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Separation of North River, Cape Breton Island Atlantic salmon (Salmo salar L.) stocks in a mixed stock fishery using multivariate analysis techniques

by

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ABSTRACT

This paper presents a new technique for identifying individuals in a sample of "unknown" origin that originated in a river from which a "known" sample was obtained. Examination of Atlantic salmon (Salmo salar L.) caught in a commercial mixed stock fishery in St. Ann's Bay, Cape Breton Island, Nova Scotia, by this technique indicated that as many as 91% of the individuals could come from North River. The technique presented here identifies fish similar to the known stock but indicates nothing about the origins of the fish in the catch that were not of this stock. The technique is useful if samples from all stocks are unobtainable or if the origins are unknown.

RESUME

L'article qui suit contient une description d'une nouvelle méthode permettant d'identifier les sujets d'un échantillon d'origine "inconnue" provenant d'une rivière dans laquelle un échantillon "connu" a été prélevé. L'examen, par cette méthode, de saumons atlantiques (Salmo salar L.) d'une pêche de stocks mixtes dans la baie Ste-Anne (île du Cap-Breton, en Nouvelle-Ecosse) indique que jusqu'à 91% des sujets aurait pu provenir de la rivière Nord. Grâce à cette méthode, on peut identifier les poissons qui ressemblent à ceux du stock connu, mais elle ne renseigne pas sur les origines de poissons qui n'appartiennent pas à ce stock. La méthode est utile s'il est impossible d'échantillonner tous les stocks ou encore si l'origine des échantillons est inconnue.

INTRODUCTION

Racial analysis of salmon caught in mixed stock fisheries is relevant to both sound management practises and life history studies. The maintenance of stock sizes sufficient to support angling and commercial fisheries for Atlantic salmon requires that adequate spawners reach the spawning grounds. Canadian east coast salmon fisheries with few exceptions exploit fish from more than one river system. Thus, some method of stock separation is required to derive total catches of a single stock.

A new approach is used in this paper to identify Atlantic salmon (Salmo salar L.) from North River, Cape Breton Island, Nova Scotia in the mixed stock fishery near its river mouth. The origin of the other stocks contributing to this fishery are not identified. This approach was necessitated because of difficulties inherent in obtaining samples of known origin in sufficient quantities even in the case where all the contributing stocks to the mixed stock fishery have been identified.

METHODS

Scales from 50 adult Atlantic salmon were collected from the angling fishery on North River, Cape Breton Island, Nova Scotia during June-August of 1978 (Fig. 1). These were used as the 'learning' sample to test the population of 29 individuals of unknown origin from the commercial fishery near the river mouth (Fig. 1) at St. Ann Harbour, Cape Breton Island, collected during June-August, 1978. Scales were taken from the left side of the fish approximately midway between the lateral line and dorsal fin and generally in a line between the dorsal and anal fins. Impressions were made of the scales on preheated plastic slides. These impressions were projected onto the ground-glass screen of a microprojector at a magnification of 30X. The river and sea ages were then examined using the method described by Lear and Misra (1978); the four characters used being:

(1) largest anterior radius of the first river zone (WR^1);
(2) largest anterior radius of the second river zone (WR^2);
(3) largest anterior radius of the third river zone (WR^3);
(4) largest anterior radius of the first sea zone (WS^1).

A multivariate statistical procedure recognizes interdependence of variables and provides a single composite of these, obtained in some optimal way, as opposed to several univariate statistical analyses carried out separately for each variable, which ignore correlations among variables. For an exposition of the multivariate analysis employed here consult Morrison (1976).

At the univariate level, the problem of whether or not a single individual sampled at random belongs to a given population has been considered (Sokal and Rohlf 1969, p. 223). The individual of unknown origin may be regarded as a sample, of size 1, and the difference between the means of this sample and a sample from the population tested by a t-test. This methodology was extended to the multivariate level by one of us (RKM) who also wrote the computer program (in FORTRAN IV and supported under IBM/370) in the following way.

Hotelling's T^2 statistic was estimated for the difference between the vector of the four measurements of an unknown individual and the corresponding mean vector of the learning sample of the known stock. One individual at a time was analyzed employing error covariance matrix based on 'within sample' variations pooled over 2 samples, which in the present case is the same as within learning sample covariance matrix. T^2 values, with degrees of freedom (df) equal to 4 and 49, and associated F-values with df = 4 and 46 were then calculated and compared with their corresponding critical values for significance.

The "Leave-one-out" method, similar to the "Jacknife" technique (Quenouille 1956 and Tukey 1958) was employed to estimate the total number of misclassifications from the known sample. This method entails carrying out an analysis on individuals by removing the first individual and then comparing this individual to the other N-1 individuals, by T^2 on df = 4 and 48 and associated F on df = 4 and 45. This is repeated for all individuals, each time removing one of the individuals and then comparing it to all the others.

RESULTS

Samples from the 'sport' and 'commercial' population consisted of 50 and 29 individuals respectively, which had none of the four measurements missing. Table 1 gives the mean and standard error for each measurement of the sport sample.

Hotelling's T^2 (and it's associated F-statistic) was employed to test the overall null hypothesis that the sport and commercial fish populations do not differ in their means on any four measurements. Estimate 13.14 of T^2, on degrees of freedom (df) = 4 and 77, was significant (probability level of significance, $P < 0.05$). The null hypothesis was therefore rejected. The T^2 procedure was then extended to test the significance of the difference between four measurements of each individual fish of the commercial sample and the means for the sport sample. Five (out of 29) associated F-values were significant (at $P < 0.05$ for 1 individual and < 0.01 for 4 individuals). This indicated that 24 of the 29 fish or 83% of the commercial sample from fish caught in nets set near St. Ann Harbour, Cape Breton Island originated from North River. The origin of the other 5 fish or 17% of the sample came from rivers other than North River and remains unknown.

The rate of misclassification as identified from the "Leave-one-out" test was 4 out of 50 or 8% of the sample were incorrectly identified and did not originate from North River. This error rate was deemed as acceptable. Thus, if all 29 fish in the unknown sample had originated in North River T^2 would have misidentified approximately 2.32 fish. Therefore, as many as 91% of the sample could come from North River.

DISCUSSION

A number of methods have been variously employed to determine the river of origin of salmon stocks caught in mixed stock fisheries. Tags applied to fish in the adult or smolt stage is one of the simplest and more reliable methods. Tags applied to salmon smolts have shown that salmon caught in the Newfoundland commercial fishery originated from rivers in Labrador, Newfoundland, Quebec, New Brunswick and Nova Scotia (Pratt et al. 1974; Kerswill 1971; Elson 1971; Murray 1966). Nonreporting of tags, high numbers of tagging mortalities and subsequent low overall numbers of returns makes derivation of total catches from single stocks using tag recaptures difficult if not impossible.

Other techniques based on biological characters of the stocks have been examined for their efficiency in stock separation. For example, using parasites as biological tags, Pippy (1969) could not differentiate between Canadian Atlantic salmon stocks. Payne (1974), using serum electrophoresis, found it impossible to distinguish between populations of salmon originating in Newfoundland and Maritime rivers.

Wider usage has been made of morphometric and meristic characters of fishes to identify stock components in mixed stock fisheries. Morphological characters have been analyzed by discriminant functions to identify continent of origin of Pacific salmon (Fukuhara et al. 1962; Amos et al. 1963; Dark and Landrum 1964).

Scale characters have been incorporated into a linear discriminant function that has been used to identify origins of chum and sockeye salmon from mixed stock fisheries in the Pacific ocean into populations of Asian and North American origin (Anas and Murai 1969; Tanaka et al. 1969). Lear and Sandeman (1980) successfully used meristic scale characters to identify European and North American populations of Atlantic salmon in the West Greenland area. Lear and Misra (1978) employed a discriminant function to identify a clinal trend in scale characters of stocks of Atlantic salmon. Reddin and Misra (1978) presented a technique by which areas of origin of salmon caught in a specific fishery might be identified.

Recently, Cook and Lord (1978) have proposed a polynomial discriminant method for the racial classification of stocks of sockeye salmon. This method utilized scale characters and a priori probability estimates to identify Bristol Bay sockeye salmon in an unknown sample taken on the highseas south of the central Aleutian Islands. The use of this technique to identify racial stocks has two significant drawbacks. Intrinsic to the discriminant function method is that the unknown specimen or group of unknown specimens genuinely belong to one of the populations from which the known sample originated from Reyment 1966). Also discriminant function analysis is not very robust relative to the a priori probabilities used (Corruccini 1975).

What is the biological basis for separation?

The Atlantic salmon is a distinctive species characterized by its anadromous life history. Thus, salmon live in both marine and freshwater environments and return to their natal freshwater stream to spawn. This genetic isolation creates separate stocks that because of difference in ecological factors in these specific environments gives rise to varying scale characteristics. In the sea, growth of each stock is influenced by differences in timing and in location of entry into the sea giving rise to further differences in stock characteristics.

Generally, Atlantic salmon parr smoltify when they are about 15-20 cm. The rate at which this size is attained is determined by factors in the rivers such as food, density of parr and other competitors, water temperatures, etc. The period of time spent to attain this size before smolt migration increased with latitude from 2.25 years in Maine to 5.5 years in Ungava Bay (Templeman 1967). In Europe, it increases from about 1.2 years in southern England to 3.0 years in northern Scotland. European smolts enter the sea about 1-2 months earlier than do those from North America and enter the North Atlantic drift as opposed to those from North America which have to enter water influenced by the Labrador Current. Significant differences among scale characteristics of the sea zone are created by the different growth rates of salmon in the relatively warmer North Atlantic drift as opposed to the colder Labrador Current (and can be utilized to differentiate stocks).

Salmon is a valuable resource with approximately one-sixth of the world's commercial Atlantic salmon landings and 90% of Canada's taken in Newfoundland and Labrador waters. Similarly, about one-half of the salmon caught in the Canadian recreational fishery are angled from Newfoundland and Labrador rivers (Chadwick et al. 1978). As declines in some regions of salmon populations become only too obvious; sound management allowing the required number of spawners necessary for future generations to reach the spawning grounds are essential. Management is further complicated because declining stocks are mixed along migration routes with healthy stocks which still may be exploited intensively. Thus, it is not only necessary to exploit these stocks differentially but some mechanisms for stock separation are essential.

Techniques other than tagging are required because of the expense and because of the infrequent recaptures of tagged fish in these studies. The technique presented here will tell us the composition of the catch that is of local origin but nothing about the more distant stocks. It is of use when samples from all the known rivers of origin are impossible to obtain or when they are unknown.

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Table 1. Means and standard errors of four measurements of sport sample.

Variable	Mean	S.E.
WR[1]	31.0	0.89
WR[2]	30.6	1.06
WR[3]	25.7	0.92
WS[4]	181.4	2.72

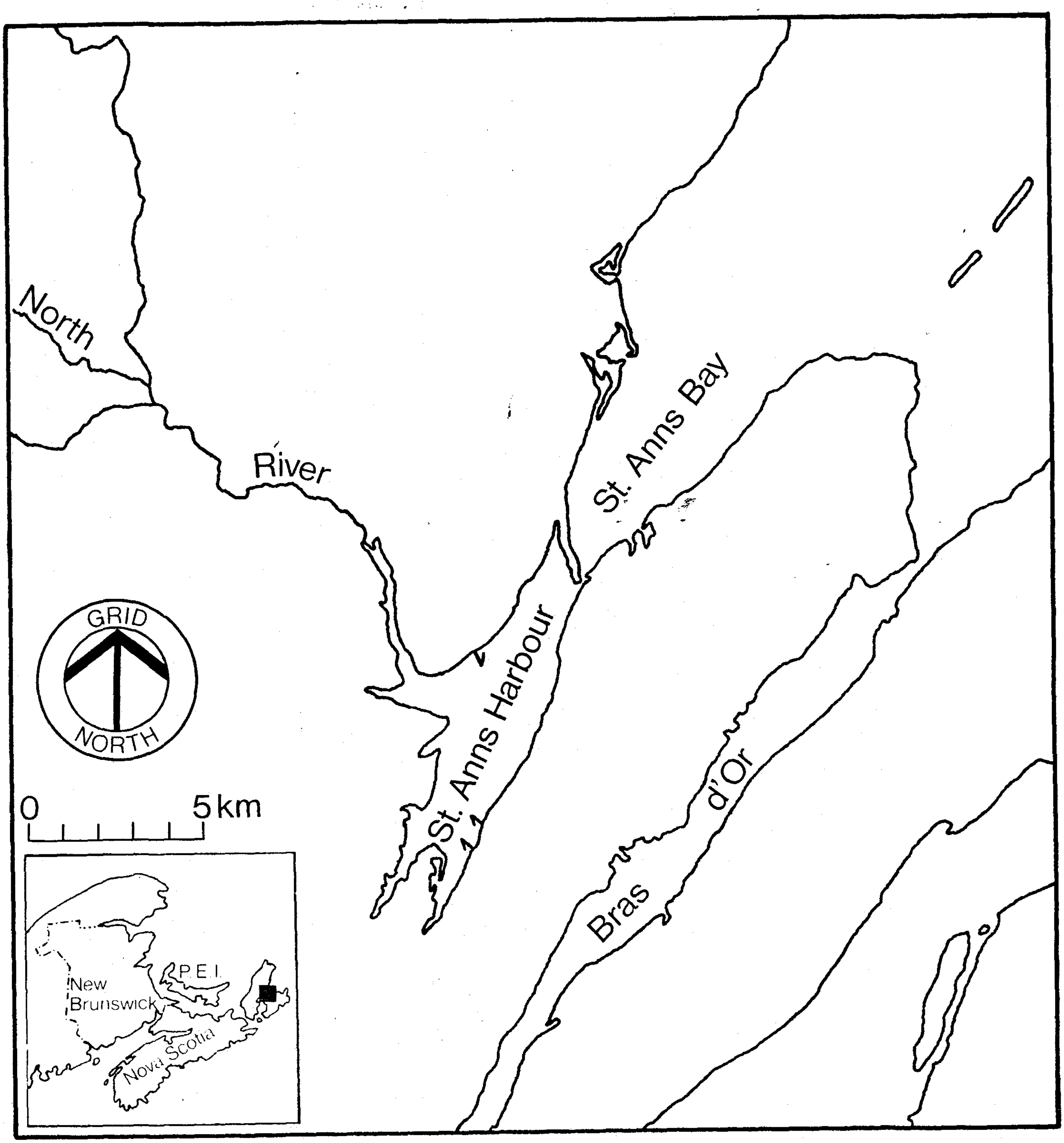

Fig. 1. St. Ann's Harbour, Cape Breton Island showing location of three commercial traps and the North River from which respective commercial and sport samples were taken.