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The value of parasites as biological tags in Atlantic salmon at West Greenland[1]

by

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INTRODUCTION

Development of a major Atlantic salmon (Salmo salar) fishery began in West Greenland in 1959 (Saunders, 1966). Tagging returns (Pyefinch, 1958. Allan and Bulleid, 1963; Hansen, 1965; Saunders et al, 1965) and age composition studies (Nielsen, 1961) indicated that a large proportion of salmon taken by the fishery originated in North America and Europe. As a result of a joint ICES/ICNAF meeting held in May 1965 to discuss establishment of a program to study the Greenland fishery, Canada undertook certain research projects on the biology of Atlantic salmon. One project involved studies of salmon parasites to determine which parasite species might be useful to ascertain the continental origin of salmon caught on the high seas and in Greenland coastal waters.

Published accounts of Atlantic salmon parasites occur in many general papers (Pippy, 1968). Publications such as those by Dollfus (1942) and Dawes (1947) deal with the systematics and distribution of several parasites found in salmon; others deal with a single species. Intensive surveys of salmon parasites have been geographically restricted: Heitz (1917) studied the parasites of upstream migrants of the Rhine River and reviewed the literature on salmon parasites to that date: Dogiel and Petrushevski (1934) studied the parasite fauna of juvenile salmon and returning adults in several rivers in the USSR. Few papers give the prevalence and mean number per host of the parasites considered. Accordingly, in 1966, a program was started to determine the relative abundance and distribution of the parasites of Atlantic salmon in the North Atlantic.

In 1966-67 emphasis was placed on establishment of geographic distribution and abundance of parasites of freshwater origin and their occurrence in adult salmon at sea. By spring, 1968, there was sufficient evidence to indicate that several parasites of freshwater origin survive in salmon at sea but that these were of doubtful use in a large scale program to determine proportions of North American and European salmon stocks on the high seas. Further studies were concentrated on certain parasites of marine origin which the 1966-67 observations indicated would be more useful as biological tags. This report summarizes the results obtained from studies on Atlantic salmon parasites and emphasizes those which were, during the course of the investigation, seriously considered as potential biological tags.

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MATERIAL AND METHODS

Smolts: Complete parasitological examinations were performed on 1665 juvenile salmon collected in 1966 and 1967 from 68 North American and European rivers and one river at West Greenland. Partial examinations of an additional 1149 smolts were made in 1968.

Adults Complete examinations were performed on 698 adult salmon caught during 1966 to 1968 from various sampling stations in the North Atlantic, and partial examinations of an additional 2899 specimens were completed from 1969 to 1973.

Details on the methods of collection, examination of the hosts and preparation and examination of the parasites have been presented elsewhere (Pippy, 1969).

RESULTS AND DISCUSSION

I. Parasites of juvenile salmon

Juvenile salmon usually spend from 1 to 5 years in freshwater before migrating to sea. During this period they acquire a parasite fauna which is both qualitatively and quantitatively typical of the juvenile salmon population in a given area. During the young salmon's migration to sea it carries the parasite fauna typical of its area of origin. If the parasites of salmon from one area are different from those of another area, and if these parasites remain with the salmon throughout its life in the sea, they may be used to determine the origin of salmon in mixed populations in the sea.

A total of 23 metazoan species of parasites were recovered from the smolts (Table 1). All but one of these (Brachyphallus crenatus) were of freshwater origin. Many of the species were abundant in smolts on both sides of the Atlantic (e.g Discocotyle sagittata, Crepidostomum farionis, Diplostomulum spathaceum, Metabronema salvelini and Capillaria salvelini). Others were rare in one area and absent in samples from another area (e.g. Phyllodistomum limnosa, Phyllodistomum sp., Azygia longa, Ligula sp., and Contracaecum sp.). Several species were fairly abundant in one area and absent in samples from other areas. Apophallus brevis, Diplostomulum retinalis, Pomphorhynchus laevis and Salmincola salmoneus. The larval trematode Apophallus brevis is encysted in the skin of the host and is lost shortly after the smolts enter salt water. The remaining three parasites can very likely remain in or on their host for some time after the smolt migrate to sea.

Diplostomulum retinalis

This larval trematode was found in the retina of 5 of 25 smolts from Kapisigdlit River Greenland, but was absent in samples from North America and the United Kingdom. The presence of this parasite in the eye of a salmon at sea would therefore indicate origin in West Greenland, possibly Kapisigdlit River, the only river in Greenland known (Meilsen, 1961) to produce Atlantic salmon.

Pomphorhynchus laevis

This acanthocephalan was found only in smolts from the U.K. and has been reported in returning adult salmon in Scotland and Ireland (McIntosh, 1863, Tosh, 1905 Kane, 1966). A detailed account of its use as a biological tag has been previously published (Pippy, 1969). Pippy concluded that if P. laevis was present in salmon in Greenland, it appeared to be rare, and therefore of little use in a large scale program to distinguish eastern from western Atlantic salmon stocks.

Salmincola salmoneus

This parasitic copepod was found on the gills of smolts only in rivers of Newfoundland, Labrador and Cape Breton Island. It was more prevalent on the smolts from Newfoundland and Labrador (7.7% infected) than on those from rivers on the mainland (1.2%). Although this species is well known on adult salmon in rivers and on previous spawners in the sea (Friend, 1941), its occurrence on smolts in Canada is apparently unique. Thus its presence on the gills of the salmon which had not yet returned to freshwater for the first time would indicate North American origin of the fish.

II. Parasites of adult salmon

After leaving freshwater, Atlantic salmon generally spend from 1 to 3 years in the ocean before returning to their river of origin. During this period they feed on marine organisms in the different areas in which they feed. In different geographic localities of the marine environment the parasites found may differ both qualitatively and quantitatively. If some salmon stocks frequent certain distant feeding grounds which others do not, or some frequent certain feeding grounds more or at different times of the year than others, salmon may acquire qualitatively or quantitatively distinctive parasite faunae. If these remain with the salmon throughout the remainder of its life, they may be considered as biological tags to separate stocks of salmon in the sea.

Several of the parasites found in adult salmon (Table 2) require short comments while others, which became the subject of more intensive study, will be treated in greater depth.

Brachyphallus crenatus

This trematode was present in the gut of 42.7% of the North American salmon but was absent in the 32 salmon taken off the Southwest coast of England. However, there have been several published reports of this species in salmon in European waters and its absence in the sample from Southwest England is therefore not indicative of an absence of this species in salmon from all European river systems.

Diplostomulum spathaceum

These larval trematodes had been picked up by the salmon in the rivers before they migrated to the sea. Those found in smolts from North America were morphologically identical to those found in smolts from the United Kingdom. However, they were different from the form carried by juvenile salmon in West Greenland (D. retinalis). Thus the presence of this parasite in 13% of the salmon in 1966 confirmed the non-Greenlandic origin of the bulk of the salmon off the west coast of Greenland.

Tentacularia coryphaenae and Pelichnibothrium sp.

Both these larval cestocles have been previously reported from fish on both sides of the Atlantic Ocean. The absence of these species in the European sample is likely related to the small sample size and the low prevalence of these parasites in salmon.

Contracaecum aduncum

This nematode was found in the gut of salmon in North America and off Greenland. Its absence in the sample off the west coast of England is more likely a characteristic of that particular sample than it is indicative of absence in all European salmon stocks. C. aduncum has been previously reported from salmon in Europe and is common in a wide variety of marine fishes throughout the North Atlantic.

Salmincola salmoneus

This copepod was not found on the gills of any of the adult salmon taken at sea during this survey. However, Templeman (1967) reports finding a single specimen on the gills of a maiden 1-sea-year salmon taken in the Labrador Sea during the spring of 1966. This finding conforms with the opinion (May 1973) that the salmon in the Labrador Sea during the spring are primarily of North American origin.

Eubothrium crassum

This adult tapeworm was found in the alimentary canal of 81.2% of 3597 salmon taken in Canadian waters from 1966 to 1972. In contrast, it was found in only 28% of 32 salmon collected off the southwest coast of England during 1967. Published data confirm its relatively low prevalence in salmon in European waters. At West Greenland it was more prevalent in tagged salmon from North America than in tagged salmon from Europe (Table 4). Also at Greenland, the prevalence increased with increasing river age of the salmon. This increase resulted from the combined effects of a higher prevalence among salmon from North America and generally higher river ages among North American salmon than among salmon from European rivers.

Nothing is known of the normal life span of E. crassum in Atlantic salmon at sea. There is some evidence that changes in the physiology or diet at different stages of the salmons' migrations at sea may cause these tapeworms to be lost (Hoar, 1939). If a significant number are lost or gained between Greenland and home waters, the prevalence observed in salmon in home waters is not a reliable estimate of the prevalence in salmon in West Greenland. This investigation has shown that salmon may pick up this parasite while feeding at West Greenland in the fall. No evidence was found which might suggest the prevalence of this parasite remained constant for the period between the salmons' entry into the West Greenland fishery and their entry into home waters (Table 4). Also it is unreliable to use the prevalence of this parasite in fish of known continental origin (tagged) to estimate proportions because tagged fish usually originated in geographically restricted areas and the prevalence of the parasites in fish from these areas could be atypical. The use of differences in prevalence of this parasite as biological indicators was further complicated by dramatic annual variations within North American salmon stocks (Table 4).

There was an inverse correlation between the prevalence of E. crassum and the abundance of larvae of the nematode A. simplex in the body cavity of salmon caught in the Canadian waters. One possible explanation for this relationship is that the presence of massive quantities of E. crassum in the gut of the salmon inhibits penetration of the nematodes through the gut wall.

Anisakis simplex

The relative abundance of these larval nematodes in salmon was based on counts of larvae found in the body cavity of the salmon. They were found in salmon from both sides of the Atlantic but three aspects of the data collected suggested the mean number of larvae in North American salmon collected from the fall of 1968 to the summer of 1971 was lower than the mean in European salmon. Firstly, the means for samples of 2-sea-year salmon taken in North America varied from 2.92 to 6.13 while the means in the United Kingdom varied from 6.00 to 14.20. Secondly, the means per North American tagged salmon caught a West Greenland during 1968, 1969 and 1970 were all lower than the means of mixed stocks but were within the ranges found among North American samples the following year. Thirdly, the mean numbers of larvae per North American tagged salmon caught at West Greenland in both 1969 and 1970 were lower than the means found in European salmon in the same area and during the same fishing seasons (Table 3). The relative abundance apparently reversed in 1971 and samples taken from that fall to the summer of 1973 suggested that the larvae had become more abundant in North America than in European salmon (Table 3).

Statistical analyses on data from eight sampling stations in 1969 suggested there was little heterogeneity in abundance among the various North American samples. When the study was repeated in 1970 with an additional

three samples from the United Kingdom, there were significant variations in the mean number of parasites found in salmon from different sampling stations in both North America and the United Kingdom. Continental heterogeneity was confirmed in a similar study on samples collected in 1971. The observed heterogeneity among different samples taken in North America and in the United Kingdom made it impossible to use the data to estimate the mean numbers of larvae in the total populations of salmon in North America and in Europe. The reason for this is that the mean number of larvae calculated from combinations of data from various samples would depend on the number of hosts examined from each of the sampling stations. For example, if many salmon were examined from an area which had high levels, the calculated mean of both samples combined might be higher than the true mean for the combined populations.

There was good evidence that in the years covered in this study larval A. simplex was more abundant in salmon from one side of the Atlantic than in those from the other side. However, the data did not provide a reliable estimate of the abundance in salmon from each area or of the magnitude of the difference in abundance. Thus the absence of a reliable estimate of the relative abundance of the larvae in salmon from the two areas, and the observation of significant annual variation in the relative abundance precluded the possibility of using the difference to estimate the proportions of North American and European salmon at Greenland.

CONCLUSION

None of the species which had discontinuous geographical distributions were abundant enough to serve as biological tags in a large scale program to estimate the proportions of North American and European salmon stocks off West Greenland. Also, two species which were abundant enough for detailed statistical analysis (Eubothrium crassum and Anisakis simplex) displayed too much geographic and annual variations to be of any value in the study. Therefore, despite the discontinuities observed, parasites must be considered to be of little value in estimating proportions of major Atlantic salmon stocks off West Greenland.

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Table 1. Relative abundance (% infested) the parasites found in 1690 Atlantic salmon smolts collected in 1966 and 1967 from North America, the United Kingdom, and Kapisigdlit River, Greenland.

Parasite	North America N=1062	United Kingdom N=603	West Greenland N=25
Trematoda			
Discocotyle sagittata	11.9	11.0	0
Crepidostomum farionis	49.7	34.7	0
Phyllodistomum limnosa	0.7	0	0
Phyllodistomum sp.	0	0.8	0
Azygia longa	.3	0	0
*Apophalus brevis**	8.5	0	0
Apophalus sp.*	0	1.5	0
Tetracotyle sp.*	3.7	4.8	0
*Diplostomulum spathaceum**	33.5	6.5	0
*Diplostomulum retinalis**	0	0	20.0
Brachyphallus crenatus	0.2	0	0
Cestoda			
Eubothrium salvelini	1.1	0.5	0
Cyathocephalus truncatus	0.2	0.7	0
Bothrimonus sturionis	1.4	0.2	0
Diphyllobothrium sp.*	0.1	0.3	0
Ligula sp.*	0	0.2	0
Acanthocephala			
Echinorhynchus spp.	35.0	21.4	0
Pomphorhynchus laevis	0	24.2	0
Nematoda			
Metabronema salvelini	65.5	57.4	0
Capillaria salvelini	3.1	3.5	92.0
Contracaecum sp.	0.3	0	0
Rhaphidascaris sp.	0.8	1.2	0
Copepoda			
Salmincola salmoneus	3.6	0	0

*larval form

Table 2. Prevalence of the parasites found in adult Atlantic salmon collected from 1966 to 1972 in Canadian, Greenlandic and European waters. Prevalence in %; number examined in brackets

Parasite	North America	United Kingdom (N=32)	West Greenland
Trematoda			
Gyrodactyloides bychowskii	0 (56)	0	18.6 (185)
Derogenes varicus	74.2 (124)	100	90.2 (185)
Hemiurus levenseni	1.7 (116)	9.4	13.3 (185)
Hemiurus sp.	0 (124)	3.1	0 (185)
Brachyphallus crenatus	42.7 (124)	0	12.6 (185)
Leathaster gibbosus	29.2 (124)	71.9	28.1 (185)
Lampritrema nipponicum	0.8 (124)	0	0.5 (185)
Azygia sp.	0 (124)	3.1	0 (185)
Discocotyle sagittata	0 (124)	0	1.1 (185)
*Diplostomulum spathaceum**	7.0 (71)	0	13.4 (185)
Tetracotyle sp.*	0	0	0.5 (185)
Cestoda			
Eubothrium crassum	81.2 (3597)	28.1	44.1 (185)
*Hepatoxylon trichiuri**	12.4 (387)	12.5	6.1 (185)
*Tentacularia coryphaenae**	11.4 (376)	0	1.4 (1[illegible])
Pelichnibothrium sp.*	0.8 (376)	0	78.4 (185)
Nematoda			
Anisakis simplex	90.2 (3582)	93.0	91.5 (1277)
Contracaecum aduncum	20.0 (120)	0	93.6 (185)
Acanthocephala			
Echinorhynchus gadi	2.3 (87)	0	15.4 (185)
Copepoda			
Lepeophtheirus salmonis	+	+	+ (185)
Salmincola salmoneus	+	0	0 (185)

*larval form

Table 3. Comparisons of the mean number of larval Anisakis simplex in samples of Atlantic salmon from West Greenland and North America. Numbers examined in brackets.

	West Greenland: 1-sea-year			North America: 2-sea-year		
Year	Random sample	N. Amer. tagged	Eur tagged	Year	Mean	Range of means
1968	5.77 (155)	4.50 (8)	-	1969	3.77 (531)	2.99-4.57
1969	6.17 (205)	4.35 (147)	7.20 (20)	1970	4.07 (803)	2.92-4.55
1970	6.34 (162)	4.17 (139)	5.28 (54)	1971	5.13 (658)	4.13-5.46
1971	3.65 (288)	-	-	1972	5.96 (111)	4.00-6.13
1972	3.02 (228)	-	-	1973	2.87 (115)	2.68-3.38

Table 4. Comparisons of the prevalence of Eubothrium crassum in samples of Atlantic salmon from West Greenland and North America. Prevalence in %; number examined in brackets

	West Greenland: 1-sea-year			North America: 2-sea-year		
Year	Random sample	N. Amer. tagged	Eur tagged	Year	Total of samples	Rang
1966	54.6 (97)	-	-	1967	42.5 (72)	40.0-85.7
1967	31.8 (88)	-	-	1968	62.1 (201)	42.7-94.1
1968	52.9 (155)	62.5 (8)	-	1969	73.4 (531)	51.6-100
1969	17.6 (205)	20.4 (147)	0 (20)	1970	39.4 (803)	18.1-83.3
1970	12.4 (162)	23.7 (139)	7.0 (54)	1971	37.8 (658)	25.0-100
1971	23.7 (249)	-	-	1972	72.7 (55)	68.0-76.7
1972	7.9 (241)	-	-	1973	12.4 (113)	11.4-14.7