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Preliminary studies on the use of parasites of Atlantic salmon as a means of distinguishing between Eastern and Western Atlantic salmon stocks

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Introduction

Tag recoveries from Atlantic salmon caught in the coastal waters of West Greenland indicate that an appreciable proportion of the salmon caught by Greenland's salmon fishery originate in rivers of Canada, the United States and Great Britain. As a result of the joint meeting of ICNAF and ICES held in Madrid in May of 1965, the Fisheries Research Board of Canada began an investigation of the parasites of Atlantic salmon to determine which parasitic species, if any, may be useful to distinguish stocks of Atlantic salmon on the high seas and in Greenland's coastal waters. It is hoped that the use of naturally occurring parasites as biological tags will complement studies on age and growth comparisons, tag returns, and serology. The first phase of the study was a detailed examination of as many smolts from as many different localities as time and manpower would permit. Arrangements were made for obtaining most of the samples in the Spring of 1966 and by September of the same year a reasonable investigation of

the published literature on the parasites of Atlantic salmon had been made and examination of smolts had begun. In order to obtain a reference collection of parasites and to get some idea of the abundance of the various species found in salmon in Greenland, a limited number of adult fish was examined from that area. In October and November of 1966, some time was spent in Godthaab, Greenland, examining adult salmon from that area.

Thirty-two parasitic species have been identified, at least to genus, from smolt and adult salmon during this survey. This figure compares with about 80 species which have been recorded in the literature. However, not all the recorded species seem to be valid. It is expected that the number of species considered in this work will increase as more samples are obtained from different localities. Also, further studies on specimens which have as yet only been identified to genus may increase the number of species over and above that which is reported here.

Records of the parasites of Atlantic salmon stem from many publications in various general contexts and from a few intensive surveys. The latter have been limited to extremely restricted areas. Heitz (1917) studied the parasites of upstream migrants of the Rhine River and reviewed the literature on the Atlantic salmon to that date. Dogiel and Petrushevski (1934) studied the parasite fauna of the young inhabiting the rivers, downstream migrants, and adults returning to several rivers in Northern U.S.S.R. : the Onega, the Vyg, and tributaries of the North Dvina. Publications such as those by Dollfus (1942) and Daves (1947) deal with several species of parasites of Atlantic salmon, while still others are restricted to discussion or mention of only a single record.

The 32 species of parasites found in this study include 13 digenetic trematodes, 2 monogenetic trematodes, 8 cestodes, 3 acanthocephala, 6 nematodes, and 2 copepods. A total of 20

species were found in smolts and 14 species in adult salmon only. Two of those found in adults were also found in smolts.

Methods

Smolt samples for this study were collected by various agencies in several countries in the North Atlantic Ocean. Twenty-seven samples of about 25 smolts each were received from Canadian rivers and 10 samples were received from the British Isles. Of these 37 samples, 3 were in very poor condition and are of little use to this study.

In 1966, the major part of the sampling effort was oriented towards the examination of smolts in the hope of gaining some idea of what freshwater species to expect in examination of the adults. Consequently, a total of 347 smolts has been examined compared with 54 adults. Forty-five adults came from Greenland and 9 from the Machias River, Maine.

Studies on Atlantic salmon in Greenland were carried out during October and November of 1966, the salmon being caught by the Danish research vessels "Adolf Jensen" and "Tornak" in Praestifjord and Kigdlut iluat, near Godthaab, Greenland. They were taken in nylon gill nets with 5 to 6 inch mesh (stretched) and examined as soon as possible after capture.

Smolts were collected either by angling or by trapping, preserved in 10% formalin and later shipped to St. Andrews, N. B.

In the laboratory the fish were weighed, measured, and scale samples were taken. The following structures were then examined:

(a) eyes
(b) liver
(c) spleen
(d) skin
(e) gills
(f) mouth
(g) oesophagus
(h) stomach
(i) muscles
(j) pyloric caecae
(k) intestine
(l) body cavity
(m) urinary bladder
(n) ureters
(o) air bladder
(p) gonads
(q) heart
(r) pericardial cavity
(s) mesenteries

Gall bladders were removed and preserved in 10% formalin for later study. Blood samples were taken from the heart of freshly caught adults but the blood of smolts was not suitably preserved for study. Parasites were removed from the various organs, tentatively identified with the aid of a dissecting microscope, and placed in labelled vials.

The same basic procedure of examination was carried out for both adults and smolts, with one exception: the alimentary canal of smolts was simply divided into several sections, slit open in a petri dish containing water, and the contents examined for parasites. Examination of the adults required a somewhat more complicated procedure. After the gut had been cut into several sections (oesophagus, stomach, pyloric caecae, and intestine), the contents of each was scraped into a 1-litre cylinder containing 0.7% sodium bicarbonate solution in water. This was agitated to remove the parasites from the mucus and the parasites were then allowed to settle, following which the supernatant fluid was poured off. This procedure was repeated until the supernatant fluid was clear. The final sediment of parasites and other gut contents was poured into a petri dish and the parasites removed and preserved.

Removal of the parasites from the alimentary canal of the adults was greatly impeded by the presence of large amounts of thick mucus, and although sodium bicarbonate solution helped to remove the parasites from the mucus, it was far from adequate for complete separation. Sometimes several hours were required to free the parasites from the mucus of a single gut.

Flukes and tapeworms were fixed in 10% formalin while copepods and nematodes were fixed in 70% ethyl alcohol. The helminths were stained with Mayer's paracarmine or borax alcoholic carmine solution, cleared in oil of cloves, methyl salicylate or cedarwood oil, and mounted in Canada balsam or "Permount". Copepods were examined unstained and nematodes

were cleared in lacto-phenol before examination. Dried blood smears were fixed in absolute alcohol and stained with Giemsa stain.

Considerable cooperation was given in this program by personnel of the Department of Fisheries of Canada, the Department of Tourism, Fish and Game of Quebec, the Atlantic Sea Run Salmon Commission of Maine, U.S.A., the Department of Agriculture and Fisheries for Ireland, the Department of Agriculture and Fisheries for Scotland, Salmon and Freshwater Fisheries of England, and the Greenland Fisheries Research Board in Denmark.

Parasites of Atlantic salmon

The incidence and abundance of the parasites found in smolts and adults are summarized in Tables I and II respectively. It is apparent that certain species, such as Cremidostomum farionis, Discocotyle sagittata, Eubothrium salvelini and Metabronema salvelini are found in smolts on both sides of the Atlantic, while other species, such as Apothallus brevis and Pomphorhynchus laevis, are recorded from one side of the Atlantic only. The bulk of the species given are parasites common in the salmonidae and only a few are apparently able to survive in the adult salmon in the sea. Of these few, only one species appears to be restricted to one side of the Atlantic (Pomphorhynchus laevis). Table II lists 14 parasites which, with the exception of Discocotyle sagittata and Diplostomulum are commonly reported from adult salmon in the sea. For brevity, I shall confine my discussion to (1) those species which indicate differences in geographic distribution, (2) species which may possibly survive in the salmon in the sea, and (3) those about which sufficient information is available to warrant discussion in the context of this study.

Parasites found in smolts

a) Trematoda

Cryptocotyle lingua: a larval trematode found encysted in the skin of 0 to 70% of the smolts from Canadian rivers. The adults of this species is known to infect fish-eating birds. It is unlikely that this species will be of any use as a biological tag as personal observations on this species in a river in Newfoundland indicate that the cysts fall free of the smolts shortly after they enter salt water.

Phyllodistomum coregoni (?): an adult trematode found in the ureters and urinary bladder of smolts from Exploits, Gander and Indian rivers in Newfoundland. This species has not yet been reported from Britain or Europe. No information is available on its longevity in salmon in the sea but it has never been reported from adult salmon.

Phyllodistomum sp: Three contracted specimens were recovered from the ureters of one smolt from Owenea River, Ireland. It is probably P. folium which is common in fish in that area. P. folium has never been reported from adult salmon.

Azygia longa: an adult trematode in the stomach and intestine of salmonids in North America. It was found in 3 of 10 smolts from the Miramichi River. The larval stage of this trematode has been shown to utilize the snail Amnicola limnosa as its host (Sillman, 1953). Again there is nothing known of its survival in anadromous fish at sea.

b) Cestoda

Cystocephalus baycreatus: an adult cestode found with its scolex firmly embedded in the distal blind tips of the pyloric caecae in 7 out of 15 smolts from the River Dreed, Scotland. Although not yet reported from smolts in Canada,

it has been reported from other salmonids, and its absence in Canadian smolts is probably the result of insufficient sampling. Awachie (1966) reports that the C. truncatus has an annual life cycle in Salmo trutta in a trout stream in North Wales. Therefore, if C. truncatus were to survive to complete a normal life span in salmon at sea, it would not be expected to remain in the salmon for more than a year after the smolts leave the river, and almost certainly would be lost by the time the salmon could be caught in the Greenland Fishery (about one and one half years after leaving the river).

Diplocotyle olrikii: Four specimens were found in a single smolt from Great Codroy River, Newfoundland. This species has also been found in salmonids in the eastern Atlantic countries. Again, nothing is known of its longevity in its host at sea.

Ligula sp: A single plerocercoid larvae of the cestode genus Ligula was found in one of 15 smolts examined from River Tweed, Scotland. Since Ligula is a larval parasite found in the body cavity of the fish, it seems likely that it will persist for sometime in the salmon at sea. It is a common parasite of freshwater fish on both sides of the Atlantic and therefore would be of no use as a means of determining the origin of individual fish. A much larger sample will be necessary before any trends in relative abundance of the parasite can be observed. Further sampling in Canada may well reveal its presence in smolts here also. Hardie and McLeod (1952) state that adult L. intestinalis (genotype and only known species) is recorded repeatedly from the alimentary tract of diving and wading birds in Europe, but is only known from mergansers in North America. This may be due to a difference in the relative abundance of the parasite, in host specificity, or in the amount of research carried out on the parasites of birds in North America.

c) Acanthocephala

Pomphorhynchus laevis (?): This is an acanthocephalan parasite of freshwater origin found as adults in 1 of 10 smolts from the Burrishode River, and in 2 of 10 from the Owenea River, Ireland. Each of the three fish harboured one worm which was located in the intestine with its bulbous head and neck firmly embedded in the intestinal wall. Each of the specimens was too poorly fixed to be positively identified, and the tentative identification is based on some of the characteristics which were clearly visible.

It is thought that P. laevis may be worth further attention as it has only been reported, in both immature and adult Atlantic salmon, from countries in the north-eastern Atlantic. Yamaguti (1963) cites reports of this species from various hosts in England, Southern Italy, Finland, Czechoslovakia, Polish Baltic, Finnish Gulf, Rumania, Germany, and elsewhere in the east. The only possible report of P. laevis in North American waters was made by Linton (1889) who reported Echinorhynchus proteus (= P. laevis) in the striped bass Roccus lineatus (= R. saxatilis) at Woods Hole, Mass. Yamaguti, for some unspecified reason, considers Linton's specimens (which are poorly described) to be P. tereticolle, another species otherwise only reported from the eastern Atlantic. Examination of Linton's description of the number of rows of hooks and the number of hooks per row indicates that they may possibly be P. bulbocolli, a typically North American species.

Although P. laevis is found in a great number of both marine and freshwater fishes, it is a parasite of freshwater origin and, according to Engelbrecht (1957), probably requires only one intermediate host, which may be Gammarus spp. or Corophium volutator. The species of marine fishes in which P. laevis is found are those which sometimes enter freshwater or estuaries, for example Gobius and Cottus.

Heitz (1917) reports that P. laevis was found by other workers as mature worms in young salmon descending to the sea in the Rhine River while he (who examined adult fish only) found it as larvae in adults returning to the river. Zschokke (1891) four P. laevis in 3.1% of 129 salmon returning to the Rhine while Holten found the larvae in 1.1% of 170 adults. P. laevis was found by Tosh (1905) to be not uncommon in adult salmon returning to the River Tweed, and by MacIntosh (1884) in salmon returning to the River Tay, Scotland. The present record extends its distribution to the Barrishode and Owenca rivers in Ireland. It is therefore clear that P. laevis can survive at sea for a period in salmon, but the length of this period is as yet unknown. It is not clear if the specimens observed in adult salmon by Heitz, Tosh and MacIntosh were in fact those, or the progeny of those, which were carried to sea in the smolts, or whether they were later picked up in other rivers by the adult fish during their wanderings. According to Heitz P. laevis is found in fish in the "Arctic Sea, coast of Murmansk, and Greenland", however, he does not make clear which hosts are involved.

From the above discussion, it is evident that P. laevis may possibly serve as an indicator of eastern Atlantic origin of its hosts. It was not found in any of the 45 salmon examined from Greenland, but considering the small sample size, this is not significant.

d) Nematoda

Contracaecum sp: A single specimen was found in the pyloric caecae of a smolt from Cains Stream, P. E. I.

e) Copepoda

Salmincola sp: The parasitic copepod Salmincola sp. has been found on 5 of 124 (4%) of the smolts from Newfoundland and Labrador or on 2.5% of all the Canadian smolts, but was not found on any from the British Isles. It has not yet been

determined if the species encountered is the common salmon gill-maggot, Salmincola salmonea L., or a similar species, S. gordoni. These species are morphologically almost identical. It has been pointed out (Friend, 1941) that, whereas salmonea is found on the gills, gordoni may be located anywhere inside the gill cavity. It is felt that the location of these copepods on the host may not be a very important diagnostic feature. Different habitats may cause slight morphological differences which are not necessarily genetically determined. The specimens found in this study were located on the gills, on the inside of the opercula, and on the inside and outside of the isthmus. A single specimen was found on the gills of a grilse returning to the Harry's River system in Newfoundland (Pippy, 1965), however, it is not known if this was the result of infection at the smolt stage or if the copopod was recently acquired in the river.

Gurney (1933) states that gordoni is distinguished from salmonea by its larger cephalothorax. But he points out that "The two species are, however, very close in other respects and it is possible that this species should be regarded as a sub-species, or even as the parent form of salmonea." Wilson (1915) gives the length of salmonea as 7 to 8 mm. (without egg strings) while Gurney gives the length of gordoni as about 3 mm. Measurements of the present specimens were closer to those of gordoni. Hutton (1923) points out that the gill-maggots found on fish returning to the river are much larger than those found on kelts or on fish which have spent some time in fresh water. If salmonea and gordoni are conspecific, ecological and/or physiological factors may be involved in the difference in their size and distribution on the host. In this respect, a more detailed study on its morphology, life history, and its distribution on the host may be warranted. The majority of the specimens collected thus far have been forwarded to Dr. Z. Kabata of the Marine

Biological Laboratory, Aberdeen, Scotland, who is familiar with the problems involved in the study of this genus.

Salmincola is of particular interest because whereas S. salmonea has been reported on adults from both sides of the Atlantic it has not previously been recorded from parr or smolts. Thus, if S. salmonea were to be found on smolts on one side of the Atlantic only, and if it survives in the sea, it could be used as an indicator or geographic origin of its host. However, if further research should reveal that salmonea and gordoni are in fact valid species, and if the specimens found on Canadian smolts are gordoni, it is doubtful that these copepods will be of any use as biological tags, at least qualitatively.

Parasites found in adults

a) Cestoda

Eubothrium crassum: an adult tapeworm of marine origin found primarily in the pyloric caecae of the salmon. In such cases, the caecae are obviously swollen and the lighter colour of the tapeworm within can be seen.

The incidence of Eubothrium seems to be fairly constant in Atlantic salmon from various regions. It was present in 56% of 9 adult salmon returning to the Machias River, Maine, in August of 1966. Pippy (1965) found it in 64% of 14 grilse returning to 8 rivers in Newfoundland and Templeman (1966) reports its presence in 60% of 10 salmon from the Labrador Sea. The only reports of the incidence of Eubothrium in the eastern Atlantic which have been examined are those of Heitz (1917) who reports a rate of 58% for the Rhine River, Germany. It was found in 51% of the 45 salmon examined from the Godthaab area of Greenland during the fall of 1966. All these figures are compared with those reported by Templeman (1966) for salmon from the west Greenland banks and the oceanic depths west of Cape Farewell

and Cape Desolation, which were 15% of 13 and 27% of 15 salmon respectively. At this time it is difficult to say whether these significantly lower rates are a result of habitat, age of the fish, or some other factor. Templeman pointed out that there were "indications that the percentage of salmon possessing tapeworms, Eubothrium crassum, may increase with length of river life and that the presence of this parasite may be worth following for area of origin of West Greenland salmon". Since information regarding the length of river life is derived from the scales which have not yet been examined, comments on this aspect of its occurrence cannot be made at this time.

Several immature tapeworms 2-3 mm in length, with typical Eubothrium scoleces were found in the pyloric caecae and intestine of some of the salmon taken in Greenland, indicating that the species may be acquired in the sea near Greenland. More information on this species will have to be compiled before the significance of the data collected can be assessed.

b) Nematoda

Anisakis: Larvae of the nematode genus Anisakis were found encysted in the muscles, on the viscera or free in the body cavity in 100% of the 45 salmon examined from Greenland (see Table III). The intensity of infestation varied from one up to 53+*, with an average of 12 larvae per fish. The muscles were the most heavily infested parts of the fish (80% infested with 10 larvae per infestation) and the urinary bladder (1 fish with 1 larva) was least infested.

Anisakis larvae, which are not sufficiently developed for specific identification, occur in the viscera and

*This particular fish which was collected by a local fisherman, bore a Canadian tag and was gutted with head on. Most likely there were other Anisakis encysted on the discarded viscera.

musculature of many marine fishes. The adult is found in the intestine of marine mammals and sea birds.

Novotny and Uzmann (1960) point out that the occurrence of Anisakis in fish is cumulative, the intensity of the infection increasing with the time spent in the sea. Since it has already been shown (Anon, 1966) that practically all (98%) of the fish caught in the Greenland area are the same age, one would expect that, if there is a difference in the degree of infestation of the salmon from either side of the Atlantic, a bimodal curve would result when the number of larvae per host is plotted against the number of hosts infested. However, a much larger sample from Greenland, and an estimate of the abundance of the larvae in salmon in home waters is required before such an analysis is practicable. Any larvae which were acquired in Canadian coastal waters would presumably be still in the salmon on its arrival in Greenland.

c) Copepoda

Lepeophtheirus salmonis (sea louse): a external parasitic copepod of marine origin. It was present on 50 of 101 salmon taken in Greenland. Although an average of 4 parasites per infested fish was noted, it is thought that this is below the actual rate of infestation. Doubtlessly some specimens are lost during the salmon's struggle in the nets and others were observed to leave the salmon and adhere to the vertical surfaces of the holding tank on board the "Adolf Jensen". Furthermore, it was not possible to determine the actual number on any individual fish after it came out of the net as transfer from one host to another in the holding tank was observed. Thus, the data collected for any given fish are apparently inaccurate and almost certainly minimal. It is therefore impossible to say that the incidence of this parasite on fish in the inshore waters of Greenland is in fact below that reported by

Templeman (1966) (86.8%) for the Labrador sea and the high seas off West Greenland.

Of a total of 226 sea lice observed, 18% were males. This figure is lower than the 45% reported by White (1942) from the Gulf of St. Lawrence and the Bay of Fundy, but higher than the observations of Wilson (1905) who reports a single male in a collection of more than 24 specimens from North America and England. Scott and Scott (1913) reports the males to be comparatively scarce (area not specified).

The only immature stages of this parasite found were developing young in the egg sacs, and nauplius larvae on the gills and wandering freely over the surface of the salmon. These observations are compared with those of White (1942) who, while observing the other larval stages, did not find any nauplius larvae on the fish and, although he examined many heavily infested fish, did not find any stage of the parasite within the gill cavity. Because this parasite can apparently reproduce on salmon in the sea near Greenland, and because there are such varied rates of infection reported, which are in themselves, seemingly inaccurate, it is clear that the use of quantitative data on this parasite would be unreliable as a means of differentiating stocks. Also it is unlikely that this species will be of any use as a tag on a qualitative basis. It has been reported on both sides of the Atlantic Ocean (Wilson, 1905) as well as from the Pacific (Margolis, 1958).

Parasites found in smolts and adults

Trematoda

Diplostomulum sp: a larval trematode of freshwater origin found in the humors of the eye and sometimes in the lens. It has been found in the eyes of smolts both from Canada and the British Isles although it was more prevalent in the samples of smolts from Canada. It was found in

the eyes of from 10-38% of the smolts from half the rivers of the British Isles and in 10-100% of the smolts from 77% of the rivers from Canada. Margaree River (Canada) smolts had the highest infestations, average 448, and up to 736 larvae per host. Diplostomulum was also found in the eyes of 3 (7%) of 45 adults examined from Greenland; the average infestation was 2 larvae per host.

Comparisons of Diplostomulum larvae from Canadian and British smolts have failed to reveal any morphological differences. It may therefore be concluded that this species will probably prove to be of little qualitative use as a natural tag.

It is possible that there may be significant differences in the abundance of this parasite in eastern and western smolts and that these differences may be expressed in the abundance of the larvae in the adults. However, such differences can only be recognized in data from adult salmon taken in their own coastal waters, on their return to the rivers, or in tagged fish. Only when such data are collected will it be possible to assess the significance of the numbers of Diplostomulum in the eyes of adult salmon in Greenland. Margolis (1963), who found very few larvae in adult sockeye returning to an area in which the smolts have a high rate of infection, concluded that the larvae "did not live long enough after the fish had migrated to sea to be of any value as a natural tag" for sockeye salmon. Dogiel and Petrushevski (1933) found D. spathaceum to be"fairly frequent" in adult Atlantic salmon returning to certain rivers in the U.S.S.R., but concluded that they were not survivors of the salmon's original parasite fauna but were newly acquired during its ascent of the rivers. The very limited amount of data collected thus far at least indicate that Diplostomulum may have a higher

survival rate in Atlantic salmon than in the Pacific salmon. Only further sampling will reveal if quantitative data on this parasite will be of any use to distinguish stocks. Interpretation of the occurrence of Diplostomulum in the eyes of salmon in Greenland may be further complicated by the possibility of locally acquired infections. Salmon are known to spawn in one river (Kapisigdlit River) in Greenland and have been reported from other rivers (Nielsen, 1961). If Diplostomulum is present in any of these rivers it is possible that the salmon could become infected in only a brief period. Entry of the parasite into the fish is by direct penetration of the free-swimming cercariae through the skin, however, recent studies (Becker and Brunson, 1966) indicate that infection by this group may also occur when fish feed on infected molluscs. No molluscs were observed in the alimentary canal of any of the fish examined. Arrangements have been made to obtain a sample of salmonids from Kapisigdlit River to explore the possibility of infection taking place locally.

Discocotyle sagittata: a monogenetic trematode of freshwater origin found on the gills of 15.2% (mean per infected host = 3) of the smolts examined from Canada, 18.2% (3) of those from the British Isles, and 4% (3) of the adults taken from Greenland waters. The incidence of this parasite on smolts from Deadmans Bay River (Canada) was up to 18 on a single host and a maximum of 10 was found on smolts from the British Isles (Owenea River, Ireland), whereas the infestations recorded from Greenland waters were 1 and 5 on the two infested fish.

That D. sagittata can survive on its salmonid host in salt water has been observed in the laboratory (Frankland, 1955) and in nature (Slinn, 1963). But it is not known if D. sagittata can reproduce in the marine environment. Slinn reported that while the eggs appeared normal in sea water, attempts to hatch them in salt or fresh water were unsuccessful.

One of the specimens from salmon in Greenland contained a single egg. No studies have yet been carried out on the egg formation, deposition, and larval development of this species. In the few species which have been studied, egg formation can occur in a matter of minutes, deposition in days and larval development within the egg in a matter of weeks (Bychowsky, 1957). It is not known what effect the marine environment has on the reproductive capacity of D. sagittata. As with other monogeneans, it undoubtedly does not require a second host.

Observations by Llewell and Owen (1960) indicate that it is unlikely that adult D. sagittata move around much on the gills, and when they are forcibly detached, re-attachment was usually incomplete, with the attachment clamps on one side only being used. It would therefore seem that, if reproduction does not occur in the marine environment, the specimens found on the adult salmon in Greenland originated in the home rivers of the fish. However, in the absence of such knowledge on reproduction of the species at sea, it is not practicable to consider quantitative differences of this parasite as a means of stock differentiation at this time.

For some time it was thought that the American form, D. salmonis was a different species from the European D. sagittata. Sporston (1946) regards the two species as valid, Price (1943) doubts the distinction, and Brinkman (1952) synonymizes both species as D. sagittata. It is therefore evident that this species would also be of little use as a qualitative tag on Atlantic salmon in the high seas.

Parasites of salmon of known origin

A total of 8 salmon of Canadian origin was taken in Greenland and turned over to this study by Danish authorities. Four have not yet been examined; two entire specimens have been examined; and the muscles only of two incomplete specimens (local fishermen gut their fish before

selling them to processing plants) were examined. The results of examination of two complete Canadian salmon which were tagged as smolts in the Northwest Miramichi River in 1965 are given in the following table.

Parasites	Salmon #29	Salmon #30
Lamellanes variolus	1	5
Brachicotyloides bychowskii	-	6
Pelichnibothrium sp.	46	149
Dibothrium cordatum	+	+
Anisakis sp.	5	2
Contracaecum sp.	25	23
Leptocephalus salmonis	3	2

Because of the great masses of the tapeworm Dibothrium in the pyloric caecae and pyloric region of the intestine in many of the salmon, it was deemed impractical to attempt time-consuming counts. Instead, the total volume of each infestation was recorded and the specimens preserved. The volumes of tapeworms found in these two salmon were 31 and 44 cc. respectively.

The muscles of two other Canadian salmon from the same river, contained 4 and 53 Anisakis larvae.

The single Scottish salmon (Tag number SC5-1788), which was gutted with head on when received, harboured 4 Anisakis larvae in the muscles and parietal peritoneum and 7 Brachicotyloides bychowskii on the gills.

In our present state of knowledge, it is impossible to interpret the zoogeographical significance of the occurrence and abundance of the various species of parasites found in each of these fish.

In August of 1966, 9 adult salmon were examined

from Lachine River, Maine. The parasite fauna of these salmon was basically similar to salmon caught in Greenland except for the presence of the adult trematode Brachyphallus crenatus, a very common marine parasite, in the alimentary tract of 3 of the fish (average infestation - 108), and more than 500 cysts of the parasitic protozoan Ichthyosporidium in the muscles of one of the fish.

Discussion

In dealing with the possibilities of using parasites as biological tags to distinguish North American from Asian stocks of sockeye salmon, Margolis (1963) clearly illustrates the usefulness of parasites which are acquired in freshwater, retained throughout the marine life of the salmon and brought back to fresh water in the spawning fish. Kabata (1963) points out that while the parasite should be common in one population and rare or absent in another, an incidence as low as 2% can be tolerated if samples numbering several thousands of fish are examined. It is therefore clear that the very small sample of both smolts and adults examined thus far precludes any positive arguments for or against many of the parasites found in the Atlantic salmon.

At the present stage of this investigation one can only discuss apparent trends in the data acquired. Thus, the limited amounts of information compiled on the occurrence of Acanthocephalus (2.1% in smolts from the British Isles) seems to indicate that it may possibly be of use as a biological tag. Conversely, too little information is yet available on the distribution and abundance of marine parasites such as Anisakis marina, Lecithaster gibbosus and Hemiurus [illegible], etc., even to speculate on their use as tags.

Information gained on the occurrence of parasites such as Salmincola and Diplostomulum will be of very little practical use unless rates of occurrence of these parasites are established for adult salmon stocks of known origin. Future studies of adult salmon returning to Canadian rivers and the

results of the "A.T. Cameron" cruise this summer should yield useful information in this respect. But, in the final analysis, unless some idea of the occurrence of the various parasites can be established for adult fish in the eastern Atlantic as well, very few, if any, sound conclusions will be feasible. With this in mind, the possibilities of such a study on the parasites of adult salmon from the eastern Atlantic are being explored.

Summary

1) This report summarizes some of the more pertinent preliminary observations on the parasites of Atlantic salmon from samples collected in 1966.

2) The distribution and abundance of parasites collected from 204 smolts from Canada, 143 from the British Isles, and 45 adult salmon from Greenland is presented.

3) Methods of collection, preservation and examination of the salmon are given, and techniques used for collection and staining of the parasites are described.

4) Discussion is confined to (a) the species which indicate differences in geographic distribution, (b) species which may possibly survive in the salmon at sea, and (c) those about which sufficient information is available to warrant discussion in the context of this study.

5) Anonchallus brevis, Phyllodistomum spp., Agyrin longa, Cyathocephalus truncatus, Diplocotyle olrikii, Limia sp., Pomphorhynchus laevis (?), Salmincola sp., and Contracaecum sp. appear to have different geographic distributional patterns. Anonchallus brevis found on smolts in Canada is probably lost as soon as the salmon enters salt water. Nothing is known of the longevity of Phyllodistomum spp., Agyrin longa, Cyathocephalus truncatus and Diplocotyle olrikii in salmon.

6) The acanthocephalan Pomphorhynchus laevis (?) was found in

smolts from Ireland and published reports indicate that it is found only in the eastern Atlantic. Although the parasite was not found in salmon in Greenland, there are reports of it in salmon returning to rivers in Scotland and Germany. Its apparently low incidence of 1.1 to 3.1% may possibly account for its not having been recovered in the sample of salmon from Greenland. This species at least shows some promise as a biological tag.

7) The parasitic copepod Salmincola sp. was found only on Canadian smolts. However, until the present problem regarding the validity and/or synonomity of the two species S. salmonea and S. gordoni is solved, and the survival or non-survival of the parasite on salmon in the sea is ascertained, the significance of the presence of this parasite on smolts will remain uncertain.

8) Information available on the incidence of the cestode Eubothrium crassum indicates that there is little, if any, difference in its occurrence in salmon on each side of the Atlantic.

9) Data on the incidence and abundance of the larval nematode Anisakis in salmon is presented.

10) The parasitic copepod Lernaeolophus salmonis is discussed and its used as a possible biological tag is dismissed.

11) Two parasitic species of freshwater origin were found in salmon in Greenland: the larval trematode Diplostomulum, found in the eyes of 7% of 45 adults and the monogenetic trematode Dioscocotyle sagittata from the gills. More information on the distribution and abundance of Diplostomulum in salmon in the sea is necessary before its use as a tag can be considered. Dioscocotyle sagittata will probably not be of any use as a biological tag.

12) Examination of several salmon tagged as smolts in Canada and Scotland and recovered in Greenland did not reveal any

evidence as to which parasites might be useful as biological tags.

13) In order to provide a basis of comparison for the parasite fauna of salmon caught in Greenland, samples of adult salmon from the high seas and coastal waters on either side of the North Atlantic will be required.

14) Because of the limited amount of data collected to date, it is not possible to form any definite conclusions on the use of any species of parasites as indicators of geographic origin at this time.

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Table 1. Incidence and abundance of parasites of smolts, by species and area of origin, 1966

	No. Hosts Examined	TREMATODA: Crepidostomum farionis	TREMATODA: Apophallus brevis	TREMATODA: Phyllodistomum folcrondi	TREMATODA: Tetracotyle sp.	TREMATODA: Discocotyle sagittata	TREMATODA: Azygia lonea	TREMATODA: Diplostomulum sp.	CESTODA: Phyllobothrium sp.	CESTODA: Eubothrium salvelini	CESTODA: Diphyllobothrium sp.	CESTODA: Cystocephalus sp.	CESTODA: Proteocephalus sp.	NEMATODA: Ligula	ACANTHOCEPHALA: Echinorhynchus	ACANTHOCEPHALA: Pomphorhynchus laevis(?)	NEMATODA: Metabronema salvelini	NEMATODA: Capillaria salvelini	NEMATODA: Rhabdascaris sp.	NEMATODA: Contracaecum sp.	COPEPODA: Salmincola sp
Canada	204																				
Maritime Mainland	114																				
Restigouche Bay R.	10	100(45)	70(14)	-	-	30(11)	-	-	-	-	-	-	-	-	100(14)	-	100(54)	70(18)	-	-	-
Escuminac R.	16	75(8)	63(13)	6(1)	6(7)	25(3)	-	75(4)	-	6(4)	6(3)	-	-	-	6(1)	-	88(25)	-	-	-	-
Gaspe R.	13	85(8)	-	8(4)	54(11)	15(1)	-	69(3)	-	15(2)	-	-	-	-	77(3)	-	92(15)	-	-	-	8(1)
Great Village R.	13	69(29)	-	-	8(1)	8(5)	-	62(5)	-	-	-	-	8(4)	-	77(12)	-	92(11)	8(2)	-	-	8(1)
Indian R.	20	100(15)	44(8)	25(3)	30(70)	-	-	95(14)	-	5(1)	-	-	-	-	25(5)	-	90(14)	1(1)	-	-	-
North Harbour R.	25	88(12)	-	-	-	-	-	4(1)	-	-	-	-	-	-	12(5)	-	100(51)	-	-	-	-
Shoady Brk(Humber)	17	100(12)	18(3)	-	18(2)	68(3)	-	64(6)	-	-	-	-	-	-	24(18)	-	24(5)	-	-	-	23(1)
Labrador	10																				
Mecatina R.	10	70(6)	20(1)	-	-	20(1)	-	70(19)	-	-	-	-	-	-	30(7)	-	100(3)	-	-	-	10(1)
Prince Edward I.	10																				
Dains Stream(Hill R.)	10	30(3)	-	-	-	-	-	20(2)	-	-	-	-	-	-	90(6)	-	10(12)	-	-	10(1)	-
Nova Scotia	27																				
Margaree R.**	27	-	-	-	-	-	-	100(448)	-	-	-	-	-	-	8(1)	-	-	-	-	-	-
New Brunswick	43																				
Big Salmon R.	23	13(1)	13(2)	-	-	-	-	-	-	-	-	-	-	-	-	-	91(23)	-	-	-	-
Millbank(Miramichi R)	10	60(5)	20(2)	-	-	30(1)	30(4)	-	-	-	-	-	-	-	-	-	80(3)	20(3)	20(1)	-	-
Saint John R.	10	-	-	-	-	-	-	10(1)	-	10(1)	-	-	-	-	10(1)	-	30(8)	20(1)	10(1)	-	-
British Isles	143																				
England	72																				
Usk R.	25	44(4)	-	-	-	-	-	-	-	-	-	-	-	-	44(2)	-	64(10)	-	-	-	-
R. Axe	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8(1)	-	-	-	-
R. Dee	22	1(1)	-	-	-	-	-	-	-	-	-	-	-	-	0.5(1)	-	0.5(1)	-	-	-	-
Ireland	20																				
Burrishode R.	10	20(2)	-	-	10(5)	20(1)	-	10(2)	-	10(1)	10(4)	-	-	-	50(14)	10(1)	80(9)	-	-	-	-
Owenea R.	10	70(4)	-	-	10(5)	20(7)	-	-	10(3)	-	10(6)	-	-	-	10(3)	20(1)	80(10)	-	-	-	-
Scotland	51																				
R. Tran	11	18(7)	-	-	21(2.5)	90(2)	-	18(2)	-	-	-	-	-	-	-	-	73(11)	-	-	-	-
River Tweed	15	53(4)	-	-	33(4)	67(4)	-	13(6)	-	7(1)	-	47(5)	-	7(1)	73(5)	-	93(33)	-	-	-	-
North EskR.	26	59(2)	-	-	38(5)	38(2)	-	38(4)	-	-	-	-	-	-	62(3)	-	-	8(3)	4(1)	-	-
Total	347																				

* The first figure gives the percentage of salmon infected while the bracketed figure gives the average numbers of parasites per infected fish.

** Very smolts; intestinal tracts in very poor condit therefore figures

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Table II. Incidence and abundance of parasites, by species, in 45 adult salmon caught in Greenland coastal waters, 1966.

Species	Occurrence
Trematoda	
Lepidogenes varicus	84(10)
Lecithaster gibbosus	69(18)
Myodactyloides bychowskii	42(13+)
L. confusus	9(11)
Hemiurus sp.	...
Diplostomulum sp.	7(2)
Discocotyle sagittata	4(3)
Cestoda	
Pelichnibothrium sp	78(79)
Eubothrium crassum	51(..)
Nepotoxylon trichiuri	44(1)
Nematoda	
Anisakis larvae	100(12)
Contracaecum sp.	93(17)
Acanthocephala	
Echinorhynchus gadi	27(2)
Crustacea	
Lernaeophtheirus salmonis	67(4)

Table XXI. Incidence and abundance of Anisakis larvae in 45 salmon caught near Godthaab, Greenland, 1966.

Infected organ	% fish infected	range	mean per infected organ
Viscera	91		6
Pyloric caecae	78	1-15	4
Liver	47	1-4	2
Body cavity (free)	29	1-5	2
Stomach	27	1-3	1
Intestine	16	1-2	1
Mesentery	13	1-13	4
Spleen	4	2-3	3
Oesophagus	4	1	1
Air bladder	4	1	1
Urinary bladder	2	1	1
Muscles	88	1-53+	10
Total	100	1-53+	12