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The use of parasites for separating stocks of Greenland halibut (Reinhardtius hippoglossoides) in the Atlantic Ocean off Canada

by

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Abstract

A study was conducted to determine the usefulness of parasites as biological tags for stocks of Greenland halibut occurring off the Atlantic coast of Canada and in the Gulf of St. Lawrence. More than 40 species of parasites were identified from examination of a total of 231 large fish (>39 cm) collected from eight localities. Analyses using five taxa (Corynosoma strumosum juvenile, Otodistomum sp. metacercaria, Contracaecinea spp. larva, Anisakis simplex larva and Pseudoterranova decipiens larva) gave highly accurate results (almost 100% correct classification) for the separation of fish from the Gulf of St. Lawrence from those collected from adjacent areas of the Saguenay Fjord and the Atlantic Ocean off Labrador. It is concluded that little, if any mixing of subadult or adult fish occurs among these areas.

Résumé

Une étude a été menée afin de déterminer l'utilité des parasites comme étiquettes biologiques pour l'identification des stocks de flétan du Groënland de la côte atlantique et du golfe du Saint-Laurent. Plus de 40 espèces de parasites ont été identifiées chez les 231 poissons de taille supérieure à 39 cm provenant de huit sites d'échantillonnage. Des analyses discriminantes utilisant cinq taxons (la forme juvénile de Corynosoma strumosum, le stade métacercaire d'Otodistomum sp., et le stade larvaire de Contracaecinea spp., d'Anisakis simplex et de Pseudoterranova decipiens) ont réussi à séparer de façon très précise les poissons du golfe du Saint-Laurent de ceux des régions adjacentes du fjord du Saguenay et de l'océan Atlantique au large du Labrador. Presque 100% des poissons ont été reclassifiés correctement dans leur région d'origine. On peut conclure qu'il y a très peu ou pas de migration des flétans du Groënland immatures ou adultes entre ces régions.

The Greenland halibut (Reinhardtius hippoglossoides) is a species of high commercial importance to Canada's Atlantic fisheries, having recently been the second most valuable groundfish in the Gulf of St. Lawrence.

The current concept of stock structure, based on morphometric, meristic, biochemical genetic analysis and parasitological evidence, is that a single stock exists for Canadian waters from Georges Bank to Hudson Strait. A discrete spawning is believed to occur in the Gulf of St. Lawrence with an unknown amount of recruitment into this stock from the larger northwest Atlantic stock (see Templeman 1970, Tremblay and Axelsen 1981; Fairbain 1981, Khan et al. 1982, Misra and Bowering 1984, Bowering 1988, Bowering and Chumakov 1989, Riget et al. 1992). Greenland halibut occurring in the Saguenay Fjord are believed likely to be an isolated population but to date no biological studies have been conducted to confirm this hypothesis.

Bowering (1982), based on similar peaks in annual abundance, suggested that a significant recruitment of fish to the stock in the Gulf of St. Lawrence comes from the larger population of Greenland halibut occurring off Labrador. Young stages are believed to migrate or to be carried by prevailing currents into the Gulf via the Strait of Belle Isle. The absence of larger Greenland halibut in the Gulf (i.e., males over 60 cm and females over 70 cm) was considered likely due to their emigration upon approaching maturity. It was hypothesized that these fish may undergo a unidirectional migration outside the Gulf to participate in spawning in the Davis Strait with the larger northwest Atlantic stock. The occurrence of high concentrations of fish in an advanced stage of maturation in the northwestern part of the Gulf of St. Lawrence in late autumn and the presence of mature individuals at the end of November, as well as conditions which are conducive to successful reproduction led Tremblay and Axelsen (1981) to believe that a significant amount of spawning occurs in the Gulf.

Although Margolis and Arthur (1979) were only able to list four species of parasites as having been reported from Greenland halibut in Canadian Atlantic waters up to 1975, more recent studies have provided a reasonably complete picture of the parasites of this fish. Wierzbicka (1988) reported 19 species of parasites (4 Protozoa, 1 Monogenea, 2 Cestoda, 7 Digenea, 2 Nematoda, 2 Acanthocephala and 1 Copepoda) from examination of 155 Greenland halibut collected in 1976 in the Labrador region (Hawke Channel); while in a less extensive study, Zubchenko (1980) reported 15 taxa from 20 Greenland halibut collected between northeastern Newfoundland and Baffin Island. Other recent studies are of a limited nature, being focused on the taxonomy of Protozoa, intestinal helminths and crustaceans of this fish (see Rokicki 1982, Kovaleva et al. 1983, Wierzbicka 1986, Rubec 1988, Scott and Bray 1989). Despite these studies, the complete spectrum of species infecting Greenland halibut, as well as their individual abundances and geographical distributions remain poorly known, particularly for the Gulf of St. Lawrence and Saguenay Fjord, where no detailed surveys have been conducted.

Parasites have been widely used as "biological tags" to provide information for fisheries management on the movements and population discreteness of their fish hosts (for summaries, see MacKenzie 1983, Lester 1990, Moser 1991). The present study was undertaken to determine if parasites could be used to provide information on the discreteness of stocks of Greenland halibut occurring in Canadian Atlantic waters. This work is complementary to and coordinated with studies on the population genetics of Greenland halibut being conducted by J.-M. Sévigny of the MLI Invertebrates and Biostatistics Division.

MATERIALS AND METHODS

As preliminary investigations showed that small Greenland halibut (<20 cm) are very lightly parasitized, only large fish were used for this study. A total of 231 Greenland halibut of size 39 cm or greater were examined from eight areas off the Atlantic coast of Canada. These include one sample of fish collected from Cumberland Sound using longline, two from off Labrador (Hamilton Bank and Hawke Channel) and four from the Gulf of St. Lawrence (Estuary, Sept-Iles, North Anticosti and Esquiman Channel) using bottom trawl, and one from the Saguenay Fjord collected by handline (Fig. 1). Fish were measured and individually bagged and deep frozen immediately after capture for later laboratory examination. As all fish from Cumberland Sound and the Saguenay Fjord were received frozen, estimates of fresh length were made for these fish using a regression of fresh length onto frozen length obtained from fish from Sept-Iles. In the few cases where age could not be determined from saccular otoliths, ages were estimated from age/length regressions for the individual collections involved. Summary statistics for all collections are presented in Table 1.

Complete examinations for protozoan and metazoan parasites were performed using standard parasitological methods. Fish were thawed in the laboratory and the external surface rinsed. The rinse was then collected, settled and the sediment examined for ectoparasites using a stereomicroscope. Fish were then measured (total length) and weighed. The gills were removed, rinsed and the arches examined individually. The head was rinsed and the opercula, eyes and rinse water examined separately. Saccular otoliths were removed for subsequent age determination. The fins were removed, skinned, and individually examined for encysted parasites. The internal organs (heart, liver, spleen, gall bladder, digestive tract, gonads, kidney, urinary bladder) were then separated and individually examined. The stomach, pyloric caeca and intestine were separated, opened longitudinally, and their contents rinsed into beakers where they were mixed with sodium bicarbonate and settled to remove endoparasitic helminths. The walls of the stomach, pyloric caeca and intestine, and the liver, spleen, kidney and heart were compressed between glass plates and examined for parasites. The body cavity was rinsed and the rinse collected and examined. Squash preparations made from liver, spleen, kidney, gonads, intestine, muscle and brain tissue and scrapings from the urinary and gall bladders were examined for Protozoa using a compound microscope at a magnification of 400X. Preparations not found to harbor protozoans after 5 minutes examination were considered uninfected. The body musculature was removed from the vertebral column, the skin removed from the fillets, and the fillets and flaps thinly sliced and inspected for helminths and protozoan cysts. The above techniques are effective for the recovery of all but three groups of parasites. Freezing typically destroys ectoparasitic protozoans and small monogeneans. It also makes examination of blood smears for hematozoans impossible.

All parasites were sorted into major taxonomic groups, cleaned, counted for each organ (metazoans only) and fixed in 10% buffered formalin (Protozoa), 70% alcohol with 10% glycerin (Nematoda, Crustacea), or alcohol-formalin-acetic acid (AFA) (platyhelminths and Acanthocephala) for later identification to lowest possible taxon.

In the context of this study, parasites for use as possible biological tags for Greenland halibut were chosen based on three criteria: (1) that infections be of relatively long duration (years rather than months), (2) that no reproduction occurs on the host, and (3) that they be relatively abundant in at least one of the eight collections examined. Of the more than 40 parasites which have been identified (see Table 2), 14 were considered potentially useful as long-term biological tags and five met all of the above three criteria. These included one digenean metacercariae (*Otodistomum* sp.), three larval nematodes (*Anisakis simplex* (Rudolphi, 1809), *Pseudoterranova decipiens* (Krabbe, 1878), and Contracaecinea spp.) and one juvenile acanthocephalan (*Corynosoma strumosum* (Rudolphi, 1802)).

Statistical Analyses

Summary statistics for the five parasite taxa are given in Table 3. Data given include prevalence (% infected) and intensity of infection (number of parasites per infected fish), expressed as the mean $\pm$ the standard deviation, followed by the range as recommended by Margolis *et al*. (1982).

Since parasite counts for all areas were not normally distributed and normality could not be achieved using various transformations, non-parametric discriminant analyses (SAS version 6) were used to investigate the usefulness of parasites in separating host collections. As all parasites used in this study are relatively long-lived and are thus accumulated with host age (length), trends due to associations between parasite numbers and fish length were removed by adjusting counts for fish length. For each parasite species from each area, a regression of parasite numbers on fish length was undertaken, and the resulting relationship used to adjust the parasite number to that expected for a fish of 513 mm, which is the overall average host length for the eight collections. After this adjustment GLM tests did not show any association between corrected parasite numbers and fish length, weight or sex. Non-parametric discriminant analysis was conducted using the normal kernel density estimation with an R value of 1.0 (SAS version 6). Cross validation was used to estimate the accuracy of classification rules. Using this technique, each fish is removed from the "training" data set, the classification rule is recalculated and the classification of the omitted fish is estimated.

Results of discriminant analyses are presented as matrices showing the numbers and percentages of fish correctly and incorrectly classified by cross validation for the eight areas sampled and for the subsequent second set of analyses following the regrouping of collections.

RESULTS

Eight Category Discriminant Analysis

Cross validation results for nonparametric discriminant analysis using eight categories are given in Table 4. Results showed a high level of separation for fish from the Saguenay Fjord (100% correct classification; misclassification of only a single fish from all other collections to this area); and Hamilton Bank (96.7% correct classification; no other fish misclassified to this area). Fish from the four collections from the Gulf of St. Lawrence (Estuary, Sept-Iles, North Anticosti and Esquiman Channel) could not be distinguished from one another, correct classification ranging from 100% for North Anticosti to 3.3% for Esquiman Channel, but with substantial misassignment among collections. No fish collected from the Gulf of St. Lawrence were misclassified to the three collections taken from the Atlantic Ocean proper (Cumberland Sound, Hawke Channel and Hamilton Bank) or to the collection originating from the Saguenay Fjord. Although fish from Hawke Channel were accurately classified (100% correct), this collection could not be clearly separated from Cumberland Sound, with 70% of fish from this area being misclassified to it.

Four Category Discriminant Analysis

Based on the above analyses, the eight collections were regrouped into four categories: (1) the Saguenay Fjord; (2) the Gulf of St. Lawrence (Estuary, Sept-Iles, North Anticosti, and Esquiman Channel); (3) Hamilton Bank; and (4) Cumberland Sound/Hawke Channel.

Results of reanalysis of the data using four categories are presented in Table 5. Overall percent correct classification was 99.6%. All fish were correctly classified with the exception of a single fish from Hamilton Bank which was misassigned to the Saguenay Fjord.

DISCUSSION

The results demonstrate that parasites can be used to separate fish from the Gulf of St. Lawrence from those from adjacent waters of the Saguenay Fjord and the Atlantic Ocean off Labrador with an extremely high level of accuracy. Fish from the Gulf are characterized by high levels of infection with the nematode Anisakis simplex and metacercariae of the digenean Otodistomum sp., and relatively low levels of infection with the acanthocephalan Corynosoma strumosum and the nematode Pseudoterranova decipiens (see Table 3). Those from the Saguenay Fjord are characterized by high levels of Corynosoma, Pseudoterranova, and Anisakis, and an absence of Otodistomum metacercariae. Fish from Hamilton Bank and Hawke Channel/Cumberland Sound are characterized by relatively low levels of infection by Anisakis, Pseudoterranova, and Corynosoma, and the complete absence of Otodistomum.

These differences reflect variation in the ecological conditions found in these regions, and are a result of the non-uniform distributions and abundances of the parasites' final and perhaps, first intermediate hosts. Anisakis simplex, also known as the "whaleworm", uses euphausiids as first intermediate hosts and fish as second intermediate and transport hosts (Oshima 1972). It develops to maturity in various cetaceans (see Margolis and Arai 1989). Its high abundance in collections in the Gulf of St. Lawrence is probably directly related to the large number of whales which frequent this region.

Pseudoterranova decipiens is believed to use various benthic invertebrates as first intermediate hosts and ground fish as second intermediate and transport hosts (McClelland 1990, McClelland et al. 1990). It develops to maturity in various pinnipeds, of which the grey seal (Halichoerus grypus) is the most important in Canadian Atlantic waters (see Bowen 1990).

The acanthocephalan Corynosoma strumosum uses amphipods as intermediate hosts, fish as transport hosts, and various seals (grey seal, harbour seal and bearded seal) as final hosts (see Van Cleave 1953, Margolis and Arai 1989). Although seals are not particularly abundant in the Saguenay Fjord (M. Hammill, pers. comm.), it is possible that the high abundances of Pseudoterranova and Corynosoma in Greenland halibut from this region are due to the presence of deep water close to their hauling-out sites, thus facilitating transmission. It is also possible that small whales, such as the beluga, may play an important role in the localized transmission of Corynosoma.

The complete life cycle of Otodistomum sp. has not been elucidated (Gibson and Bray 1977). The first intermediate host is probably a deep-water mollusc. Greenland halibut may act as true second intermediate hosts, or possibly may acquire infections by feeding on infected crustaceans or on smaller fishes, thus acting as transport hosts. Adult Otodistomum are parasitic in the spiral valve or body cavity of elasmobranch fishes, while metacercariae are found in a variety of fishes. The restricted distribution of this parasite in Greenland halibut is probably related to the geographical distribution of the as-yet-unknown molluscan host.

Scott and Bray (1989) noted the occurrence of Otodistomum in Atlantic halibut (Hippoglossus hippoglossus) from the Scotian Shelf (NAFO divisions 4W and 4Vs, with prevalences of 2 and 32%, respectively), and in one of nine Greenland halibut examined from 4Vs. Scott (1975) noted that the occurrence of metacercariae in witch flounder (Glyptocephalus cynoglossus) was considerably higher in fish from the Gulf of St. Lawrence than in those from the Scotian Shelf (35.0% vs 13.7%). Otodistomum metacercaria has not been reported in fishes collected further north on the continental shelf than NAFO division 4Vs (Banquereau Bank).

Contracaecinea larvae represent larval stages of the genera Phocascaris and Contracaecum, adults of which are parasites of various marine mammals, and in the case of the latter genus, also piscivorous birds. Morphological features necessary for genus and species identification are not developed in 3rd stage larvae found in fish. Material from Greenland halibut probably contains at least two species, Phocascaris phocae Host, 1932 and Contracaecum osculatum (Rudolphi, 1802), both common parasites of pinnipeds off Atlantic Canada. It is possible that additional species of Contracaecum, particularly those using piscivorous birds as definitive hosts, may also be contained in this taxon.

The results of these parasitological studies do not provide information towards the definition of Greenland halibut populations, which is best addressed through analysis of population genetics. Rather, they provide insight on the movements and degree of mixing between stocks of older fish in the areas studied. The high level of separation between fish from the Gulf of St. Lawrence and those from adjacent areas of the Saguenay Fjord and the

Atlantic Ocean proper (Hamilton Bank and Hawke Channel) indicates that there is little interchange of subadult or adult fish between these areas. Results of tagging experiments conducted off the coast of Newfoundland and Labrador by Bowering (1984) support the hypothesis that there is little, if any, movement of large Greenland halibut from this region into the Gulf of St. Lawrence. The shallower water of the Strait of Belle Isle (maximum depth of 75 meters) separating Esquiman Channel from nearby Hamilton Bank and Hawke Channel probably effectively prevents older Greenland halibut from moving between these areas. Similarly, Greenland halibut in the Saguenay Fjord are separated from fish occurring in the Estuary of the St. Lawrence by a shallow water barrier (three ledges, the shallowest of which has a depth of only 18 meters), the existence of a thermo-halocline and other hydrological features (see Drainville 1968; De Ladurantaye et al. 1984).

Separation of Greenland halibut from Hamilton Bank from those of nearby Hawke Channel and from Cumberland Sound appears to be based mainly on the relatively high level of infection by Contracaecinea larvae in the latter two collections (see Table 3). These results indicate that fish from Hamilton Bank probably remain in a rather restricted geographical area during the period up to their spawning migration. Although it can be expected that the Hamilton Bank area is continually repopulated by juveniles carried southward by the Labrador current from each year's spawning in the Davis Strait, it is possible that should this area be heavily fished, its recovery would be slow due to lack of entry by older fish from adjacent areas. Riget and Boje (1989), in their summary of the biology of Greenland halibut in West Greenland waters, considered fish occurring in West Greenland fjords to be mainly stationary. Our parasitological findings indicate that this is probably also the case for fish occurring in the Saguenay Fjord and on Hamilton Bank. This may also be true for Cumberland Sound, although the inability to distinguish this collection from fish from Hawke Channel based on the five parasite taxa used does not provide support for this hypothesis. The similar parasite abundances found in these two areas possibly reflect similar ecological conditions rather than actual mixing of fish between these areas before spawning.

The only other study attempting to use parasites to separate stocks of Greenland halibut is that of Khan et al. (1982), who analyzed differences in the prevalences of two blood protozoans. Their results suggested that Greenland halibut from the Davis Strait (NAFO divisions 2G-2H and 3L) constitute one stock complex, while fish from off southern Labrador and northern Newfoundland (divisions 2J-3K) were thought to be an isolated group or a cline between areas. Greenland halibut from the Gulf of St. Lawrence and Fortune Bay, Newfoundland appeared to represent distinct stocks. However the results of this study, combining data from fish collected over a three year period, must be treated with caution, as a recent study on haemogregarines in the blood of Atlantic mackerel (Scomber scombrus) by Maclean and Davies (1990) has demonstrated both seasonal and annual variation in prevalence. These authors concluded that the use of blood smears alone in the detection of hematozoans gives an unreliable indicator of prevalence.

Otodistomum sp. metacercaria, found in almost 60% of all Greenland halibut greater than 39 cm sampled from the Gulf of St. Lawrence but absent in all other collections, is a potentially useful tag for Gulf halibut. With appropriate sampling it should be possible to determine whether or not these fish leave the Gulf to spawn with the larger stock of fish in the Davis Strait, and, if they do, to follow their migrations and determine the extent of mixing with other stocks.

CONCLUSIONS

Parasites are shown to be highly accurate discriminators for collections of Greenland halibut taken off Atlantic Canada.

The separation of fish from the Gulf of St. Lawrence from adjacent collections made in the Saguenay Fjord and off southern Labrador with a correct classification of almost 100% indicates that little, if any, mixing of subadult or adult fish occurs between these areas.

The finding that fish from Hamilton Bank are well separated from those from nearby Hawke Channel indicates that these fish probably remain in a very limited geographical area prior to maturation.

Metacercariae of Otodistomum appear to provide a reliable tag for Greenland halibut originating from Gulf waters which could be used to follow the movements of these fish if they undergo spawning migrations outside the Gulf.

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Table 1. Summary of data for collections of Greenland halibut.

Area	Latitude	Longitude	Date	Depth (m)
Cumberland Sound	65°47'	66°05'	-/01/90	500
Hamilton Bank	54°25'	56°08'	11/11/90	440
Hawke Channel	53°02'	52°44'	5/11/90	470
Esquiman Channel	49°25'-50°12'	57°45'-59°08'	24-26/08/90	143-320
North Anticosti	49°36'-49°48'	61°28'-62°54'	3-26/09/90	179-279
Sept-Iles	49°34'-50°00'	65°05'-66°20'	5-9/09/90	202-361
Estuary	48°40'-48°49'	68°07'-68°38'	11-12/09/90	210-350
Saguenay Fjord	48°15'-48°25'	70°11'-70°51'	31/01-10/03/91	85-150

Table 1. (continued).

Area	N	Total Length[a] (mm)	Age[a] (yr)	Sex Ratio (m:f)
Cumberland Sound	30	688.4 ± 101.1 (492-872)	11.2 ± 1.9 (8-15)	0:30
Hamilton Bank	30	447.0 ± 45.9 (400-560)	7.5 ± 0.9 (6-10)	12:18
Hawke Channel	30	448.0 ± 35.1 (410-550)	7.6 ± 0.9 (6-10)	11:19
Esquiman Channel	30	537.1 ± 62.8 (416-659)	8.5 ± 1.4 (6-12)	9:21
North Anticosti	30	494.1 ± 58.1 (412-619)	7.7 ± 1.0 (6-10)	9:21
Sept-Iles	30	473.0 ± 59.9 (390-650)	7.1 ± 1.0 (6-10)	18:12
Estuary	21	531.0 ± 71.1 (410-660)	8.5 ± 1.3 (7-11)	2:19
Saguenay Fjord	30	487.5 ± 44.0 (413-555)	7.4 ± 0.9 (6-9)	8:22

[a] mean ± standard deviation (range)

Table 2. List of parasites identified from Greenland halibut.

Protozoa
Ceratomyxa ramosa Awerinzew, 1907
Myxidium incurvatum (Thélohan, 1892) sensu Wierzbicka, 1988[a]
Ortholinea divergens (Thélohan, 1895) sensu Wierzbicka, 1988[a]
Paramyxoproteus reinhardti Wierzbicka, 1986

Monogenea
Entobdella hippoglossi (O.F. Müller, 1776)

Digenea
Brachyphallus crenatus (Rudolphi, 1802)
Derogenes varicus (O.F. Müller, 1784)
Genolinea laticauda (Manter, 1925)
Gonocera phycidis Manter, 1925
Hemiurus levinseni Odhner, 1905
Lecithaster gibbosus (Rudolphi, 1802)
Lecithophyllum botryophorum (Olsson, 1868)
Neophasis sp. immature
Neophasis sp. metacercaria[b]
Otodistomum sp. metacercaria[b]
Podocotyle atomon (Rudolphi, 1802)
P. reflexa (Creplin, 1825)
Podocotyle sp. immature
Progonus muelleri (Levinsen, 1881)
Prosorhynchus squamatus Odhner, 1905
Steganoderma formosum Stafford, 1904
Stenakron vetustum Stafford, 1904
Stephanostomum baccatum (Nicoll, 1907) metacercaria[b]
Steringophorus fuciger (Olsson, 1868)
Steringophorus sp.[a]

Cestoda
Eubothrium parvum Nybelin, 1922
Bothriocephalus scorpii (O.F. Müller, 1776)
Grillotia erinaceus (van Beneden, 1858) plerocercoid[b]
Scolex pleuronectis O.F. Müller, 1788 plerocercoid
Proteocephalus sp.[c]
Pseudophyllidea gen. sp. plerocercoid[b]

Nematoda
Anisakis simplex (Rudolphi, 1809) larva[b]
Ascarophis filiformis Polyansky, 1952
Contracaecinea gen. spp. larva[b]
Hysterothylacium aduncum (Rudolphi, 1802) adult & larva[b]
Pseudoterranova decipiens (Krabbe, 1878) larva[b]
Spirurida larva[b]

Acanthocephala
Corynosoma reductum (von Linstow, 1905) juvenile[b]
C. strumosum (Rudolphi, 1802) juvenile[b]
C. validum Van Cleave, 1953 juvenile[b]
C. wegeneri Heinze, 1934 juvenile[b]
Echinorhynchus gadi Zoega in O.F. Müller, 1776

Crustacea
Neobrachiella rostrata (Krøyer, 1837)
Gnathia elongata (Krøyer, 1849) juvenile

Hirudinea
Notostomum laeve Levinsen, 1882

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[a]Probable new species.
[b]Species potentially useful as biological tag.
[c]Probable accidental infection.

Table 3. Data summary for parasites used to separate collections of Greenland halibut.

	Cumberland Sound (n=30)		Hamilton Bank (n=30)		Hawke Channel (n=30)		Esquiman Channel (n=30)	
Parasite	P(%)[a]	Intensity (range)[b]	P(%)	Intensity (range)	P(%)	Intensity (range)	P(%)	Intensity (range)
Anisakis simplex (l)[c]	10.0	1.0±0.0 (1)	40.0	1.6±0.8 (1-3)	66.7	2.2±1.5 (1-6)	100.0	7.6±5.1 (1-26)
Corynosoma strumosum (j)	30.0	1.6±0.7 (1-3)	26.7	1.1±0.4 (1-2)	0.0	—	3.3	2.2±0.0 (2)
Pseudoterranova decipiens (l)	0.0	—	3.3	1.0±0.0 (1)	0.0	—	10.0	1.7±0.6 (1-2)
Otodistomum sp. (m)	0.0	—	0.0	—	0.0	—	66.7	21.9±23.8 (1-68)
Contracaecinea (l)	100.0	12.4±9.5 (2-37)	96.7	6.4±4.4 (1-21)	96.7	16.7±11.9 (5-50)	86.7	6.4±6.3 (1-28)

[a] Prevalence (percent infected).
[b] Intensity (mean ± SD) followed by range in parentheses.
[c] l, larva; j, juvenile; m, metacercaria.

Table 3. (continued).

Parasite	North Anticosti (n=30)		Sept-Iles (n=30)		Estuary (n=21)		Saguenay (n=30)	
	P(%)[a]	Intensity (range)[b]	P(%)	Intensity (range)	P(%)	Intensity (range)	P(%)	Intensity (range)
Anisakis simplex (l)[c]	100.0	6.8±3.9 (1-16)	100.0	7.5±6.4 (1-28)	100.0	16.5±10.3 (3-38)	96.7	7.9±5.8 (1-25)
Corynosoma strumosum (j)	0.0	—	3.3	1.0±0.0 (1)	19.1	1.8±1.0 (1-3)	93.3	9.4±4.9 (1-18)
Pseudoterranova decipiens (l)	16.7	1.2±0.4 (1-2)	16.7	2.2±1.6 (1-5)	33.3	5.1±2.4 (2-9)	63.3	1.5±0.9 (1-4)
Otodistomum sp. (m)	66.7	20.3±18.6 (3-82)	43.3	44.0±70.8 (1-217)	47.6	71.0±73.8 (11-229)	0.0	—
Contracaecinea (l)	90.0	4.5±3.6 (1-18)	90.0	7.7±11.8 (1-59)	81.0	6.6±5.0 (1-17)	60.0	12.6±15.9 (1-54)

[a] Prevalence (percent infected).
[b] Intensity (mean ± SD) followed by range in parentheses.
[c] l, larva; j, juvenile; m, metacercaria.

Table 4. Eight category misclassification matrix.

	ANTI[a]	CUMB	ESQ	ESTU	HAM	HAWK	SAG	SEPT
ANTI	30[b] 100.0%	0	0	0	0	0	0	0
CUMB	0	9 30.0%	0	0	0	21 70.0%	0	0
ESQ	29 96.7%	0	1 3.3%	0	0	0	0	0
ESTU	13 61.9%	0	0	6 28.6%	0	0	0	2 9.5%
HAM	0	0	0	0	29 96.7%	0	1 3.3%	0
HAWK	0	0	0	0	0	30 100.0%	0	0
SAG	0	0	0	0	0	0	30 100.0%	0
SEPT	25 83.3%	0	0	2 6.7%	0	0	0	3 10.0%

Total Correct Classification = 59.7% (138/231)

[a] ANTI = North Anticosti, CUMB = Cumberland Sound, ESQ = Esquiman Channel, ESTU = Estuary, HAM = Hamilton Bank, HAWK = Hawke Channel, SAG = Saguenay, SEPT = Sept-Iles.

[b] Indicates number of fish classified to category followed by percentage.

Table 5. Four category misclassification matrix.

	Cumberland/ Hawke	Gulf	Hamilton	Saguenay
Cumberland/ Hawke	60[a] 100.0%	0	0	0
Gulf	0	111 100.0%	0	0
Hamilton	0	0	29 96.7%	1 3.3%
Saguenay	0	0	0	30 100.0%

Overall % correct classification = 99.6% (230/231).

[a] Number of fish classified to category followed by percentage.

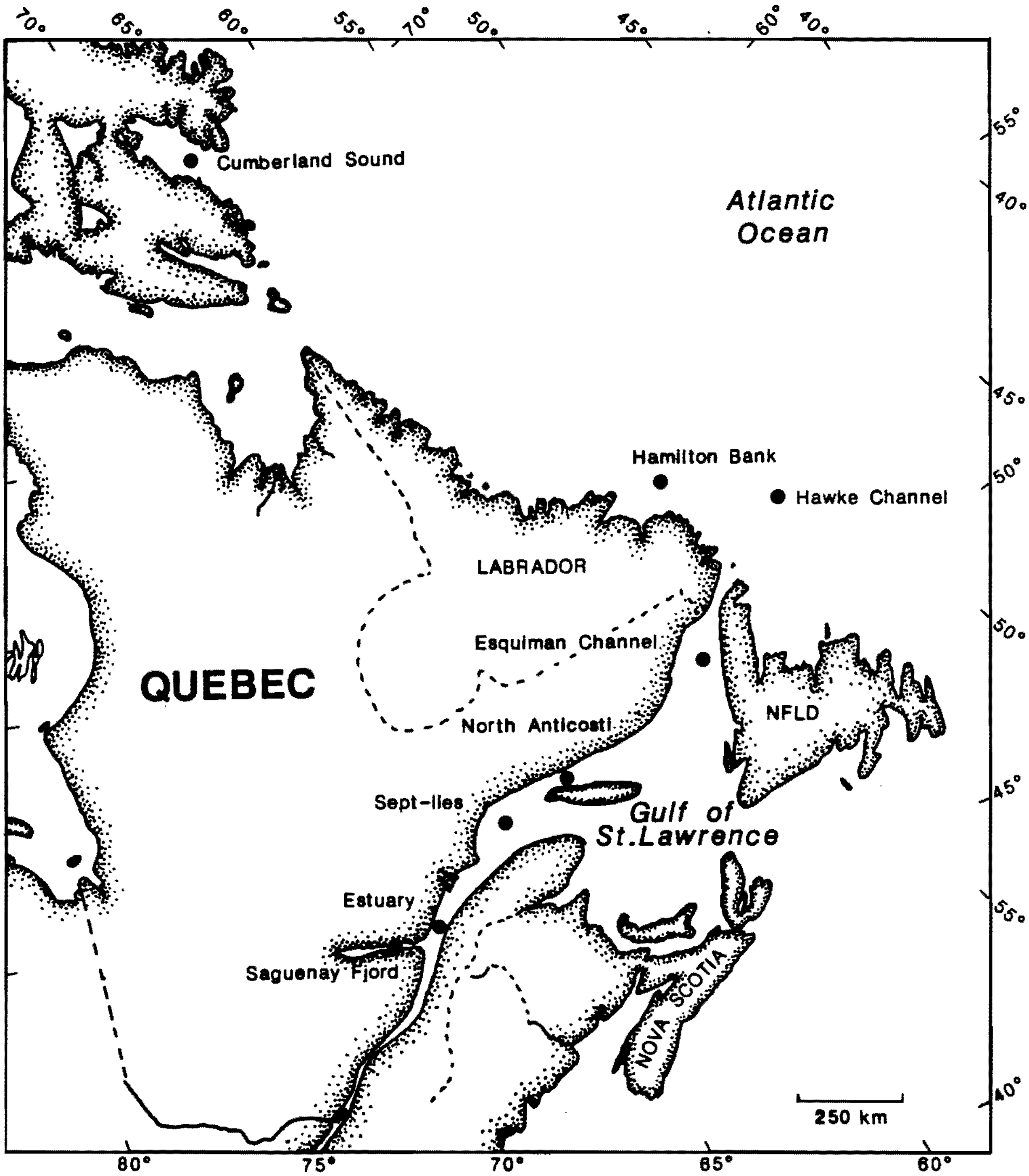

Figure 1. Map of Eastern Canada showing collection localities for Greenland halibut