Use of Variation in Biological Characters for the Classification of Anadromous Rainbow Smelt (*Osmerus mordax*) Groups[1]

A. FRÉCHET[2] AND J. J. DODSON

Département de biologie, Université Laval, Sainte-Foy (Qué.) G1K 7P4

AND H. POWLES

Department of Fisheries and Oceans, Gulf Region, Fisheries Research Branch, C.P. 15 500, Quebec, Que. G1K 7Y7

FRÉCHET, A., J. J. DODSON, AND H. POWLES. 1983. Use of variation in biological characters for the classification of anadromous rainbow smelt (*Osmerus mordax*) groups. Can. J. Fish. Aquat. Sci. 40: 718 – 727.

Analysis of meristics, growth patterns, and fecundity to somatic weight relationships of spawning anadromous rainbow smelt (*Osmerus mordax*) in Quebec waters demonstrated the existence of three geographical groups (Chaleur Bay, south shore of the St. Lawrence Estuary, and Saguenay Fjord). Although homing to spawning rivers does not appear to occur, the degree of heterogeneity of spawning smelt of different geographical areas is less at the extremes of their Quebec distribution. Classification of smelt from the commercial fishery catch indicates limited mixing of these groups during open-water migration. The existence of a fourth group is suggested by classification analysis of smelt caught along the lower north shore of the St. Lawrence Estuary.

FRÉCHET, A., J. J. DODSON, AND H. POWLES. 1983. Use of variation in biological characters for the classification of anadromous rainbow smelt (*Osmerus mordax*) groups. Can. J. Fish. Aquat. Sci. 40: 718 – 727.

L'analyse de variables portant sur des caractères méristiques, de croissance et de relations fécondité-poids somatique de l'éperlan (*Osmerus mordax*) anadrome du Québec pendant la période du frai, indique l'existence de trois groupes géographiques (la Baie des Chaleurs, la rive sud du fleuve Saint-Laurent et le fjord du Saguenay). Même si le phénomène du homing ne semble se produire ici, le degré d'hétérogénéité des regroupements d'éperlans d'origines géographiques différentes est moins important aux limites de leur distribution au Québec. La classification de l'éperlan de la pêche commerciale indique un faible degré de mélange de ces groupes lors de leur migration en pleine mer. Les résultats de la classification de l'éperlan capturé le long de la basse Côte-Nord de l'estuaire du Saint-Laurent suggèrent l'existence d'un quatrième groupe.

Received September 3, 1982
Accepted February 25, 1983

Reçu le 3 septembre 1982
Accepté le 25 février 1983

A fish stock has been described by Larkin (1972) as "a population of organisms which, sharing a common gene pool, is sufficiently discrete to warrant consideration as a self-perpetuating system which can be managed." This is founded on the presence of isolating mechanisms that limit gene flow. Discreteness in fish stocks is a property that results from the interaction between ecological and genetic factors. This duality has led investigators to qualify given stocks as genotypic or phenotypic (Booke 1981).

Members of the genotypic stock should conform to the Castle–Hardy–Weinberg law whereas the phenotypic stock would display a clinal pattern of biological variables (Spangler et al. 1981). Phenotypic stocks are characteristic of *r*-selected, short-lived fish, pelagic as fry, and dependent on very few age classes in the spawning stock (MacLean and Evans 1981; Ryder et al. 1981). Various processes may help to establish and maintain such stocks. Homing is one that limits gene flow. Stock discreteness can also be obtained by mutation, selection, and genetic drift (MacLean and Evans 1981).

Tagging studies (Magnin and Beaulieu 1965) in the St. Lawrence Estuary have demonstrated that seasonal open-water migrations in rainbow smelt (*Osmerus mordax*) are generally between 80 and 160 km. Marcotte and Tremblay (1948) found a north–south gradient in the vertebral counts of anadromous rainbow smelt of the Gaspé Peninsula. Homing has not been demonstrated in anadromous rainbow smelt (Magnin and Beaulieu 1965); thus, the extent of gene flow between the various spawning rivers is unknown.

---

[1]Contribution to the program of GIROQ (Groupe interuniversitaire de Recherche océanographique du Québec).

[2]Present address: Department of Fisheries and Oceans, C.P. 15 500, Quebec, Que. G1K 7Y7.

Printed in Canada (J7052)
Imprimé au Canada (J7052)

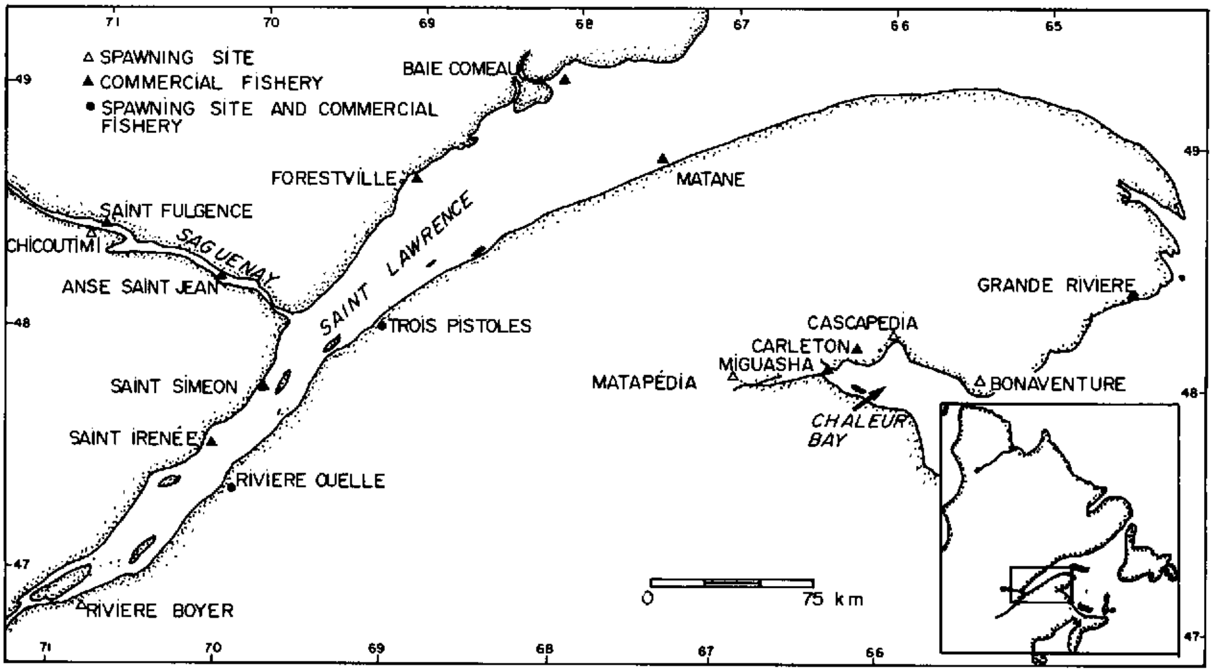

FIG. 1. Study areas on the Saguenay Fjord, the St. Lawrence Estuary, and Chaleur Bay.

The objective of this paper is to assess the degree of spatial integrity of smelt groups in rivers and in open waters using variation in the biological characteristics of meristics, growth, and fecundity. It is proposed that substantial differences in these characters between smelt of adjacent spawning rivers would be indicative of homing and the presence of discrete genetic stocks. Once spawning smelt populations are characterized and the extent of overlap in their biological characters is evaluated, a classification method is applied to the commercial fishery catch to assess the degree of spatial integrity of smelt stocks during their open-water migrations.

Materials and Methods

A total of 2239 anadromous spawning smelt were sampled by dipnetting during April and May, 1979 and 1980, at spawning sites in eight rivers located along the Saguenay Fjord (region I), the south shore of the St. Lawrence Estuary (region II), and Chaleur Bay (region III) (Fig. 1). A minimum of 200 fish was sampled at each spawning site. Physical characteristics of these rivers are diverse, drainage basin areas ranging from 22.7 to 79 800 km^2 and maximum flow ranging from 233 to 5830 $m^3 \cdot s^{-1}$. Another 2500 smelt were obtained from coastal commercial fisheries during the summers and winters of 1979 and 1980 (Fig. 1). Fishing gear of the commercial fishery was nonselective (box nets and weirs) in 80% of all samples and areas whereas gill nets of varying mesh sizes accounted for the remaining 20%.

All fish were frozen upon capture for subsequent analysis. Shrinkage in standard length due to freezing was compensated by applying the regression equation $y = 1.07x - 2.38$ ($R^2 = 0.986$, $n = 140$) to standard lengths measured from

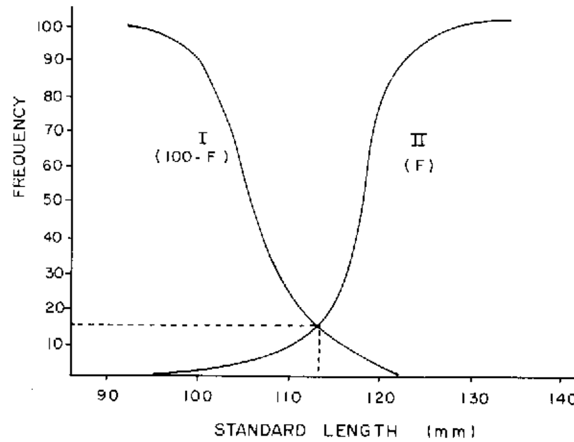

FIG. 2. Example of method for calculating the critical length interval for length-at-age values of spawning smelt.

frozen fish (x = standard length of frozen fish, y = standard length of fresh fish).

Standard length (to the nearest millimetre), total weight (grams), gonad weight (grams), sex, and state of maturity (Nikolsky 1963) were noted for each specimen. Age was determined from scales (McKenzie 1958). Meristic counts included total left pectoral fin and anal fin rays, spines of the first left gill arch, and vertebrae (hypural excluded). Fecundity values were estimated by the dry weight method (Bagenal 1978) after treatment with Gilson's fluid and 24 h of drying at 57°C. Five samples of 100 eggs were taken from each of 208 females and weighed to the nearest 0.1 mg. The

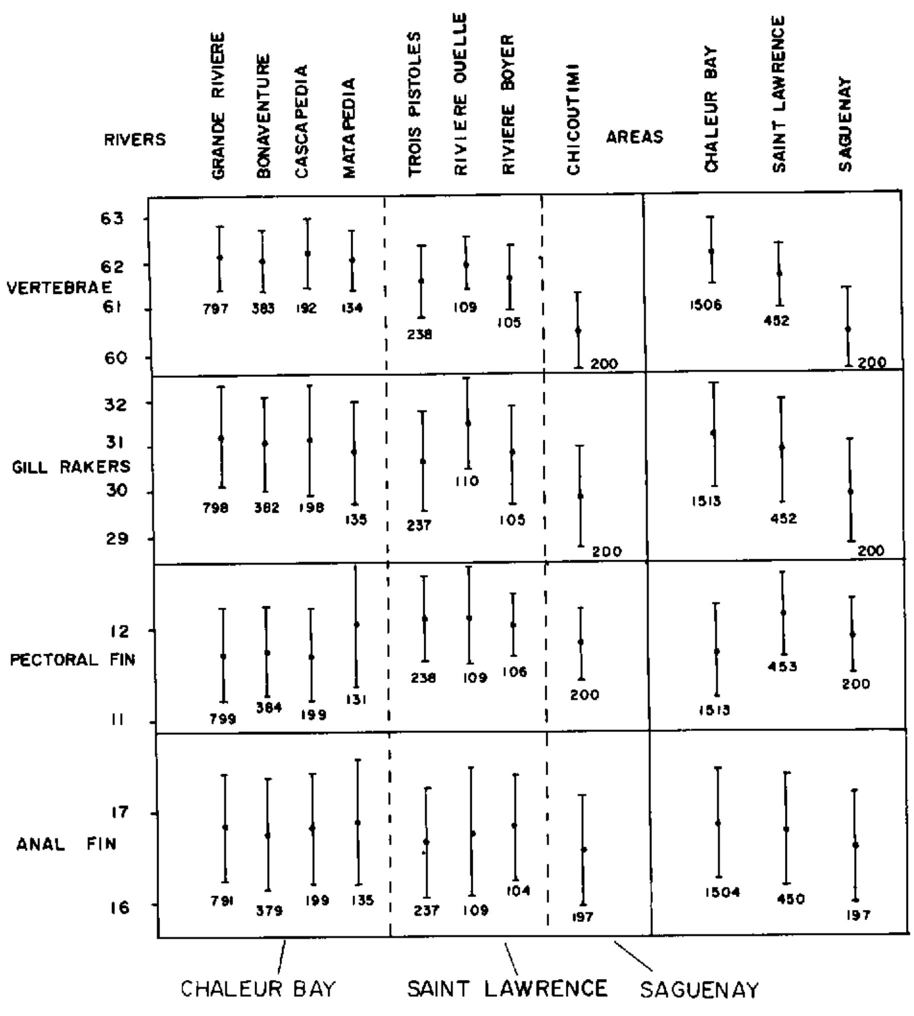

FIG. 3. Means, standard deviations, and numbers of the meristic variables recorded for spawning smelt by river and area.

TABLE 1. Univariate F value (ANOVA) of meristic values before and after pooling. $F(7, \infty, 0.001) = 3.47$; $F(2, \infty, 0.001) = 6.91$.

Character	n	Eight spawning rivers	Three areas
Vertebrae	2158	123.4	413.7
Gill raker	2165	44.0	118.0
Pectoral	2151	33.9	79.9
Anal	2166	6.0	15.7

procedure was repeated when the size of the 95% confidence interval was greater than 10% of the estimated mean fecundity. This occurred in only 25 cases.

Data Analysis

SPAWNING SITE SAMPLES

After testing interyear and between-sex differences, data were pooled for year and sex, and the variation of each of the four meristic characters between the eight spawning rivers was tested using a one-way analysis of variance (ANOVA). Significant differences were identified using the Student–Newman–Keuls (SNK) test (Sokal and Rohlf 1969). As a result of this analysis, the eight rivers were regrouped into three geographical regions, and Wilk's λ test confirmed the validity of the pooling ($P = 0.005$). Multivariate discriminant analysis was performed to identify the relative importance of the four meristic variables used in separating the three geographical regions. Mahalanobis D^2 distance (Mahalanobis 1936) was used to calculate the percentage of fish correctly assigned to their area of origin.

The statistical treatment of growth patterns involved an analysis of variance of mean length at age for each sex and age class over the eight spawning rivers. Student–Newman–Keuls tests were carried out to identify significant differences and pool samples. Sex and regional differences in growth were tested by the Hotelling T^2 test (Bernard 1981) on parameters of the von Bertalanffy growth equation

TABLE 2. Number of significant differences (SNK, $P \leq 0.05$) of four meristic variables in the eight spawning rivers.

	Area III				Area II			Area I, Chicoutimi
	G. Rivière	Bonaventure	Cascapédia	Matapédia	T. Pistoles	R. Ouelle	R. Boyer	
Chaleur Bay (III)								
G. Rivière (800)	—							
Bonaventure (384)	1	—						
Cascapédia (200)	1	0	—					
Matapédia (135)	2	1	1	—				
Saint Lawrence (II) south shore								
T. Pistoles (239)	4	3	3	3	—			
R. Ouelle (110)	2	2	2	1	2	—		
R. Boyer (106)	3	2	2	1	0	2	—	
Saguenay (I)								
Chicoutimi (200)	4	4	4	4	3	4	4	—

TABLE 3. Standardized canonical coefficients of discriminant analysis of spawning smelt.

Variable	Function 1	Function 2
Anal fin rays	0.05899	−0.04958
Pectoral fin rays	−0.18641	0.97482
Gill rakers	0.47344	0.15947
Vertebrae	0.85952	0.12634

(Abramson 1965).

As the growth of smelt was significantly different among regions and between sexes, length-at-age intervals characteristic of spawning groups were calculated using a simple method based on the cumulative frequency distribution of observed standard lengths of male and female smelt. An example, using fictitious data (Fig. 2), illustrates the method. After having calculated frequency (f), cumulative frequency (F), and the complement of cumulative frequency ($100 - F$) of the standard lengths of same-age fish of two adjacent groups (groups I and II), the cumulative frequency distribution of group II is plotted against the complement ($100 - F$) of group I. The point at which these two curves intersect (at 113 mm in this case) determines the critical standard length that distinguishes smelt of the same age and sex of the two adjacent groups. Overlaps in length frequency of smelt from adjacent geographical areas rarely exceeded 20%. The procedure is repeated to calculate the critical standard length distinguishing smelt of the same age and sex of groups II and III, thus establishing a critical length interval by age and sex for smelt from region II. The upper limit of the critical length interval for group III was based on the maximum observed standard lengths of spawning smelt captured in region III. The lower limit of the critical length interval for group I was based on the minimum observed standard lengths of spawning smelt captured in region I. Using these three critical length intervals by age and sex, smelt from the commercial fishery catch could thus be classified to a given region (I, II, or III) on the basis of their length-at-age values.

Initially, no length interval could be established for the single sample of spawning smelt of Chicoutimi (region I), as only one age class accounted for 94% of the fish sampled. This appeared to result from the temporal and spatial heterogeneity of smelt on the spawning grounds combined with the punctual nature of the sampling program. However, fish from the commercial samples at Anse St-Jean ($n = 236$) were smaller at a given age than smelt from regions II and III and displayed a wider age span than the Chicoutimi spawning samples. Therefore, the Anse St-Jean fish were considered a spawning sample, thus enabling us to calculate the critical length interval by age and sex for group I. Use of this commercial sample to replace a spawning sample is justified by the similarity of length at age 2 of the two samples and the geographical proximity of the sampling sites.

Comparison of regression lines for the fecundity to somatic weight relationship was tested by analysis of covariance (ANCOVA) (Snedecor and Cochran 1978).

TABLE 4. Classification results of discriminant analysis of meristic variables of spawning smelt.

		Predicted group membership		
Actual group	No. of cases	Chaleur Bay (%)	Saint Lawrence south shore (%)	Saguenay Fjord (%)
Chaleur Bay (III)	1477	67.0	26.8	6.2
Saint Lawrence (II) south shore	441	32.2	47.2	20.6
Saguenay Fjord (I)	197	4.6	18.3	77.2

TABLE 5. Results of SNK tests of male standard length (SL) by spawning river and age ($P = 0.05$). Nonsignificantly different means are underlined.

Age (yr)	Spawning rivers							
2	Chicoutimi	R. Ouelle	R. Boyer	Cascapédia	G. Rivière	T. Pistoles	Bonaventure	Matapédia
SL	95.07	118.96	125.71	127.77	131.30	132.44	133.29	142.71
(*n*)	(185)	(5)	(17)	(135)	(171)	(5)	(153)	(135)
3	R. Boyer	R. Ouelle	T. Pistoles	Cascapédia	Bonaventure	G. Rivière	Matapédia	
SL	145.39	145.41	145.46	152.46	162.51	162.60	171.44	
(*n*)	(70)	(77)	(59)	(20)	(114)	(153)	(45)	
4	R. Ouelle	Cascapédia	R. Boyer	T. Pistoles	Bonaventure	G. Rivière	Matapédia	
SL	165.26	166.33	168.83	168.99	179.25	179.46	185.94	
(*n*)	(12)	(3)	(3)	(13)	(12)	(17)	(3)	
5	Cascapédia	R. Boyer	T. Pistoles	G. Rivière	Bonaventure			
SL	180.59	181.78	187.44	189.58	196.03			
(*n*)	(5)	(9)	(5)	(5)	(7)			

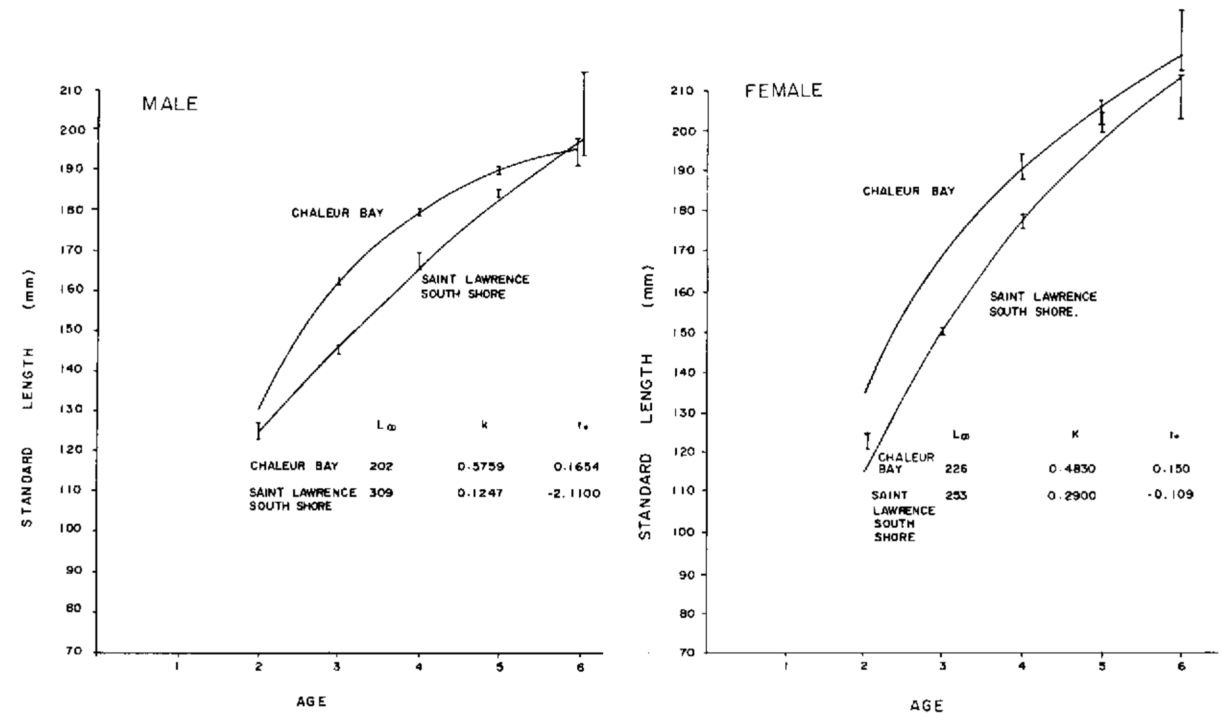

FIG. 4. von Bertalanffy growth curves for length-at-age data of spawning smelt (vertical bars represent ±1 SE of measured length).

Each method of classification (meristics, length-at-age) was then validated by the degree of overlap of accurately predicted group membership of individual fish by a simultaneous application of both methods to the spawning run samples.

COMMERCIAL FISHERY SAMPLES

To assign smelt caught in the coastal commercial fisheries to one of the spawning groups previously identified, the Mahalanobis D^2 generalized distance was calculated based on the four meristic variables. Fish from the commercial fishery were also assigned to one of the three areas of origin based on their length-at-age value.

The fecundity to somatic weight relationship could not be used for classifying fish from the commercial fishery because no fecundity count could be made between spawning runs.

TABLE 6. Results of the Hotelling T^2 test applied to von Bertalanffy growth coefficients ($L\infty$, asymptotic length; t_0, hypothetical age at zero length; k, growth coefficient; NS, not significant; $^{**}P \leq 0.01$; T_0^2 = critical value of T^2 for significance).

Test	T^2	T_0^2	Relative importance (critical F_0) No. 1	No. 2	No. 3
Saint Lawrence south shore, between sexes	4093.9**	11.39	t_0 (318.75)	k (275.91)	$L\infty$ (35.28)
Chaleur Bay, between sexes	33399.3**	11.36	$L\infty$ (2462.17)	k (395.79)	t_0 (2.47) (NS)
Males, between areas	14193.3**	11.36	k (5327.63)	t_0 (2547.10)	$L\infty$ (759.47)
Females, between areas	3242.9**	11.37	k (542.84)	$L\infty$ (361.84)	t_0 (71.62)

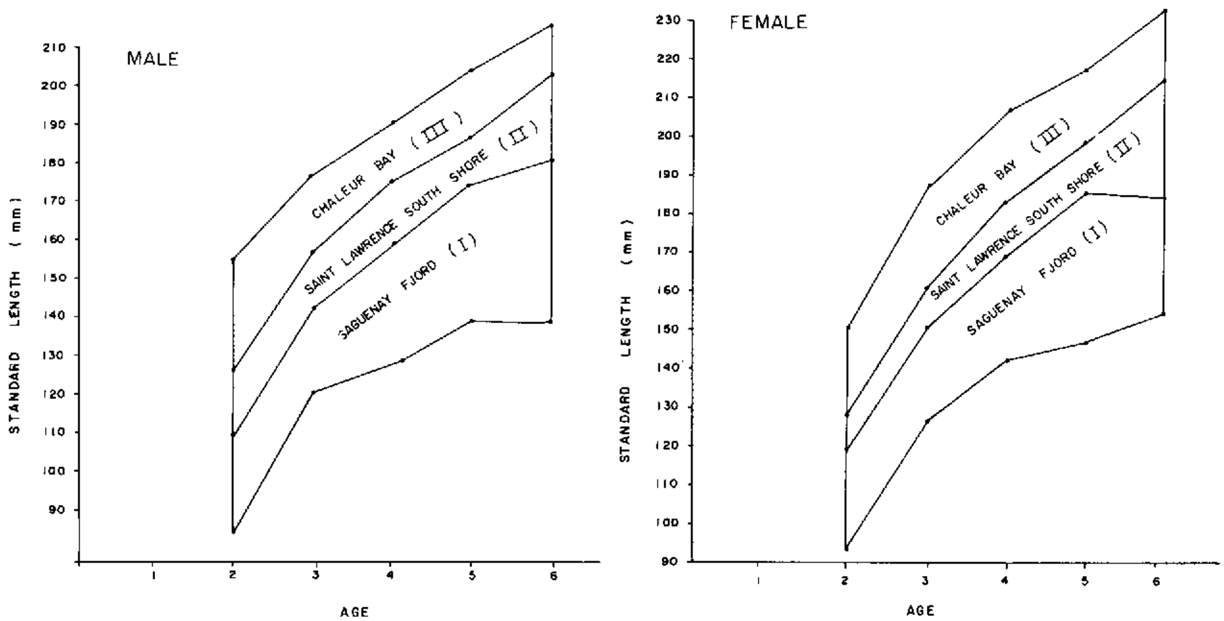

FIG. 5. Intervals of standard length-at-age based on spawning smelt for assignment of commercial fishery catch.

Results

SPAWNING RUNS

Meristics — As no significant differences were found between year and sex ($P > 0.05$), the four meristic variables recorded at each spawning river (Fig. 3) were pooled for year and sex. Each variable showed significant variance between rivers (ANOVA, $P = 0.01$) (Table 1). The a posteriori SNK test indicated an increase in the number of significant differences closely related to the geographical distance separating each spawning river (Table 2). Three geographic groups (areas, Fig. 3) were thus defined: Saguenay (I), the St. Lawrence Estuary (II), and Chaleur Bay (III). The Saguenay Fjord has the greatest number of differences in meristic counts when compared with spawning rivers of Chaleur Bay. Intermediate numbers of differences arise when one compares either area to the St. Lawrence spawning rivers. Small numbers of significant differences occur within each of the three areas.

This observation led us to pool results from the spawning rivers into three areas (I, II, and III) to obtain maximum separation of groups. The usefulness of this pooling is revealed by the increase of the F value for each meristic variable considered over the larger geographic scale (Table 1). Furthermore, a significant Wilk's λ ($P = 0.005$) confirmed the hypothesis of having effectively three smelt groups. The standardized canonical discriminant function coefficients (Table 3) of the first two functions illustrate the relative importance of the four meristic variables used. The first axis explained 89.5% of the variance between these three groups and was mainly due to the effect of vertebrae and gill raker counts.

Classification results (Table 4) based on Mahalanobis D^2 distance yield an overall value of correctly classified fish from the spawning runs of areas I, II, and III ranging from 47.2 to 77.2%.

TABLE 7. Classification results of spawning and commercial fishery catch of smelt on the basis of growth pattern.

			Predicted group membership (%)		
Actual group	No. of cases	Not assigned	Chaleur Bay	Saint Lawrence south shore	Saguenay Fjord
Chaleur Bay spawners (III)	1490	3.3	76.6	18.5	1.6
Saint Lawrence south shore spawners (II)	454	0.9	20.9	43.2	35.0
Saguenay Fjord spawners (I)	200	4.0	0.0	2.5	93.5
Commercial fisheries					
Chaleur Bay	448	11.6	54.4	28.6	5.4
Saint Lawrence south shore	410	2.2	15.6	43.2	39.0
Saint Fulgence (June 26, 1980)	92	19.6	0.0	0.0	80.4
Anse Saint Jean (Aug. 23, 1979)	52	13.5	1.9	7.7	76.9
Anse Saint Jean (May 15, 1980)	87	10.4	28.7	11.5	49.4
Anse Saint Jean (July 20, 1979)	97	36.1	0.0	1.0	62.9
Saint Irenée (Sept. 9, 1979)	145	0.0	7.5	22.8	69.7
Saint Irenée (Oct. 11, 1980)	71	2.8	4.3	43.6	49.3
Saint Siméon (July 20, 1979)	57	1.8	8.8	36.8	52.6
Saint Siméon (July 21, 1979)	61	4.9	3.3	45.9	45.9
Saint Siméon (July 22, 1979)	46	19.6	2.2	21.7	56.5
Saint Siméon (Aug. 5, 1980)	90	0.0	10.0	32.2	57.8
Forestville (Aug. 23, 1979)	141	20.6	9.9	15.6	53.9
Forestville (Aug. 3, 1980)	82	6.1	25.6	31.7	36.6
Forestville (June 12, 1979)	147	23.8	24.5	20.4	31.3
Baie Comeau (Aug. 2, 1980)	104	40.4	34.6	13.5	11.5
Baie Comeau (Aug. 29, 1979)	116	21.6	39.7	29.3	9.5

Growth patterns — Because smelt growth is different ($P \leq 0.05$) for the two sexes but not different between years ($P > 0.05$), length-at-age data were tested separately by sex. Differences were significant between the eight spawning rivers from age 2 through 5 ($P = 0.05$). The SNK test was then performed on male length-at-age to test significance of differences between spawning river samples. Results (Table 5) display a geographical gradient, with the northernmost hydrographic system having the smallest length-at-age. Samples showing no significant differences were quite close geographically and often from the same area (I, II, or III). Because a geographical gradient was established and because samples from the same area often showed non-significant differences, sampling sites were pooled on the

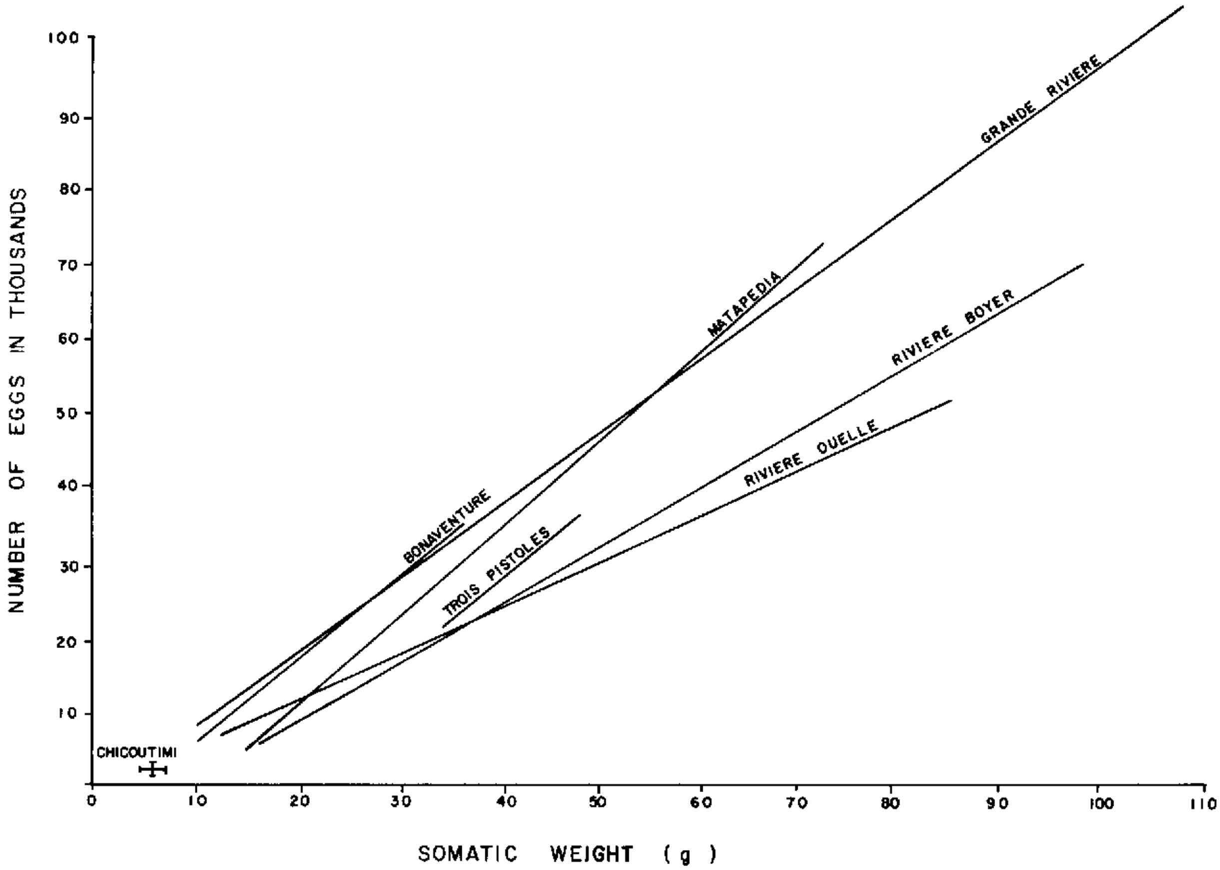

FIG. 6. Fecundity to somatic weight regressions of spawning anadromous smelt (vertical and horizontal bars for Chicoutimi sample represent ±1 SE).

TABLE 8. F values (ANCOVA) of the fecundity to somatic weight relationship (NA, not applicable; $^{**}P \leq 0.01$).

	F (elevation)	F (slope)
Saint Lawrence (II) south shore	8.61**	2.72
Chaleur Bay (III)	7.38**	1.24
Saint Lawrence south shore vs. Chaleur Bay	NA	34.89**

basis of their geographical distribution (I, II, or III). A similar pattern was observed for female standard length, but low numbers of females at certain spawning sites did not provide sufficient data for fine-scale comparison.

von Bertalanffy growth curves were fitted by area and sex (Fig. 4). None were fitted at the Saguenay spawning site (Chicoutimi) because the fish sampled lacked an adequate age span. The Hotelling T^2 test was then performed to compare von Bertalanffy growth parameters between sexes and areas (Table 6). All differences were significant except between sexes (t_0 parameter) in Chaleur Bay.

Before attempting to classify fish from the commercial fishery catch to a given spawning area, the application of length-at-age intervals (Fig. 5) to fish from spawning river samples was tested. Here, 1524 of 2144 (71.1%) fish could be correctly assigned to their spawning area (Table 7).

Once methods for classifying fish on the basis of meristics and growth had been tested, they were used simultaneously. Of a possible 1344 fish assigned to their area of origin by only one method, 996 (74%) fish were successfully assigned to their area of origin using both methods, thus validating the application of both methods to the commercial fishery catch.

Fecundity analysis — The fecundity to somatic weight regressions were calculated for smelt from each spawning site (Fig. 6). Simple linear regressions of fecundity on somatic weight gave better fits than regressions of transformed values (e.g. log transform). As values obtained for Chicoutimi were small (number of eggs ranging from 506 to 2862 and somatic weight from 5.8 to 7.3 g (n = 10)), no regression could be applied. Regression coefficients within a given area did not differ (ANCOVA, $P > 0.05$) (Table 8). However, the two areas (south shore of the St. Lawrence and Chaleur Bay) are significantly different (ANCOVA, $P < 0.01$) (Table 8). The regression equations were as follows: St. Lawrence south

TABLE 9. Classification results of commercial fishery based on discriminant analysis of meristic values of spawning smelt.

Actual group	No. of cases	Predicted group membership (%) Chaleur Bay	Saint Lawrence south shore	Saguenay Fjord
Chaleur Bay (III)	455	63.3	32.5	4.2
Saint Lawrence (II) south shore	451	22.6	45.9	31.5
Saguenay Fjord (I)	372	16.4	17.5	66.1
Saint Lawrence north shore				
Saint Irenée (Sept. 3, 1979)	102	6.9	18.6	74.5
Saint Irenée (Oct. 11, 1980)	97	8.2	19.6	72.2
Saint Siméon (July 20, 1979)	68	3.0	14.7	82.3
Saint Siméon (July 21, 1979)	66	3.0	7.6	89.4
Saint Siméon (July 22, 1979)	59	8.5	23.7	67.8
Saint Siméon (Aug. 5, 1980)	100	2.0	22.0	76.0
Forestville (June 12, 1979)	102	36.3	27.4	36.3
Forestville (Aug. 23, 1979)	174	35.0	41.4	23.6
Forestville (Aug. 3, 1980)	98	51.0	25.5	23.5
Baie Comeau (Aug. 29, 1979)	116	27.6	39.6	32.8
Baie Comeau (Aug. 2, 1980)	99	22.2	27.3	50.5

shore, $E = 718.71W - 3281.22$ ($R^2 = 0.760$, $N = 97$); Chaleur Bay, $E = 1061.96W - 4110.79$ ($R^2 = 0.846$, $N = 92$); where E = number of eggs and W = somatic weight.

COMMERCIAL FISHERIES

Meristics — The classification of smelt from commercial fishery samples on the basis of meristics revealed varying degrees of mixing of the three spawning groups during their open-water migrations. In the Saguenay Fjord 66.1% of the commercial catch was assigned to the Saguenay spawning group, and in Chaleur Bay 63.3% of the commercial catch was assigned to the Chaleur Bay spawning group (Table 9). Commercial catches from the south shore of the St. Lawrence exhibited the greatest degree of heterogeneity, with 45.9, 22.6, and 31.5% being assigned to the south shore, Chaleur Bay, and Saguenay Fjord spawning groups, respectively (Table 9).

As no spawning river has been identified on the north shore of the St. Lawrence, all commercial samples from this area were assigned to the already established spawning groups. Fish from the four sampling sites on the north shore fall into two groups. The first includes the St-Irenée and St-Siméon samples and are well assigned to the Saguenay group (I). A second group of samples from the downstream portion of the St. Lawrence (Forestville, Baie Comeau) are variously assigned to all spawning groups.

Growth patterns — Fish from commercial samples were assigned by the length-at-age interval method to spawning groups. The commercial fishery catch shares almost the same growth patterns as those of local spawners (Table 7). As no spawning site was found on the north shore, all commercial fishery samples were classified and two distinct groups were observed. One consisted of samples from St-Irenée and St-Siméon, which are assigned to the Saguenay group (45.9–69.7%) (Table 7). A second group of samples (Forestville and Baie Comeau) is variously assigned to all spawning stocks, with a high proportion of individuals being not assigned at all.

Discussion

Significant variations are found in three biological characters of anadromous smelt in Quebec waters. Meristics, growth patterns, and fecundity to somatic weight relations indicate significant variability between the eight spawning rivers sampled. An analysis of the pattern of variability revealed three geographical groups.

This study has demonstrated that homing to spawning rivers does not appear to occur because differences between rivers within a geographical area are small. However, the degree of heterogeneity of spawning smelt of different geographical areas is less at the extremes of their Quebec distribution. Differences between these geographical groupings are most likely due to both genetic and environmental factors. Classification of spawning smelt to an area other than the area of sampling may thus reflect either mixing of smelt from neighbouring areas or the variability of biological characters along an environmental cline, characteristic of geographical stocks.

The classification of smelt from commercial catches provides an insight into the extent of mixing over the summer season. Fish captured at the extremes of their Quebec distribution have the greatest affinity to the local spawning group. This indicates that open-water migrations are limited to the geographical area of origin and, to a lesser degree, to adjacent areas. Such local migratory movements are consistent with those recorded by tagging (Magnin and Beaulieu 1965) of smelt in the St. Lawrence Estuary, which indicated average movements from 80 to 160 km in the upstream–downstream direction. Magnin and Beaulieu (1965) also found very limited migrations between the north and south shores of the St. Lawrence Estuary.

Because no spawning river was found on the north shore of the St. Lawrence between Quebec and Baie Comeau, it is of interest to note the splitting of the four sampling sites on the north shore into two groups. Meristics as well as growth patterns assign the upstream group (St-Irenée, St-Siméon) quite well to the Saguenay area (I) whereas the downstream group (Forestville, Baie Comeau) does not relate clearly to any spawning area. This suggests the existence of an as yet unsampled spawning site along the lower north shore of the St. Lawrence Estuary. The survey for spawning rivers stopped at Franquelin, a village approximately 25 km downstream from Baie Comeau, but there may be a spawning river farther downstream that could be the source of these samples.

Fecundity observations showed a geographical gradient and record values. A maximum of 93 000 eggs was found in a 5-yr-old female at Grande-Rivière (area III). Smallest values were obtained for Chicoutimi smelt (area I). Spawning females sampled in the Saguenay exhibit growth, maturity, and fecundity similar to previously studied "stunted" freshwater smelt (Delisle 1969).

A further indication supporting the existence of at least three discrete smelt groups is the similarity between the locations of fishing areas and the identified groups. Fisheries are extremely limited between Matane and Gaspé, suggesting that smelt are relatively rare in this area and thus that estuary and Chaleur Bay populations are distinct. Finally, information on distribution of parasites (Fréchet et al. 1983) confirms the existence of groups identified here.

Acknowledgments

We thank Esther Bonneau, Alain Gagné, and Denis Croteau for their assistance in both the laboratory and the field. Special thanks to all commercial fishermen who collaborated in the sampling. Scale readings were validated by Drs D. Copeman and C. Delisle. Funding was provided by the Government of Canada, Department of Fisheries and Oceans, Quebec Region, and FCAC.

ABRAMSON, J. J. 1965. von Bertalanffy growth curve II, IBM 7094, Univac 1107, Fortran IV. Trans. Am. Fish. Soc. 94: 195–196.

BAGENAL, T. 1978. Methods for assessment of fish production in fresh waters. Blackwell Scientific Publications, Oxford, London, Edinburgh, and Melbourne. 365 p.

BERNARD, D. R. 1981. Multivariate analysis as a means of comparing growth in fish. Can. J. Fish. Aquat. Sci. 38: 233–236.

BOOKE, H. E. 1981. The conundrum of the stock concept — are nature and nurture definable in fishery science? Can. J. Fish. Aquat. Sci. 38: 1479–1480.

DELISLE, C. 1969. Écologie, croissance et comportement de l'éperlan du Lac Heney, comté de Gatineau ainsi que la répartition en eau douce au Québec. Ph.D. thesis, Department of Biology, University of Ottawa, Ottawa, Ont. 180 p.

FRÉCHET, A., J. J. DODSON, AND H. POWLES. 1983. Les parasites de l'éperlan anadrome (*Osmerus mordax*) du Québec et leur utilité comme étiquettes biologiques. Can. J. Zool. 61: 621–626.

LARKIN, P. A. 1972. The stock concept and management of Pacific salmon, p. 11–15. *In* R. C. Simon and P. A. Larkin [ed.] The stock concept in Pacific salmon. University of British Columbia, Vancouver, B.C.

MACLEAN, J. A., AND D. O. EVANS. 1981. The stock concept, discreteness of fish stocks, and fisheries management. Can. J. Fish. Aquat. Sci. 38: 1889–1898.

MAGNIN, E., AND G. BEAULIEU. 1965. Quelques données sur la biologie de l'éperlan *Osmerus eperlanus mordax* (Mitchill) du Saint-Laurent. Natur. Can. 92(3–5): 81–105.

MAHALANOBIS, P. C. 1936. On the generalized distance in statistics. Proc. Nat. Inst. Sci. India 12: 49–55.

MARCOTTE, A., AND J. L. TREMBLAY. 1948. Notes sur la biologie de l'éperlan *Osmerus mordax* (Mitchill) de la province de Québec. Contrib. Stn. Biol. St-Laurent, Can. No. 18: 107 p.

MCKENZIE, R. A. 1958. Age and growth of smelt, *Osmerus mordax* (Mitchill), of the Miramichi River, New Brunswick. J. Fish. Res. Board Can. 15: 1313–1327.

NIKOLSKY, G. V. 1963. The ecology of fishes. Academic Press, London and New York. 352 p.

RYDER, R. A., S. R. KERR, W. W. TAYLOR, AND P. A. LARKIN. 1981. Community consequences of fish stock diversity. Can. J. Fish. Aquat. Sci. 38: 1856–1866.

SNEDECOR, G. W., AND W. G. COCHRAN. 1978. Statistical methods. 6th ed. Iowa State University Press, Ames, IA. 593 p.

SOKAL, R. R., AND F. J. ROHLF. 1969. Biometry. W. H. Freeman and Company, San Francisco, CA. 776 p.

SPANGLER, G. R., A. H. BERST, AND J. F. KOONCE. 1981. Perspectives and policy recommendations on the relevance of the stock concept to fishery management. Can. J. Fish. Aquat. Sci. 38: 1908–1914.