relationships for Gander River, Notre Dame Bay (SFA 4), Newfoundland.

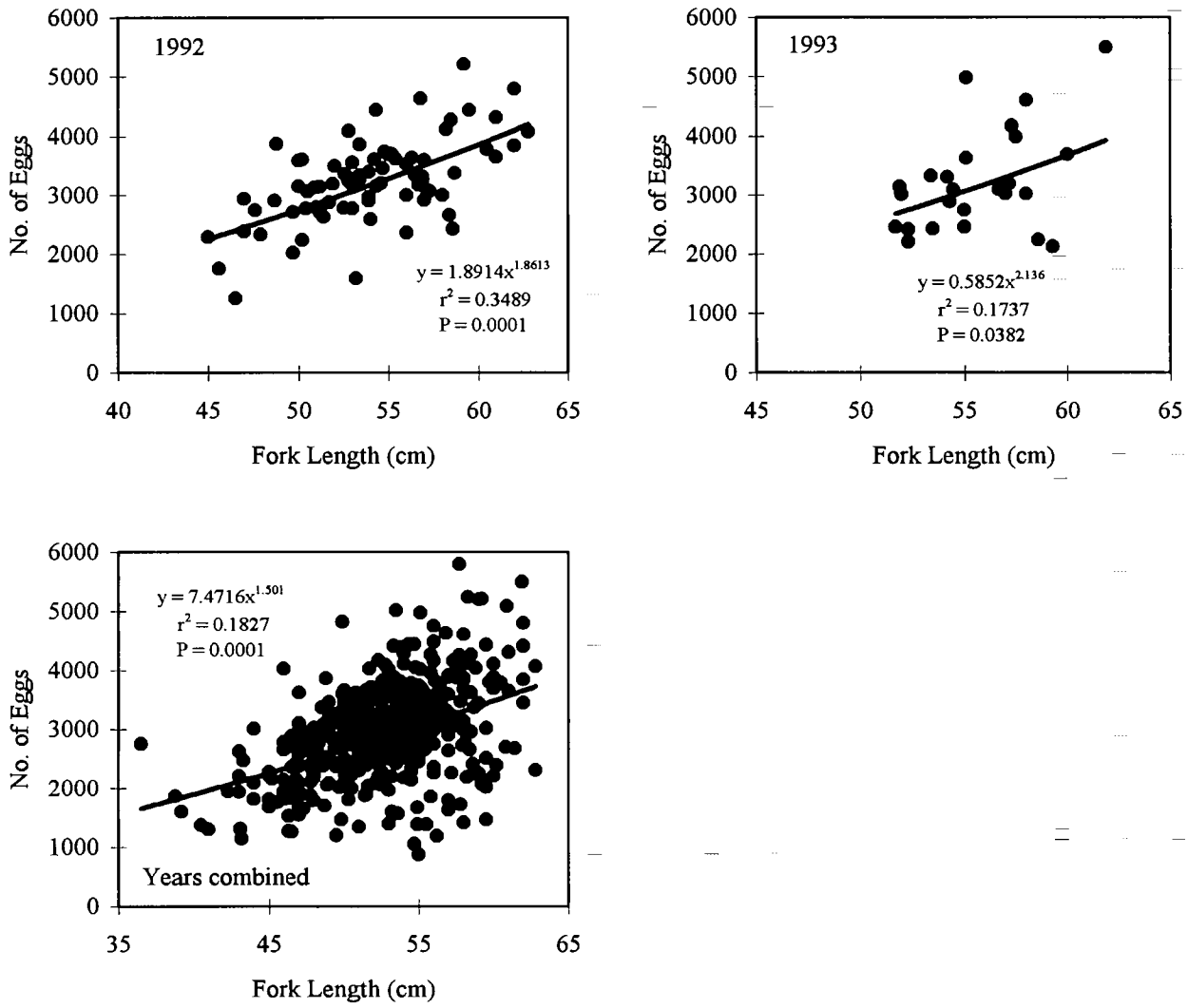

1992
y = 1.8914x^1.8613
r² = 0.3489
P = 0.0001
No. of Eggs
Fork Length (cm)
1993
y = 0.5852x^2.136
r² = 0.1737
P = 0.0382
No. of Eggs
Fork Length (cm)
y = 7.4716x^1.501
r² = 0.1827
P = 0.0001
Years combined
No. of Eggs
Fork Length (cm)

Fig. 5. (cont'd)

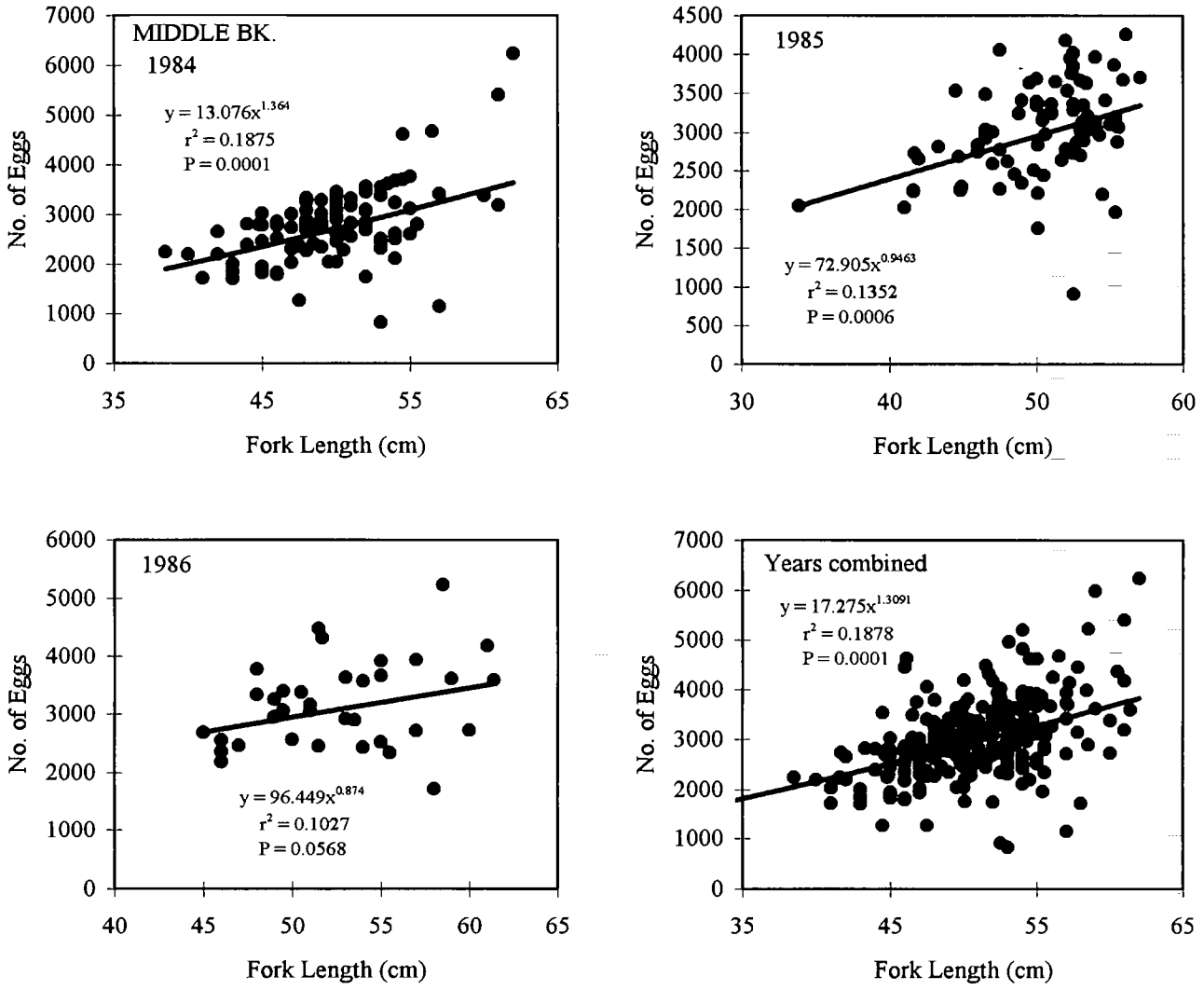
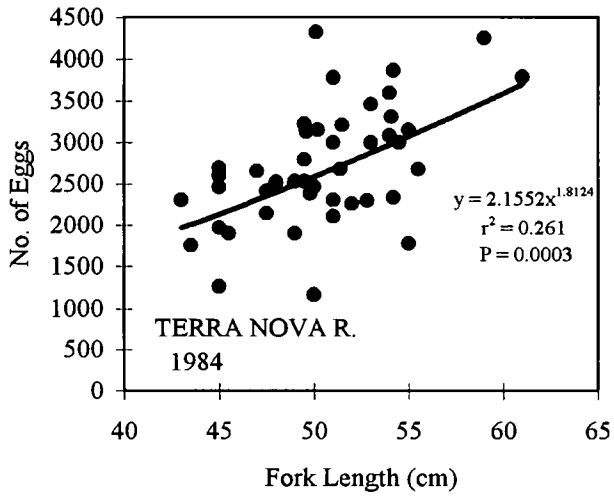


Fig. 6. Fecundity-length relationships for Middle Brook, Bonavista Bay (SFA 5), Newfoundland.



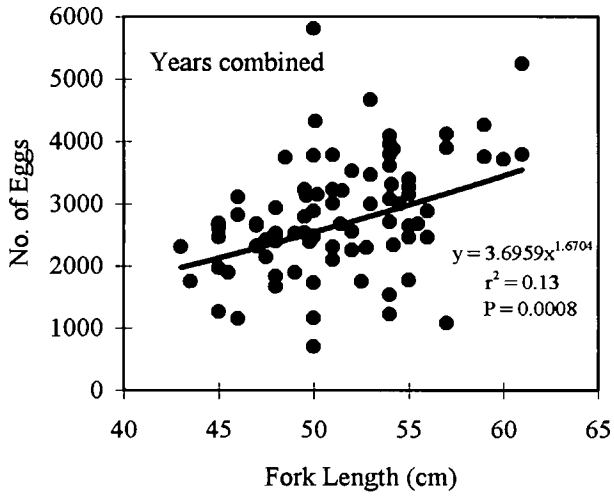


Fig. 7. Fecundity-length relationships for Terra Nova River, Bonavista Bay (SFA 5), Newfoundland.

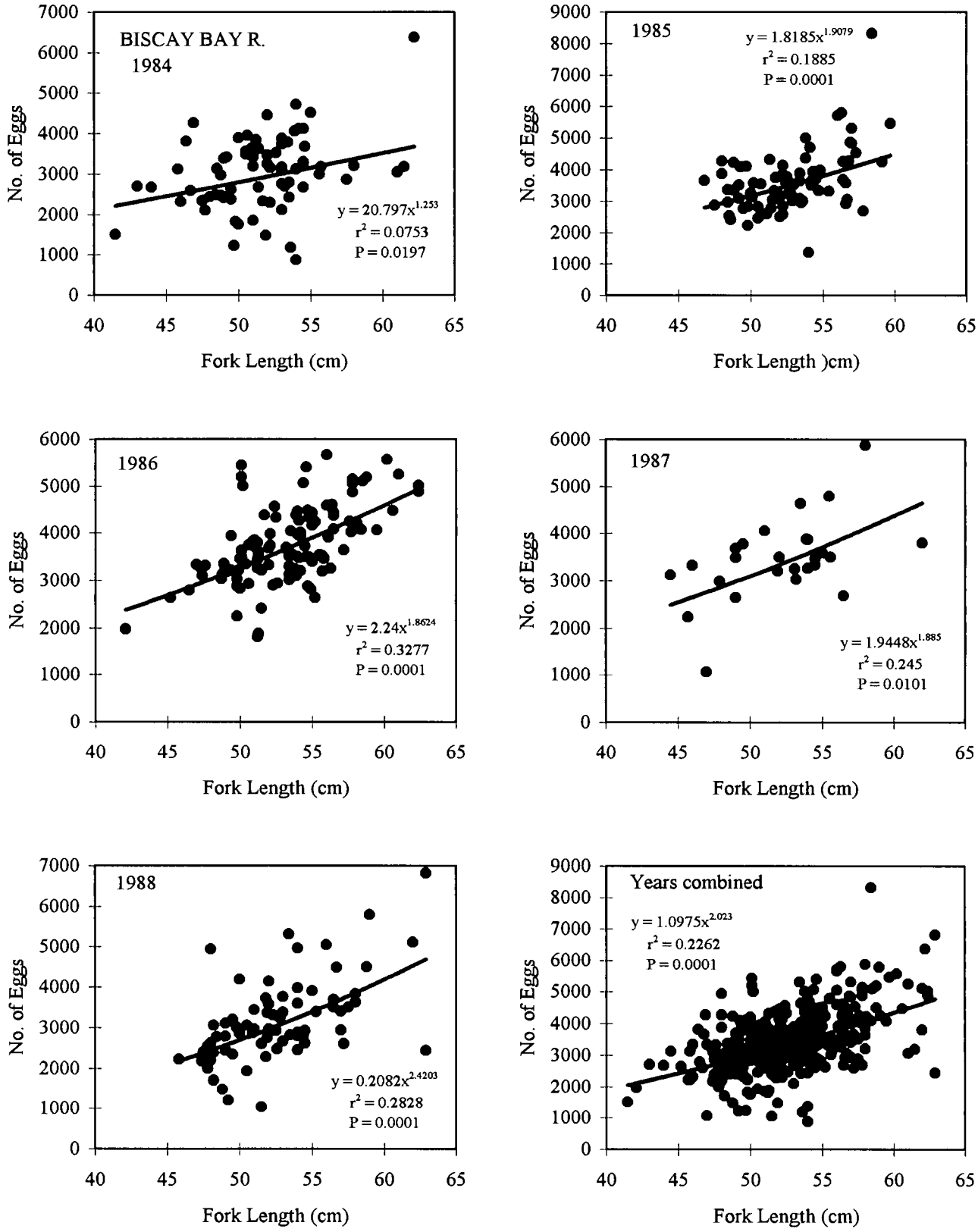


Fig. 8. Fecundity-length relationships for Biscay Bay River, St. Mary's Bay (SFA 9), Newfoundland.

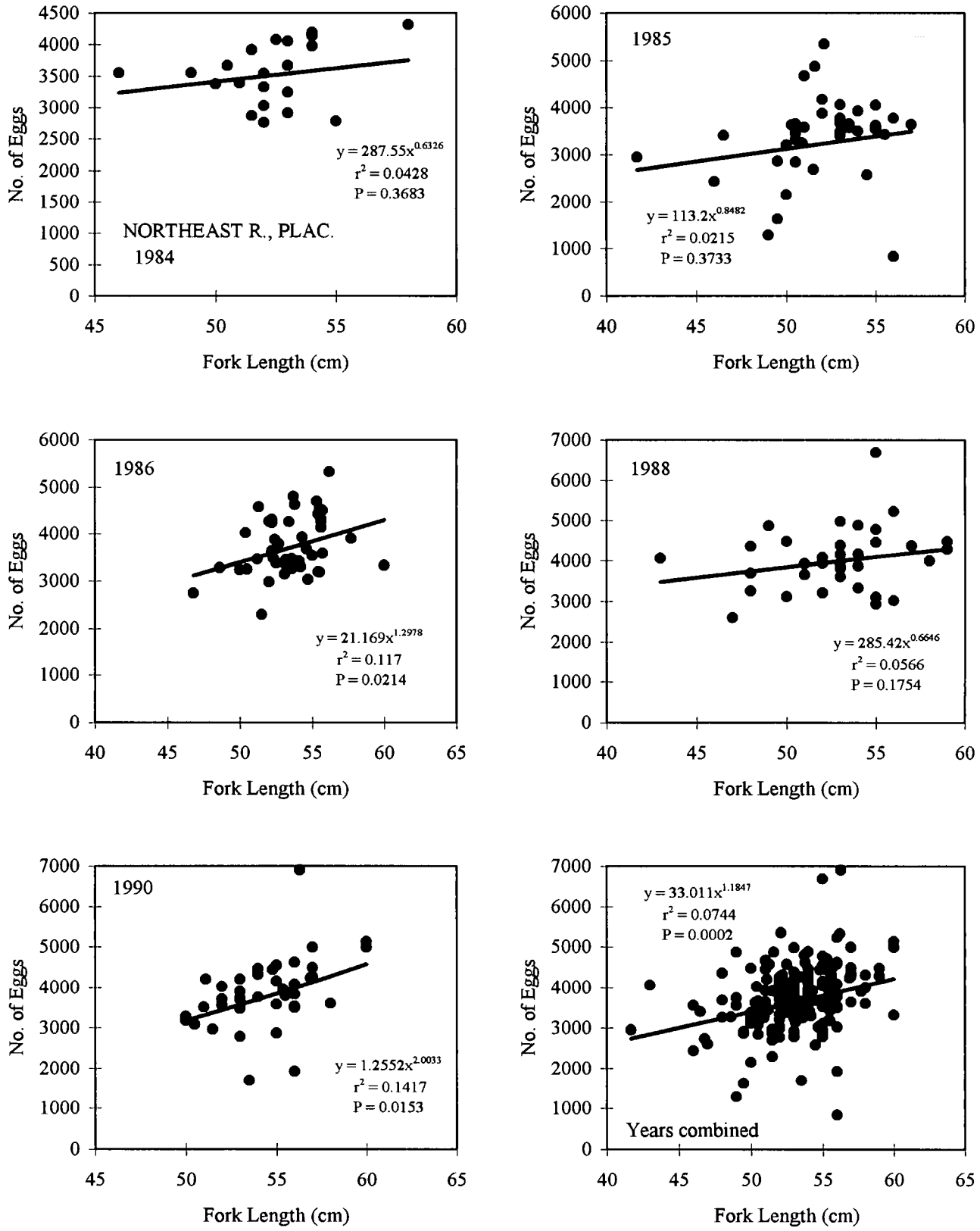


Fig. 9. Fecundity-length relationships for Northeast River, Placentia Bay (SFA 10), Newfoundland.

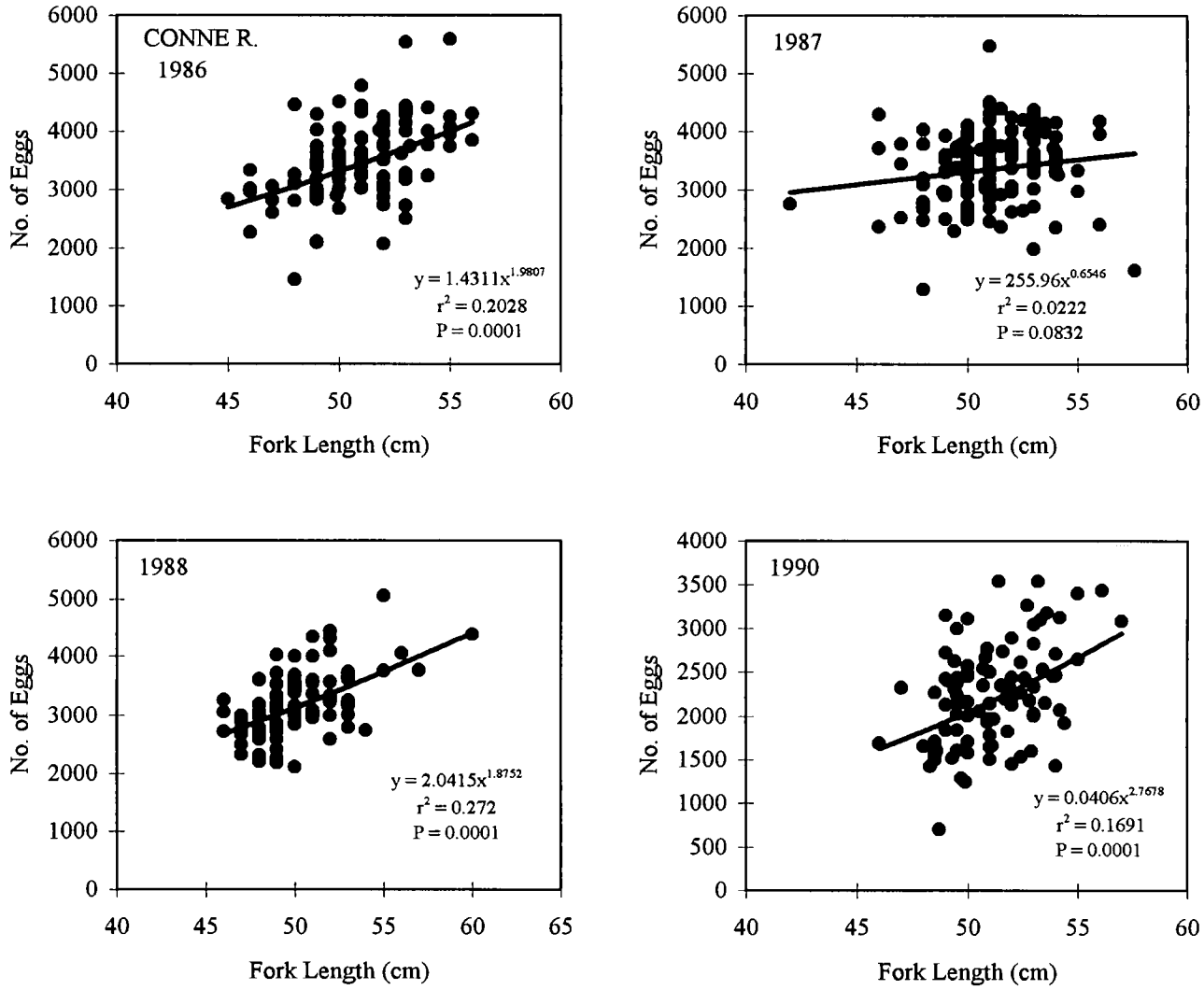


Fig. 10. Fecundity-length relationships for Conne River, Bay D'Espoir (SFA 11), Newfoundland.

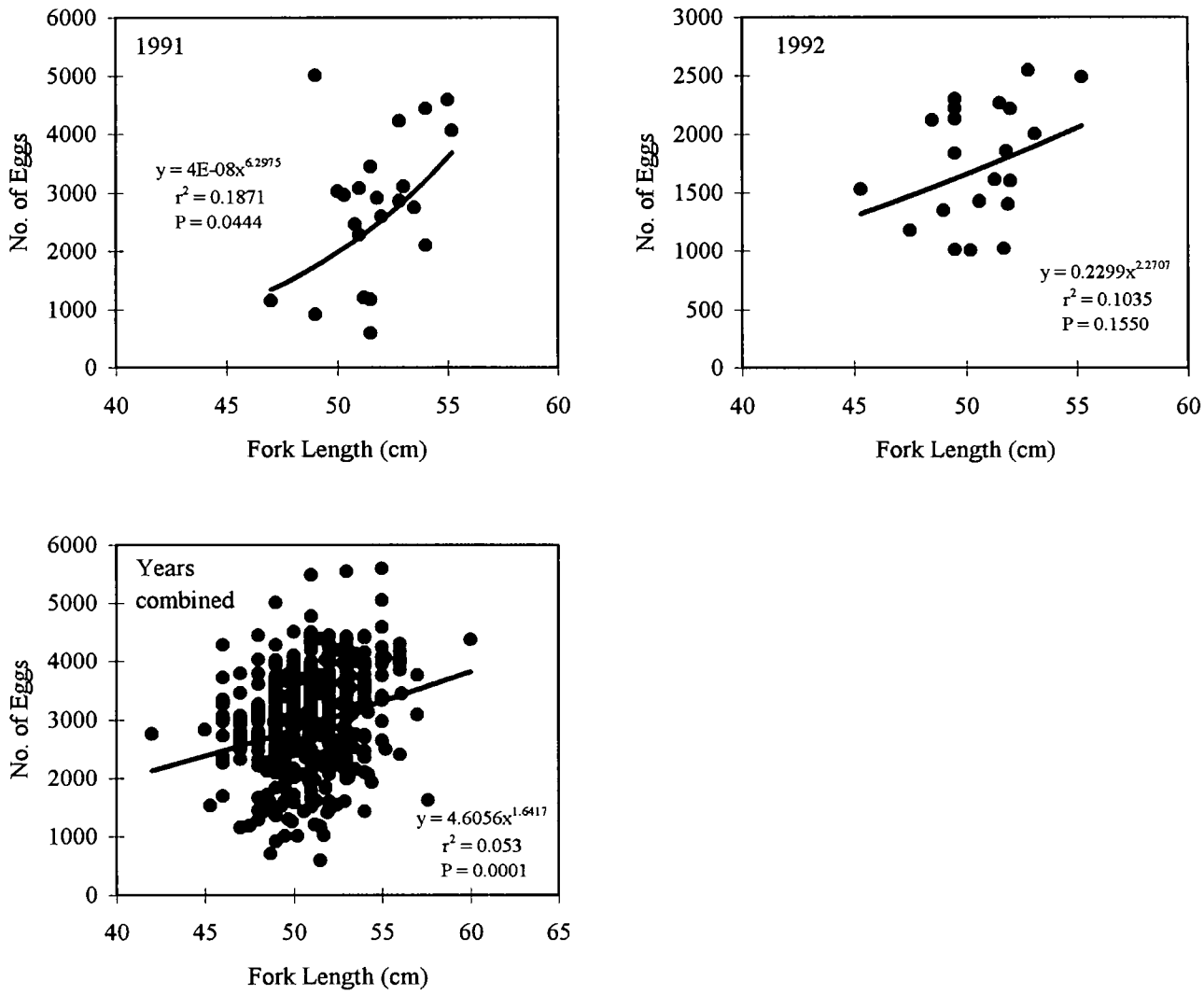

1991
y = 4E-08x^6.2975
r² = 0.1871
P = 0.0444
No. of Eggs
Fork Length (cm)
1992
y = 0.2299x^2.2707
r² = 0.1035
P = 0.1550
No. of Eggs
Fork Length (cm)
Years combined
y = 4.6056x^1.6417
r² = 0.053
P = 0.0001
No. of Eggs
Fork Length (cm)

Fig. 10. (cont'd)

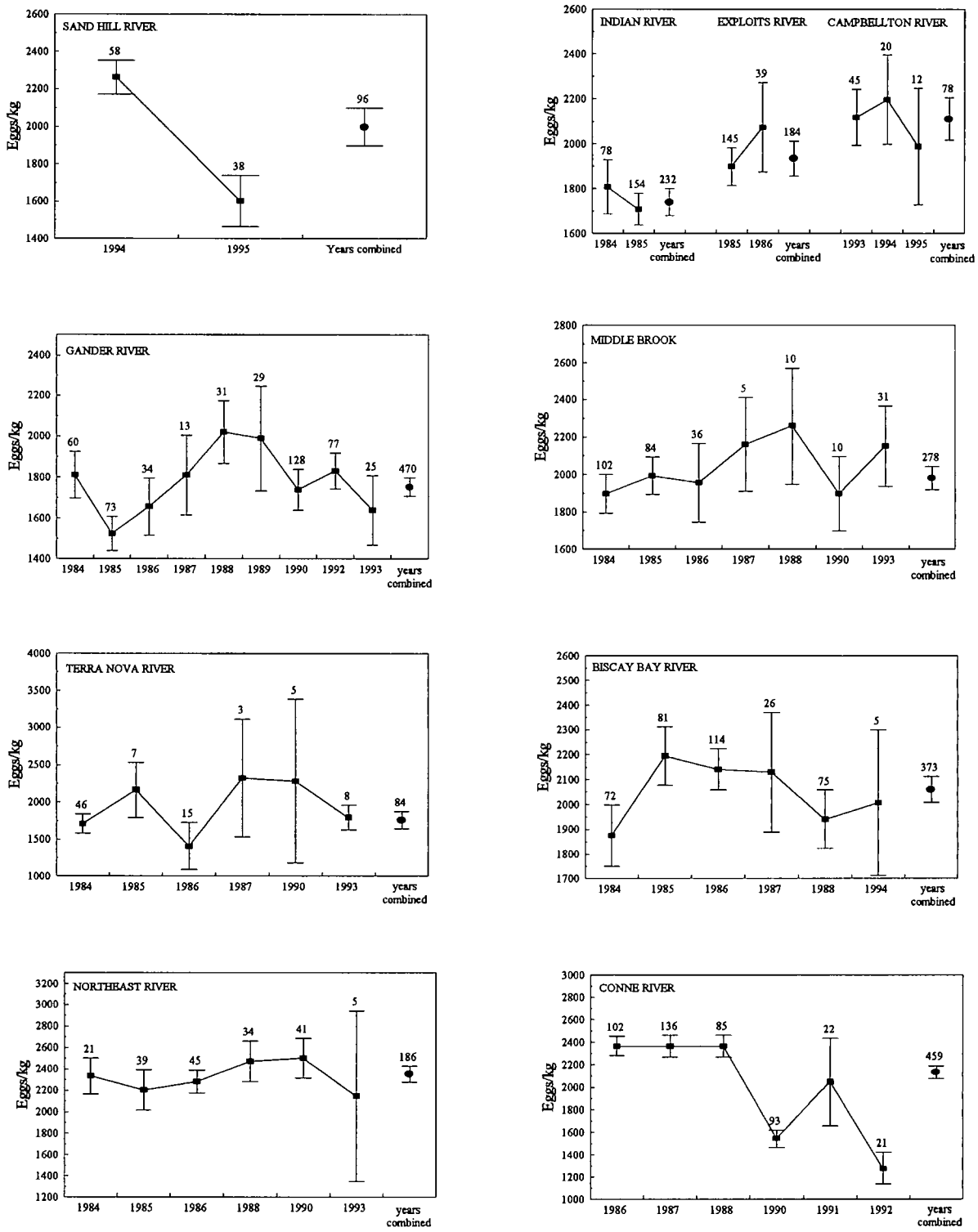


Fig. 11. Relative fecundity in terms of whole weight for each river by year. Vertical lines are the 95% confidence intervals.

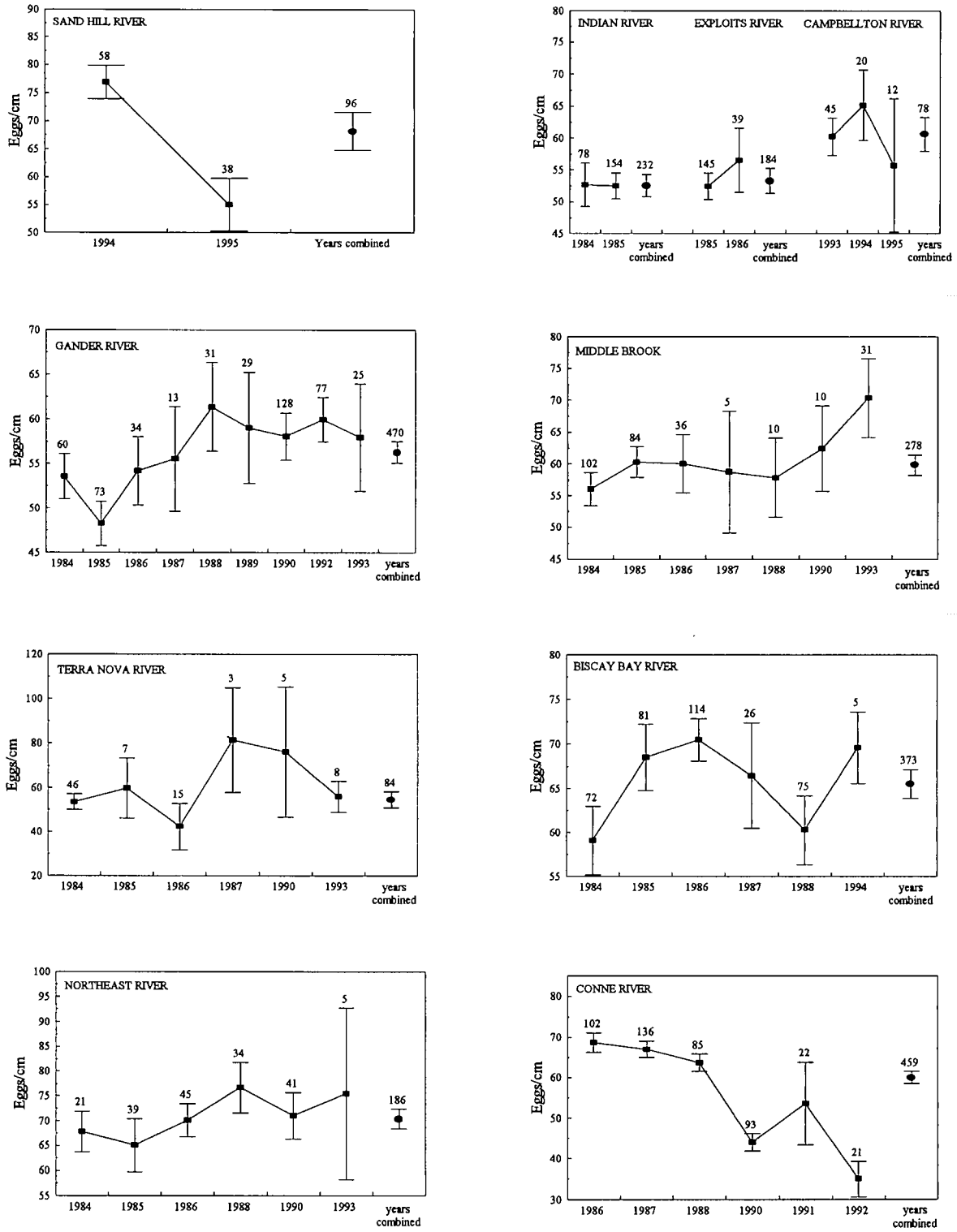


Fig. 12. Relative fecundity in terms of fork length (eggs/cm) for each river by year. Vertical lines are the 95 % confidence intervals.

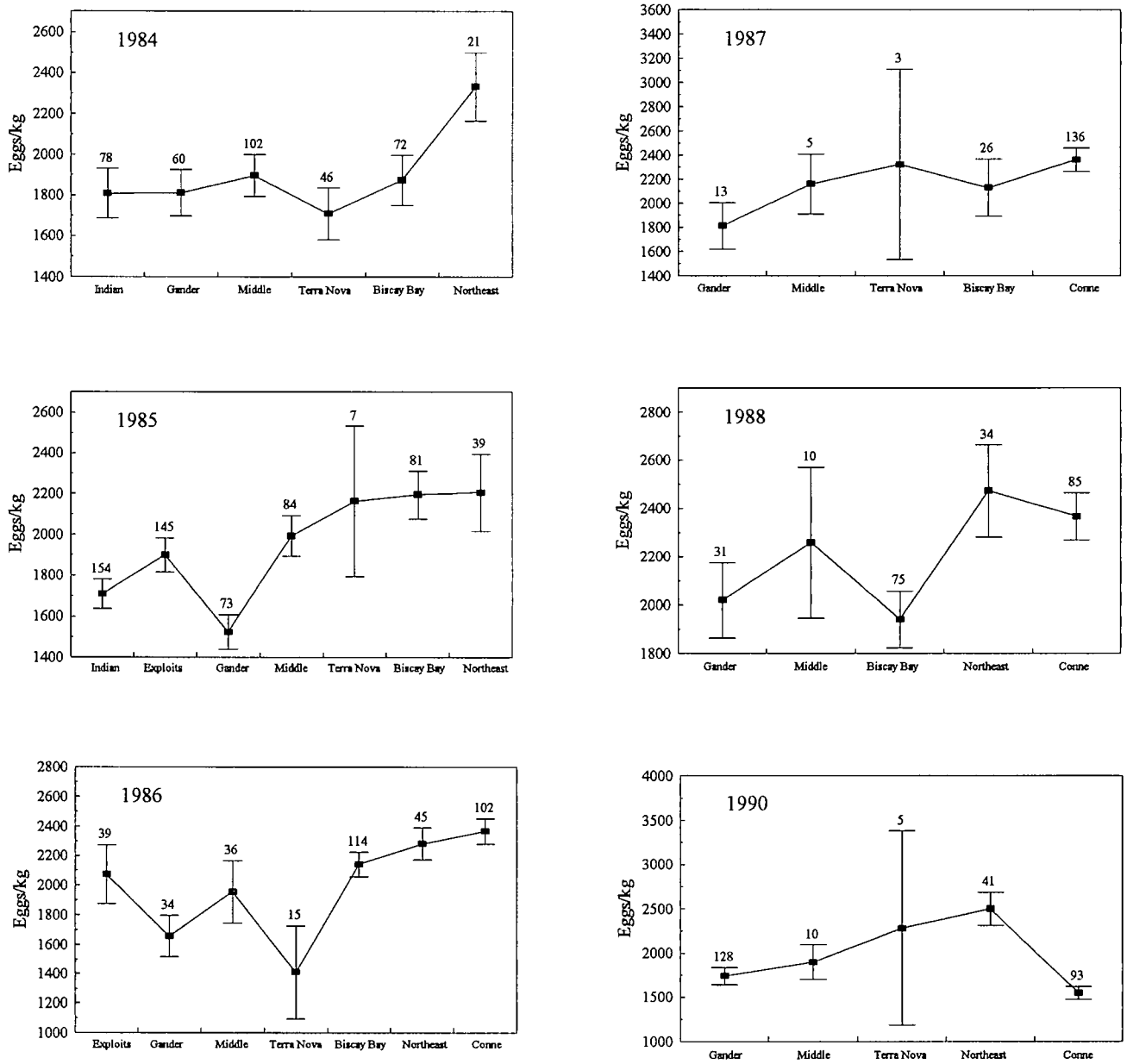


Fig. 13. Relative fecundity in terms of whole weight (eggs/kg) for each year by river. Vertical lines are the 95 % confidence intervals.

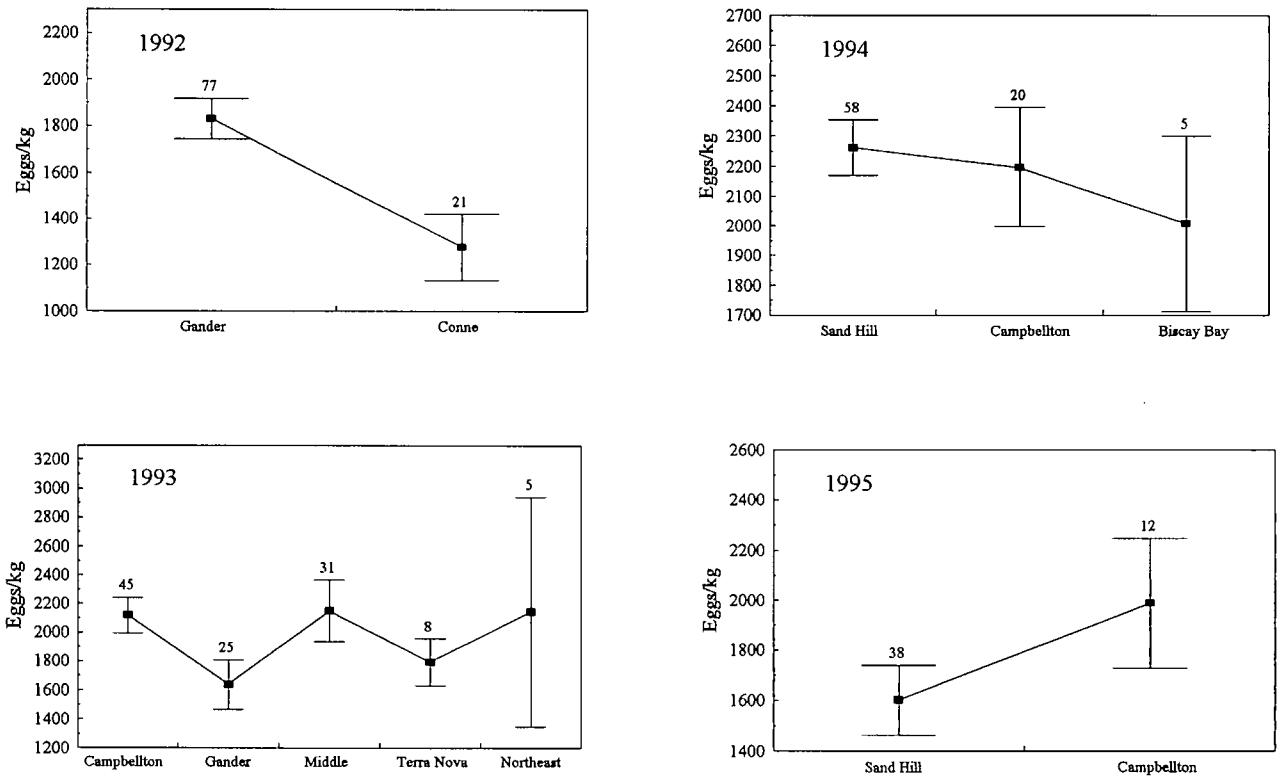

1992
Eggs/kg
2200
2000
1800
1600
1400
1200
1000
77
21
Gander
Conne
1994
Eggs/kg
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
58
20
5
Sand Hill
Campbellton
Biscay Bay
1993
Eggs/kg
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
45
25
31
8
5
Campbellton
Gander
Middle
Terra Nova
Northeast
1995
Eggs/kg
2600
2400
2200
2000
1800
1600
1400
38
12
Sand Hill
Campbellton

Fig. 13 (cont'd)

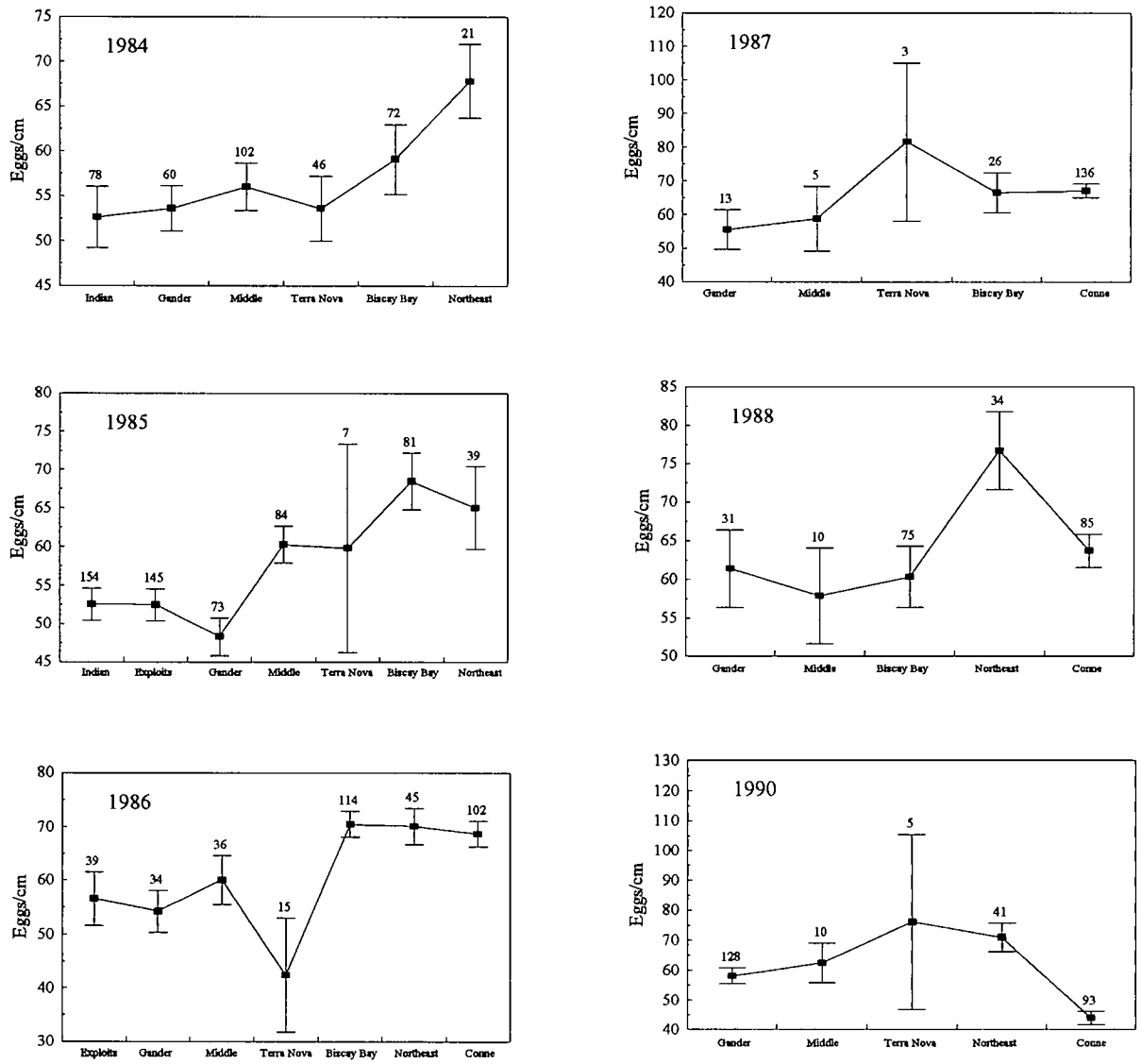


Fig. 14. Relative fecundity in terms of fork length (eggs/cm) for each year by river. Vertical lines are the 95 % confidence intervals.

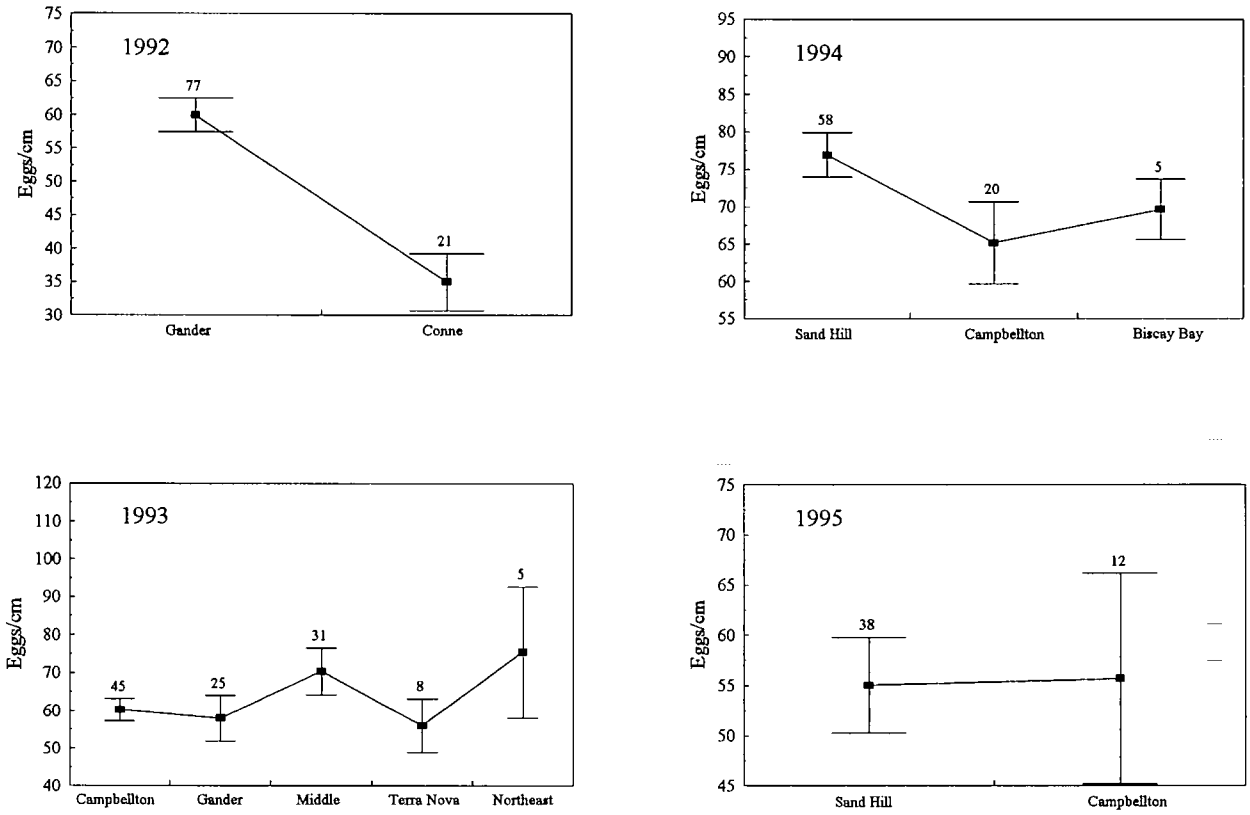

1992
Eggs/cm
75
70
65
60
55
50
45
40
35
30
77
21
Gander
Conne
1994
Eggs/cm
95
90
85
80
75
70
65
60
55
58
20
5
Sand Hill
Campbellton
Biscay Bay
1993
Eggs/cm
120
110
100
90
80
70
60
50
40
45
25
31
8
5
Campbellton
Gander
Middle
Terra Nova
Northeast
1995
Eggs/cm
75
70
65
60
55
50
45
38
12
Sand Hill
Campbellton

Fig. 14 (cont'd)

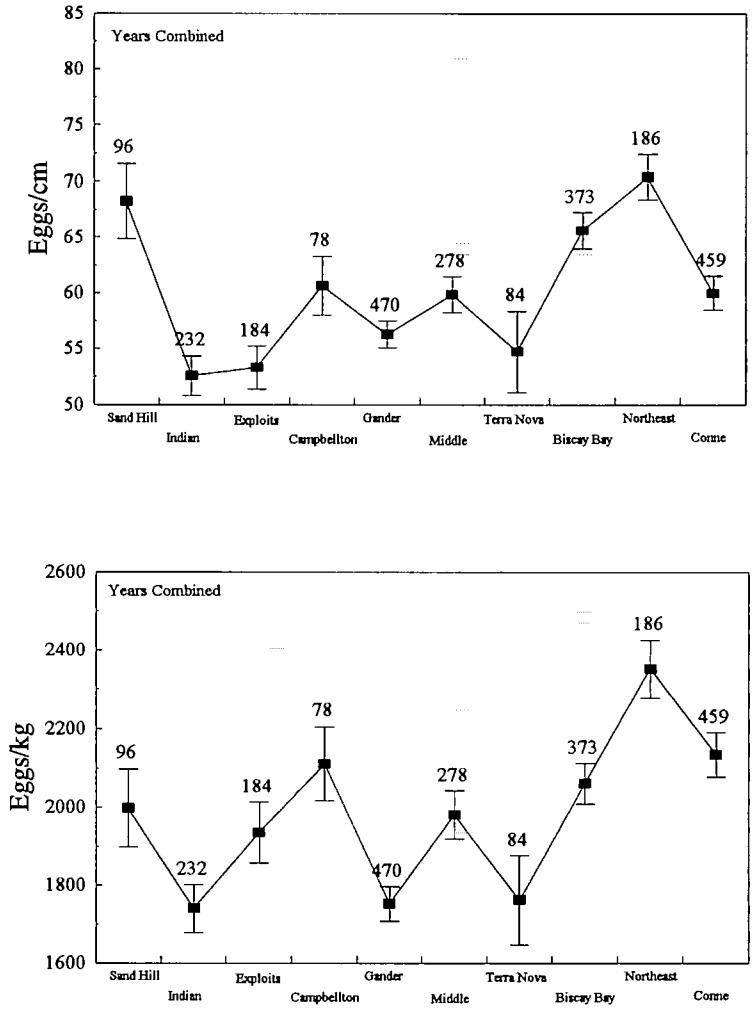


Fig. 15. Relative fecundity in terms of fork length (eggs/cm) and whole weight (eggs/kg) for years combined for each river. Vertical lines are the 95 % confidence intervals.

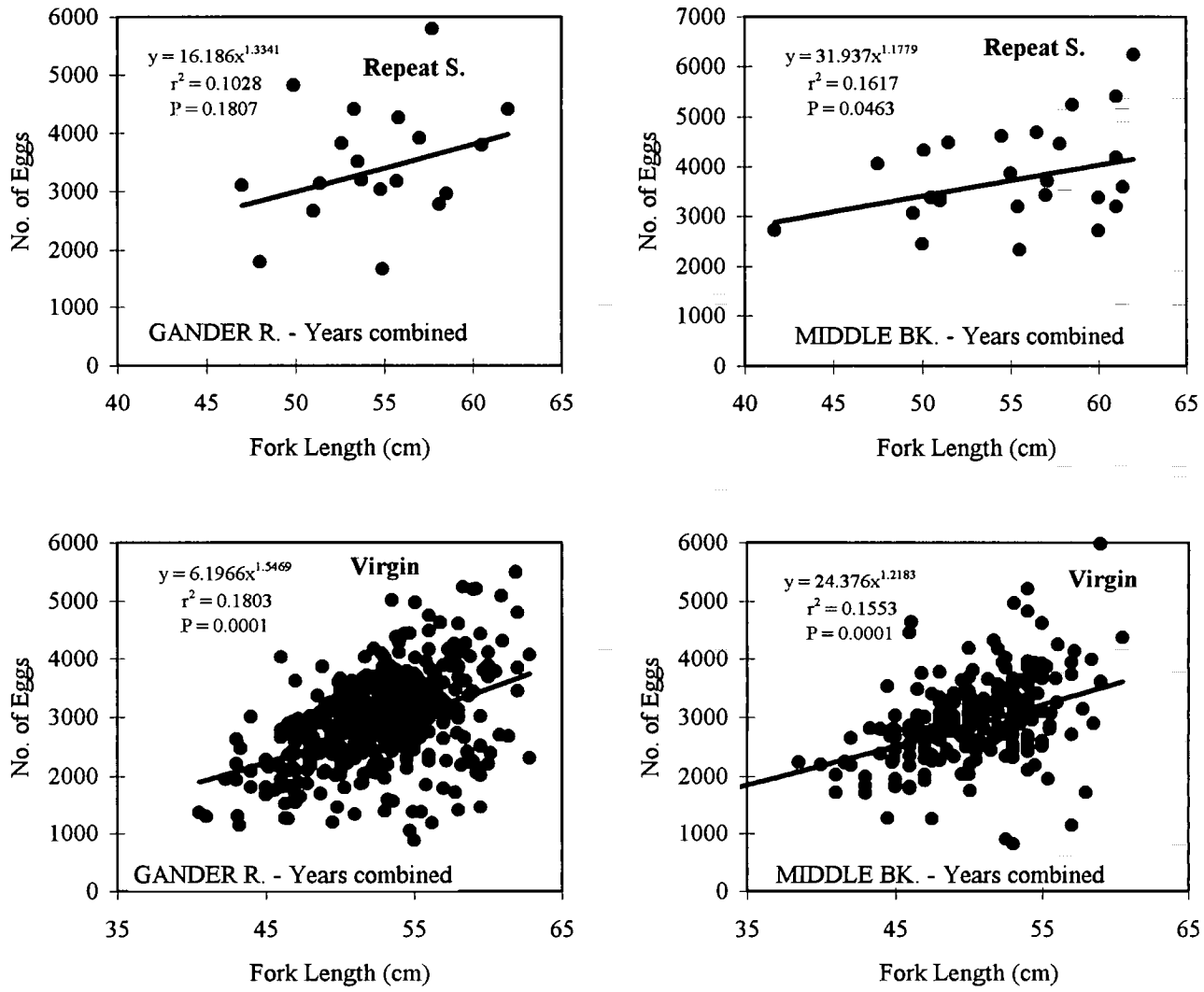


Fig. 16. Fecundity-length relationships for repeat spawning grilse and virgin grilse, data combined for all years, for Gander River and Middle Brook.

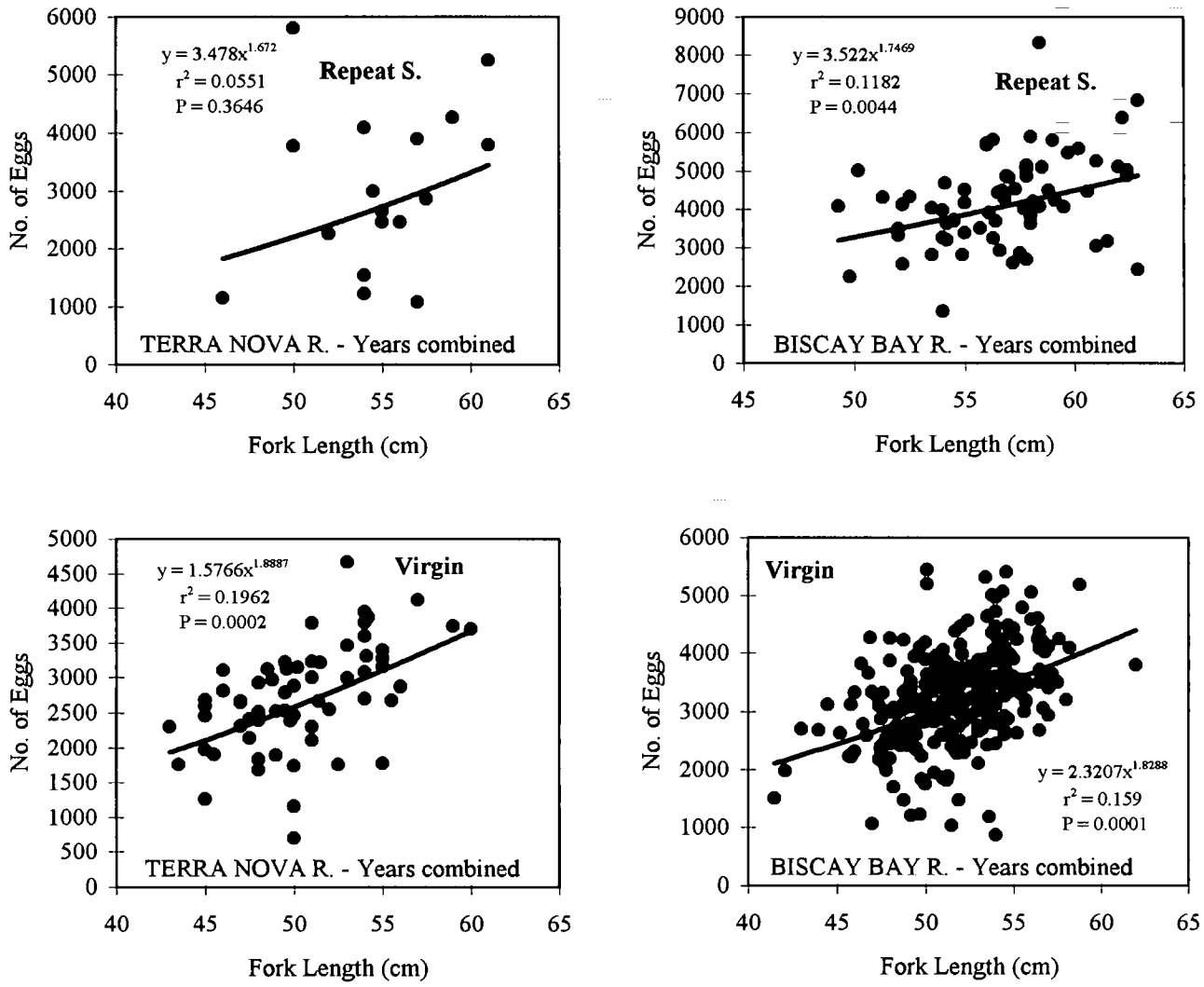


Fig. 17. Fecundity-length relationships for repeat spawning grilse and virgin grilse, data combined for all years, for Terra Nova River and Biscay Bay River.

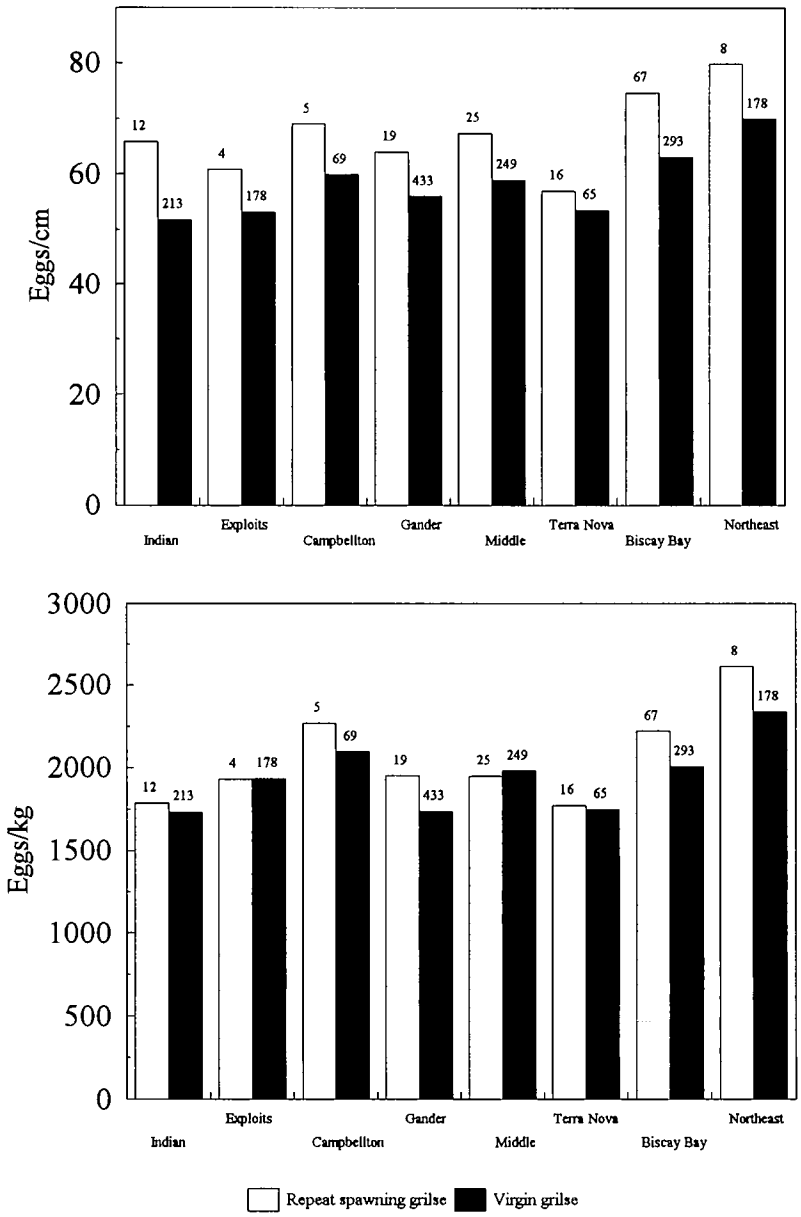


Fig. 18. Relative fecundity in terms of fork length (eggs/cm) and whole weight (eggs/kg) compared between repeat spawning grilse and virgin grilse with data combined by year for each river.