International Council for the Exploration of the Sea

C.M. 1971/M:14
Anadromous and Catadromous Fish Committee

GENETIC DIVERSITY IN SALMON

By

Dag Møller *)
Fisheries Research Board of Canada
Biological Station, St. Andrews, N.B.

INTRODUCTION

Studies on the genetics of raciation of Atlantic salmon (*Salmo salar*) were started at the Biological Station, St. Andrews, in 1968. Both blood typing and electrophoretic studies were carried out. Three main patterns of transferrins, Tf AA, Tf AC, and Tf CC, made up of two molecular types, were found in plasma of hatchery and wild salmon (Møller 1970a). Several papers dealing with gene frequencies have been published (Møller 1970a, b, and c). This report gives a survey of the material sampled and analysed up to now.

MATERIAL AND METHODS

Over 5500 blood specimens distributed on 56 samples from 38 localities in Eastern Canada and United States have been collected in 1969 and 1970 (Table 1, Figure 1). Blood specimens from both parr, smolt, grilse, and adult salmon are represented . The methods of sampling, handling, the electrophoretic technique used, and the interpretation of electrophoretic patterns have been described elsewhere (Sick 1965, Møller 1966, 1970a).

RESULTS

Table 2 shows the observed distributions of the transferrin patterns compared to the expected distributions of the types according to the Hardy-Weinberg law of genotype distributions in large random mating populations. Only six of the 56 samples show significant differences between the two distributions (marked x in the table).

*) Present address: Institute of Marine Research, Bergen

The frequency of the $\underline{Tf}^A$ allele varies greatly (Figure 2). The lowest value, .071, was found in Aides Str., Nfld., while the highest value, .650, was present in the sample from MacDonald R., Anticosti. Low values were found else in Labrador and Newfoundland, while high values were found south in New Brunswick and in Maine.

Great differences in frequencies over short distance (less than 200 km)(Figure 2) were observed between Mingan (.241) and MacDonald (.650); Middle R. (.536) and East R. (.292); and Big Salmon R. (.300-.360)/ St. John R. (.229-.425) and Dennis Str. (.500). In the first case the distance between the mouths of the rivers is about 80 km.

Figure 3, 4, and 5 illustrates the confidence intervals of the observed gene frequency of $\underline{Tf}^A$ (q^A) in the samples. The vertical lines give the observed frequencies, and the horizontal ranges of the bars indicate the 95 % confidence limits. All figures show significant differences of the gene frequencies between neighbouring rivers or between samples collected at different localities in the same river. Another noticeable feature is the similarity between samples collected at the same locality (sample 41-42, 45-46, 52-53, 54-55). Exceptions are some of the samples from Miramichi R. (Figure 4, sample 15 to 38) and St. John R. (Figure 5, sample 47 to 51).

Miramichi R. is probably the worlds biggest salmon river. The river has a heavy ramification, and the two main branches, NW Miramichi R. (sample 15 to 32) and SW Miramichi R. (sample 33 to 35) join just before the estuary (sample 36 to 38). Sample 21 to 27 were collected during the smolt run in 1970 at the river fench at Curventon in NW Miramichi R. The specimens were sampled once a week, some times twice a week. The differences between the samples 21, 22, 23, and 24 are insignificant (Figure 4). However, in the course of three days the frequency of smolts changed from .317 to .479 (sample 24 and 25). The cause of this jump could be that sample 25 represented smolts from the group of individuals up in Little River which were identified by the catch of parr (sample 16) during the same summer.

The significant differences of q^A between sample 34 and some of the other samples representing adult salmon in the same river system were also very interesting. Especially since the sample from the estuary representing fish coming back from the sea (sample 38) shows an intermediate value.

DISCUSSION

The existence of significant differences in the value of the gene frequency q^A between samples, together with the fact that the distribution of transferrin types, with the exception of six samples, are in accordance with Hardy-Weinberg law, are consistent with the general view that nearly all species are made up of genetically distinct populations.

The significant differences between observed and expected distributions in six samples could partly be caused by chance and partly collecting blood specimens from more than one population. Sample 17, 28, 29, 34, and 36 are collected in one river system with a complex structure. Together with the different values of q^A in the same river system, it is obvious to assume that the significant differences between observed and expected distributions in each sample are caused by the presence of several populations of salmon in the river system (Saunders 1967).

One question concerns the influence of artificial stocking on the genetic diversity. Over the years there has been a considerable degree of interchange of stocks within West Atlantic salmon which could have contributed greatly to the present heterogeneity. The difference between samples from St. John R. (sample 47 to 51) is difficult to interprete. The detected heterogeneity could pertly be caused by the heavy stocking in this river over the last few years.

Stocking, however, can not explain all the differences detected. Stocking is not reported between rivers in Labrador (sample 1), Newfoundland (sample 2 to 4), or Anticosti (sample 7 and 8). It is not possible to detect any real difference between areas without stocking or areas where stocking has occurred. One would believe that an exchange of individuals between rivers would break down the isolation mechanisms and lead to panmixia. This does not seem to have occurred. The reason for this could be the common occurrence of the efficient homing instinct or some other possible premating mechanisms. Investigations indicate that populations have their own migration routes at sea. The difference between Mingan (sample 5) and MacDonald (sample 7) can hardly be explained without the existence of an isolating mechanism (see Figure 2).

By any means the complex genetic diversity in salmon together with the lack of difference between areas with and without stocking, should be a warning for the policy of stocking in the future.

Lately, another report has been published concerning transferrin variation in the Atlantic salmon (Payne, Child, and Forrest 1971). The authors explain partly the presence of different populations of Atlantic salmon as the progeny of interstadial populations. The importance of environmental changes of the past for raciation should not be underestimated. However, more importance should be attached to the balance between the evolutionary forces of today and the reaction to these forces from salmon as one species. The complex picture of genetic diversity in salmon in the present report seems to emphasize this balance in the nature comparable to many of the results obtained lately in different animal groups (see for instance Berry and Southern 1970 and Koehn 1969).

LITERATURE

Berry, R.J. and Southern, H.N. 1970. Variation in mammalian populations. Academic Press, London, 403 pp.

Koehn, R.K. 1969. Esterase heterogeneity: Dynamics of a polymorphism. Science 163: 943-944.

Møller, D. 1966. Polymorphism of serum transferrin in cod. Fiskidir. Skr. Ser. Havunders. 14: 51-60.

- 1970a. Transferrin polymorphism in Atlantic salmon (Salmo salar): J. Fish. Res. Bd. Canada 27: 1617-1625.

- 1970b. Genetic diversity in Atlantic salmon and salmon management in relation to genetic factors. Spec. Publ. Ser. int. Atlant. Salm. F.d.n. 1(1): 7-29.

- 1970c. Artsstrukturen i Atlantisk laks - Betydning for kulturarbeidet (in Norwegian, English summary). Swedish Salmon Res. Inst. Report L.F.I. Medd. S: 29 pp.

Saunders, R.L. 1967. Seasonal pattern of return of Atlantic salmon in the northwest Miramichi River, New Brunswick. J. Fish. Res. Bd. Canada 24: 21-32.

Sick, K. 1965. Haemoglobin polymorphism of cod in the Baltic and the Danish Belt Sea. Hereditas 54: 19-48.

TABLE 1

Locality, date, gear, type of animal and number of specimens of collected samples.

Sample no.	Locality	Date of sample	Gear	Type of animal	Number of specimens
1	Sand Hill R., Labrador	23.-29. 7/69	Counting fence	Grilse	130
2	Indian R., Nfld.	15. 6/70	Counting fence	Smolt	120
3	Terra Nova R., Nfld.	12.-17. 8/70	Fishway trap	Grilse	54
4	Adies Stream, Nfld.	1. 8/69	Counting fence	Grilse	112
5	Mingan R., P.Q.	28.-29. 7/70	Electro seining	Parr	27
6	Saquenay R., Tadoussac	3. 11/70	Trapnet	Grilse/adults	120
7	MacDonald R., Anticosti Is.	23.-24. 7/70	Electro seining	Parr	143
8	Juniper R., Anticosti Is.	20.-22. 7/70	Electro seining	Parr	154
9	Matane, P.Q.	2.-10. 7/70	Fishway trap	Grilse/Adults	122
10	Dartmouth R., P.Q.	11.-13. 7/70	Counting fence	Grilse	164
11	St. Jean R., P.Q.	22.-23. 7/70	Electro seining	Parr	115
12	Grand Cascapedia R., P.Q.	1. 7/70	Electro seining	Parr	146
13	Carleton R., P.Q.	1. -25. 6/69	Trapnet	Grilse/adults	120
14	Restigouche R., N.B.	2. 9/69	Seine	Grilse/adults	120
15	Crawford Pool, NW Miramichi, N.B.	11. 8/70	Electro seining	Parr	73
16	Little R., NWM, N.B.	14. 8/70	Electro seining	Parr	26
17	Stoney Bk + Little Bald NWM, N.B.	20.-26. 8/70	Electro seining	Smolt	80
18	NW Miramichi, N.B.	25.-26.-28. 8/70	Electro seining	Smolt	80
19	NW Miramichi, N.B.	27.-28. 8/70	Electro seining	Smolt	59

Locality, date, gear, type of animal and number of specimens of collected samples.

Sample no.	Locality	Date of sample	Gear	Type of animal	Number of specimens
20	Curventon, NWM, N.B.	5/69	Counting fence	Smolt	93
21	Curventon, NWM, N.B.	20. 5/70	Counting fence	Smolt	120
22	Curventon, NWM, N.B.	26. 5/70	Counting fence	Smolt	120
23	Curventon, NWM, N.B.	29. 5/70	Counting fence	Smolt	120
24	Curventon, NWM, N.B.	2. 6/70	Counting fence	Smolt	120
25	Curventon, NWM, N.B.	5. 6/70	Counting fence	Smolt	70
26	Curventon, NWM, N.B.	9. 6/70	Counting fence	Smolt	120
27	Curventon, NWM, N.B.	12. 6/70	Counting fence	Smolt	120
28	Curventon, NWM, N.B.	3.-6. 7/69	Counting fence	Grilse	117
29	Curventon, NWM, N.B.	17.-29. 7/69	Counting fence	Grilse	146
30	Curventon, NWM, N.B.	3.-30. 6/70	Counting fence	Adults	97
31	Curventon, NWM, N.B.	7.-22. 7/70	Counting fence	Adults	116
32	Sevolge R., NWM, N.B.	3.-25. 6/70	Electro seining	Parr/smolt	44
33	Bartholomew R., NWM, N.B.	31. 5/70	Seine	Smolt	90
34	SW Miramichi R., N.B.	1., 9.-31. 10/69	Trapnet	Grilse	117
35	SW Miramichi R., N.B.	28. 10/70	Trapnet	Adults	62
36	Millbank, N.B.	26.-28. 5/69	Trapnet	Smolt	120
37	Millbank, N.B.	3. 6/70	Trapnet	Smolt	120
38	Millbank, N.B.	24.-29. 7/69	Trapnet	Grilse/adults	59
39	R. Philip, N.S.	1. 7.-30. 9/69	Fishway trap	Grilse/adults	120
40	Wallace R., N.S.	9. 7/70	Electro seining	Parr	70

Sample no.	Locality	Date of sample	Gear	Type of animal	Number of specimens
41	MargareeR., N.S.	1. 7.-30. 9/69	Seine	Grilse/adults	95
42	Margaree R., N.S.	20. 8/70	Electro seining	Parr	115
43	Middle R., Cape Breton	16. 9/70	Electro seining	Parr	110
44	East R., N.S.	9. 6/70	Counting fence	Smolt	120
45	Big Salmon R.,, N.B.	4. 6/70	Counting fence	Smolt	120
46	Big Salmon R., N.B.	5.-9. 9/70	Fishway trap	Adults	114
47	Saint John R., N.B.	1. 5.-30. 6/69	Fishway trap	Grilse/adults	105
48	Saint John R., N.B.	1. 7.-15. 10/69	Fishway trap	Grilse/adults	142
49	Saint John R., N.B.	16.-31. 10/69	Fishway trap	Grilse/adults	91
50	Saint John R., South Esk	9.-10. 11/70	Fishway trap	Grilse/adults	60
51	Saint John R., South Esk	9.-10. 11/70	Fishway trap	Grilse/adults	60
52	Dennis Stream, N.B.	5.-7. 8/70	Electro seining	Parr	40
53	Dennis R., Maine	8. 10/70	Electro seining	Parr	76
54	Machias R., Maine	1. 6.-30. 9/69	Counting fence	Grilse/adults	32
55	Machias R., Maine	11.-13. 8/70	Fishway trap	Parr	124
56	Narraguagus R., Maine	1. 6.-30. 9/69	Counting fence	Grilse/adults	24

TABLE [illegible]

TRANSFERRIN POLYMORPHISM IN SALMON

	TfAA		TfAC		TfCC	
SAMPLE	OBS.	EXP.	OBS.	EXP.	OBS.	EXP.
1	2	0.93	18	20.14	110	108.94
2	3	2.4	28	29.19	89	88.4
3	1	0.59	6	6.81	20	19.60
4	1	0.57	14	14.85	97	96.57
5	2	1.56	9	9.87	16	15.57
6	10	8.27	43	46.46	67	65.27
7	56	60.47	74	65.04	13	17.49
8	39	42.61	84	79.79	31	34.60
9	17	13.45	47	54.11	58	54.43
10	30	27.27	52	57.46	33	30.26
11	38	39.63	59	55.76	18	19.62
12	30	25.35	60	60.29	52	47.36
13	22	20.42	55	58.16	43	41.42
14	21	20.01	56	57.98	43	42.01

TRANSFERRIN POLYMORPHISM IN SALMON

	TfAA		TfAC		TfCC		
SAMPLE	OBS.	EXP.	OBS.	EXP.	OBS.	EXP.	
15	7	8.56	36	22.88	30	31.56	
16	5	5.29	13	12.42	7	7.29	
17	15	8.78	23	35.46	42	35.78	x
18	5	6.91	37	33.20	38	39.91	
19	6	5.80	25	25.41	28	27.79	
20	11	11.36	43	42.29	39	39.35	
21	13	13.67	55	53.66	52	52.67	
22	13	12.04	52	51.94	56	56.03	
23	10	11.60	54	50.80	54	55.60	
24	10	12.04	56	51.94	54	56.03	
25	19	16.03	29	34.94	22	19.03	
26	17	16.14	54	55.74	49	48.13	
27	15	15.05	55	54.90	50	50.05	
28	22	15.08	40	53.84	55	48.07	x
29	28	22.25	58	69.50	60	54.25	x
30	9	9.59	43	41.83	45	45.59	
31	17	18.64	59	55.73	40	41,63	
32	5	6.57	24	20.86	15	16.57	
33	12	11.38	40	41.25	38	37.37	
34	10	5.78	32	40.44	75	70.78	x
35	11	9.68	27	29.64	24	22.68	
36	21	16.50	47	55.99	52	47.51	x
37	15	15.77	57	55.46	48	48.77	
38	7	4.90	20	24.20	32	29.90	

TRANSFERRIN POLYMORPHISM IN SALMON

	TfAA		TfAC		TfCC	
SAMPLE	OBS.	EXP.	OBS.	EXP.	OBS.	EXP.
39	12	12.68	54	52.65	54	54.67
40	7	6.09	27	28.82	35	34.09
41	19	18.57	46	46.86	30	29.57
42	20	23.52	64	56.97	31	34.51
43	28	31.65	62	54.71	20	23.64
44	10	10.12	50	49.57	60	60.20
45	11	10.08	50	50.4	59	58.8
46	15	14.82	52	52.44	47	46.74
47	8	5.49	32	37.03	65	62.48
48	14	10.71	50	56.57	78	74.72
49	10	7.72	33	37.57	48	45.72
50	8	10.84	35	29.33	17	19.84
51	7	8.07	30	27.86	23	24.07
52	8	10.00	24	20.00	8	10.00
53	27	25.47	34	37.06	15	13.47
54	10	11.28	18	15.44	4	5.28
55	5	5.29	13	12.42	7	7.29
56	9	8.76	11	11.48	4	3.76

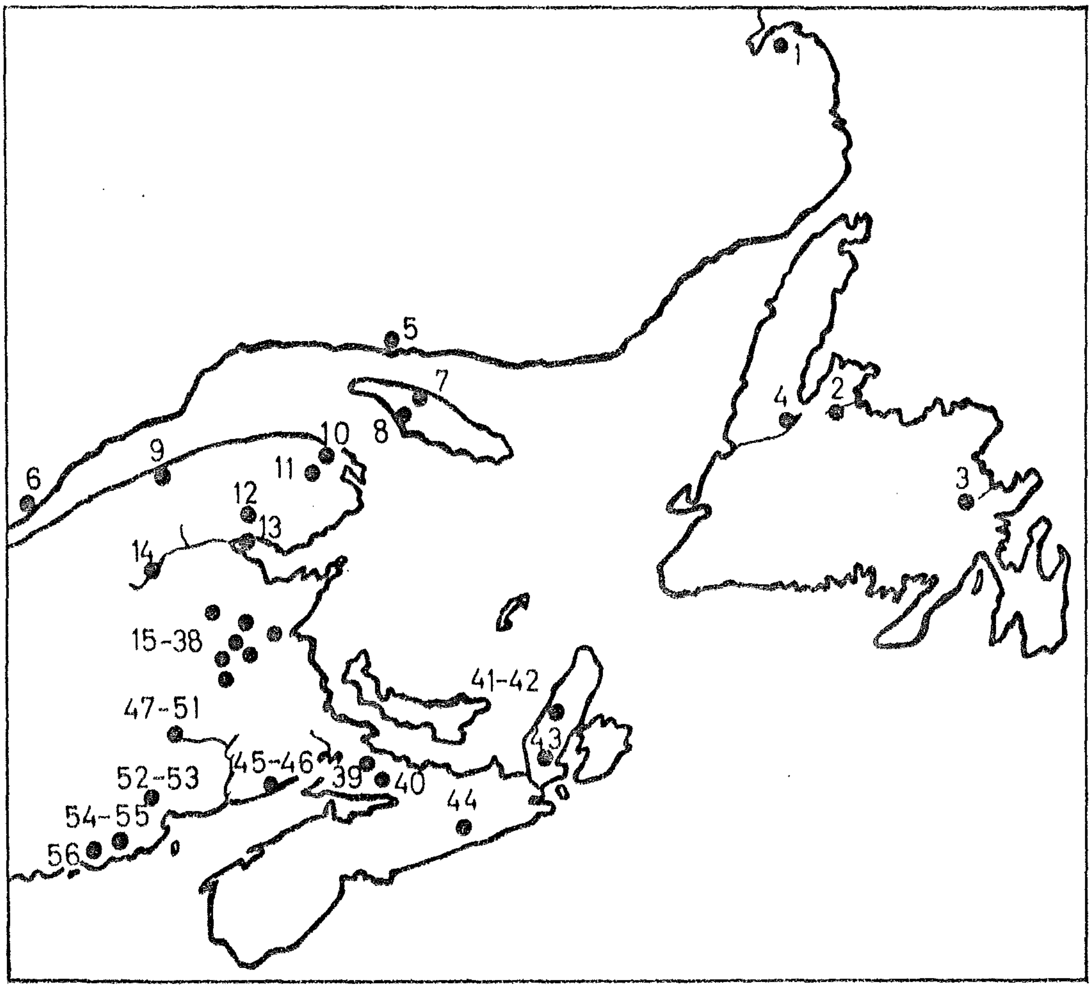

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15-38
39
40
41-42
43
44
45-46
47-51
52-53
54-55
56

FIGURE 1

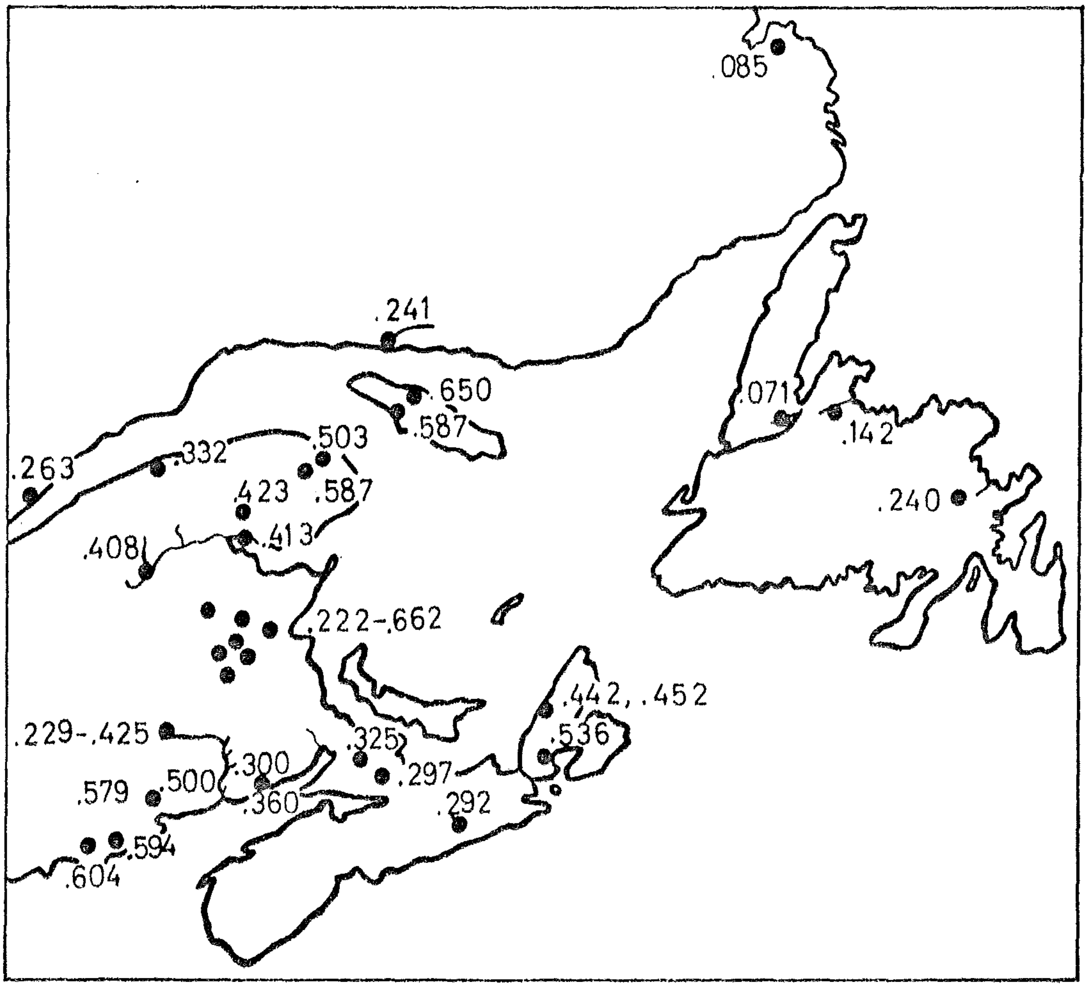

.085
.241
.650
.587
.071
.142
.263
.332
.503
.423
.587
.240
.408
.413
.222-.662
.442, .452
.536
.229-.425
.300
.325
.297
.579
.500
.360
.292
.594
.604

FIGURE 2

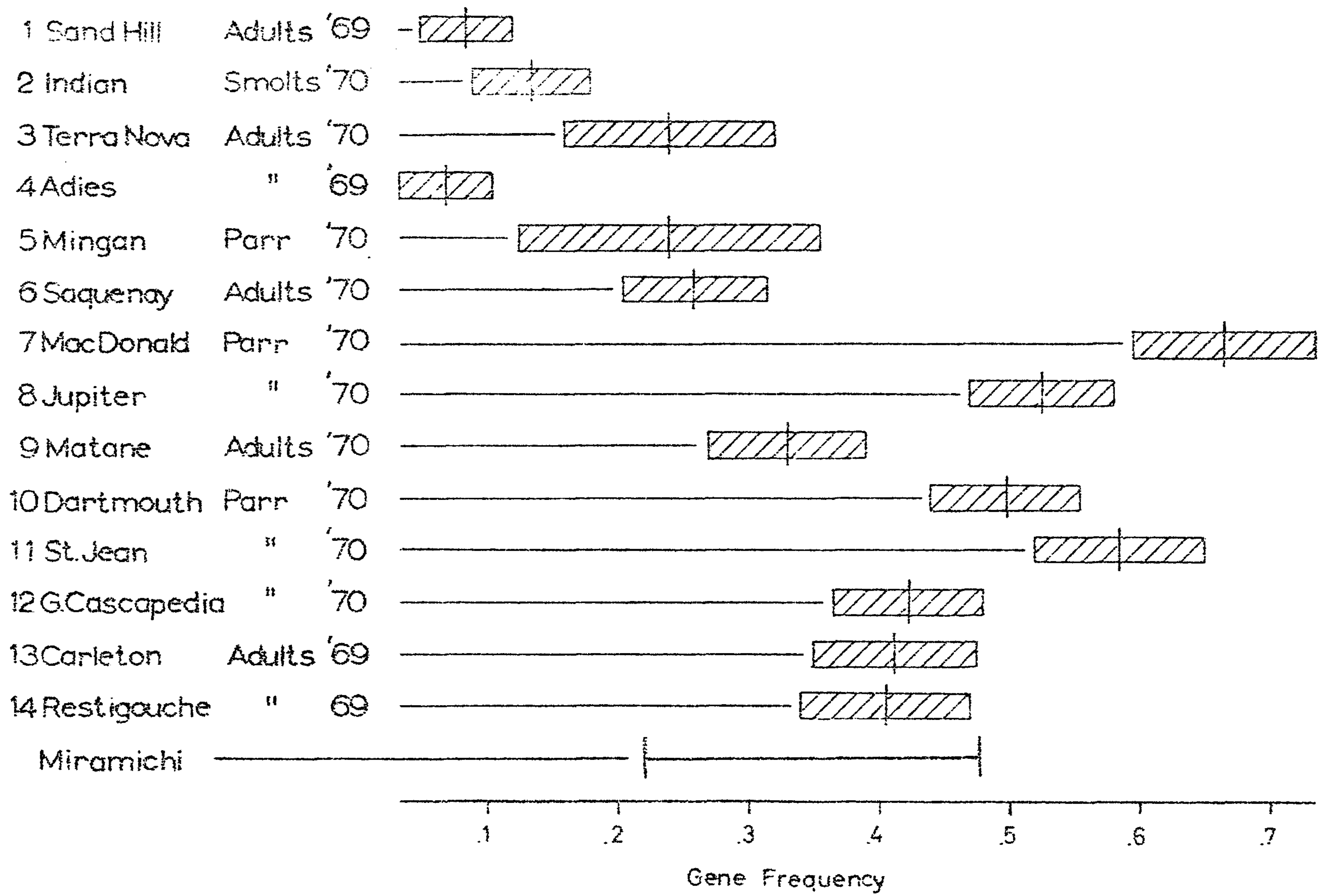

1 Sand Hill Adults '69
2 Indian Smolts '70
3 Terra Nova Adults '70
4 Adies " '69
5 Mingan Parr '70
6 Saquenay Adults '70
7 MacDonald Parr '70
8 Jupiter " '70
9 Matane Adults '70
10 Dartmouth Parr '70
11 St. Jean " '70
12 G.Cascapedia " '70
13 Carleton Adults '69
14 Restigouche " 69
Miramichi
.1
.2
.3
.4
.5
.6
.7
Gene Frequency

FIGURE 3

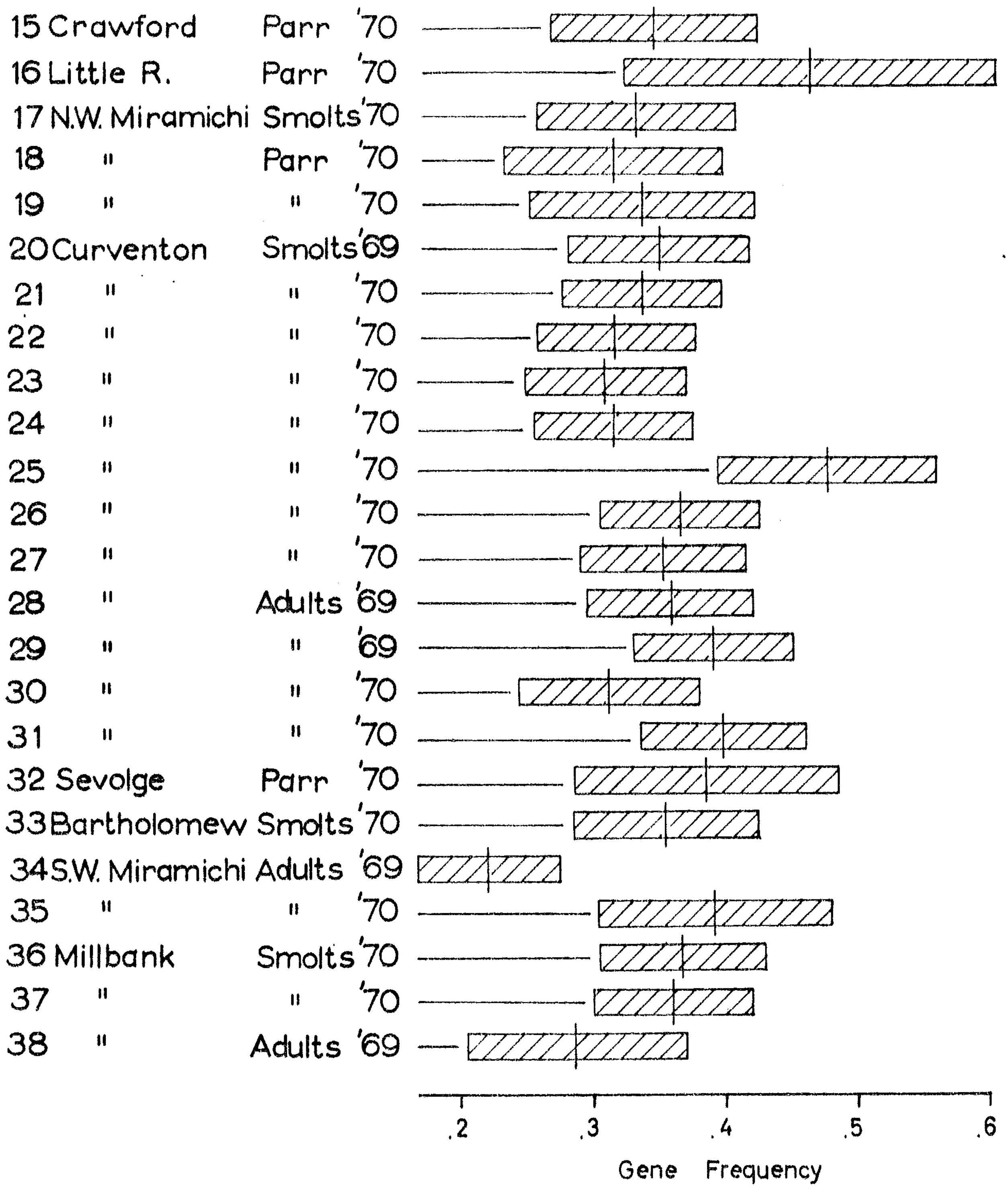
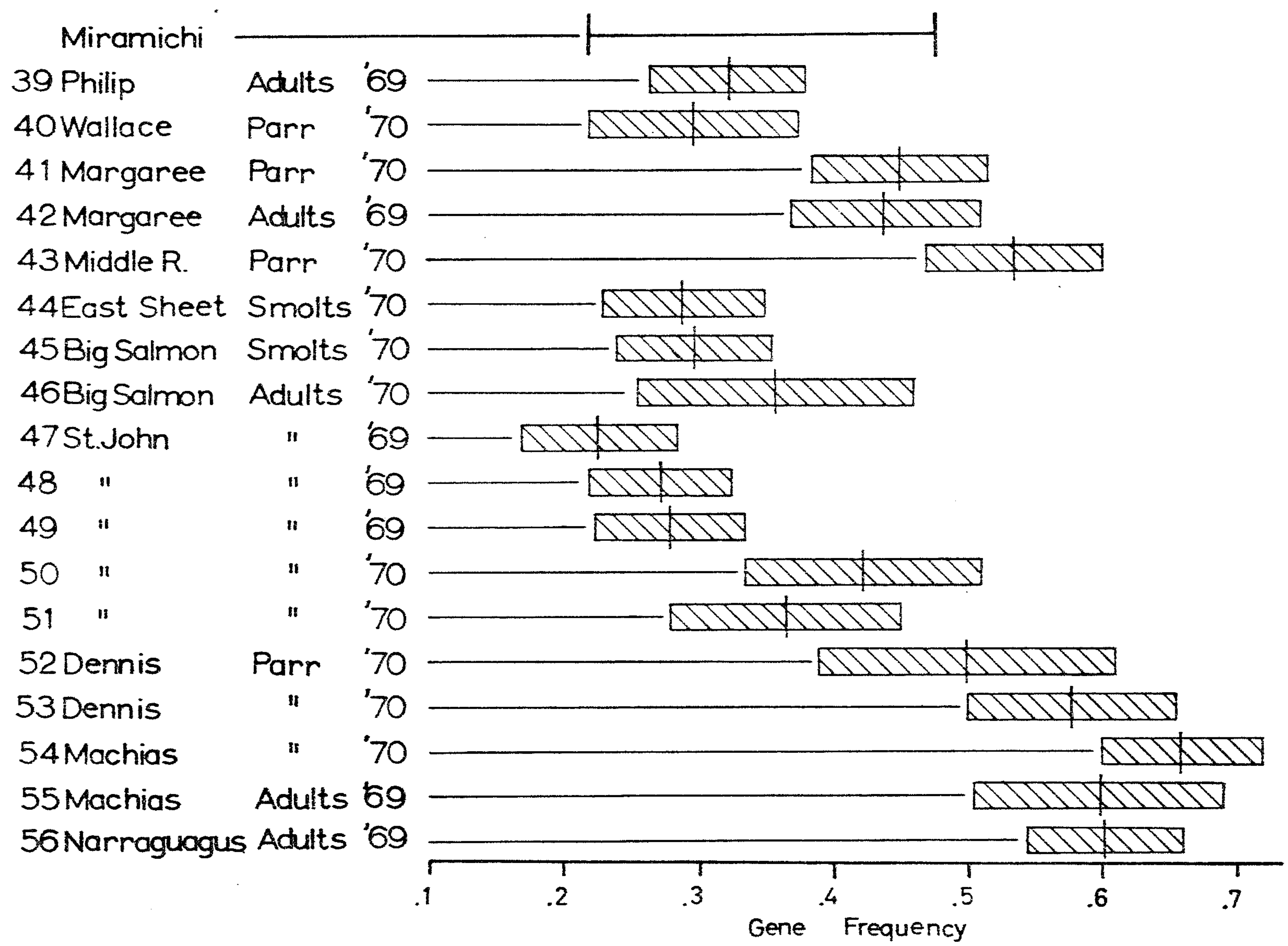

15 Crawford Parr '70
16 Little R. Parr '70
17 N.W. Miramichi Smolts '70
18 " Parr '70
19 " " '70
20 Curventon Smolts '69
21 " " '70
22 " " '70
23 " " '70
24 " " '70
25 " " '70
26 " " '70
27 " " '70
28 " Adults '69
29 " " '69
30 " " '70
31 " " '70
32 Sevolge Parr '70
33 Bartholomew Smolts '70
34 S.W. Miramichi Adults '69
35 " " '70
36 Millbank Smolts '70
37 " " '70
38 " Adults '69
.2
.3
.4
.5
.6
Gene Frequency

FIGURE 4



Miramichi
39 Philip Adults '69
40 Wallace Parr '70
41 Margaree Parr '70
42 Margaree Adults '69
43 Middle R. Parr '70
44 East Sheet Smolts '70
45 Big Salmon Smolts '70
46 Big Salmon Adults '70
47 St. John " '69
48 " " '69
49 " " '69
50 " " '70
51 " " '70
52 Dennis Parr '70
53 Dennis " '70
54 Machias " '70
55 Machias Adults '69
56 Narraguagus Adults '69
.1
.2
.3
.4
.5
.6
.7
Gene Frequency

FIGURE 5