APPENDIX LVI

Canadian Atlantic Fisheries
Scientific Advisory Committee

CAFSAC
Advisory Document 81/11
(Revised)

Management of Grey Seals

CAFSAC, at its meeting of 30 October 1981, considered the available information and analyses on the stock status of grey seals in the northwestern Atlantic and on the questions of fixed gear damages by grey seals and the codworm problem as it may relate to grey seals. Based on these considerations, management advice was formulated as follows.

Based on pup mark-recapture experiments, it is estimated that pup production in 1977 to 1979 was in the range of 8,800 to 10,000 per annum. Based on these estimates and estimates of maturation at age and accepting the assumptions that age composition of age 1+ animals in the bounty kill is representative of that in the population and that the sex ratio is 1:1, the population estimate at the beginning of 1980 is about 11,000 pups and 44,000 age 1+ animals if natural mortality is the same as that estimated for British grey seals i.e. $M = 0.067$. If M is as high as 0.10 the estimates are 10,000 pups and 41,000 age 1+ animals. Cohort analysis estimates that the population back in 1967 was approximately one half to one third of the estimated 1980 levels and hence that the population has been increasing at an instantaneous rate of 0.04 to 0.07 during this period.

These estimates do not have a very high degree of reliability and, given sufficient time, they could be improved upon through further analysis of available data. More reliance can be placed on the estimate of 1980 stock size than in that for 1967. Thus, the estimated rate of population increase in the intervening period is also less reliable. That substantial increase has occurred is, nonetheless, well supported by available evidence.

Recent study of the incidence of codworm (Phocanema decipiens) indicates that this parasite has become far more abundant in cod in Div. 4Vn than it was 25 years ago. American plaice and grey sole in Div. 4Vn, which were rarely infested 25 years ago, are now subject to heavy infestation. There are also, as yet unverified, reports from processors that cod, flatfish, and even haddock in some cases, from the offshore banks of the Scotian Shelf now have a worm problem. Fish from this area were relatively worm free 25 years ago.

It is an intractable scientific problem to prove that the increasing population of grey seals is the causitive factor in the increase in incidence of codworm and such proof cannot be expected in the forseeable future. The coincident population trends and the established biological relationship between the two animals, the grey seal being the primary definitive host for the codworm, are however, sufficient in themselves to strongly suggest that this is so. It is, therefore, considered most likely that a reduction in the population size of grey seals would result in a decrease in the severity of codworm infestations in fish. Given that the life history of this parasite through the egg and immature phases in various intermediate hosts can be a long one, there could be a considerable time lag between a decline in seal abundance and a reduction in the incidence of codworm in groundfish. The length of this lag time cannot be predicted.

An estimate of fixed gear damage caused by grey seals was made based on a questionnaire survey of fishermen in the affected area of eastern Cape Breton and the eastern shore of mainland Nova Scotia in 1978. A maximal estimate of losses due to grey seal damage to gear was a total of $157,500 for the whole area in that year. The highest estimate of average loss per fisherman in the worst affected area was about $300. As groundfish gillnet gear is the one mostly affected, policies which have been in existence in recent years which discourage gillnetting for groundfish will likely have the incidental effect of reducing losses due to seal damage.

If a management objective to reduce the incidence of codworm in groundfish catches (i.e. in fish as they come from the sea) is adopted, the only available approach is to reduce the population of grey seals very substantially - perhaps by as much as 50%. This has a high likelihood of being successful but only after seal abundance has been substantially reduced for some period of time. As an indication of the management action implied by such a decision, a kill of 8,000-10,000 seals consisting of 50% pups and 50% age 1+ animals in each of the next two years would only limit the population to the 1980 level based on this stock assessment. The number of animals to be killed to meet a particular objective is, however, very sensitive to the sex and age composition of the animals killed. It is recommended that, if a management objective is decided upon which requires substantial kills of grey seals, a joint planning session be held between those who could evaluate the feasibility of alternative strategies for killing various sectors of the grey seal population and the biologists who can evaluate the impact of these strategies on population production so that kill targets can be calculated.

Given the uncertainties in estimates of population status, it is particularly important that any kills should be planned so as to increase stock assessment accuracy, and a stepwise approach be taken so that there is high confidence that each step will not be detrimental to the continuing productivity of the grey seal. It is pointed out that a cull, at this stage, on Sable Island would compromise existing research efforts. However, an intensified cull of pups on the ice in the Gulf of St. Lawrence could contribute significantly to establishment of the accuracy of population size estimates.

Information gained as a result of the bounty kill is an essential element of this assessment. If, for any reason, it is decided to terminate the bounty, an alternative source of age composition information will be required if future population trends are to be monitored. A controlled cull specifically designed to provide population age composition information would be a suitable replacement for the bounty programme. It is recommended, therefore, that if the bounty is terminated, it be replaced immediately by a controlled cull.

Canadian Atlantic Fisheries
Scientific Advisory Committee

CAFSAC Advisory Document 83/20

Status of Grey Seal Population in the Northwest Atlantic

CAFSAC, at its meeting of June 29, 1983, considered the available information and analysis on present pup production and population size and trends in these parameters for grey seals in the Northwest Atlantic.

Estimates of pup production were derived from the results of several large scale mark-recapture experiments carried out between 1977 and 1983 on Sable Island and in the southern Gulf of St. Lawrence. On this basis, point estimates for pup production in 1977-79 ranged from 11,000 to 16,000 and nominal 95% confidence limits ranged from 8,600 to 25,000. The interpretation of these estimates is complicated by two considerations. Firstly, the estimates are based on assumptions especially regarding the mixing of marked and unmarked animals in the population and the reporting rates of catches of marked and unmarked animals. High geographical variation in the ratio of marked to unmarked seals in reported recaptures indicates that marked seals are not randomly mixed among unmarked seals, especially during the first year following marking. The impact of uneven mixing is exacerbated by concentration of marking at Sable Island. Estimates presented are based on recaptures one or more years following marking when mixing is more complete but unknown potential biases remain. Information on recaptures is based on returns of tags and jaws for rewards. Unevenness in submission of tags and jaws has occurred and reduces the reliability of estimates presented. Secondly, during this period, pup production at Sable Island is known to have been about 3,000 by extensive direct observation and marking. If the above estimates of total pup production are taken at face value, then the Sable Island production represents only about 20% of the total pup production and only about 12% of the nominal upper confidence limit. Efforts to locate the remaining 80% of pup production elsewhere, particularly in the Gulf of St. Lawrence, have been unsuccessful. Thus, total pup production is considered likely to have been about 10,000 during the period 1977-79.

Using the nominal limits of pup production for the 1978 experiment, estimates of maturation and pregnancy rates at age from biological sampling, and assuming that the age composition of bounty kills is representative of the population and that the population sex ratio was 1:1, the population of animals aged 1 and older (1+) in 1978 was calculated. Population abundance was then projected forward to 1983 assuming rates of increase of 7% observed for grey seals at the British Isles and 12% observed at Sable Island.

Pup Production	1+ Population Size in		Rate of Increase
1978	1978	1983	%
8,600	42,000	59,000	7
10,000	48,000	68,000	7
15,100	74,000	104,000	7
8,600	42,000	74,000	12
10,000	48,000	85,000	12
15,100	74,000	130,000	12

Given the elements of uncertainty described above, CAFSAC concluded that grey seal abundance in the Northwest Atlantic in 1983 can be estimated only very roughly with available data. The abundance of age 1+ in 1983 is likely to lie between 60,000 and 130,000. The accuracy of these estimates could be greatly improved by large scale tagging of grey seal pups in the Gulf of St. Lawrence in 1983 since previous tagging experiments have succeeded in marking large numbers of seals only at Sable Island.

Canadian Atlantic Fisheries
Scientific Advisory Committee

CAFSAC Advisory Document 83/22

Grey Seals and Associated Parasites

CAFSAC, at its meeting of October 21, 1983 considered the available information and analyses on the distribution and abundance of the grey seal *Halichoerus grypus* and the associated nematode *Phocanema decipens* in the Northwest Atlantic together with related biological information.

Geographical Distribution and Abundance of the Grey Seal

The distribution of grey seals in the Northwest Atlantic is described in the 1977 Fisheries and Marine Service Technical Report No. 704 by Mansfield and Beck. Grey seals are found from Labrador to Cape Cod with the greatest numbers found in NAFO Division 3P and Subarea 4, particularly the south coast of Newfoundland, the Gulf of St. Lawrence, and the Scotian Shelf. The most important breeding areas are on Sable Island and on drifting ice in Northumberland Strait and St. Georges Bay.

Information from the recapture of tagged grey seals shows that individual seals may travel long distances although there is a tendency of the proportion of tagged animals from a given tagging site in bounty catches to be higher closer to the tagging site. The range of movement is illustrated in Figure 1.

CAFSAC Advisory Document 83/20 presented estimates of the abundance of grey seals in the Northwest Atlantic. These estimates were derived in two stages. First, pup production in 1977-79 was estimated from mark-recapture experiments at Sable Island and in the southern Gulf of St. Lawrence. Then, the pup production estimates were related to the population aged one and older using a life table and maturity schedule. There are several sources of uncertainty in these estimates, of which non-random mixing of marked and unmarked animals, differential reporting rates of recaptures of marked and unmarked animals and the life table are particularly important. Given the elements of uncertainty, CAFSAC, concluded that the abundance of grey seals aged one and older in 1983 in the Northwest Atlantic was likely between 60,000 and 130,000.

The ability of CAFSAC to estimate grey seal abundance in future depends on continued large scale tagging and sampling of the population of animals aged one and older, including immature seals via the existing bounty program or equivalent means. Increased tagging of pups in the Gulf of St. Lawrence would considerably improve the accuracy of the above estimates. No new information was available to permit revision of the above advice.

Distribution, Incidence and Infestation Rates of Phocanema decipens in Groundfish

Phocanema decipens is a nematode (worm) parasite found in a number of groundfish species. In the Northwest Atlantic, cod, American plaice, witch flouder, and yellowtail flounder are all intermediate hosts. The parasite is also sometimes found in haddock and has been reported in over 30 fish species. The range of distribution in the Northwest Atlantic is from Labrador to Cape Cod. Within that area, the highest levels of incidence are in NAFO Divisions 3P, 4T, 4V, 4W, and to a lesser extent 4X. *P. decipens* is also common in groundfish in the Northeast Atlantic, especially at Scotland, Norway and Iceland.

Recent studies by DFO of groundfish sampled in 1982 show increasing incidence and infestation rates with increasing length of all fish species examined. This is due to the accumulation of worms consumed over a period of years by the fish. The extent of this tendency in cod in NAFO Subdivision 4Vs and Division 4W is illustrated in Figure 2. Both incidence (the proportion of fish in a sample of 100-200) and infestation rates (the number of worms per fish) vary from sample to sample, partly due to the size composition of the sample. Cod in Division 4T and Subdivision 4Vn in 1982 samples had rates of incidence from 8-100% and infestation rates of 0.1. to 17.0 per fish. In Subdivision 4Vs and 4W, the rates were similar except on Sable Island Bank and Western Bank where infestation rates of 0.4-42.0 and 0.2-34 worms per fish, respectively, were observed. Trends in the observed incidence and infestation rates in cod with increasing distance from Sable Island are illustrated in Figure 3.

Surveys of fillets conducted in the 1950's found *P. decipens* to be most abundant in cod from the lower Bay of Fundy, the southwestern Gulf of St. Lawrence, and southwestern Newfoundland. Scotian Shelf cod were found to be only lightly infected.

It is difficult to compare historical and current surveys due to difference in technique (i.e. fillets vs whole fish examinations, systematic flesh destruction vs fillet slicing vs commercial candling) which could increase the efficiency in detection of worms in recent studies by 2-5 times, and lack of length frequencies and season of capture for the historical data.

There is not sufficient evidence to conclude that the current infestation rate of the worm in cod Division 4T differs from that 25 years ago. The infestation rate in cod in Subdivision 4Vn appears somewhat higher than previously reported; but abundance in 4Vs and 4W cod is far greater than reported 25 years ago (e.g. infestation rates in fillets of steak cod in some cases, were more than 100 times greater) even given the difficulties in making comparisons.

American plaice in Division 4T were more heavily infested than cod per unit fillet weight and although this problem is a recent one according to fish processors, the earlier studies indicate that similar infestation levels occurred 25 years ago. Heavy infestation levels in Subdivision 4Vn however, are new since earlier studies found incidence in 4Vn plaice extremely rare. Infestation levels in plaice and other flatfish in Subdivision 4Vs and Division 4W are significantly greater than found 25 years ago and increase with proximity to Sable Island.

Monitoring Trends in Incidence and Infestation Rates of P. decipens

DFO is implementing in 1983, a program to monitor P. decipens in samples of American plaice and Atlantic cod in Atlantic Canada waters. Attention has been focused on American plaice as an indicator species of the parasite in the marine environment since they are relatively sedentary, easy to sample at sea, easy to examine for worms, have a weaker relation of infestation rates to fish length than cod and are widely distributed in the area to be monitored.

This program will provide a baseline for measuring future trends in abundance of the nematode. Repetition of the program in future years at the same level of coverage will permit detection of changes of 25% or less in incidence and infestation rates of American plaice in a NAFO Division or Subdivision. Given the time lags associated with the life cycle of the parasite, the monitoring program need not be repeated every year.

Life Cycle of Phocanema decipens

Eggs are passed with the faeces of the seal host, settle to the bottom and adhere to the substrate. Eggs can develop at water temperatures between 2-24°C. The development time to hatching is dependent on water temperature and ranges from 8 days at 20°C to 52 days at 5°C.

Upon hatching, the larvae anchor themselves to the substrate until they either die, or are ingested by copepods. The larvae grow rapidly in the copepod host, but do not undergo significant morphological change, thus indicating that the copepods are not true intermediate hosts.

Benthic macro-invertebrates, including crustaceans (mysids, isopods, amphipods, decapods, etc.) errant polychaetes and molluscs, become infected by ingesting copepods. Gammaridean amphipods appear to be the most suitable host. Evidently P. decipens reaches the stage at which it can infect the definitive seal host, while in the amphipod host. Hence the life cycle can be completed without a fish host, if an infested amphipod is eaten by a seal. There is however, no information to indicate that this is a signficiant source of infestation in seals.

The parasite infects a broad range of fish species. The worm, once in the stomach of the fish may penetrate the stomach wall, but usually the gut wall and migrate to the musculature. Once established in the tissue of the fish they continue to grow to lengths of up to 60 mm. Encapsulation by host connective tissues appears to occur after the parasite has been in residence for some time or larval growth is completed.

When an infested fish is consumed by a seal, the parasite escapes from the tissue and partially embeds itself in the stomach wall of the seal. P. decipens reach sexual maturity after 15-25 days in the seal. Adult worms may grow to 104 mm in length; adult females may contain 200,000-500,000 eggs and lay several thousand eggs a day. The average life span in the seal is approximately 35 days, the maximum approximately 75 days.

The grey seal appears to be the main definitive host (host in which the nematode matures) in the North Atlantic. The average infestation rate in grey seals is about 10 times that in harbour seals and is, on average, several hundred worms per stomach in some seasons. The infestations found in the lower Bay of Fundy, however, are probably related to harbour seals. The intensity of infestation in harp seals is quite low (< 10 worms per seal). Seals do not appear to develop a resistance to re-infection by nematodes, rather they appear to adapt to its presence and support progressively heavier infestations as they get older. There appears to be a strong correlation between the distribution of grey seals and heavy infestations of *P. decipens* in cod on both sides of the North Atlantic.

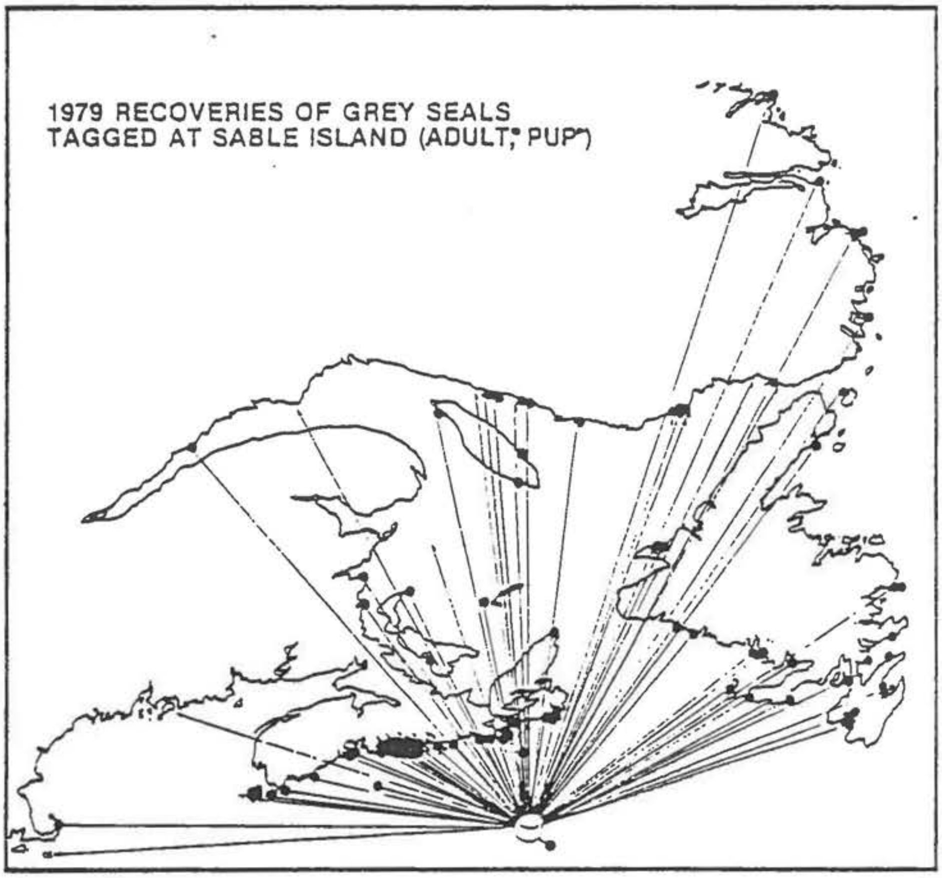
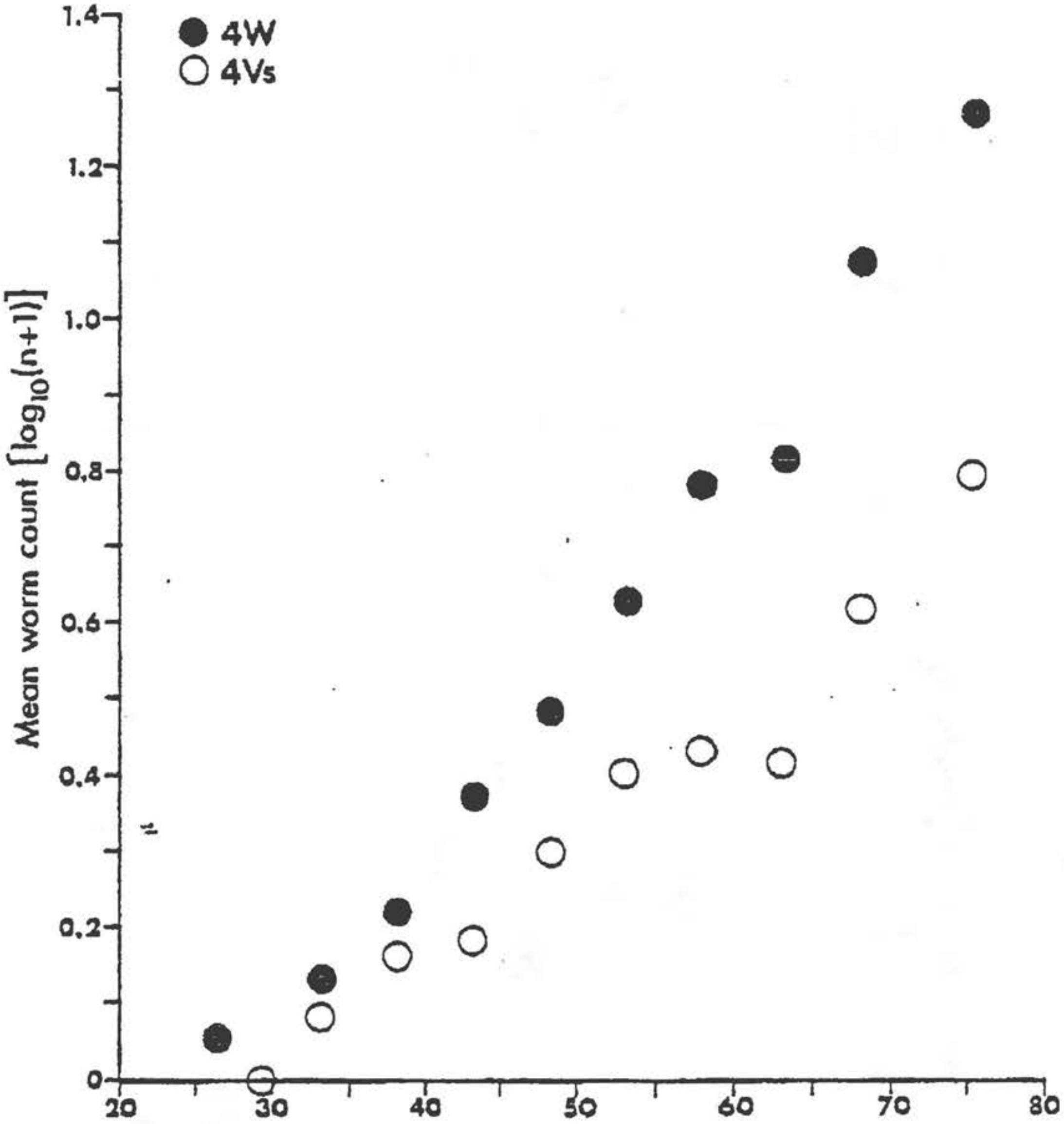


Figure 1. Dispersal of tagged grey seals from Sable Island as illustrated from 1979 recoveries.

Data from Mr. B. Beck.



Mean length of cod (cm.)

Figure 2. Mean transformed worm count versus mean host length for 5-cm length strata of 4Vs and 4W cod; comparison of worm counts in 4Vs and 4W samples. (Sample from East Bar, Sable Island Bank, omitted.)

Data from Dr. G. McClelland.

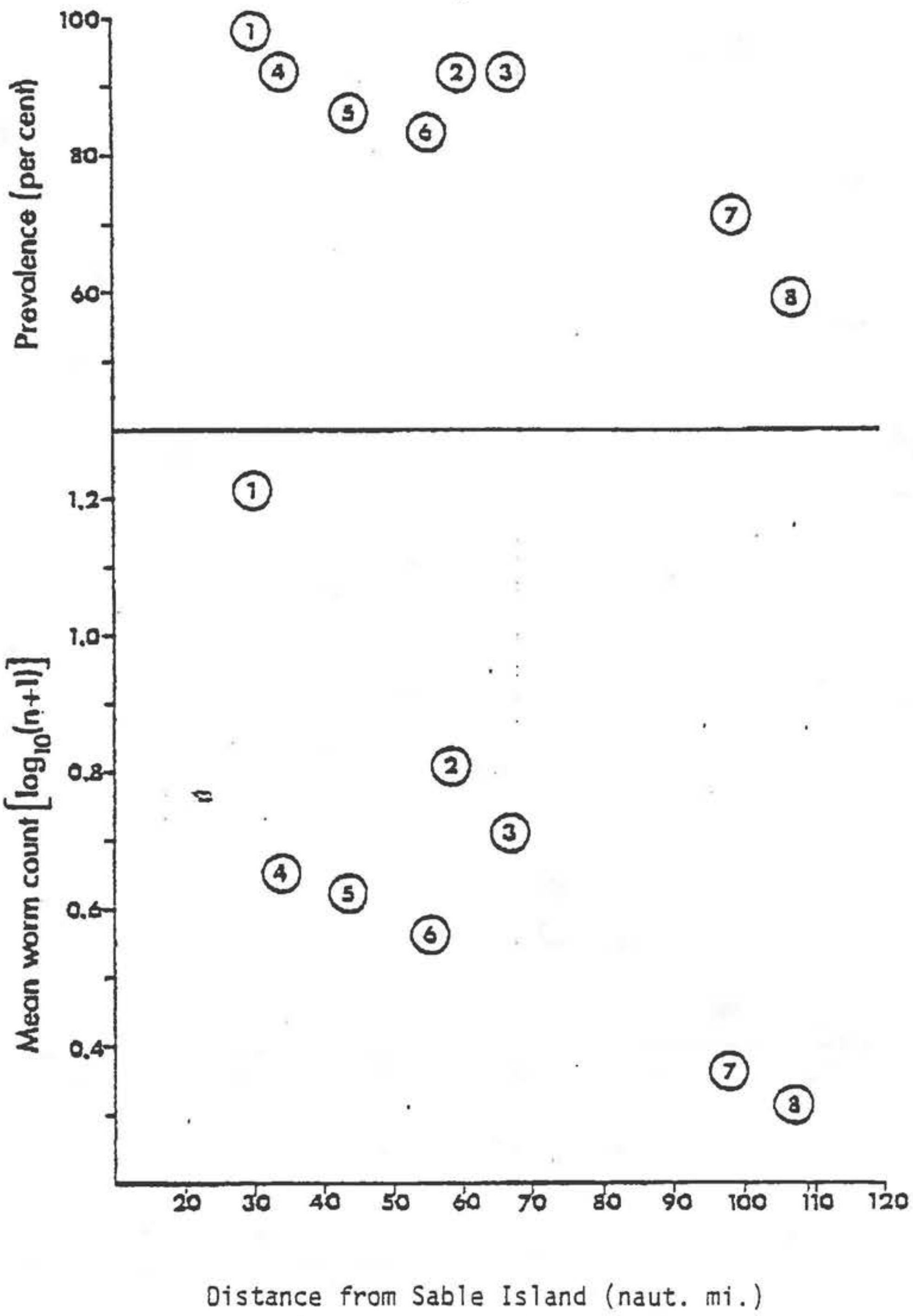


Figure 3. Prevalence and abundance of worm infection in Scotian Shelf (4Vs and 4W) cod, 51-70 cm in length, versus distance from Sable Island (1. Sable Island Bank, 2. Western Bank, 3. Edge of Western Bank, 4. Middle Bank, 5. West Banquereau Bank, 6. Canso Bank, 7. East Banquereau Bank, 8. Misaine Bank.)

Data from Dr. G. McClelland.

Canadian Atlantic Fisheries
Scientific Advisory Committee

CAFSAC Advisory Document 84/21

Status of the Grey Seal Population in the Northwest Atlantic

CAFSAC at its November 28-29, 1984 meeting, considered the most recent available biological data on current pup production and population size and trends in these parameters for grey seals in the Northwest Atlantic. This advisory document updates abundance estimates provided in CAFSAC Advisory Document 83/20 and biological information provided in Advisory Document 83/22.

Distribution. Recent tag returns indicate a wide dispersal of grey seal pups from Sable Island and the southern Gulf of St. Lawrence which implies considerable intermixing of pups from these two main pupping areas. Aerial surveys indicate that Anticosti Island in the Gulf of St. Lawrence is the site of a large spring/summer concentration and hence, like Sable Island, must be considered as a major moulting area.

Feeding. A growing body of evidence from studies on grey seals and other true seals indicates that previously held views on quantities of food consumed were too high. Recent information gathered from studies of animals in captivity suggests that grey seals consume about 1.6 t of food per year consisting mainly of fish and to a lesser extent invertebrates.

Population size. A mark-recapture experiment was conducted in 1984 to determine pup production of the northwest Atlantic grey seal population. All seals born on Sable Island were marked, while a sample of 1,441 pups were tagged on the ice floes in the southern Gulf of St. Lawrence. From returns of these Gulf-marked pups from the bounty kill and from random samples obtained on Sable Island, estimated pup production in the Gulf of St. Lawrence was about 6,300 ± 2,100 (mean ± 95% confidence limits). This combined with the known production on Sable Island of 5,983, indicates a total production of about 12,300 ± 2,100 in 1984. The estimated pup production in 1984 was used to calculate total population numbers utilizing an estimate of the ratio of pups to total population assuming a stable age distribution with the constant vital rates used in previous assessments. These calculations resulted in an estimate of population size of age 1+ animals of 50,000 to 75,000 in 1984.

The rate of increase in the Gulf component is not fully known, however the rate of increase at Sable Island which has about 50% of the total stock has been calculated to be about 12% annually. CAFSAC emphasizes again that there is one grey seal population in the Northwest Atlantic with considerable intermixing between the Gulf and Atlantic components.

APPENDIX LVII

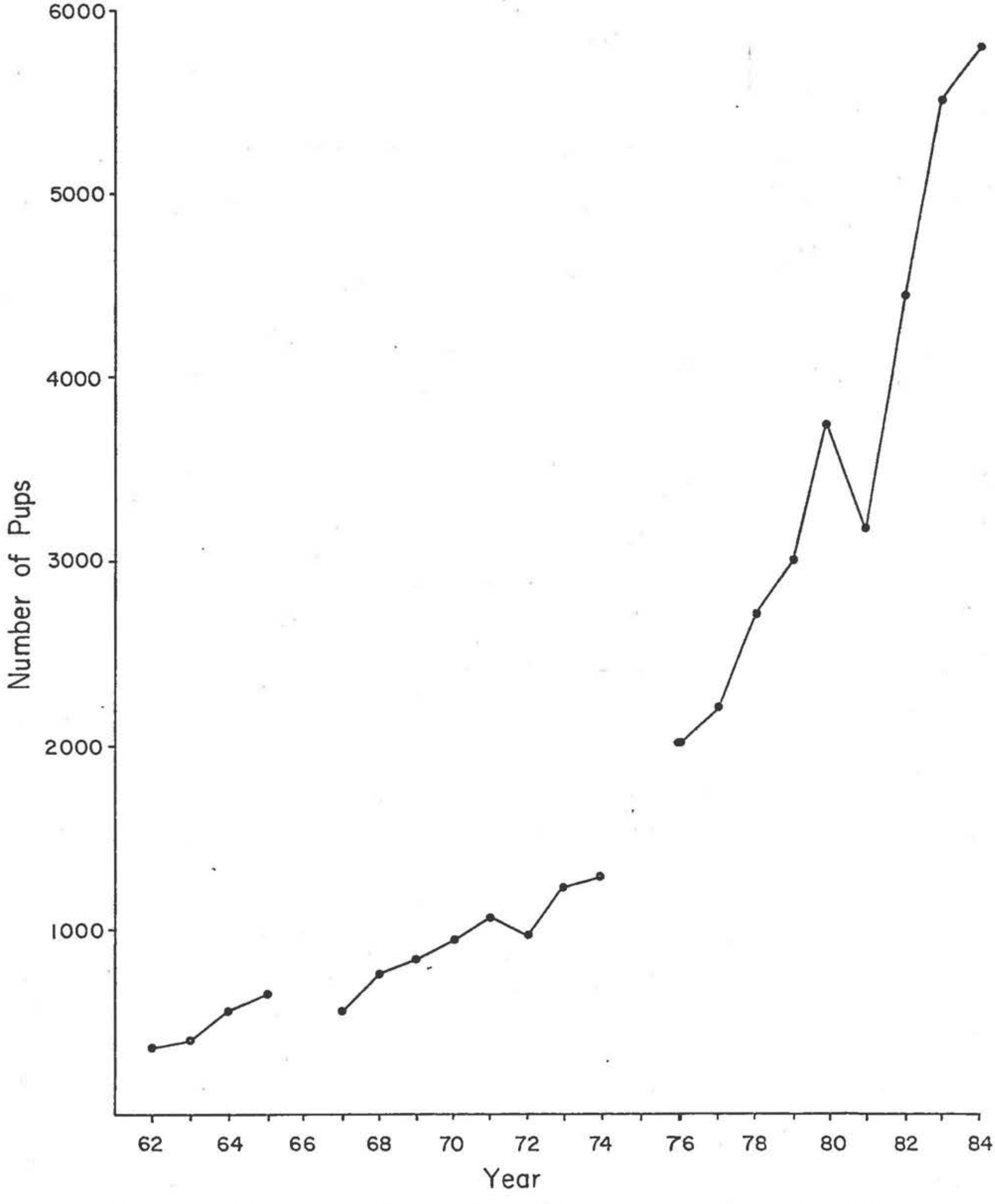
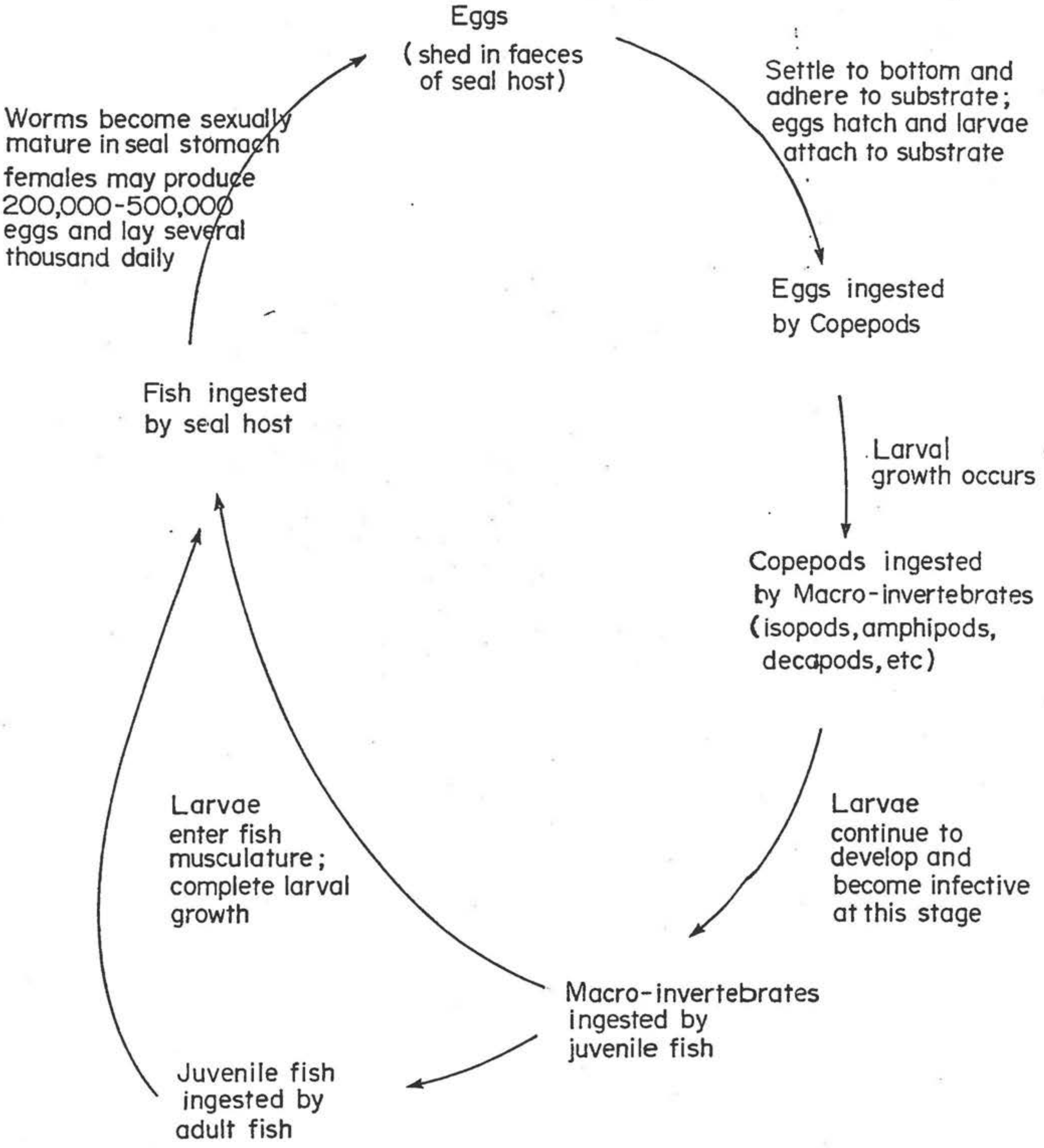


Figure 5. Pup production on Sable Island, Nova Scotia, since 1962. Data partly from Mansfield and Beck (1977) and from actual counts in later years.

APPENDIX LVIII

Life Cycle of Phocanema decipiens
(codworm/sealworm)



Canadian Technical Report of
Fisheries and Aquatic Sciences No. 1201

October, 1983

VARIATIONS IN ABUNDANCE OF LARVAL ANISAKINES, SEALWORM (*PHOCANEMA DECIPIENS*) AND RELATED SPECIES IN COD AND FLATFISH FROM THE SOUTHERN GULF OF ST. LAWRENCE (4T) AND THE BRETON SHELF (4Vn)

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ABSTRACT

McClelland, G., R.K. Misra and D.J. Marcogliese. 1983. Variations in abundance of larval anisakines, sealworm (*Phocanema decipiens*), and related species in cod and flatfish from the southern Gulf of St. Lawrence (4T) and the Breton Shelf (4Vn). Can. Tech. Rep. Fish. Aquat. Sci. No. 1201, ix + 51 p.

The life cycle, medical importance, and geographic distribution of "sealworm" (*Phocanema decipiens*) are reviewed and methods for controlling the parasite are discussed. Also reported here are current records of the abundance of sealworm and related species of anisakine nematode (*Anisakis* sp. and *Contracaecum* sp.) in cod (*Gadus morhua*), American plaice (*Hippoglossoides platessoides*), and gray sole (*Glyptocephalus cynoglossus*) from the southern Gulf of St. Lawrence (4T) and Breton Shelf (4Vn). Sealworm occurred mainly in the fillets, although they were also found in the "flaps" (hypaxial musculature of the abdomen) and in the body cavity of the fish host. The parasite was most numerous in inshore cod but was uniformly abundant in offshore cod from 4T and from 4Vn summer and winter fisheries. While worm abundances in 4T cod were similar to those recorded 25 years ago, infections in 4Vn cod, plaice, and gray sole were far heavier than previously reported. *Anisakis* sp. and *Contracaecum* sp. larvae were encysted on visceral organs and mesenteries but occurred infrequently in the flesh. These latter nematode species were most abundant in cod and plaice in the southern Gulf. *Contracaecum* sp. larvae were found infrequently in local 4Vn cod and were not detected in 4Vn plaice or sole. Because of the disparity in abundance of *Contracaecum* larvae in 4T and 4Vn cod, this parasite is an ideal tag for migrant 4T stocks. Prevalence and abundance of larval anisakines invariably increased with length of fish host. Analysis of variance revealed that variations in abundance with host length and geographic origin were highly significant, but abundance did not vary significantly with host sex. When fish were stored in the round on ice, adult and immature specimens of a fourth ascaridoid nematode, *Hysterothylacium aduncum*, migrated from the gastrointestinal tract of the fish and were found in the body cavity and flesh or leaving the host via the gills and mouth. There was no evidence, however, that larval *Anisakis* migrate from the viscera to the flesh of iced round cod.

Key words: Sealworm, *Phocanema decipiens*; *Anisakis* sp.; *Contracaecum* sp.; *Hysterothylacium aduncum*, nematodes; parasitic anisakine; cod, *Gadus morhua*; American plaice, *Hippoglossoides platessoides*; gray sole, *Glyptocephalus cynoglossus*; southern Gulf of St. Lawrence; Breton Shelf; prevalence; abundance; variations; geographic; host length; and host sex.

RÉSUMÉ

McClelland, G., R.K. Misra and D.J. Marcogliese. 1983. Variations in abundance of larval anisakines, sealworm (*Phocanema decipiens*), and related species in cod and flatfish from the southern Gulf of St. Lawrence (4T) and the Breton Shelf (4Vn). Can. Tech. Rep. Fish. Aquat. Sci. No. 1201, ix + 51 p.

Nous passons en revue, dans l'article qui suit, le cycle de vie, l'importance médicale et la distribution géographique du ver de phoque (*Phocanema decipiens*) et examinons les méthodes de contrôle du parasite. Nous mentionnons également les données courantes sur l'abondance du ver de phoque et espèces apparentées de nématodes anisakines (*Anisakis* sp. et *Contracaecum* sp.) dans la morue (*Gadus morhua*), la plie canadienne (*Hippoglossoides platessoides*) et la plie grise (*Glyptocephalus cynoglossus*) du sud du golfe du Saint-Laurent (4T) et du plateau du Cap-Breton (4Vn). Le ver de phoque se trouve surtout dans les filets, bien qu'il y en ait également dans les "volets" (musculature hypaxiale de l'abdomen) et dans la cavité du corps du poisson hôte. Le parasite est plus abondant dans la morue côtière, mais il est uniformément abondant dans la morue du large de 4T et dans celle des pêches d'été et d'hiver de 4Vn. Bien que l'abondance des vers dans la morue de 4T soit semblable à celle signalée il y a 25 ans, les infestations dans la morue, la plie canadienne et la plie grise de 4Vn sont de beaucoup supérieures à celles rapportées antérieurement. Les larves d'*Anisakis* sp. et de *Contracaecum* sp. sont enkystées sur les organes et les mésentères viscéraux, mais se rencontrent rarement dans la chair. Ces espèces de nématodes se trouvent en plus grande abondance dans la morue et la plie canadienne du sud du Golfe. Les larves de *Contracaecum* sp. observées dans la morue locale de 4Vn et ne l'ont pas été dans la plie canadienne ou la plie grise de cette division. A cause de la différence d'abondance des larves de *Contracaecum* dans la morue de 4T et 4Vn, le parasite est une marque idéale pour les stocks migrateurs de 4T. La prévalence et l'abondance des larves anisakines augmentent invariablement en fonction de la longueur du poisson hôte. L'analyse de variance indique que les variations dans l'abondance des vers en fonction de la longueur de l'hôte et de son origine géographique sont très significatives, mais que l'abondance des vers ne varie pas notablement en fonction du sexe de l'hôte. Quand des poissons entiers sont entreposés dans la glace, les sujets adultes et immatures d'un quatrième nématode ascaridoide, *Hysterothylacium aduncum*, émigre du tractus gastro-intestinal du poisson, et on l'a trouvé dans la cavité du corps et la chair, ou encore quittant l'hôte par voie des branchies et de la bouche. Il n'y a toutefois pas de preuves que des larves d'*Anisakis* émigrent des viscères à la chair du poisson conservé rond dans la glace.

INTRODUCTION

AN OVERVIEW OF THE SEALWORM PROBLEM

The occurrence of larval parasitic nematodes commonly known as "sealworm," *Phocanema* (*Terranova*, *Porrocaecum*) *decipiens* in the flesh of cod (*Gadus mornua*) and other groundfish species is a chronic cosmetic problem in eastern Canadian fisheries. Now, in light of recent evidence that sealworm ingested in raw, marinated, or undercooked fish may infect humans (Jackson 1975; Margolis 1977), the problem had developed medical overtones.

As Margolis (1977) points out, however, infection with sealworm "Phocanemiasis" can hardly be considered a major public health problem in North America. Of the 46 confirmed cases documented throughout the world, 37 occurred in Japan where fish is traditionally eaten raw. In North America, where fish is usually deep frozen and/or well cooked beforehand, a mere handful of cases (six in the U.S.A., one in Canada) have been reported. While symptoms such as severe epigastric pain, nausea, and vomiting frequently occurred in Japanese cases, North American cases were virtually asymptomatic. When the infection is allowed to run its course, the partially embedded nematodes either withdraw or are expelled from the tissues of the stomach wall and the symptoms quickly disappear ("self cure"). Recovery can be expedited by removing the worm with gastrofiberoptic biopsy forceps.

Although sealworm would seem to have little public health significance in North America, the elevation of the parasite to a status of medical importance can only aggravate the existing cosmetic problem. Now, processed fish will be subject to much closer scrutiny, not only by those government agencies who regulate the quality of seafood products, but also by wholesalers, retailers, and consumers alerted to the problem through government publications, trade journals, and the popular media. Thus, it becomes increasingly important to reduce the number of worms in fillets to the satisfaction of potential customers and not merely to comply with government regulations. Indeed, under existing tolerances for maximum numbers of worms in fish fillets (one worm per three pounds of fillet in Canada, one per two pounds of fillet in the U.S.A.), the average consumer of cod stands a good chance of finding sealworm. By selling fish which merely complies with government standards regarding worm infestation, retailers could run into numerous complaints from consumers and, as a consequence, they would seek out suppliers whose products have the fewest worms. In the end, the marketplace decides what level of worm infestation is acceptable and products free of worms and other flaws find the most lucrative markets.

Unfortunately, the renewed concern over sealworm has come at a time when eastern Canadian fisheries are attempting to expand operations and enter new markets as a result of the extension of Canada's offshore jurisdiction (Appy 1978). In North American markets, eastern Canadian cod is reputed to be wormy (Chitwood 1970), even to the extent the problem is perceived as uniquely Canadian (Odense 1978). Odense considers this a myth as many offshore cod stocks in eastern Canada are rather lightly infected, while sealworm has become a problem in competing European cod fisheries, particularly those of Iceland, Britain, and Norway (Young 1972; Platt 1975; Bjorge et al. 1981). Odense feels that the Europeans, however, have been coping with their sealworm problem somewhat better than eastern Canada through superior quality control and promotion.

LIFE CYCLE

Ova

Ova of *P. decipiens* are 45 m to 50 m in diameter and partially embryonated when passed with the faeces of the seal host (Scott 1955). The ova settle in sea water and adhere to the substrate. Development to ensheathed second- (third- ?) stage larva occurs within the ova, with mean development time to hatch varying from eight days at 20°C to 52 days at 5°C (McClelland 1982). The lowest temperature at which embryonic development and hatching are known to occur is 2°C, while temperatures ≥24°C are lethal to ova.

Ensheathed Second- (Third- ?) Stage Larvae

The larval nematodes which hatch from the eggs are approximately 200 μm in length and have retained the cuticle of the previous larval stage as a sheath (Scott 1955). The larvae anchor themselves to the substrate by their caudal extremities and oscillate vigorously at temperatures >10°C; at 5°-10°C the larvae are rather sluggish and at <5°C, virtually inactive. As stored food reserves of the non-feeding larvae are consumed, activity declines; and, if not ingested by a suitable host, the nematodes ultimately become inactive and die. The post-hatch survival period for ensheathed larvae varies from ≤48 h at 20°C to 140 days at 5°C (McClelland 1982).

First Intermediate Host

When ingested by benthic, epibenthic and natant copepods of the Harpacticoida and Cyclopoida, recently hatched larvae of *P. decipiens* ensheath in the gut of the crustacean and penetrate to the haemocoel (McClelland 1982). Mature female copepods develop the heaviest infections, while light infections occur in adult males and fifth copepodite females. In the copepod haemocoel the larval nematodes begin to grow, body length increasing at an exponential rate which varies with temperature. Within the life span of its copepod host, *P. decipiens* grows an average of 60% and a maximum of 130% in length; such growth occurs within seven days at 15°C, 15 days at 10°C, and 35 days at 5°C. However, the nematode does not moult or undergo significant morphological change in copepods; and this indicates that these particular crustaceans are transfer or paratenic hosts, not true intermediate hosts. Although copepods have frequently been infected with *P. decipiens* in the laboratory and appear to be suitable hosts, natural infections in copepods have not yet been detected.

Second Intermediate Host

Benthic macroinvertebrates, including crustaceans (mysids, isopods, amphipods, cumaceans, and decapods), errant polychaetes, and molluscs (Nudibranchia:*Coryphilla* sp.), become infected with *P. decipiens* by ingesting copepods (McClelland 1983a). The nematodes invade the haemocoels of crustaceans, the coelom of polychaetes, and the visceral mass of molluscan hosts. Laboratory experiments have shown that the most suitable of the above hosts are gammaridean amphipods, Unciola irrorata and Gammarus lawrencianus; and natural infections have been detected in the latter species. When groups of G. lawrencianus were fed copepods infected with P. decipiens, 100% became infected with the parasite; the mean intensity of infection was 60 nematodes per amphipod. However, in a natural population of G. lawrencianus, only 3 (0.15%) of 2,000 amphipods were infected and each case was a single-worm infection. Natural infections have also been found in the amphipod, Caprella septentrionalis (Val'ter 1978), and in the polychaete, Lepidonotus squamatus (Val'ter and Popova 1974).

Larval P. decipiens undergo significant growth and morphological development in the amphipod haemocoel (McClelland 1983a). Initially, growth is rapid, with body length increasing at an exponential rate; the nematodes reach 2-3 mm in length within 30 days at 15°C, 60 days at 10°C, and 140 days at 5°C. The nematodes subsequently enter an asymptotic growth phase, reaching 7-10 mm in length after 90 days at 15°C. While in amphipods, P. decipiens also develops lip primordia and the characteristic intestinal caecum and, with rapid growth and differentiation of the genital primordium, become sexually dimorphic. Evidently, P. decipiens reaches the infective stage, i.e., the stage at which they can infect the definitive seal host, in amphipods; and hence the life cycle may be completed without a fish host.

Fish Hosts

Larval P. decipiens >2 mm in length are infective to marine fish (McClelland 1983b). Smelt (Osmerus mordax), juvenile cod, and various flatfish species which feed primarly on invertebrates probably become infected via amphipods or other macroinvertebrate hosts. However, large piscivorous fish such as mature cod may also accumulate the parasite by feeding on smaller fish hosts (Scott 1953). Sealworm infects a broad range of fish species (Margolis and Arthur 1979); and variations in abundance of the parasite with host species or population are probably related to host diet, proximity to seal colonies, and environmental temperature.

When infected amphipods are ingested by fish, larval P. decipiens escape from the haemocoel of the partially digested crustaceans and penetrate the gut wall of the fish; early penetrations occur in the stomach, but subsequent penetrations may occur in the intestines (McClelland 1983b). The nematodes traverse the coelom, often by burrowing through the liver or other visceral organs, and enter the hypaxial musculature. Although some nematodes may remain in the viscera or hypaxial musculature, many ultimately migrate into the epaxial musculature. In smelt maintained at 15°C, sealworm 2-7 mm in length escape from amphipod haemocoeles and penetrate the stomach wall within 2-3 h of ingestion; the larvae reach the hypaxial muscles within 12 h and the epaxial muscles within 24 h. However, the migration rate varies with size of sealworm, size of fish being invaded, and ambient temperature.

Once established in the tissues of a fish host, small sealworm larvae continue to grow, with the rate of increase in body length being linear at first but ultimately becoming asymptotic. The average length of sealworm in smelt maintained at 15°C increased from 4 mm (2-7 mm) to 28 mm (25-31 mm) over an eight-week period (McClelland 1983b). Sealworm in the tissues of fish maintained at temperature ≥10°C usually remain fully extended and active, while at ≤10°C they assume a spirally coiled position. The capsule of host connective tissues surrounding some nematodes presumably develops after the parasite has been in residence for some time and/or has completed larval growth. Although sealworm larvae >5 mm in length are infective to seals, they may grow to 60 mm in length in fish hosts.

Seal Host

When fish or crustaceans infected with sealworm are ingested by seals, the parasite escapes from the tissues (or haemocoel) of the intermediate host during digestion and partially embeds itself in the stomach wall (McClelland 1980a). Usually, only the cephalic extremity of the worm is embedded, with the head being anchored in the submucosa by a "hyaline cap." Here the nematode performs its third and fourth larval moults, the third moult occurring after 2-5 days in the seal stomach and the fourth and final moult after 5-15 days. Sealworms reach sexual maturity after 15-25 days in seals, and eggs may be laid and subsequently passed in the faeces of seals as early as the 16th day. During development in seals, the worms occasionally leave the stomach wall to feed on gut contents and reattach themselves between meals.

After 35-50 days in seals, adult females and adult males of P. decipiens may reach 82 mm (70-104 mm) and 64 mm (54-73 mm) in length, respectively; adult females may contain 200,000-500,000 eggs and lay several thousand eggs daily (McClelland 1980b). The average life span of the worms in seals is approximately 35 days, and the maximum is approximately 75 days.

The grey seal (Halichoerus grypus) appears to be the most important definitive host of P. decipiens in the North Atlantic (Young 1972; Platt 1975; Mansfield and Beck 1977; McClelland 1980b; Bjørge et al. 1981). Heavy sealworm infestations in the cod stocks of Great Britain, Norway, Iceland and eastern Canada are clearly related to the distribution and density of grey seal populations, although infestations in some areas where grey seals are rare, e.g. the southern Nova Scotia inshore and lower Bay of Fundy, are probably related to harbour seal (Phoca vitulina) populations. The average intensity of P. decipiens infection in eastern Canadian grey seals (approximately 600 worms per seal) is about ten times greater than in harbour seals (approximately 60 worms per seal) from the same region. Further, laboratory experiments have shown that survivorship, growth, and fecundity of P. decipiens are greater in grey seals than in harbour seals (McClelland 1980b), while at the same time the parasite is less pathogenic in the former host than in the latter (McClelland 1980c). All these factors suggest that the sealworm has an affinity for grey seals. In spite of their large numbers, harp seals (Phoca groenlandicus) evidently do not have a significant influence on the abundance of sealworm in eastern Canada; intensity of infection in this seal is quite low (<10 worms per seal).

As a rule, P. decipiens is non pathogenic in free-living seals (Young and Low 1969); but it can often be pathogenic in captive seals which presumably are under stress (McClelland 1980c). In captive seals, lesions or localized inflammatory areas are frequently found in association with dense clusters of worms embedded in the stomach wall.

SEALWORM IN EASTERN CANADIAN COD

According to the major surveys of Scott and Martin (1957) and Templeman et al. (1957), sealworm was most abundant in the fillets of cod from the lower Bay of Fundy, the southwestern Gulf of St. Lawrence, and southwestern Newfoundland. Scott and Martin simply recorded the numbers of nematodes recovered from graded fillets by routine candling at processing plants, and there was only a rough indication of where the fish were caught. Templeman et al., on the other hand, recorded length, weight and sex of cod as well as sampling locations; in this study fillets were sliced to facilitate detection of the parasites. Neither study reports the time of year when samples were taken, a factor of considerable importance in areas where there is seasonal migration of cod, such as in the southern Gulf of St. Lawrence (4T) and Sydney Bight (4Vn).

Subsequent to the surveys above, there have been few attempts to document sealworm abundance in eastern Canadian cod. Scott and Martin (1959) recorded the numbers of nematodes in the fillets of young cod from southwestern Nova Scotia (Lockeport inshore) and the southern Gulf (northern New Brunswick and the Magdalen Islands); in this study, cod samples were stratified by age. Wiles (1968) examined cod from Newfoundland water previously surveyed by Templemen et al. (1957) in an effort to determine whether the imposition of a bounty on harbour seal had alleviated the sealworm problem. Finally, during a research cruise in 1975, Appy (1978) observed the prevalence (percentage of hosts infected in a sample or population) of sealworm infection in the fillets of cod from Fundy, Scotian Shelf and southern Gulf regions, and noted that geographic variations in prevalence of the parasite were similar to those reported by Scott and Martin (1957). Unfortunately, Appy examined only a few fish from each sampling location, used a very crude method for candling the fillets and did not record the numbers of nematodes present in the fillets.

Canadian records of worm infestation in cod are clearly inadequate and out of date. This is particularly true in light of the apparent growth of the grey seal population over the past two decades (Mansfield and Beck 1977; Zwanenburg et al. 1981). As this seal appears to be the most important definitive host of the parasite, corresponding increases in abundance of sealworm might be anticipated. Processors interviewed during the preparation of this report noted that worm infestations had become a problem in Scotian Shelf (4Vs, 4W) cod and that this problem seemed to be getting worse. According to the records of Scott and Martin (1957) and Templeman et al. (1957), Scotian Shelf cod were lightly infected 25 years ago.

SEALWORM IN EUROPEAN COD

European records show heavy worm infestations in cod from the west coast of Scotland, Irish Sea, Bristol Channel, west English Channel and northeast English coast (Young 1972), as well as in cod from the Faroe Plateau and most Icelandic fisheries (Platt 1975). However, these records document the abundance of the parasites in the flesh, including worms in the flaps (hypaxial musculature surrounding the coelomic cavity) with those in the fillets. Significant numbers of worms occur in the flaps and they become increasingly prevalent in this location in older cod. The abundance of sealworm, i.e., mean number of worms per fish, in western Icelandic cod, for example, is higher (8.4) than that reported in cod from the southern Gulf of St. Lawrence; but in terms of numbers of worms per unit fillet weight, the infections may be similar.

The abundance of sealworm in cod from southern Norwegian coastal waters (8.5) (Bjørge et al. 1981) is similar to that reported in western Icelandic cod, and hence worm infections in Norwegian cod may also rival those in cod from the southern Gulf of St. Lawrence. Unfortunately, Norwegian records do not indicate lengths and weights of cod sampled or the distribution of worms in host tissues.

DISTRIBUTION OF SEALWORM IN TISSUES OF COD

As Canadian records to date document numbers of sealworm in cod fillets alone, they do not provide an accurate indication of the true abundance of the parasite. It is clear from European records that significant numbers of sealworm also occur in the flaps (Young 1972; Platt 1975) and visceral mesenteries (Pälsson 1979). Further, the distribution of the parasite in host tissues varies with the age of the host. In yearling cod from western Iceland, 92% of the sealworms occur in the fillets; but in four-year-old cod from the same area, only 70% of the worms occur in the fillets. The flaps are the primary site of infection in large British and Icelandic cod (>50 cm in length) (Young 1972; Platt 1975). For example, in Icelandic cod >100 cm in length, >80% of the parasites occur in the flaps.

VARIATIONS IN SEALWORM INFECTION WITH AGE (LENGTH, WEIGHT) OF COD

In a recent survey of eastern Canadian fish processors, Odense (1978) found that there was some confusion as to whether small or large cod were now heavily infected with sealworm. Odense speculates that large cod generally have more worms on a per-fish basis but fewer worms on a per-unit-weight basis than small cod. Certainly, records of worm infestations in eastern Canadian cod fillets (Scott and Martin 1957, 1959; Templeman et al. 1957) seem to support this view. Prevalence and abundance in cod fillets generally increase while numbers of worms per unit fillet weight decrease with size (age) of host. There are exceptions, namely in southern Gulf of St. Lawrence and Cape Breton cod where the numbers of parasites per unit fillet weight remain constant or actually increase with size of host.

Scott and Martin (1957) and Templeman et al. (1957) point out that the parasites are more difficult to detect in larger fillets; and this may explain, in part, the apparent decrease in numbers of worms per fillet weight in larger fillets. Another explanation for this phenomenon would be the tendency of the nematodes to locate in the flaps or viscera of larger cod as reported by European investigators (Young 1972; Platt 1975; Pälsson 1979). Abundance of sealworm clearly increases with host size (age) in British and Icelandic cod, but this is largely due to accumulation of the parasites in the flaps. The abundance of sealworm in the fillets remains more or less constant or, at least, does not increase in proportion to fillet weight. Consequently, the number of nematodes per unit weight declines.

OTHER FISH HOSTS OF SEALWORM

P. decipiens or Phocanema-type larvae have been reported in more than 30 species of marine and anadromous fish in eastern Canada (Margolis and Arthur 1979). Most of the host species are groundfish belonging to the cod, flatfish, and sculpin families. In inshore areas near seal colonies, sealworm may be quite abundant in many of these fish hosts, even in brook trout caught in freshwater several miles inland. As a rule, however, widespread infestations seem to be limited to cod and three or four other species.

Eastern Canadian smelt are generally more heavily infected with sealworm than cod on a per-unit-weight basis, and on a per-fish basis in some areas (Scott 1955; Templeman et al. 1957). According to fish processors interviewed during the preparation of this report, sealworm has recently become a problem in American plaice and witch flounder (gray sole) throughout the southern Gulf of St. Lawrence (4T), Sydney Bight (4Vn), and Scotian Shelf (4Vs and 4W) regions. Infestations in plaice are extremely severe (as many as 70 worms per fillet) in the Cabot Strait and Chedabucto Bay areas. Evidently, the parasite has also increased in abundance in haddock from some areas of the Breton and Scotian shelves to the extent that the occasional catch has to be candled.

There are few European records of sealworm infestation in marine fish species other than Atlantic cod. Wootten and Waddell (1977) found infections with larval Phocanema in long rough dab (American plaice), witch flounder, haddock, whiting (Merlanguis merlangus), poor cod (Trisopterus minutus), and dragonet (Callionymus lyra) from Scottish waters; but occurrences in these latter fish hosts were limited to isolated inshore locations and in each case the prevalence of infection was extremely low.

OTHER ASCARIDOID NEMATODES IN COD

Cod and other marine fish from eastern Canadian and European waters are host to a number of ascaridoid nematodes, such as Anisakis spp., Contracaecum spp., Phocascaris spp. larvae and adults of Hysterothylacium (Thynnascaris, Contracaecum) aduncum (Wootten 1978; Margolis and Arthur 1979; Pälsson 1979). These nematodes bear a superficial resemblance to sealworm and microscopic examinations may be required to separate the species.

Anisakis spp. larvae commonly known as "herring worm" belong to the anisakinae, the same ascaridoid sub-family as the sealworm. The life cycle is similar to that of the sealworm, with the definitive host again being a marine mammal but, in this case, usually a cetacean (Smith and Wootten 1978). The first intermediate hosts of herring worm are believed to be krill (Euphausiidae) (Smith 1971). Infective larvae of Anisakis spp. are found encysted both in the flesh and on the visceral mesenteries of marine fish but are often more prevalent in the latter location (Parsons and Hodder 1971; Wootten 1978; Pälsson 1979). Herring worm are important fish parasites in their own right as they can be extremely pathogenic to humans when ingested in raw, undercooked and marinated fish. Herring worm disease "Anisakiasis" has been a public health problem in the Netherlands and Japan (Van Thiel et al. 1960; Ruitenberg 1970; Oshima 1972; Smith and Wootten 1978) although it has not been reported frequently in North America (Jackson 1975; Margolis 1977).

Occurrences of Anisakis larvae on the visceral mesenteries of herring in eastern Canada were extensively surveyed by Parsons and Hodder (1971), but little is known of the distribution of the parasite in eastern Canadian cod. Templeman et al. (1957) documented abundances of Anisakis larvae in the fillets of eastern Canadian cod but, as the flaps and viscera were not examined, these records are incomplete. In this study, the prevalence of the parasite in fillets of cod was generally <2%, the abundance <0.01. Anisakis larvae were greatly outnumbered by sealworm in the fillets except in cod from some Newfoundland fisheries such as Flemish Cap and the Grand Banks, which were lightly infected with Phocanema. Anisakis larva were not found in cod from the southern Gulf of St. Lawrence.

Evidently, the flesh of European cod is often heavily infested with Anisakis larvae, although the parasite is far more prevalent in the flaps than it is in the fillets (Young 1972; Platt 1975). Larval Anisakis is particularly abundant in Arcto-Norwegian cod which is lightly infected with sealworm.

Contracaecum and Phocascaris spp. are anisakine nematodes which mature in the gastro-intestinal tract of piscivorous birds and marine mammals (Berland 1963; Huizinga 1967). Experimental evidence indicates that the first intermediate hosts of these nematodes are copepods (Huizinga 1967; Davey 1969). Infective larvae usually encyst on the visceral mesenteries of the fish host, with mesenteries of the pyloric caecae apparently being the preferred site in Atlantic cod (Pälsson 1979). According to Berland (1963), infective larvae of Contracaecum and Phocascaris spp. are morphologically inseparable, and hence specific identification of the larvae would be extremely difficult. Contracaecum osculatum, for example, is a species which occurs in seals throughout the world and yet there has been only one positive identification of C. osculatum larvae in a fish host, that being in Baltic Sea cod, (Fägerholm 1982).

Hysterothylacium (Thynnascaris, Contracaecum) aduncum is an ascaridoid which utilizes marine fish as intermediate and definitive hosts (Berland 1961). Larvae of this nematode occur primarily in the body cavity (rarely in the flesh), while adults are found in the gastro-intestinal tract (Pälsson 1979). Hysterothylacium larvae are also found in a broad range of invertebrate hosts including coelenterates, molluscs, annelids, crustaceans, echinoderms, and chaetognaths (Norris and Overstreet 1976).

POST-MORTEM MIGRATIONS OF ASCARIDOID NEMATODES IN FISH TISSUES

Many eastern Canadian fishermen and fish processors interviewed during the present study claimed that sealworm moves from the flesh to the body cavity of cod stored (in the round) on ice;

thus, it would follow that round cod reaching processing plants would have fewer worms in the fillet than cod gutted at sea. Although there is no documented evidence to support this rationalization, it has frequently been cited as justification for the continued acceptance of round cod at fish plants in some areas, particularly in the southern Gulf of St. Lawrence.

As the viscera decay more rapidly than the flesh of fish, it is far more likely that parasitic nematodes would migrate from the body cavity to the flesh rather than in the opposite direction. Cheng (1976) found that *Hysterothylacium* (*Contracaecum*) *aduncum* escaped from the gastro-intestinal tract of dead cod and summer flounder (*Paralichthys dentatus*) via the anus and gills or by migrating through the disintegrating gut wall to the body cavity and the flesh. As nematodes found in the coelom and flesh were morphologically identifiable as enteric forms (fourth-stage larvae and adults), there was no doubt that migration had occurred. Normally, only the third-stage larvae of *Hysterothylacium* occurs in the coelom or flesh (Palsson 1979).

There is some controversy as to whether there is a significant migration of medically important *Anisakis* spp. larvae from the body cavity to the flesh of round fish. Some European investigators report experimental evidence of such a migration occurring in mackerel (Vik 1966) and herring (Smith and Wootten 1975). In these studies, relative abundances of *Anisakis* larvae in the flesh of fish stored round for periods of several hours to several days were compared with abundances of the parasite in the flesh of fish gutted at time of catch. Other investigators (Khalil 1969; Davey 1972) performing similar experiments found no evidence of a significant migration.

CONTROL OF THE PROBLEM

Odense (1978) described a number of possible solutions to the sealworm problem in the areas of biological control, technological innovations in quality control of fish processing and better promotion. Many of these solutions were subsequently discussed at a "Codworm (Sealworm) Workshop" conducted at the Department of Fisheries and Oceans Halifax Laboratory in March, 1979.

Biological Solutions

As sealworm reproduce in the stomachs of seals (see life cycle above), the primary biological solution to the problem is control of seal populations. Grey seals (*Halichoerus grypus*) appear to be the most important definitive host, and there appears to be a strong correlation between the distribution of grey seals and heavy sealworm infestations in cod stocks on both sides of the North Atlantic (Young 1972; Platt 1975; Mansfield and Beck 1977; McClelland 1980b); other North Atlantic seals, such as harbour (*Phoca vitulina*) and harp seals (*Phoca groenlandicus*), are of relatively minor importance as sealworm hosts.

Annual culls have been conducted in grey seal breeding colonies in eastern Canada since 1967. The positive aspect of this program is that it is a humane kill by commercial sealers, with pelts and other products being utilized. However, as the seals breed in mid winter and most of the population is widely dispersed and inaccessible, only a few hundred animals, mainly pups, have been taken each year (Mansfield and Beck 1977; Zwanenburg et al. 1981). The harvest is neither commercially feasible nor effective as a control of the seal population or the sealworm problem. Pups normally suffer a high mortality rate and require several years to reach the reproductive age. The seal population can be reduced more efficiently by culling mature animals which, as it happens, also support the heaviest sealworm infestations (McClelland 1980b). A bounty was placed on the grey seal in 1976, resulting in an additional 600-1,000 seals being eliminated each year between 1976 and 1980. The total number of seals taken through the bounty and culling programs during the same years ranged from 1,300-2,000. Yet according to the most recent stock assessment, the population continues to grow (Zwanenburg et al. 1981).

Odense (1978) suggested that as an alternative to killing seals the animals might be treated with "worm medicine," anthelmintics or vaccines, thus rendering them unsuitable hosts for sealworm. Such treatments are used routinely for control of parasitic diseases in domestic or zoo animals, where the patients are available for follow-up treatment and reexposure to the parasites can be prevented but, unfortunately, would not be practical for controlling sealworm in free-living seals. Only unweaned or recently weaned grey seal pups in large island colonies are accessible and approachable for the treatment. The pups do not become infected with sealworms until they have left the breeding sites and learned to catch fish. They are subsequently exposed to reinfection with the parasite throughout their lives. In many parasitic diseases, the host normally develops a resistance to reinfection; but, in the case of sealworm, seals appear to adapt to the presence of the parasite and support progressively heavier infections as they get older (McClelland 1980b). As seals do not develop "effective immunity" to the parasite in nature, it is unlikely that such immunity could be induced artificially with a vaccine.

Selective fishing for worm-free cod stocks is another solution to the sealworm problem. But clearly, this is only a temporary solution which merely avoids the problem and in no way controls it. Selective fishing can put excessive pressure on lightly infected stocks and ultimately it would be necessary to exploit wormy stocks again (Rae 1972). Further, wormy stocks are usually found in close association with seals (Scott and Martin 1959; Bjørge 1979), probably serving to reinfect these hosts. Failure to exploit fish stocks serving as reservoirs for larval sealworm together with the apparent growth of the seal population can only lead to increasing abundance of the parasite. As a result, the problem could spread to adjacent cod stocks and other fish species.

Young (1972), noting that abundance and distribution of sealworm in the flesh of cod varied with the age of the host, suggested that selective fishing for lightly infected age classes of cod was a possible solution to the worm problem. Platt (1975) subsequently pointed out, however, that concentration of the fishing effort on a particular age group (in this case, older cod) might not be economically feasible. Nevertheless, the manner in which worm abundance varies with age of cod could be taken into consideration when managing the stocks. The goals of maintaining healthy, productive stocks and minimizing worm infestations need not conflict.

Biological approaches to the sealworm problem may offer, at best, reductions in the abundance of worms in fish stocks over the long term. Nevertheless, these measures are necessary to ensure that processors are provided with fish that can be processed into high-quality products, at a reasonable cost.

Technological Solutions

Unlike biological approaches to the sealworm problem, technological solutions, many of which should be applied at present, offer immediate relief.

First, the potential health hazard can be eliminated through proper cooking, freezing, salting, smoking or drying of fish, although further investigation is needed to determine what degree of processing is adequate to destroy the worm in each case (Margolis 1977). Unfortunately, while a certain number of parasites may leave the flesh during some of these processes, many persist, nonviable, but still unacceptable from the aesthetic point of view. Although many of these procedures can be regulated at the processing level, cooking, for instance, is usually performed by the consumer or retailer and it follows that these parties should be apprised of the potential hazard. This, of course, draws attention to the parasite. More rigorous cooking standards are necessary to prevent potential parasitic infections from beef, pork, and mutton; parasites, such as tapeworms and trichinella are far more pathogenic than sealworm but, unlike sealworm, are not plainly visible to the naked eye.

The candling procedure used for detection and removal of the parasites from fillets has seen little or no improvement during the decades it has been in use. A number of innovations to improve the efficiency of the procedure have been proposed, such as thin slicing of fillets, optimizing transmitted and incident light conditions, and frequent rotation of candlers to avoid eyestrain, fatigue, and boredom. However, these practices were either unacceptable to processors or were practiced for a time but subsequently fell into disuse. The time has come, perhaps, to give these procedures another look. Odense (1978) has devised a new candling table incorporating crossed polarizing filters, which may provide improved opportunities for detecting the parasites and at the same time reduce eyestrain. This device is being tested currently.

There have been a number of recent attempts to develop sophisticated ultrasonic or photosensitive devices to detect worms, bones, and other flaws in fillets. Such devices would not eliminate the need for candlers but would screen out flawed fillets for subsequent candling or, perhaps, processing into fish meal or other products, while fillets free of flaws could bypass the candling operation. At present, however, use of automated worm detectors appears to be impractical under industrial conditions and perhaps too expensive for smaller processing plants.

OBJECTIVES

The main objective of the present study was to document current abundances of sealworm and related species of parasitic nematode in southern Gulf of St. Lawrence (4T) and Sydney Bight (4Vn) cod, plaice, and gray sole, indicating distributions of the parasites in the flesh and viscera of the host and variations in their abundance with sex, body length, and geographic origin of the host. A second objective was to investigate, by experimental means, possible migration of these parasites from the viscera to the flesh (or vice versa) of iced round cod.

MATERIALS AND METHODS

COLLECTION AND EXAMINATION OF FISH SAMPLES

Samples of round cod (Gadus morhua), American plaice (Hippoglossoides platessoides), and witch flounder (Glyptocephalus cynoglossus) were collected from commercial inshore and offshore draggers, Danish seiners, and long liners in the southern Gulf of St. Lawrence (4T) and Sydney Bight (4Vn). Usually the fish were measured as they were selected, in an effort to stratify the samples into 5-cm length groups containing equal numbers of fish. Cod samples, for example, were divided into ten length groups: ≤30 cm, 31-35 cm, 36-40 cm, 41-45 cm, 46-50 cm, 51-55 cm, 56-60 cm, 61-65 cm, 66-70 cm, and ≥71 cm. However, because of the type of gear being used, variations in the size of fish caught in different fisheries, or the small size of the catch, particularly from inshore boats, it was often difficult to fill the smaller and/or larger length categories. Fish in some samples, collected for the investigators by fishermen, were of random length.

The samples were transferred to DFO, Halifax Fisheries Research Laboratory, and stored either on ice for examination in the fresh condition or frozen at -17°C and examined at a later date. Parasitological examinations were similar to those described by Templeman et al. (1957), Young (1972), and Platt (1975). The fish were measured (to the nearest cm in length), weighed (to the nearest 0.1 kg), gutted, sexed and filleted. The visceral organs, mesenteries and peritoneum were scanned with the naked eye, and nematodes detected therein were tentatively identified and counted. The nematodes were placed in labelled vials of 0.9% saline and their identities subsequently verified by microscopic examination. The fillets and flaps of cod and plaice were inspected by systematic destruction of the flesh (Wiles 1968); witch fillets were simply candled. Flesh adhering to the frames was also inspected for nematodes or portions of nematodes severed during filleting. Nematodes in the flesh, clearly identifiable as sealworm, were simply counted, while those of uncertain identity were examined microscopically.

INVESTIGATION OF MIGRATIONS OF LARVAL ANISAKINES IN ROUND COD

The following experiments were performed in order to determine if larval anisakines migrate from the viscera to the flesh (or vice versa) of cod when it is stored in the round after capture. In February, 1980, 334 cod, 45-65 cm in length, were collected from a side dragger on the "Edge of Ground" (4Vn). Of these, 187 were eviscerated immediately after capture while the remainder were divided into three groups of about 50 fish each and were then stored on deck for periods of 6 h, 12 h and 24 h, respectively, prior to being eviscerated. The viscera and bodies of individual fish were stored in separate labelled polyethylene bags and were subsequently examined for nematodes as above.

In a similar experiment, 164 cod, 50-60 cm in length, were collected from a long liner on Scatari Bank (4Vn) in October, 1981. The sample was separated into three groups, each containing 50-60 randomly selected fish. Cod from one of these groups were eviscerated immediately after capture; the viscera and bodies of individual fish were stored in separate labelled polyethylene bags. The other two groups were stored round, on ice, until examination in the laboratory four days later. After a routine examination was made of viscera and flesh for larval anisakines, flesh from the flaps and fillets was retained in individual labelled polyethylene bags and subsequently digested in a pepsin-HCl solution. The digestion procedure was employed in order to detect small or unencysted nematodes which might have been overlooked during routine examinations and, at the same time, test the efficiency of the routine examination.

DIGESTION PROCEDURE

The digestion technique used herein was adapted from procedures described by Novotny and Uzmann (1960) and Smith and Wootten (1975). The solution consisted of 5 g of 1:10,000 pepsin per litre of 1% hydrochloric acid. Fillets of individual cod were placed in 4-L beakers containing 2 L of solution, the flaps in 1-L beakers with 0.5 L of solution. These mixtures were incubated in a water bath at 35°-40°C, coupled with frequent stirring. After 2-3 h of incubation, they were strained through a series of sieves ranging from 5-mm to 0.3-mm mesh. Nematodes recovered from the sieves were identified by microscopic examination.

STATISTICAL ANALYSIS

Counts of larval anisakines in individual fish were transformed by $\log_{10}(X+1)$. Variations in worm counts with sex, sample and length of host were analyzed by three- and two-way ANOVAs (Type III) using the GLM procedure (SAS 1982). Program PIV of BMDP-79 (BMDP-79 1979) was used for regression analysis of worm count/host length relationships.

Cells with zero frequency were eliminated from the analysis of cod parasites by including all fish ≤45 cm in length in a single length stratum and by deleting one sample (Chéticamp, N.S.) lacking cod ≥61 cm in length. For the same reason gray sole ≤35 cm in length were grouped in a single length stratum. Due to a scarcity of male plaice ≥41 cm in length, ANOVAs involving variations in worm counts with host sex were computed for three host length strata: ≤30 cm, 31-35 cm, and 36-40 cm. All six length strata, from ≤30 to ≥50 cm inclusive, were used, however, in two-way analyses of variance related to sampling and length of plaice. Where blank cells persisted in spite of those precautions, their influence on the results were investigated by repeating analyses with Type IV ANOVAs.

RESULTS

LARVAL ANISAKINES IN 4T AND 4Vn COD

Three species of larval anisakine, *Phocanema decipiens*, *Anisakis* sp., and *Contracaecum (Phocascaris)* sp. were found in 4T and 4Vn cod. Prevalences and abundances of each nematode species are summarized by host sample and length group in Table 1, and sampling locations are indicated in Fig. 1.

Frequency distributions of untransformed worm counts shown for combined cod samples herein (Figs. 2, 3 and 4) were in each case skewed to the right to varying degrees. Graphic tests employing normal probability plots, however, show that the distributions are brought remarkably close to normal by the log transformation. This was also the case for frequency distributions of worm counts in plaice and gray sole (Figs. 8 and 10).

P. decipiens

Of the more than 10,000 sealworm, recovered from 4T and 4Vn cod, 90% were found in the fillets, 7% in the flaps and 3% in the coelomic cavity (Table 2). Infections in the flaps and coelom were most common in large market and steak cod, particularly in specimens with heavy infestations in the fillets. Sealworm from the fillets and flaps were 15-60 mm in length while those found on the visceral organs and mesenteries and on the peritoneum were 8-42 mm in length. Nematodes in the flesh and coelom were usually encysted; however, unencysted nematodes occurred with increasing frequency when samples were stored on ice for prolonged periods.

Abundance of sealworm in 4T and 4Vn cod varied from sample to sample, with inshore fish generally being more heavily infected than offshore fish (Table 1; Fig. 5). The heaviest infections occurred in samples collected from the 4T inshore near Souris, Prince Edward Island, in the spring of 1981 and from Frenchman's Shoal (4Vn) in the summer of 1981. The lighest infections were found in 4T offshore cod collected near St. Paul's Island in November, 1980.

Invariably, worm abundance increased with host length, not only on a per-fish but often on a per-unit-weight basis (Table 1; Fig. 5). In most samples, steak cod (≥71 cm in length) had the greatest number of worms per unit fillet weight.

Although sealworm appeared to be slightly more abundant in male cod than in female cod (Table 3), a three-way ANOVA revealed that variations in worm abundance attributable to host sex were not significant in interactions or as a main effect (Table 4). Variations attributable to host length and sampling, on the other hand, were highly significant both in interaction and as main effects (Tables 4 and 5).

A priori contrasts of samples differing in respect to geographic origin and/or season of capture show that variations attributable to sampling in two-way ANOVAs were largely a result of differences in worm abundance in inshore and offshore fish (Table 5; Fig. 5). Not only did inshore and offshore fish differ significantly in mean worm count ($P \leq 0.0001$), but also in the worm count/host length interaction. Mean worm counts in cod from 4T and 4Vn offshore, on the other hand, did not differ significantly, although worm counts in 4Vn winter and summer samples differed at $P \leq 0.05$.

Plots of cell means of transformed worm counts versus host length seemed to indicate the existence of a linear relationship between sealworm abundance and host length (Fig. 5). Regression analysis, however, revealed that although regression coefficients were invariably highly significant ($P \leq 0.0001$), the resultant regressions often explained less than 10% of the variance. Distributions of residuals (error) as shown in scatter plots were far from normal; and in fact, the departure from normality was so severe that tests for significance of regression coefficients would be meaningless (see Underwood 1981). Hence, it was not possible to compare samples by covariant analysis of worm count/host length regressions.

Anisakis sp.

Anisakis larvae found in 4T and 4Vn cod varied from 12 mm to 35 mm in length and closely resembled A. simplex as described by Palsson (1979). The nematodes were usually encysted on the surface of the liver (61%) and on the mesenteries surrounding the pyloric caecae (31%) (Table 2); in cod ≥ 71 cm in length, they occurred more frequently on the pyloric caecae (49%) than on the liver (42%). Anisakis larvae were found infrequently in the flaps (1.21%) and fillets (1.11%).

Prevalence and abundance of worms invariably increased with host length, and cod collected in 4T were more heavily infected than cod from 4Vn (Table 1; Fig. 6). The three-way ANOVA (Table 4) indicates that the influences of host length and sampling on worm abundance were highly significant as main effects and in interaction, while host sex (Table 3) was not a significant factor. A priori contrasts (Table 5; Fig. 6) reveal that 4T offshore cod differed significantly from 4Vn offshore cod in mean worm count ($P \leq 0.0001$) and the worm count/host length interaction ($P \leq 0.0001$). In an overall comparison of inshore cod with offshore cod, the difference in sample means and interactions was not significant, while the difference between mean worm counts for inshore and offshore fish from 4T alone was significant at $P \leq 0.05$.

Contracaecum (Phocascaris) sp.

Larval Contracaecum from 4T and 4Vn cod were 7-23 mm in length and closely resemble larvae of C. osculatum cultivated in vitro by McClelland and Ronald (1974b). The nematodes were encysted on visceral organs and mesenteries with most (96%) occurring on the mesenteries of the pyloric caecae (Table 2); only a few (0.11%) were found in the flesh. Unlike encysted larvae of P. decipiens and Anisakis which were spirally coiled, Contracaecum larvae were either fully extended or sharply recurved (similar to a hairpin).

While they were found infrequently in small cod, Contracaecum larvae were often quite abundant in cod ≥ 61 cm length (Table 1; Fig. 7). Cod from 4T, especially offshore fish, were far more heavily infected than cod from 4Vn. According to the three-way ANOVA, worm abundance was influenced significantly by host length and sampling not only in the two-way interaction and as main effects but also in a three-way interaction with host sex (Table 4). Host sex, however, was not a significant factor in two-way interactions with length or sample or as a main effect. As indicated by a priori contrasts, variations in the ANOVA related to sampling were attributable to differences in worm abundance in inshore and offshore cod and also to differences between 4T and 4Vn cod (Table 5; Fig. 7).

LARVAL ANISAKINES IN 4T AND 4Vn PLAICE

Abundances of larval anisakines in 4T and 4Vn plaice are summarized by host sample and length group in Table 6, and sampling locations are indicated in Fig. 1. Frequency distributions for untransformed counts of P. decipiens are shown for the combined samples in Fig. 8.

P. decipiens

Sealworm in 4T and 4Vn plaice (Table 7) were found almost exclusively (98%) in the fillets. Prevalence and abundance of the parasites increased with host length in samples from the southwestern Gulf; however, in the 4Vn samples, there was a decrease in intensity of infection in fish ≥ 51 cm in length (Table 6; Fig. 10). The sample from Shediac Valley (4T) was the only one in which the parasite increased in abundance with host length on a per-unit-weight basis.

While male plaice seemed to be more heavily infected than females of corresponding length (Table 8), a three-way ANOVA for fish ≤ 40 cm in length indicates that variations in worm abundance attributable to host sex were not significant (Table 9). Variations related to host length and sampling were again highly significant, but the sample x length interaction became significant only when host length strata ≥ 41 cm were included in the analyses (Table 10). As shown by contrasts (Table 10; Fig. 9), the significance of variations in sample means and sample mean x host length interactions was mainly related to differences between southwestern Gulf (Pt. Escuminac, New Brunswick, and Shediac Valley) and southeastern Gulf (Chéticamp) and 4Vn samples. Mean worm counts and worm count/host length interactions did not differ significantly in inshore samples collected near Chéticamp (4T) and Cape Smokey (4Vn) in the fall. These inshore samples, in turn, did not differ in either of the above respects from an offshore sample taken on the "Edge of Ground" (4Vn) in winter.

Anisakis and Contracaecum (Phocascaris) sp.

Significant numbers of Anisakis and Contracaecum larvae were found in plaice from western 4T (Shediac Valley and Pt. Escuminac), but only a few specimens were found in samples from Chéticamp and 4Vn (Table 6). In fact, only one Contracaecum larva was found in the Cheticamp sample and this parasite was not detected in 4Vn samples. Only two Anisakis larvae were found in the fillets; the remainder occurred in the body cavity, most frequently (56%) on the liver (Table 7). Contracaecum larvae were found primarily on the mesenteries of the pyloric caecae, and only two specimens were detected in the fillets. The two-way ANOVA indicates that variations in abundance of these two nematode species related to host length and sampling were highly significant (Table 10).

LARVAL ANISAKINES IN 4Vn WITCH (GRAY SOLE)

All P. decipiens larvae found in 4Vn witch occurred in the fillets. Only two Anisakis larvae were found in the three samples, both in the coelom, and no Contracaecum larvae were detected.

Prevalence and abundance of *P. decipiens* and the abundance of the parasite per unit fillet weight all increased with host length (Table 11). While variations in worm abundance related to host sex (Table 12) were not significant, those associated with host length and sampling were highly significant (Table 13).

HYSTEROTHYLACIUM ADUNCUM IN 4T AND 4Vn COD AND FLATFISH

A fourth species of ascaridoid nematode was found in the coelom and occasionally in the flesh of 4T and 4Vn cod, plaice, and witch. However, aside from a few encysted third-stage larvae found in small cod and plaice from 4T, most of the specimens were unencysted fourth-stage larvae or adults of enteric origin. Records of these nematodes in the coelom and flesh (Table 14) do not reflect their overall abundance as many specimens were found protruding from the mouth, gills and anus, or free of the fish host. Further, the gastro-intestinal lumen of the host was not inspected. They are cited here nevertheless as evidence of migration of parasitic nematodes from the gut lumen to the coelom and flesh after the death of the host.

MIGRATION OF LARVAL ANISAKINES IN ROUND COD

There was no evidence of a migration of larval anisakines from the viscera to the flesh of round cod within 24 hours of catch (Table 15). Sealworm occurred primarily in the flesh, with only two (0.5%) of 408 larvae being found in the viscera of freshly gutted cod and three (1.8%) of 171 larvae in the viscera of cod left ungutted for 6-24 hours after catch. Conversely, *Anisakis* occurred mainly in the viscera and only four (3.0%) of 131 were found in the flesh of freshly gutted cod and three (1.9%) of 159 in the flesh of round cod.

The experiment with Scatari Bank cod (Table 16) also failed to provide conclusive evidence of migrations of larval anisakines in round cod. In this case, sealworm did not occur in the viscera of either freshly gutted cod or cod stored on ice for four days prior to evisceration. The distribution of *Anisakis* sp. larvae between viscera and flesh was similar in freshly gutted and round cod; nine (21%) of 43 *Anisakis* larvae occurred in the flesh of the former, 13 (24%) of 55 in the flesh of the latter. In respect to infections in flesh alone, however, round cod had relatively fewer nematodes in the flaps than freshly gutted cod; four (2%) of 203 sealworm and five (38%) of 13 *Anisakis* larvae in the flesh of round cod occurred in the flaps; while of the nematodes in the flesh of freshly gutted cod, nine (7%) of 123 sealworm and six (67%) of nine *Anisakis* were in the flaps. As the total numbers of nematodes were small and as respective distributions of sealworm and *Anisakis* in tissues of freshly gutted and round cod varied by only a few nematodes in each case, the results were not subjected to a further analysis.

Following digestion of the flesh of Scatari Bank cod, it became clear that a number of nematodes had escaped detection by routine examination of fillets and flaps (Table 16). Of the nematodes in the flesh of freshly gutted and round cod, 45 (13%) of 339 sealworm and 15 (68%) of 22 *Anisakis* sp. larvae were recovered by digestion.

DISCUSSION

Before the results of the present study can be discussed or compared with results of similar studies, several factors must be considered. Fillets, flaps, and viscera were examined for ascaridoid nematodes in our study, whereas only the fillets were examined in earlier surveys of eastern Canadian groundfish (Scott and Martin 1957, 1959; Templeman et al. 1957; Wiles 1968; Appy 1978). In our study, nematodes in the fillets and flaps were recovered by systematic destruction of the flesh. As shown in experiments in which the flesh of cod was digested following routine examination, some *P. decipiens* (13%) and most *Anisakis* sp. larvae (68%) in the fillets and flaps were not detected by systematic destruction of the flesh. Templeman et al. (1957) found *P. decipiens* and *Anisakis* sp. larvae in the fillets of eastern Canadian groundfish by cutting the fillets into thin slices prior to candling. This latter approach appears to be nearly as reliable for detection of sealworm as systematic destruction of the flesh (Power 1961) and has subsequently been adopted by European investigators (Young 1972; Platt 1975). Experiments conducted by Power (1961), however, indicate that commercial candling procedures employed in the Scott and Martin (1957) survey of eastern Canadian cod were probably less than half as efficient for finding worms as the methods above.

Records of sealworm infestation are usually reported as average numbers of worms per fish, per fillet, or per unit fillet weight; but average or mean worm counts are often misleading. Frequency distributions of worm counts are invariably skewed to the right with most fish either uninfected or lightly infected (Platt 1975; Pälsson 1979; herein). When sample sizes are small, the mean worm count may be greatly influenced by occurrences of heavy infestations in a few fish. As worm abundance varies with length or age of host (Platt 1975; herein), the mean count is also influenced by the structure of the sample with regard to length or age classes present and relative numbers of fish included in each class. The influence of length or age structure of sampling remains when mean counts are computed for broad categories such as scrod, market, or steak cod. In other studies discussed here, samples appear to have been chosen at random and have normal frequency distributions for age or length of fish. Our samples, however, were selected according to a forced orthogonal design in which they were stratified into length groups containing equal numbers of fish. Most of these samples conform with the design to some degree.

The difficulty of comparing the findings of various surveys is compounded by the fact that fish length or age strata chosen for data summaries often differ. Moreover, growth rates of cod and flatfish populations vary geographically (Kohler 1964; Powles 1965; Pitt 1975; Beacham 1982) and, hence, fish of a given year class vary in size from population to population. Conversely, fish in corresponding length strata may differ in age.

Although sampling locations in the present and earlier surveys often coincide, the times of year at which samples were collected may differ. With seasonal migrations of cod and plaice, particularly 4T stocks (Martin and Jean 1964; Powles 1965), various transient populations may occur in a given location at different times of year. In the event that the same cod or flatfish population has in fact been sampled in current and past surveys, fish in coincident length strata may differ in age due to changes in growth rates over the intervening years (Kohler 1964; Powles 1965).

Frequency distributions of worm counts in the present study are positively skewed but brought remarkably close to normality by the $\log_{10}(n+1)$ transformation. Because of the complexity of design and the lack of sufficient numbers of observations in some cells, the possibility that the distributions are negative binomials was not tested. Platt (1975) applies the above transformation to data on sealworm and Anisakis larvae in northern European cod, having first established that worm count distributions lie between Poisson and negative binomials. In Pälsson's (1979) study of larval anisakines in cod from the Icelandic inshore area, worm count distributions are in fact negative binomials.

ANOVAs reported here are of non-orthogonal design, i.e. unbalanced with unequal numbers of observations in the individual cells, and main effects (host length, sample and sex) are assumed "fixed." The disparity in cell size is often severe, with some cells, albeit a small minority, having no observations. With Type II ANOVAs offered in the SPSS and BMDP packages used for preliminary analyses here, cross-contamination of interaction and main effects may occur in analyses of unbalanced data (Fruend and Littel 1981). This problem was resolved by reanalyzing the data with Type III and Type IV ANOVAs, which subsequently became available in the GLM procedure (SAS 1982). With the Type III ANOVA, each effect is adjusted for all other effects and significance of main effects can be considered in the presence of interactions. Type IV functions have been designed for analyses in which cells of zero frequency are involved. In the few cases where this situation applied to our analyses, results of Type III and Type IV ANOVAs were similar.

Distributions of error terms were not tested for normality for the following reasons (see Underwood 1981). First, most tests for normality require large samples and, as indicated above, some cells contained few observations. Secondly, for complex designs such as the one used in the present study, none of the tests for normality are practicable. Finally, non-normality has little effect on statistical procedures which compare treatment means, and thus it may be safe to disregard this assumption.

In all likelihood, the assumption of homogeneity of variances has also been violated in this analysis. When heterogeneity of variance is severe, the probability of Type I error is greater than specified in the table of F-ratios, and the factors in ANOVA are prone to false significance (Bliss 1970; Underwood 1981). In the present study, however, the data were not tested for homogeneity of variance. According to arguments presented in Underwood's (1981) review, ANOVA is robust to many types and magnitudes of departure from homogeneity of variance and may be more valid than tests of the assumption. Hence, prior tests for homogeneity of variance may not be necessary.

A priori contrasts are non-orthogonal and consequently prone to results of false significance (as is the case with heterogeneity of variance, the probability of Type I error is greater than specified in the table of F-ratios). For descriptive purposes, it is often more convenient to confine such analyses to orthogonal contrasts; but this should not prevent the investigator from testing those contrasts of greatest theoretical importance (Harris 1975).

Given the above limitations, the results of our analysis must be interpreted with caution. While non-significance, e.g., effect of host sex, is a reliable result, significant results may be dubious (Underwood 1981). Underwood infers that one way of offsetting the possibility of false significance would be to test significance at a lower probability level; i.e., lower than the $P \leq 0.05$ level normally employed in such tests. Our analysis indicates that apparent variations in worm abundance related to host length and geographical origin are for the most part highly significant ($P \leq 0.0001$).

SEALWORM IN 4T AND 4Vn COD AND FLATFISH

It would be difficult to conclude that sealworm abundances in the fillets of 4T cod reported here differ from those reported 25 years ago (Scott and Martin 1957; Templeman et al. 1957). Although there were great variations in abundance of sealworm in 4T cod examined in present and past studies, infestations generally fall within the same range. In the recent Bradelle Bank sample, steak cod had heavier infections, while scrod and market cod had lighter infections than previously reported. Infections in small inshore cod collected off Chéticamp in the fall of 1980 were light in comparison with earlier records from this area; and yet cod samples from the neighbouring Souris, P.E.I., inshore in the spring of 1981 had extremely heavy infections, rivalling those found in cod from Caraquet, N.B., in 1946.

Sealworm seems to be somewhat more abundant in the fillets of local 4Vn cod than previously reported by Scott and Martin (1957). Worm counts were consistently greater (three- to tenfold) in the 1981 samples, regardless of sampling location or grade of cod. Our analysis revealed that differences of lesser magnitude among our own samples were often highly significant. The possibility that worm counts have inflated by inclusion of heavily infected migrant cod from 4T applies only to Scott's and Martin's study. In our study, a distinction has been made between local 4Vn cod, collected from late May through early October, and cod collected in winter which was presumably a mixture of local 4Vn and migrant 4T cod. Methods used to find nematodes in the fillets in our study, however, may have been two to five times as efficient as the commercial candling procedures employed by Scott and Martin (see Power 1961). When this factor is taken into consideration, evidence that sealworm has become more numerous in 4Vn cod is less convincing.

The 4T plaice examined in our study were heavily infected with sealworm, generally having more worms per unit fillet weight than cod. According to processors, the worm problem in 4T plaice, particularly off the Chéticamp to Pleasant Bay area of Cape Breton, is a recent development. Given the lack of historical records from this area, however, it is difficult to confirm this claim. The records of Templeman et al. (1957) show significant numbers of worms in plaice from the 4T offshore. In fact, the parasite appears to have been as abundant in plaice sampled from Bradelle Bank in this early study as it was in our sample from Shediac Valley.

On the other hand, the heavy sealworm infections in 4Vn plaice reported in this study are without precedent. According to Templeman et al. (1957), infections in 4V plaice were extremely rare; the prevalence of the parasite in a sample from Cape North 4Vn was only 4%. Similarly, sealworm infections in 4Vn gray sole (witch flounder) were much heavier in our study than reported by Templeman et al. (1957), who found only one worm in 116 witch from the "Edge of Ground" (4Vn). While current infections in sole are much lighter than those in cod and plaice, they still exceed government standards (one worm for every three pounds or 0.73 worms per kg of fillets), and candling would be required in processing.

Sealworm appears to be no more abundant in 4T and 4Vn cod than it is in many European cod stocks (Young 1972; Platt 1975; Bjørge et al. 1981). However, in European cod, the parasite accumulates more frequently in the flaps and becomes increasingly prevalent in this location in larger fish. In British cod, for example, *P. decipiens* is equally abundant in the flaps and fillets of fish <50 cm in length; in fish >50 cm in length, the numbers of worms in the fillets remain more or less constant while numbers in the flaps increase at an exponential rate with host length (Young 1972). As a consequence, European cod generally have fewer worms in the fillet and fewer worms per unit fillet weight than 4T and 4Vn cod, herein. Sealworm infections in European fisheries are confined mainly to cod; and infections in other groundfish species, such as witch or plaice (long rough dab), are rare (Wootten and Waddell 1977).

SEALWORM ABUNDANCE IN GROUNDFISH AND GREY SEAL DISTRIBUTION

The persistence of heavy sealworm infestations in 4T cod and plaice and the apparent increase in abundance of the parasite in 4Vn cod and flatfish are difficult to explain in terms of grey seal distribution, as records of the seal in the southern Gulf and Sydney Bight have been rather infrequent. Recent records of grey seal distribution, however, are based largely on frequencies of bounty kills and gear entanglements, usually involving gill nets (Zwanenburg et al. 1981). An apparent scarcity of grey seals in a given area may merely indicate that fishermen who might normally hunt the seal are more profitably occupied or, possibly, the lack of an active gill net fishery.

Comparisons of current information on worm infestations in groundfish with recent records of grey seal distribution and abundance may be misleading, as the relationship between the two phenomena is not an instantaneous one. Depending on environmental temperature, hatching and development of the parasite in poikilothermic intermediate hosts may require periods of several months to several years duration (McClelland 1982, 1983b). Upon reaching the "infective" stage (i.e., infective to seals) in the fish host, the sealworm may persist indefinitely in encysted form. Hence, there would be a considerable time lag between the growth or decline of the seal population in a given area and corresponding changes in the abundance of sealworm in groundfish.

Mansfield and Beck (1977) speculate that the ice-breeding grey seal colony in Georges Bay may have grown in recent years as a result of increased ice stability in the area following the construction of the Canso Causeway. The heavy worm infestations currently found in Souris cod and Chéticamp plaice may be related to the existence of this colony and/or increased numbers of transient seals migrating to and from the colony via the Souris/Chéticamp area. Apparent increases in sealworm abundance in 4Vn groundfish may also be attributable to the more frequent occurrence of transient seals. Grey seals migrating between the eastern Nova Scotia/Sable Island area and the Gulf of St. Lawrence via the Cabot Strait would pass through 4Vn en route. This migration route has probably been used with increasing frequency in recent years as a result of the growth of the seal population and/or the causeway having blocked access to the Gulf via the Strait of Canso. Heavy infections in cod from Frenchman's Shoal have probably resulted from the increased abundance of grey seals on Scatari Island and along the Cape Breton coast between Louisbourg and Fourchu. Numerous grey seals were also sighted on drift ice over the "Edge of Ground" 4Vn at the time we were sampling from commercial draggers in February 1980 and 1981.

ANISAKIS SP. LARVAE IN 4T AND 4Vn COD AND FLATFISH

The abundance of larval *Anisakis* in whole 4T and 4Vn cod was 1.65 in our study, with the parasite generally being most numerous in 4T fish. Abundance in the flesh was 0.038; 0.018 in the fillets, and 0.020 in the flaps. Significant numbers of the parasite also occurred in plaice from the southwestern Gulf, but infections were rare in Chéticamp and 4Vn plaice. The overall intensity of infection in plaice was 0.040, and only two larvae were found in the fillets of 1,681 plaice. In an earlier survey (Templeman et al. 1957) in which only the fillets of groundfish were examined, the overall abundance of *Anisakis* in eastern Canadian cod was 0.014. The parasite was most abundant in cod from Newfoundland waters but was not detected in either cod or plaice from the 4T offshore.

Anisakis larvae appear to be far more numerous in European cod. In fact, infections in the flesh of cod from many European fisheries are heavier than those found in whole 4T and 4Vn cod herein. According to Young (1972), abundances in the flesh of cod from the northeast and southeast British coasts and from the North Sea were 2.60, 2.54 and 1.92 respectively. Platt (1975) reports abundances in cod flesh ranging from 2.0 to 4.4 on Faroe Island Bank, from 1.7 to 2.8 in Icelandic fisheries, and from 4.1 to 10.2 in eastern Arctic and Arcto-Norwegian waters.

Since they are somewhat smaller than sealworm and greyish to yellowish-white in colour, *Anisakis* larvae are difficult to detect in the flesh of groundfish (Wootten and Waddell 1977). As shown in our digestion experiment, 68% of these nematodes in the flaps and fillets of average size (50-60 cm) cod escaped detection by slicing and systematic destruction of the flesh. Techniques used for routine examinations of the flesh in the present study, however, were similar in efficiency to those employed in surveys of European cod (Young 1972; Platt 1975). Hence, the apparent difference in abundance of *Anisakis* in the flesh of eastern Canadian and European cod is not attributable to differences in examination procedures. One may further conclude that if numbers of *Anisakis* in the flesh of eastern Canadian cod have been greatly underestimated, they have likewise been underestimated, for European cod. Given that this parasite can be pathogenic to humans (Smith and Wootten 1978) and at the same time difficult to detect by procedures routinely employed in fish processing, the fact that Canadian cod has much lighter infections than European cod should be of advantage in the marketplace.

Of course, it is possible that Anisakis may not be as abundant in areas we surveyed as they are in other eastern Canadian fisheries. According to Parsons' and Hodder's (1971) survey of herring, larval Anisakis infections in 4T stock were somewhat lighter than those occurring in the Scotian Shelf, southwestern Nova Scotian, and various Newfoundland stocks; herring from Gabarus Bay (4Vn), however, had fairly heavy infections. Appy (1978), on the other hand, reported that the prevalence of "mesenteric nematodes" (mainly larval Anisakis) was higher in cod from the southern Gulf of St. Lawrence than in Scotian Bank and Bay of Fundy cod, while abundance was fairly uniform throughout these areas.

The distribution of Anisakis larvae in the tissues of the fish host appears to vary. In the present study, these nematodes occured mainly on the liver and visceral mesenteries and only two or three percent were found in the flesh during routine examinations. When additional nematodes, however, were recovered from flaps and fillets of cod by digestion procedures, the frequency of the parasite (in the flesh) was 22% - 11% in the flaps and 11% in the fillets. Young (1972) found Anisakis larvae to be more numerous in the flesh (69%) than in the viscera (31%) of North Sea and British cod, but in a later study of North Sea cod (Wootten and Waddell 1977), mean intensity of infection in the flesh was only eight (12%) compared to 23 (88%) in the viscera. According to Pälsson (1979) the parasite occurred more frequently in the viscera of Icelandic cod, the frequency in the flesh being about 25% in one- to two-year-old and about 10% in three-year-old fish. European investigations invariably report, however, that most of the Anisakis larvae occurring in the flesh were concentrated in the hypaxial muscultyre of flaps rather than being evenly distributed between flaps and fillets as was the case herein. Of the Anisakis larvae found in the flesh of European cod, 90% (Young 1972) to 100% (Wootten 1978) were in the hypaxial musculature.

CONTRACAECUM (PHOCASCARIS) SP. LARVAE IN 4T AND 4Vn COD AND FLATFISH

Contracaecum larvae on the visceral mesenteries of cod and plaice herein closely resemble infective- (third-?) stage larvae of C. osculatum reared in vitro by McClelland and Ronald (1974b). The fact that they were more numerous by far in 4T fish is probably attributable to the seasonal occurrence of harp seals in the southern Gulf, as mature C. osculatum are most commonly found in this seal species (Berland 1963; Mansfield and Beck 1977; Pälsson 1979; McClelland 1980b). Although they visit there but a few months of the year, harp seals greatly outnumber the combined populations of other resident and migrant seal species in the southern Gulf. Moreover, among seal species of the Northwest Atlantic, harp seals are most heavily infected with C. osculatum on a per-seal basis.

There is less likelihood that the larval nematodes reported here are Phocascaris spp., although third-stage larvae of Contracaecum and Phocascaris spp. may be morphologically inseparable (Pälsson 1979). Adults of Phocascaris spp. occur in the gastro-intestinal tracts of various seal species in the Northwest Altantic, but the principal host in the southern Gulf of St. Lawrence would be the hooded seal (Cystophora cristata); infections in harp and grey seals are extremely light (Berland 1963; McClelland 1980b). The hooded seal population in the southern Gulf is small, numbering in the hundreds, and like the harp seal, occurs there only during the breeding season.

Unfortunately, it was not possible to make a positive identification of Contracaecum larvae on the basis of their morphology or geographical distribution. It may be necessary to rear some of these nematodes to maturity in order to confirm their specific identity. This can be accomplished, as shown with sealworm (Scott 1953; McClelland 1980a), by transmitting the larvae to the suspected definitive host. Alternatively, the parasite may be reared to maturity or near maturity in vitro (McClelland and Ronald 1974b). Recently, larval nematodes from the viscera of Baltic cod were identified as C. osculatum, following surgical implantation and maturation in the peritoneal cavities of laboratory rats (Fägerholm 1982).

VARIATIONS IN ABUNDANCE OF LARVAL ANISAKINES WITH LENGTH OF FISH HOST

Larval anisakine infections usually increase in intensity with length, weight or age of fish host (Scott and Martin 1957, 1959; Templeman et al. 1957; Parsons and Hodder 1971; Young 1972; Platt 1975; Wootten and Waddell 1977; Wootten 1978; Pälsson 1979; herein). These nematodes ultimately become encysted in fish tissues, emerging only upon ingestion by a subsequent host. Hence, they may persist throughout the life span of the fish, becoming increasingly numerous through cumulative reinfections. On the other hand, as indicated by occurrences of cysts containing dead and disintegrating worms, the parasites may eventually be eliminated, possibly as a consequence of a host reaction. Even under these latter circumstances, however, the nematodes would be more numerous in larger fish as the frequency of reinfection would increase with the appetite of the host.

Of course, the rate at which fish accumulate larval anisakines would depend not only on the quantity of prey consumed, but on diet preferences as well. Cod become increasingly piscivorous as they mature, and 4T and 4Vn cod are no exception in this regard (Kohler and Fitzgerald 1969). Cod may become infected with larval anisakines by feeding on invertebrate or smaller fish hosts (Scott 1954; Smith 1974; McClelland 1983b), but the parasite would probably occur more frequently in a diet of fish. For example, young plaice which become increasingly important in the diet of large cod (Powles 1965; Waiwood et al. 1980) are themselves heavily infected with sealworm.

As shown in present and earlier studies (Scott and Martin 1957; Templeman et al. 1957), increases in sealworm abundance in 4T and 4Vn cod are either proportionate to or greater than increases in host weight; and large cod have as many or more worms per unit fillet weight than smaller cod. Prevalence and abundance of worms, on a per-fish or per-fillet basis, increase dramatically with the size of the fish, while efficiency of candling procedures used to detect the parasites declines with increasing thickness of fillet (Power 1961). Given the above factors, it would seem that the worm problem in 4T and 4Vn cod might be alleviated by fishing for smaller cod and, by management practices, maintaining young cod populations in these areas. According to processors, however, the worm problem is not the only concern. Market cod are generally preferred for processing into fillets, steak and market cod for saltfish markets. Scrod may have fewer worms but take longer to process (per unit weight) and deteriorate more rapidly than market cod.

As previously discussed, sealworm tend to accumulate more frequently in the flaps than in the fillets of large European cod (Young 1972; Platt 1975). As a consequence, the parasites become less numerous per unit fillet weight with increasing length or age of host. Young (1972) suggests that, under these circumstances, selective fishing for large cod, together with removal and separate processing of flaps, might be a useful approach to the worm problem. While dismissing selective fishing as an uneconomic option, Platt endorses the separate processing of flaps, noting that infections with Anisakis sp. larvae as well as sealworm are concentrated in these tissues.

On a per-unit-fillet-weight basis, sealworm is most numerous in small plaice from 4T and 4Vn (Templeman et al. 1957; this study). The apparent decrease in the frequency of reinfection in mature plaice is probably attributable to change in diet. Crustaceans and annelids serving as precursor hosts of the parasite (Val'ter 1978; Val'ter and Popova 1974; McClelland 1983a) make up the greater part of the diet of young plaice, while the mature fish feed mainly on echinoderms and molluscs (Powles 1965; Minet 1973).

Unfortunately, we were not able to establish mathematical relationships between variations in worm abundance and host length. Plots of mean transformed worm counts versus mean host length seem to indicate the existence of linear regression, and a relationship is also implied by the significance of host length and host length/sample mean interactions in two-way ANOVAs. Regression analysis, however, reveals gross violations of the assumption of normality of the distribution of error, and under this circumstance, tests for significance of regression coefficients are meaningless (Underwood 1981). When this analysis was completed for a few samples, the regressions explained <10% of the variance, although regression coefficients were apparently highly significant ($P \leq 0.00001$). The above assumption also applies to tests of significance of correlation coefficients but may have been overlooked by Platt (1975) in computing significance of correlations between transformed worm counts (P. decipiens and Anisakis sp. larvae) and length, weight and age of host European cod.

VARIATIONS IN ABUNDANCE OF LARVAL ANISAKINES WITH SEX OF FISH HOST

According to three-way ANOVAs in this study, abundances of larval anisakines in 4T and 4Vn cod and flatfish did not vary significantly with host sex. In the case of Contracaecum sp. larvae in cod, the three-way interaction of host sex, length and sample was highly significant ($P \leq 0.0001$). The significance of this particular interaction, however, was probably attributable to the influences of sample and length, which were also highly significant ($P \leq 0.0001$) in two-way interaction and as main effects. Sex was not significant as a main effect or in respective two-way interactions with length and sample. As previously surmised by Templeman et al. (1957) and Appy (1978) with regard to larval Phocanema and Anisakis infections in cod, variations in intensity of larval anisakine infections can be considered without reference to host sex.

LARVAL ANISAKINES AS BIOLOGICAL TAGS

Our analyses (fixed-factor design - a priori contrasts) indicate that P. decipiens, Anisakis sp. and Contracaecum (Phocascaris) sp. larvae could be used as biological tags for 4T and 4Vn cod and flatfish stocks. Variations in abundance of P. decipiens and Contracaecum larvae would be useful in discriminating between inshore and offshore stocks. Quantitative comparisons of Anisakis sp. and, particularly, Contracaecum sp. infections might also be employed in distinguishing 4T from 4Vn stocks.

As they occur mainly on the visceral organs and mesenteries, Anisakis and Contracaecum are certainly more convenient to study than sealworm. With a trained eye they are readily identified and counted. If it is not possible to examine samples at sea, only the viscera need be collected for subsequent examination in the laboratory. Quantitative studies of sealworm, on the other hand, are laborious and time consuming (Appy 1978). They require that the fish be boned and skinned and that a variety of procedures such as slicing, candling or systematic destruction of the flesh be employed in detection of worms embedded in fillets and napes. Of course, the efficiency of worm detection can vary greatly with the technique employed (Power 1961). Given that proper facilities for these procedures are usually not available at sea, hundreds of kilograms of fish must be collected, stored, and transported to the laboratory.

As shown here and in earlier studies (Scott and Martin 1957; Templeman et al. 1957; Appy 1978), sealworm is most numerous ($P \leq 0.0001$) in the inshore cod of 4T and 4Vn. Once a distinction has been made between inshore and offshore samples, however, it becomes apparent that worm abundances in our 4Vn cod samples were similar to those in our 4T samples. In the past, when sealworm infections in local 4Vn cod were relatively light (Scott and Martin 1957), seasonal immigrations of 4T cod must have had a dramatic impact on the worm problem in 4Vn fisheries. With the parasite uniformly abundant in 4T and local 4Vn cod, as indicated in our current samples, this should no longer be the case. Indeed, Cape Breton processors interviewed here remarked that at one time the worm problem in 4Vn cod fisheries was most severe in winter and spring when migrant 4T cod were present; but in recent years there were no seasonal variations in worm infestations.

Sealworm counts in our samples of cod from the 4Vn winter fishery were similar to those found in offshore cod from 4T and 4Vn summer fisheries. With regard to abundances of Contracaecum and Anisakis larvae, on the other hand, 4Vn winter cod samples differed greatly ($P \leq 0.0001$) from 4T offshore cod, while appearing more similar to local cod collected from the 4Vn offshore in summer. On the basis of nematode counts, then, one would conclude that although some migrant 4T cod were included in these samples they were mainly comprised of local offshore fish. These findings are somewhat surprising in light of tagging experiments (Martin and Jean 1964; Kohler 1975) which indicate that cod overwintering along the Laurentian Channel in 4Vn are mainly migrant 4T cod. Moreover, distribution of tag recoveries from 4T show that this migrant stock is a mixture of inshore and offshore fish.

As discussed above, Contracaecum sp. larvae probably belong to C. osculatum which, like sealworm, mature and reproduce in the gastro-intestinal tract of seals. The fact that adults of this nematode abound in harp seals breeding in the southern Gulf of St. Lawrence would explain why the larvae are so numerous in 4T cod while rarely occurring in local 4Vn cod. In 4T offshore cod ≥ 61 cm in length ($n = 261$), prevalence of Contracaecum infection was 53%, abundance, 4.94. However, in cod ≥ 61 cm in length from the 4Vn winter fishery ($n = 768$), prevalence and abundance of Contracaecum were 12% and 0.91, respectively. One might therefore conclude that only a small proportion (less than one-quarter) of the cod in the 4Vn winter samples were migrants from 4T. At present, a conclusion of this nature would be presumptuous, since it is based on nematode abundances in a few samples of cod which may not be typical of commercial catches. With more extensive sampling and a larger data base, however, it may be possible to estimate (by reference to larval Contracaecum infections) what proportion of cod caught in the 4Vn winter fishery are migrant 4T fish. Harp seals are even more numerous off Labrador and northeastern Newfoundland than they are in the southern Gulf of St. Lawrence (Sergeant 1965, 1966), and larval Contracaeum might also prove to be a useful biological tag for cod stocks in these areas.

Fish parasites are most useful as tags when there is radical variation in their abundance in different host populations (Smith and Wootten 1978). With regard to larval Contracaecum infections in 4T and 4Vn cod, this criterion has been met. Similarly, Platt (1976) has shown that Icelandic and Greenland cod stocks can be distinguished by differences in sealworm abundance; the prevalence of the parasite is high in the former and low in the latter stocks. Seasonal mixing of Icelandic and migrant Greenland cod on the spawning grounds south of Iceland is indicated by sealworm prevalences intermediate to those found in the component stocks.

Our analysis of larval anisakines in 4T and 4Vn plaice illustrates the perils of attempting to define a given fish stock by its parasitic infections. Worm counts in plaice from the southeastern Gulf (Chéticamp) were consistent with those in 4Vn plaice while differing significantly from those found in plaice from the southwestern Gulf (Pt. Escuminac, N.B. and Shediac Valley). This was particularly evident with Anisakis sp. and Contracaecum sp. larvae which occurred in significant numbers in samples from the southwestern Gulf but were rare or lacking in Cheticamp and 4Vn samples. According to Powles (1965), southern Gulf plaice are a discrete stock, meristically distinct from 4Vn plaice. Powles' tagging experiments indicate, however, that the 4T stock consists of two main groups, a northern or "Miscou-Magdalen" group and a southern or "Cape Breton" group. Our samples from Pt. Escuminac and the Shediac Valley would belong to the northern group and our Chéticamp sample to the southern group.

MIGRATIONS OF ASCARIDOID NEMATODES IN ICED ROUND FISH

As indicated here and in Cheng's (1976) study, adult and immature Hysterothylacium (Thynnascaris, Contracaecum) aduncum typically found in the gastro-intestinal tract of marine fish migrate through the gut wall to the body cavity and flesh after the death of the host. These nematodes are also found escaping from the mouth, gills, and anus of fish stored on ice, in the round. The allegation that sealworm leave the fillets of round cod can probably be traced to the presence of migrant H. aduncum free among the bodies or in the body cavities of the fish. While the adults of H. aduncum are often too large (>10 cm in length) to be confused with sealworm, the immature stages of the former are similar in size, shape and colour to the latter; to the layman, the two species would be inseparable. As some H. aduncum invade the flesh after the death of the host, there would be an increase rather than a decrease in the numbers of nematodes in the fillets of round cod.

We found that the larval anisakines on the visceral organs and mesenteries were usually encysted and remained so, long after the death of the fish host, even as surrounding host tissues decayed. However, occurrences of unencysted larvae and vacated capsules among host viscera indicate that some anisakines may excapsulate and these would be free, like H. aduncum, to migrate to the flesh. Experiments in which the distributions of larval anisakines in the flesh of round and freshly gutted cod were compared (Table 16) neither proved nor disproved this possibility. Round cod had more Anisakis sp. larvae in the flesh (24% of the total) than freshly gutted cod (21% of the total), and the ratio of Anisakis in the fillets to those in the flaps was greater in the former (1.6:1) than in the latter (0.5:1). No sealworm were found in the viscera of round or freshly gutted cod, but the ratio of worms in fillets to worms in flaps was again greater in the former (49.0:1) than in the latter (13.7:1). While these results suggest that some larval anisakines may move to the fillets in iced round cod, they are far from conclusive. Distributions of the nematodes in the tissues of round and gutted cod differed by only a few worms in each case, and such differences could be attributed to natural variations.

Similar experiments performed by Smith and Wootten (1975) indicated significant migrations of Anisakis sp. larvae from the viscera to the flesh of iced round herring. While only 4% of these nematodes occurred in the flesh of freshly gutted herring, 12%-20% were found in the flesh of iced round herring examined 37 hours after capture. As the fish used in this study were heavily infected (mean intensities of infection ranging from 9 to 22 in various samples), there were noticeable increases in the numbers of nematodes in the flesh, although the shift of worms from viscera to flesh was actually rather small on a percentage basis (8%-16%). Migrations of this order would be impossible to detect in the present study because of the low abundance of Anisakis (0.77-0.96). The rate of such migrations would also be influenced by host species and size of host; cod used in our study were considerably larger (averaging 1500 g) than the herring (60-250 g) employed in Smith's and Wootten's experiments.

TABLE 1. Abundances of larval anisakines in 4T and 4Vn cod.

Host				Larval anisakines detected						
				Phocanema			Anisakis		Contracaecum	
Sample	Length range (cm)	Mean weight (kg)	n	Prevalence[a]	Abundance[b]	No. per kg fillet	Prevalence	Abundance	Prevalence	Abundance
Shediac Valley (4T) Sept. 1980	≤ 40	0.49	22	27	0.41	2.63	41	0.50	5	0.05
	41-50	0.99	52	44	0.62	1.54	77	1.63	15	0.25
	51-60	1.47	37	51	1.41	2.67	62	1.16	33	0.95
	61-70	2.50	14	79	2.71	2.95	64	1.71	57	3.14
	≥ 71	4.49	10	100	10.50	6.76	90	8.00	50	4.20
Pt. Escuminac, N.B., (4T) June 1981	≤ 30	0.17	46	26	0.26	4.80	11	0.15	0	0
	31-35	0.34	37	22	0.30	2.77	16	0.16	0	0
	36-40	0.56	35	54	0.69	3.87	40	0.60	3	0.03
	41-45	0.75	48	54	1.10	4.51	50	0.77	0	0
	46-50	1.10	44	55	1.14	3.26	48	1.20	2	0.05
	51-55	1.40	40	55	1.33	2.99	63	1.65	15	0.20
	56-60	1.82	34	82	2.29	3.63	91	2.62	44	1.74
	≥ 61	2.60	23	100	5.09	5.72	96	6.09	70	5.26
Bradelle Bank (4T) Nov. 1981	≤ 45	0.75	31	58	1.06	4.46	32	0.45	0	0
	46-50	0.98	33	21	0.42	1.36	55	0.94	0	0
	51-55	1.45	28	61	0.86	1.79	75	2.71	14	0.32
	56-60	1.72	35	69	1.31	2.42	77	2.57	20	0.40
	61-65	2.16	28	61	1.54	2.15	86	3.79	25	1.54
	66-70	2.84	25	84	2.84	2.86	76	4.04	48	1.48
	≥ 71	5.50	29	97	17.31	7.76	86	5.52	62	3.69
Souris, P.E.I., (4T) April 1981	36-40	0.59	20	30	0.45	2.42	60	1.20	0	0
	41-45	0.75	38	58	1.39	5.90	45	0.79	3	0.05
	46-50	1.00	27	63	1.93	5.96	30	0.52	7	0.07
	51-55	1.44	26	77	3.38	6.82	81	1.96	4	0.35
	56-60	1.91	36	81	5.22	8.51	69	1.28	17	0.58
	61-65	2.27	31	84	7.16	9.26	77	2.48	13	0.19
	66-70	2.74	13	92	13.92	13.84	46	1.08	15	0.85
	≥ 71	4.69	13	100	25.31	13.84	77	6.38	54	4.38
Souris, P.E.I., (4T) May 1981	36-40	0.60	11	36	0.91	4.80	18	0.27	0	0
	41-45	0.78	33	61	1.79	7.15	30	0.36	0	0
	46-50	1.06	34	79	2.91	8.60	35	0.88	9	0.15
	51-55	1.46	33	76	3.09	6.45	45	1.15	6	0.18
	56-60	1.86	36	75	5.28	8.76	64	1.81	22	0.86
	61-65	2.38	26	85	8.38	10.26	54	1.58	23	0.50
	66-70	2.81	17	94	16.35	16.92	41	0.82	12	0.18
	≥ 71	4.63	20	95	15.60	9.19	70	4.15	25	0.70
Chéticamp, N.S., (4T) Nov. 1980	≤ 35	0.32	20	35	0.40	3.52	20	0.20	0	0
	36-40	0.53	63	33	0.56	3.34	19	0.25	0	0
	41-45	0.78	62	35	0.65	2.62	32	0.37	0	0
	46-50	1.04	106	43	0.79	2.29	43	0.63	2	0.02
	≥ 51	1.43	38	58	1.24	2.73	50	0.82	0	0
St. Paul's Island (4T) Nov. 1980	≤ 50	1.01	13	8	0.08	0.24	62	1.46	8	0.23
	51-55	1.30	55	40	0.71	1.50	62	2.00	22	0.44
	56-60	1.57	55	38	0.55	1.06	73	2.91	25	1.51
	61-65	1.95	40	35	0.63	0.77	78	2.73	60	4.63
	66-70	2.48	29	38	1.28	1.50	86	3.41	59	3.03
	≥ 71	3.87	29	72	3.10	2.13	97	8.93	62	13.17
St. Paul's Island (4T) Dec. 1980	≤ 50	1.04	84	36	0.45	1.34	45	0.83	4	0.06
	51-55	1.36	99	39	0.73	1.65	64	1.40	6	0.12
	56-60	1.70	55	55	1.53	2.77	62	1.62	16	0.58
	61-70	2.39	33	61	2.88	3.45	76	2.27	48	3.09
	≥ 71	4.75	24	96	8.46	4.47	83	6.75	50	10.79

TABLE 1. Cont'd.

Host				Larval anisakines detected						
				Phocanema			Anisakis		Contracaecum	
Sample	Length range (cm)	Mean weight (kg)	n	Prevalance[a]	Abundance[b]	No. per kg fillet	Prevalence	Abundance	Prevalence	Abundance
Edge of Ground (4Vn) Feb. 1980	≤30	0.18	29	14	0.14	2.38	10	0.24	0	0
	31-35	0.31	58	36	0.84	8.53	7	0.07	3	0.03
	36-40	0.48	50	30	0.60	3.83	8	0.10	2	0.06
	41-45	0.17	53	19	0.36	1.60	13	0.34	2	0.02
	46-50	1.00	70	24	0.74	2.27	33	0.91	0	0
	51-55	1.34	100	45	1.40	3.12	33	0.95	3	0.12
	56-60	1.67	105	57	2.51	4.53	26	0.63	2	0.07
	61-65	2.09	56	48	2.16	3.10	30	1.11	9	0.46
	66-70	2.56	29	59	2.41	2.73	21	1.55	14	1.76
	≥71	3.34	27	63	5.22	4.20	22	1.26	11	0.59
Edge of Ground (4Vn) Feb. 1981	≤35	0.35	40	38	0.53	4.58	15	0.18	0	0
	36-40	0.50	58	40	0.84	5.37	34	0.62	5	0.16
	41-45	0.72	76	47	1.03	4.38	45	0.78	1	0.03
	46-50	1.02	58	41	1.34	2.75	50	1.03	3	0.19
	51-55	1.37	69	46	1.13	2.42	55	1.42	6	0.13
	56-60	1.76	54	46	2.22	3.78	48	1.24	2	0.02
	61-65	2.18	61	67	4.18	5.79	59	1.33	15	0.52
	66-70	2.71	47	81	3.68	4.09	74	2.13	30	1.06
	≥71	4.74	43	95	15.58	8.69	74	3.88	19	1.21
Edge of Ground (4Vn) Mar. 1981	≤35	0.31	52	15	0.19	1.78	10	0.12	0	0
	36-40	0.50	80	13	0.15	0.79	45	1.10	0	0
	41-45	0.68	74	34	0.74	3.32	55	1.18	0	0
	46-50	0.98	74	39	0.76	2.35	57	1.43	5	0.18
	51-55	1.34	79	46	1.38	3.17	62	1.87	13	0.23
	56-60	1.79	71	62	2.56	4.25	63	1.65	10	0.46
	61-65	2.29	66	71	2.86	3.65	71	2.65	20	2.32
	66-70	2.71	58	83	4.07	4.58	64	2.52	33	3.43
	≥71	3.78	52	96	7.79	5.37	81	2.79	29	2.08
Ingonish, N.S., (4Vn) May 1981	36-40	0.55	11	45	1.00	5.70	55	1.09	9	0.18
	41-45	0.77	22	73	1.59	6.36	45	0.82	9	0.14
	46-50	1.04	37	65	1.49	4.42	59	2.14	5	0.11
	51-55	1.34	38	63	2.66	5.74	79	2.61	18	0.71
	56-60	1.72	33	61	2.88	5.13	70	2.00	6	0.06
	61-65	2.13	36	64	2.58	3.63	72	1.89	0	0
	66-70	2.54	27	81	4.07	4.55	78	2.63	7	0.11
	≥71	4.72	26	96	13.92	6.91	77	5.23	12	2.65
Frenchmen's Shoal (4Vn) July 1981	31-35	0.38	9	44	0.56	4.64	22	0.56	0	0
	36-40	0.58	33	42	1.03	5.65	12	0.15	0	0
	41-45	0.74	34	59	1.88	7.02	18	0.18	0	0
	46-50	1.03	36	58	2.11	6.29	14	0.39	0	0
	51-55	1.29	36	89	3.83	9.15	44	0.56	0	0
	56-60	1.69	31	84	3.68	6.80	48	0.71	0	0
	61-65	2.13	33	82	9.24	10.80	55	0.94	0	0
	66-70	2.60	38	87	9.32	10.34	45	1.21	3	0.26
	≥71	3.57	33	97	11.24	8.60	76	4.36	18	1.21
Edge of Ground (4Vn) June 1981	≤45	0.65	13	23	0.23	1.12	23	0.54	0	0
	46-50	0.97	46	46	0.98	3.17	26	0.33	0	0
	51-55	1.30	49	51	1.55	3.76	37	0.74	2	0.02
	56-60	1.67	43	49	0.67	1.32	51	1.02	2	0.33
	61-65	2.05	45	62	2.07	3.15	44	0.87	2	0.02
	66-70	2.46	45	73	3.04	3.56	56	1.38	2	0.02
	≥71	3.87	46	87	6.46	4.16	61	2.72	0	0

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[a] Percent of fish infected.

[b] Mean numbers of nematodes per fish.

TABLE 2. Distribution of larval anisakines in the tissues of 4T and 4Vn cod (n = 3,760).

Host length range (cm)	Larval anisakines		Distribution of nematodes in host tissues (%)				
	sp	n	Fillets	Flaps	Liver	Pyloric caecae	Other[a]
≤30	Phocanema	18	94.44	0	0	0	5.55
	Anisakis	7	0	0	57.14	0	42.86
	Contracaecum	0	0	0	0	0	0
31-35	Phocanema	50	96.00	2.00	0	0	2.00
	Anisakis	31	0	0	83.87	6.45	9.68
	Contracaecum	0	0	0	0	0	
36-40	Phocanema	196	97.96	0.51	0	0.51	1.02
	Anisakis	212	1.42	1.89	77.83	13.21	5.66
	Contracaecum	13	0	7.69	0	92.31	0
41-45	Phocanema	457	95.84	1.53	0.44	1.31	0.88
	Anisakis	342	1.45	0.88	78.07	15.50	4.09
	Contracaecum	6	0	0	0	100.00	0
46-50	Phocanema	663	97.44	1.96	0.15	0.30	0.15
	Anisakis	622	1.45	1.13	74.60	19.61	3.22
	Contracaecum	61	0	0	0	95.08	4.92
51-55	Phocanema	943	95.33	3.71	0	0.11	0.85
	Anisakis	946	1.27	1.06	69.45	23.04	5.18
	Contracaecum	136	0	0	0	96.32	3.68
56-60	Phocanema	1202	96.76	2.75	0.08	0.08	0.33
	Anisakis	864	0.69	1.27	69.21	24.31	4.51
	Contracaecum	312	0.32	0	0.32	97.44	0.96
61-65	Phocanema	1591	90.70	5.03	0.63	2.58	1.07
	Anisakis	868	1.15	1.27	60.14	29.84	7.60
	Contracaecum	551	0	0	1.63	89.29	9.07
66-70	Phocanema	1670	91.68	6.41	0.36	0.66	0.90
	Anisakis	773	0.65	1.29	54.20	36.09	7.76
	Contracaecum	550	0	0	0.36	96.36	3.27
≥71	Phocanema	3576	82.24	11.97	1.31	2.63	1.85
	Anisakis	1549	1.23	1.23	41.83	48.81	6.91
	Contracaecum	1120	0	0.09	0.09	98.57	1.25
Totals	Phocanema	10366	89.89	6.80	0.65	1.51	1.15
	Anisakis	6214	1.11	1.21	60.67	31.01	6.00
	Contraceacum	2749	0.04	0.07	0.47	95.93	3.38

[a] Includes unencysted nematodes in the body cavity as well as nematodes encysted on the peritoneum and mesenteries of the stomach, intestines, spleen, gallblader, gonads, etc.

TABLE 3. Variations in abundance of larval anisakines with sex of host 4T and 4Vn cod.

Host			Larval anisakines detected					
			Phocanema		*Anisakis*		*Contracaecum*	
Length range	Sex	n	Prevalence	Abundance	Prevalence	Abundance	Prevalence	Abundance
≤30	m	32	28	0.31	16	0.34	0	0
	f	57	19	0.21	7	0.07	0	0
31-35	m	61	33	0.61	10	0.10	0	0
	f	137	28	0.45	16	0.20	1	0.01
36-40	m	145	34	0.68	29	0.55	3	0.06
	f	237	31	0.53	31	0.56	1	0.03
41-45	m	246	46	1.10	39	0.76	2	0.02
	f	256	40	0.80	41	0.68	0	0
46-50	m	361	43	0.93	44	1.06	4	0.11
	f	325	47	1.19	45	0.91	4	0.06
51-55	m	350	52	1.63	59	1.65	9	0.24
	f	364	51	1.41	52	1.26	7	0.15
56-60	m	286	64	2.58	57	1.45	13	0.59
	f	315	58	2.31	59	1.63	13	0.47
61-65	m	199	71	4.84	65	1.96	15	0.84
	f	264	61	2.83	61	2.06	23	1.55
66-70	m	154	79	4.94	66	2.40	27	1.73
	f	202	73	4.84	59	2.23	26	1.66
≥71	m	130	93	11.81	69	4.03	23	2.93
	f	216	90	10.12	75	4.53	31	3.38
Totals	m	1964	56	2.71	51	1.50	10	0.57
	f	2373	53	2.51	49	1.51	11	0.72

TABLE 4. Three-way ANOVA for variations in abundance of larval anisakines with sex, sample and body length of host 4T and 4Vn cod.

Source of variation	Nematode sp.	Degrees of freedom	Mean square	F[a]
Main effects				
Host sex	*Phocanema*	1	0.081	0.82
	Anisakis	1	0.090	1.16
	Contracaecum	1	0.108	2.54
Host sample	*Phocanema*	12	3.791	38.29****
	Anisakis	12	2.045	26.33****
	Contracaecum	12	1.302	30.46****
Host length	*Phocanema*	6	10.195	102.97****
	Anisakis	6	3.163	40.74****
	Contracaecum	6	2.356	55.15****
Two-way interactions				
Sex x sample	*Phocanema*	12	0.141	1.42
	Anisakis	12	0.067	0.86
	Contracaecum	12	0.056	1.31
Sex x length	*Phocanema*	6	0.073	0.73
	Anisakis	6	0.057	0.74
	Contracaecum	6	0.079	1.86
Sample x length	*Phocanema*	71	0.284	2.87****
	Anisakis	71	0.189	2.43****
	Contracaecum	71	0.277	6.49****
Three-way interactions				
(Sex x sample x length)	*Phocanema*	71	0.119	1.20
	Anisakis	71	0.089	1.14
	Contracaecum	71	0.074	1.74****
Error	*Phocanema*	3,889	0.099	
	Anisakis	3,889	0.078	
	Contracaecum	3,889	0.043	

[a] Significance at P≤0.05*, ≤0.01**, ≤0.001***, and ≤0.0001****.

TABLE 5. Two-way ANOVAs for variations in abundance of larval anisakines with sample and length of host 4T and 4Vn cod and contrasts of samples grouped according to geographic origin and/or season of capture.

		Source of variation					
		Sample means		Host length		Sample means x host length	
Contrast	Nematode species	d.f.	F[a]	d.f.	F[a]	d.f.	F[a]
Two-way ANOVA	*Phocanema*	12	34.01****	6	88.31****	72	2.96****
	Anisakis	12	24.79****	6	37.41****	72	2.74****
	Contracaecum	12	24.72****	6	58.90****	72	7.17****
Inshore vs. offshore	*Phocanema*	1	187.63****	-	-	6	3.01**
	Anisakis	1	0.14	-	-	6	1.01
	Contracaecum	1	12.13****	-	-	6	3.26**
4T inshore vs. offshore	*Phocanema*	1	99.05****	-	-	6	3.52**
	Anisakis	1	4.66*	-	-	6	0.99
	Contracaecum	1	18.16****	-	-	6	2.94**
4T offshore vs. 4Vn offshore (winter)	*Phocanema*	1	2.54	-	-	6	1.66
	Anisakis	1	66.59****	-	-	6	7.95****
	Contracaecum	1	142.25****	-	-	6	20.84****
4Vn offshore (winter) vs. 4Vn offshore (summer)	*Phocanema*	1	4.03*	-	-	6	1.43
	Anisakis	1	7.90**	-	-	6	1.17
	Contracaecum	1	19.31****	-	-	6	3.59**
4Vn offshore (summer) vs. 4Vn inshore (spring and summer)	*Phocanema*	1	68.51****	-	-	6	0.85
	Anisakis	1	17.66****	-	-	6	1.14
	Contracaecum	1	2.11	-	-	6	1.14

[a] Significance at $P \leq 0.05$*, ≤ 0.01*, ≤ 0.001*, and ≤ 0.0001****.

TABLE 6. Abundances of larval anisakines in 4T and 4Vn plaice.

Host				Larval anisakines detected						
				Phocanema			Anisakis		Contracaecum	
Sample	Length range (cm)	Mean weight (kg)	n	Prevalance	Abundance	No. per kg fillet	Prevalence	Abundance	Prevalence	Abundance
Shediac Valley (4T) Nov. 1980	≤30	0.18	57	16	0.19	3.64	0	0	0	0
	31-35	0.29	374	24	0.30	3.79	2	0.02	1	0.03
	36-40	0.42	228	28	0.39	3.38	4	0.04	4	0.10
	41-45	0.64	54	56	1.00	5.65	11	0.13	6	0.94
	≥46	1.21	15	93	2.47	7.42	20	0.27	7	0.20
Pt. Escuminac, N.B., (4T) June 1981	≤30	0.20	56	43	0.77	14.65	2	0.02	0	0
	31-35	0.30	56	50	0.96	11.84	4	0.04	2	0.02
	36-40	0.52	49	45	0.73	4.99	4	0.04	4	0.04
	41-45	0.76	63	59	1.33	6.20	3	0.08	3	0.27
	46-50	1.10	21	90	2.95	9.46	19	0.33	14	0.33
	≥51	1.44	8	100	3.50	5.15	38	2.88	25	2.13
Chéticamp (4T) Nov. 1980	≤25	0.11	93	18	0.35	12.14	1	0.01	0	0
	26-30	0.19	87	32	0.84	16.89	0	0	0	0
	31-35	0.29	33	45	1.00	12.76	0	0	0	0
	≥36	0.83	27	44	1.19	5.37	0	0	4	0.04
Ingonish, N.S., (4Vn) Oct. 1980	31-35	0.32	58	55	2.00	23.43	0	0	0	0
	36-40	0.44	75	53	1.77	15.03	0	0	0	0
	41-45	0.66	68	57	2.38	13.55	0	0	0	0
	46-50	0.96	39	51	1.97	7.59	3	0.03	0	0
	≥51	1.40	21	48	0.81	2.18	0	0	0	0
Edge of Ground (4Vn) Feb. 1981	31-35	0.31	25	32	0.96	11.68	0	0	0	0
	36-40	0.49	34	41	0.91	6.95	3	0.03	0	0
	41-45	0.69	54	63	2.67	14.41	4	0.04	0	0
	46-50	1.01	46	59	2.48	9.22	2	0.02	0	0
	≥51	1.40	41	68	1.71	4.58	2	0.02	0	0

TABLE 7. Distribution (%) of larval anisakines in the tissues of 4T and 4Vn plaice (n = 1681).

Host length range (cm)	Larval anisakines		Distribution (%) of nematodes in host tissues				
	sp	n	Fillets	Encysted on			Unencysted in body cavity
				Liver	Gastro-intestinal mesenteries	Other visceral tissues	
≤ 25	*Phocanema*	36	100.00	-	-	-	-
	Anisakis	1	-	-	-	-	100.00
	Contracaecum	0	-	-	-	-	-
26-30	*Phocanema*	124	98.39	-	-	-	1.61
	Anisakis	1	-	100.00	-	-	-
	Contracaecum	0	-	-	-	-	-
31-35	*Phocanema*	337	98.81	-	-	0.30	0.89
	Anisakis	8	12.50	50.00	12.50	-	25.00
	Contracaecum	13	7.69	-	84.62	-	7.69
36-40	*Phocanema*	300	97.67	-	-	1.00	1.33
	Anisakis	11	9.09	63.64	18.18	-	18.18
	Contracaecum	25	4.00	-	80.00	4.00	12.00
41-45	*Phocanema*	455	98.68	0.22	-	-	1.10
	Anisakis	12	-	50.00	16.67	8.33	25.00
	Contracaecum	69	-	-	97.10	-	2.90
46-50	*Phocanema*	284	97.89	0.70	-	-	1.41
	Anisakis	9	-	88.89	11.11	-	-
	Contracaecum	7	-	-	100.00	-	-
≥ 51	*Phocanema*	135	95.56	2.22	-	0.74	1.48
	Anisakis	26	-	46.15	53.85	-	-
	Contracaecum	20	-	10.00	90.00	-	-
Totals	*Phocanema*	1671	98.14	0.36	-	0.30	1.20
	Anisakis	68	2.94	55.88	29.41	1.47	10.29
	Contracaecum	134	1.49	1.49	91.79	0.75	4.48

TABLE 8. Variations in abundance of larval *Phocanema decipiens* with sex of host 4T and 4Vn plaice.

Host			*Phocanema* detected	
Length range (cm)	Sex	n	Prevalence	Abundance
≤25	m	52	23	0.48
	f	50	14	0.22
26-30	m	93	32	0.68
	f	104	28	0.59
31-35	m	113	38	0.93
	f	426	30	0.54
36-40	m	50	46	1.36
	f	345	35	0.67
41-45	m	21	48	1.52
	f	228	59	1.85
46-50	m	2	50	2.50
	f	118	64	2.36
≥51	m	-	-	-
	f	79	60	1.70
Totals	m	331	36	0.90
	f	1350	41	1.01

TABLE 9. Three-way analysis of variations in abundances of larval *Phocanema* with sex, sample and body length of host 4T and and 4Vn plaice[a].

Source of variation	Degree of freedom	Mean square	F[b]
Main effects			
Host sex	1	0.004	0.09
Host sample	4	0.261	5.70***
Host length	2	0.296	6.47**
Two-way interactions			
Sex x sample	4	0.059	1.28
Sex x length	2	0.022	0.48
Sample x length	8	0.040	0.87
Three-way interaction			
Sex x sample x length	7	0.051	1.12
Error	1204	0.162	

[a] For host length strata ≤40 cm.
[b] Significance at $P \leq 0.05$*, ≤0.01** and ≤0.001***.

TABLE 10. Two-way ANOVAs for variations in abundance of larval anisakines with sample and length of host 4T and 4Vn plaice and contrasts of samples.

Contrast	Nematode species	Sample means		Host length		Sampe means x host length	
		d.f.	F[a]	d.f.	F[a]	d.f.	F[a]
Two-way ANOVA	*Phocanema*	4	3.96**	5	11.30****	20	3.40****
	Anisakis	4	27.58****	5	14.91****	20	9.30****
	Contracaecum	4	11.73****	5	4.41***	20	3.40****
West 4T vs. east 4T and 4Vn	*Phocanema*	1	4.31*	-	-	5	6.84****
	Anisakis	1	90.63****	-	-	5	22.69****
	Contracaecum	1	31.81****	-	-	5	6.78****
West 4T, inshore vs. offshore	*Phocanema*	1	9.94**	-	-	5	0.93
	Anisakis	1	9.94**	-	-	5	3.57*
	Contracaecum	1	9.84**	-	-	5	3.41**
4T vs. 4Vn	*Phocanema*	1	0.16	-	-	5	4.08**
4T inshore vs. offshore	*Phocanema*	1	1.28	-	-	5	1.39
Pt. Escuminac, N.B., (4T) vs. Cheticamp, N.S., (4T)	*Phocanema*	1	8.89**	-	-	5	1.71
Cheticamp (4T) vs. Ingonish, N.S., (4Vn)	*Phocanema*	1	0.92	-	-	5	0.69
Cheticamp-Ingonish vs. 4Vn offshore	*Phocanema*	1	0.20	-	-	5	1.57

[a] Significance at $P \leq 0.05^{*}$, $\leq 0.01^{**}$, $\leq 0.001^{***}$ and $\leq 0.0001^{****}$.

TABLE 11. Larval anisakines in 4Vn witch.[a]

Host				*Phocanema* detected		
Sample	Length range (cm)	Mean weight (kg)	n	Prevalence	Abundance	No. per kg fillet
Ingonish Oct. 1980	31-35	0.25	33	6	0.06	0.91
	35-40	0.41	99	10	0.16	1.22
	41-45	0.58	135	18	0.19	1.25
	46-50	0.83	49	43	0.53	2.11
	≥51	1.12	8	50	0.88	2.92
Edge of Ground Feb. 1980	≤40	0.29	55	2	0.02	0.24
	41-45	0.50	66	12	0.12	0.90
	46-50	0.73	56	16	0.21	1.10
	≥51	1.08	19	26	0.32	1.10
Edge of Ground Mar. 1981	≤35	0.22	45	0	0	0
	35-40	0.36	55	2	0.04	0.37
	41-45	0.49	65	11	0.12	0.92
	46-50	0.76	39	26	0.28	1.39
	≥51	1.04	9	67	1.78	6.38

[a] Single *Anisakis* larvae were found in the Cape Smokey and the Edge of Ground (Feb. 1980) samples; both larvae occurred in the body cavity.

TABLE 12. Variations in abundance of larval *Phocanema decipiens* with sex of host 4Vn witch.

Host			Larval *Phocanema* detected	
Length range (cm)	Sex	n	Prevalence	Abundance
≤35	m	41	2	0.02
	f	45	2	0.02
36-40	m	114	5	0.10
	f	87	7	0.09
41-45	m	102	19	0.21
	f	163	12	0.13
46-50	m	35	23	0.40
	f	108	30	0.32
≥51	m	3	33	0.33
	f	33	42	0.85
Totals	m	295	12	0.16
	f	436	17	0.21

TABLE 13. Two- and three-way analyses of variations in abundances of *Phocanema decipiens* with sex, sample and length of host 4Vn gray sole.

Source of variation	Degree of freedom	Mean square	F^a
Three-way ANOVA main effects			
Host sex	1	0.003	0.22
Host sample	2	0.120	8.25***
Host length	4	0.217	14.96****
Two-way interactions			
Sex x sample	2	0.021	1.47
Sex x length	4	0.003	0.22
Sample x length	8	0.054	3.69***
Three-way interaction	6	0.005	0.37
Error	703	0.015	
Two-way ANOVA main effects			
Host sample	2	0.131	9.06****
Host length	4	0.365	25.30****
Two-way interaction			
Sample x length	8	0.057	3.92***
Error	717	0.014	

[a] Significance at $P \leq 0.05$*, ≤ 0.01**, ≤ 0.001*** and ≤ 0.0001****.

TABLE 14. Migrant adults and fourth-stage larvae of *Hysterothylacium aduncum* in the body cavity and flesh of 4T and 4Vn cod.

Host		*Hysterothylacium* detected	
Length range (cm)	n	Prevalence	Average no.
≤30	95	7	0.13
31-35	201	8	0.23
36-40	386	8	0.09
41-45	504	7	0.09
46-50	686	8	0.10
51-55	714	11	0.19
56-60	601	11	0.15
61-65	471	8	0.16
66-70	356	8	0.11
≥71	353	12	0.24
Totals	4367	9	0.15

TABLE 15. Larval anisakines in viscera and flesh of freshly eviscerated cod and round cod.

Host				*Hysterothylacium* detected			
Time[a] (hr)	n	Mean length (cm)	Mean weight (kg)	Sp	Prevalence	Abundance	% in flesh
0	187	55	1.51	*P. decipiens*	49	2.18	99.51
				Anisakis sp	26	0.70	3.05
6	49	55	1.42	*P. decipiens*	45	1.33	98.46
				Anisakis sp	20	0.88	0
12	48	54	1.45	*P. decipiens*	33	1.21	98.27
				Anisakis sp	50	1.27	3.28
24	50	55	1.53	*P. decipiens*	40	0.96	97.92
				Anisakis sp	34	1.10	1.82

[a] Hours elapsed between time fish were caught and time they were eviscerated.

TABLE 16. Abundances of larval anisakines in the viscera and flesh of gutted and round cod (50-60 cm length range) from Scatari Bank (4Vn), October 1981.

		Gutted cod (n = 56; mean weight = 1.54 kg)		Round cod (n = 57; mean weight = 1.53 kg)		Control (n = 51; mean weight = 1.55 kg)	
		Phocanema	Anisakis	Phocanema	Anisakis	Phocanema	Anisakis
Larval anisakines detected by destruction of flesh	Prevalence	55	41	77	42	63	53
	Abundance	2.07	0.66	3.11	0.81	2.06	1.51
	No. per kg fillet	4.02	0.04	6.36	0.07	4.10	0.20
	% in fillets	95	3	99	4	98	6
	% in flaps	5	5	1	4	1	0
	% in viscera	0	92	1	91	1	94
Larval anisakines detected after digestion of flesh	Prevalence	61	50	81	49		
	Abundance	2.36	0.77	3.63	0.96		
	No. per kg fillet	4.50	0.11	7.37	0.29		
	% in fillets	93	7	98	15		
	% in flaps	7	14	2	9		
	% in viscera	0	79	0	76		
	No. detected by digestion as % of total no. in flesh	12	67	14	69		
	No. detected by digestion as % of total no.	12	14	14	16		

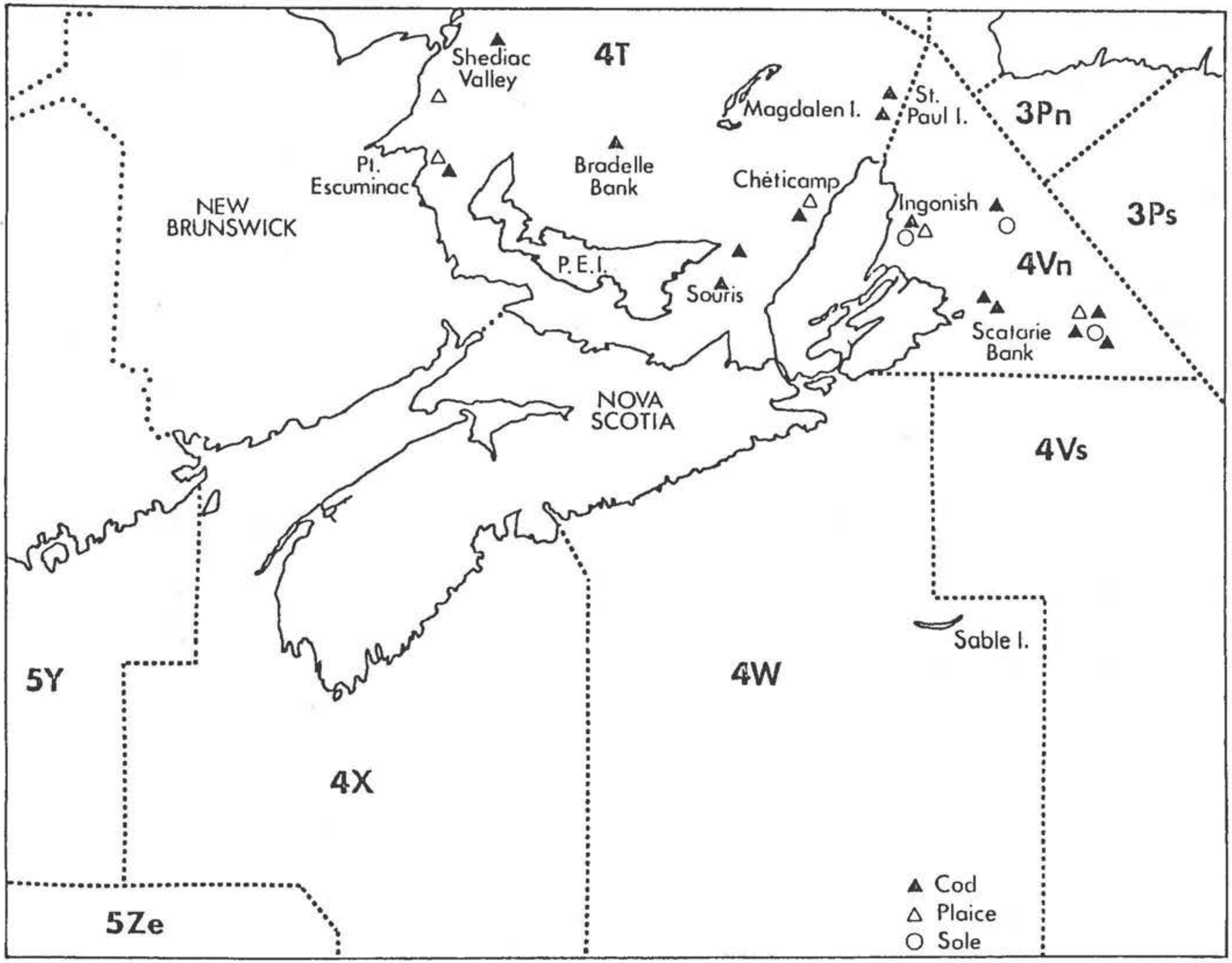

FIG. 1. Sampling locations.

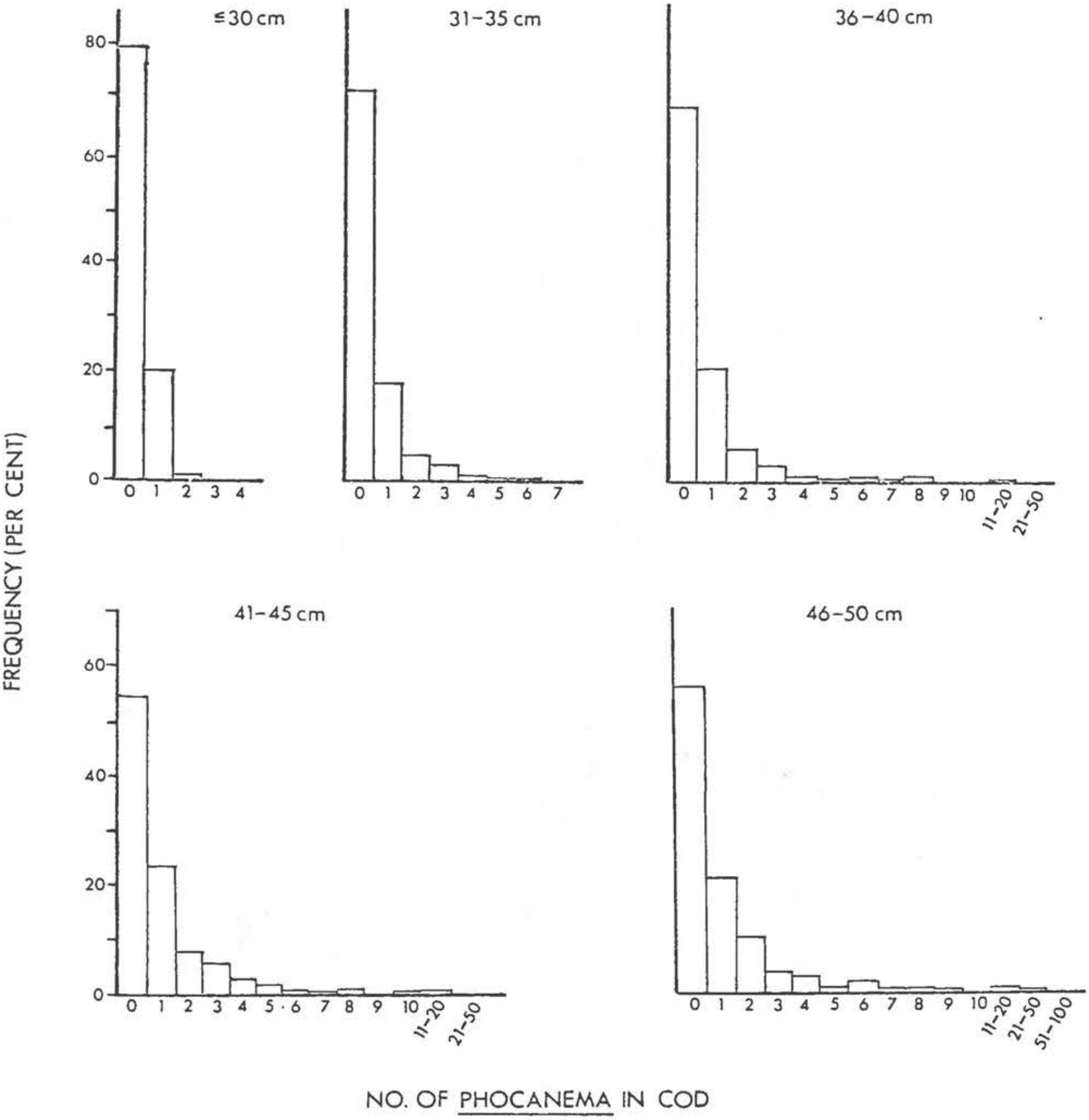

FIG. 2. Frequency distributions of worm counts for Phocanema decipiens in 4T and 4Vn cod: cod stratified into 5-cm length groups.

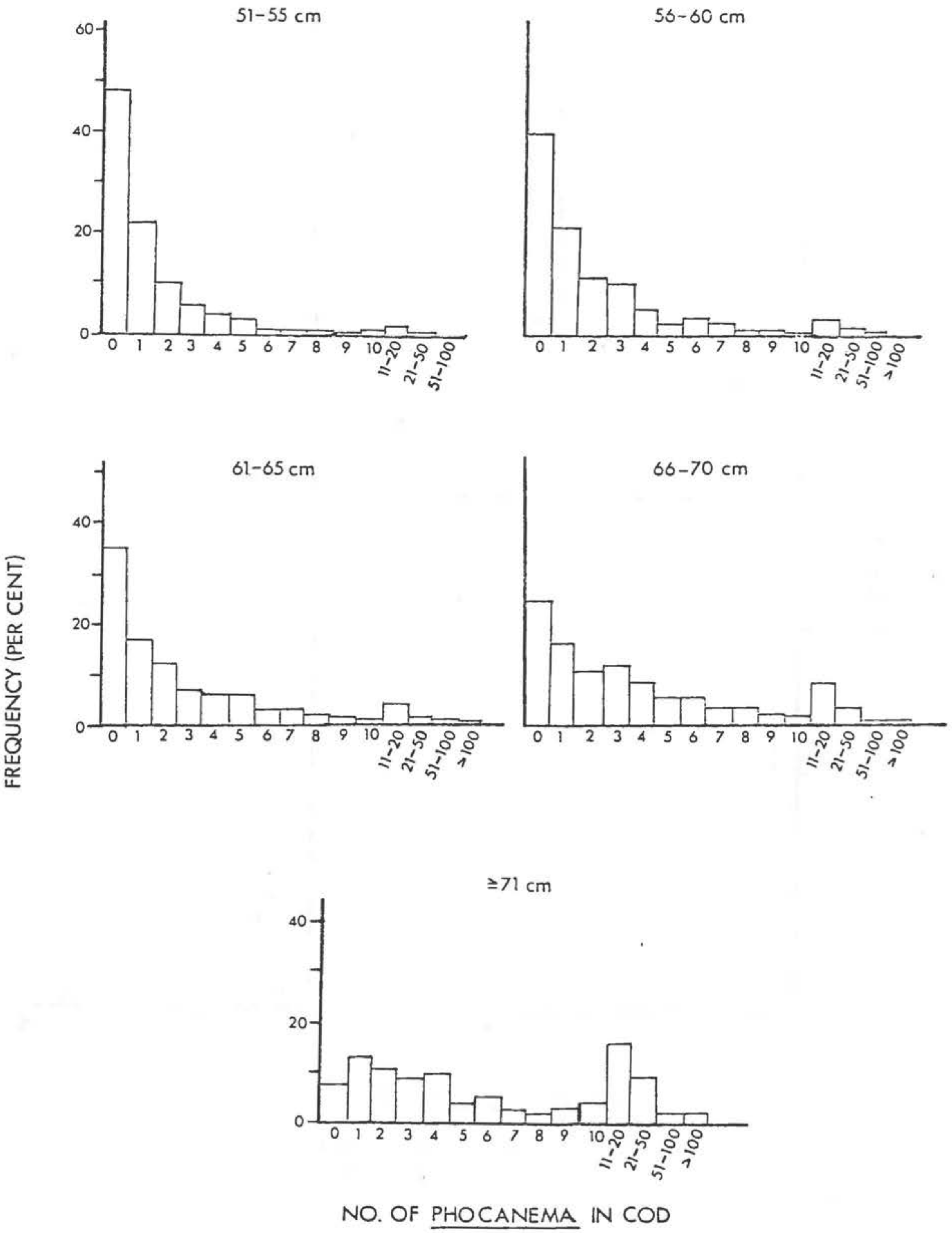

FIG. 2. Continued.

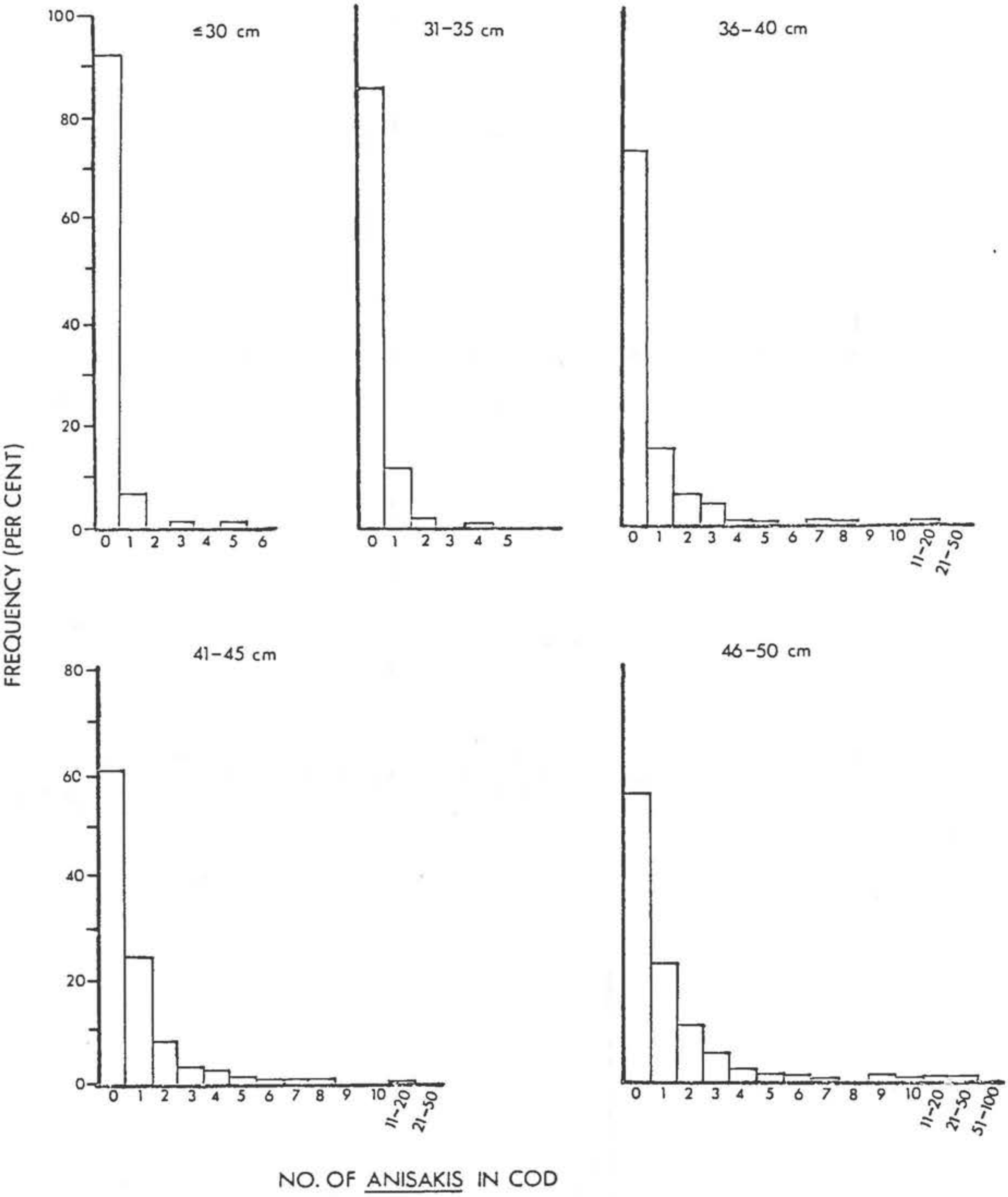

FIG. 3. Frequency distributions of worm counts for Anisakis sp. in 4T and 4Vn cod: cod stratified into 5-cm length groups.

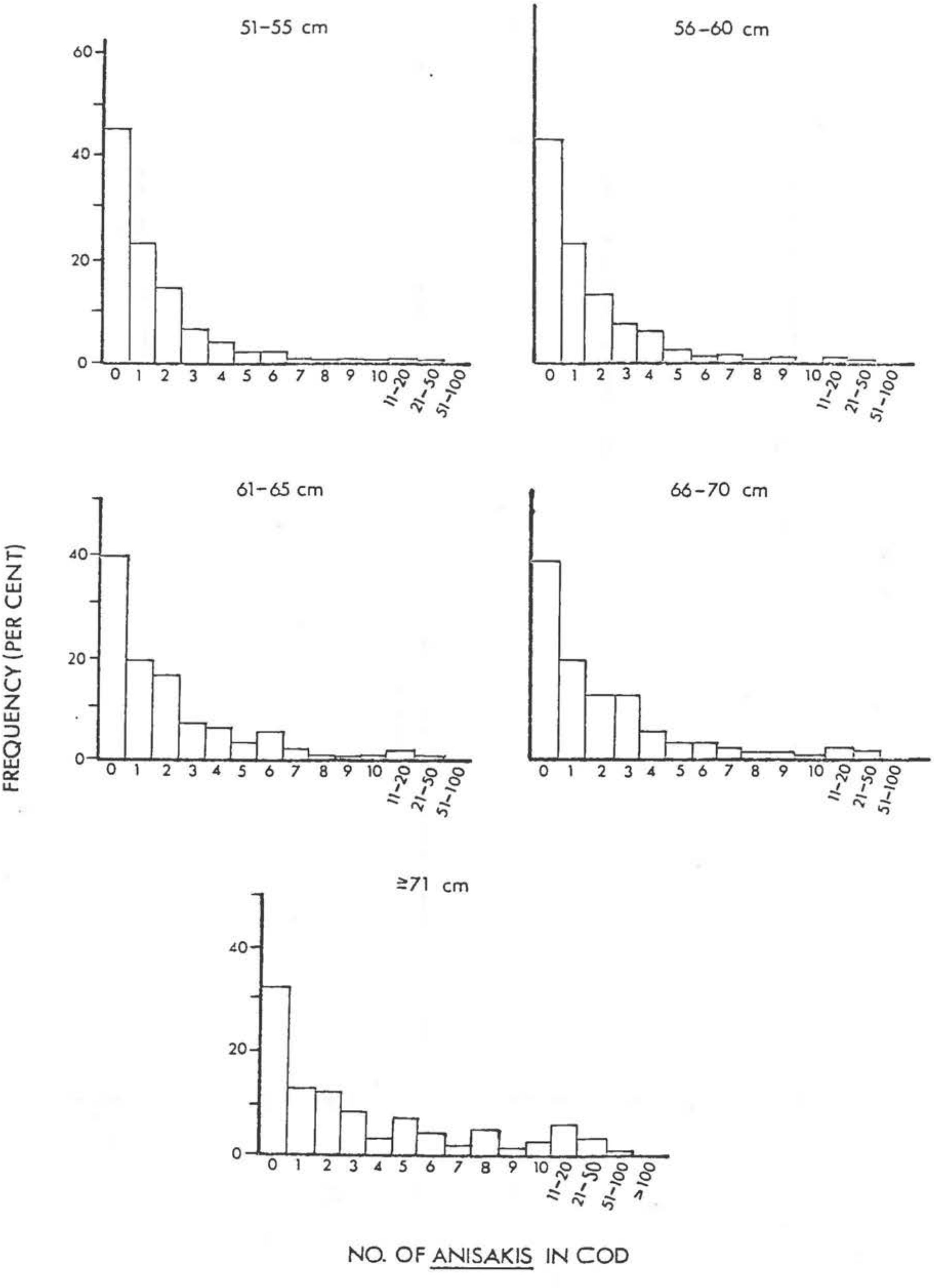

FIG. 3. Continued.

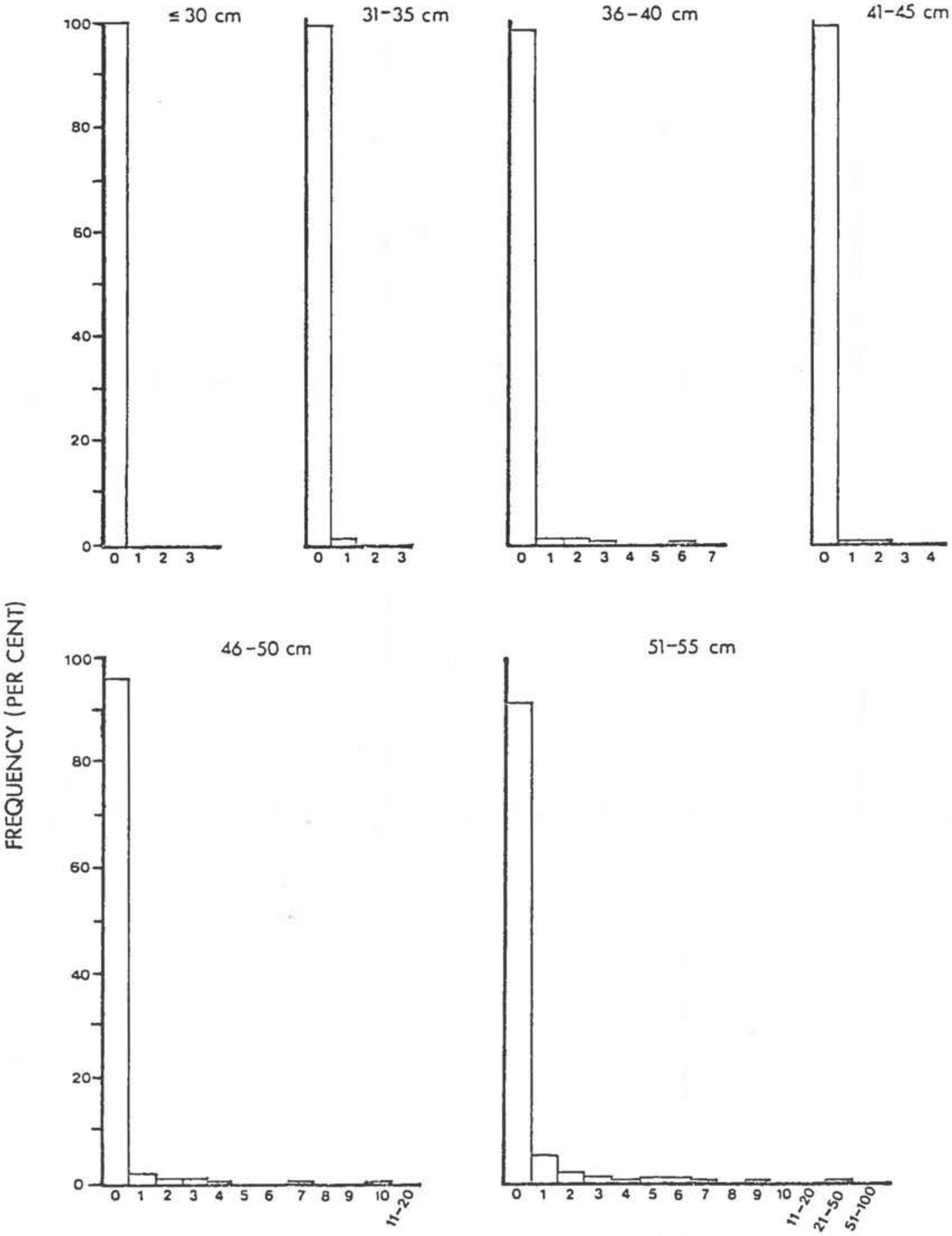

FIG. 4. Frequency distributions of worm counts for *Contracaecum* (*Phocascaris*) sp. in 4T and 4Vn cod: cod stratified into 5-cm length groups.

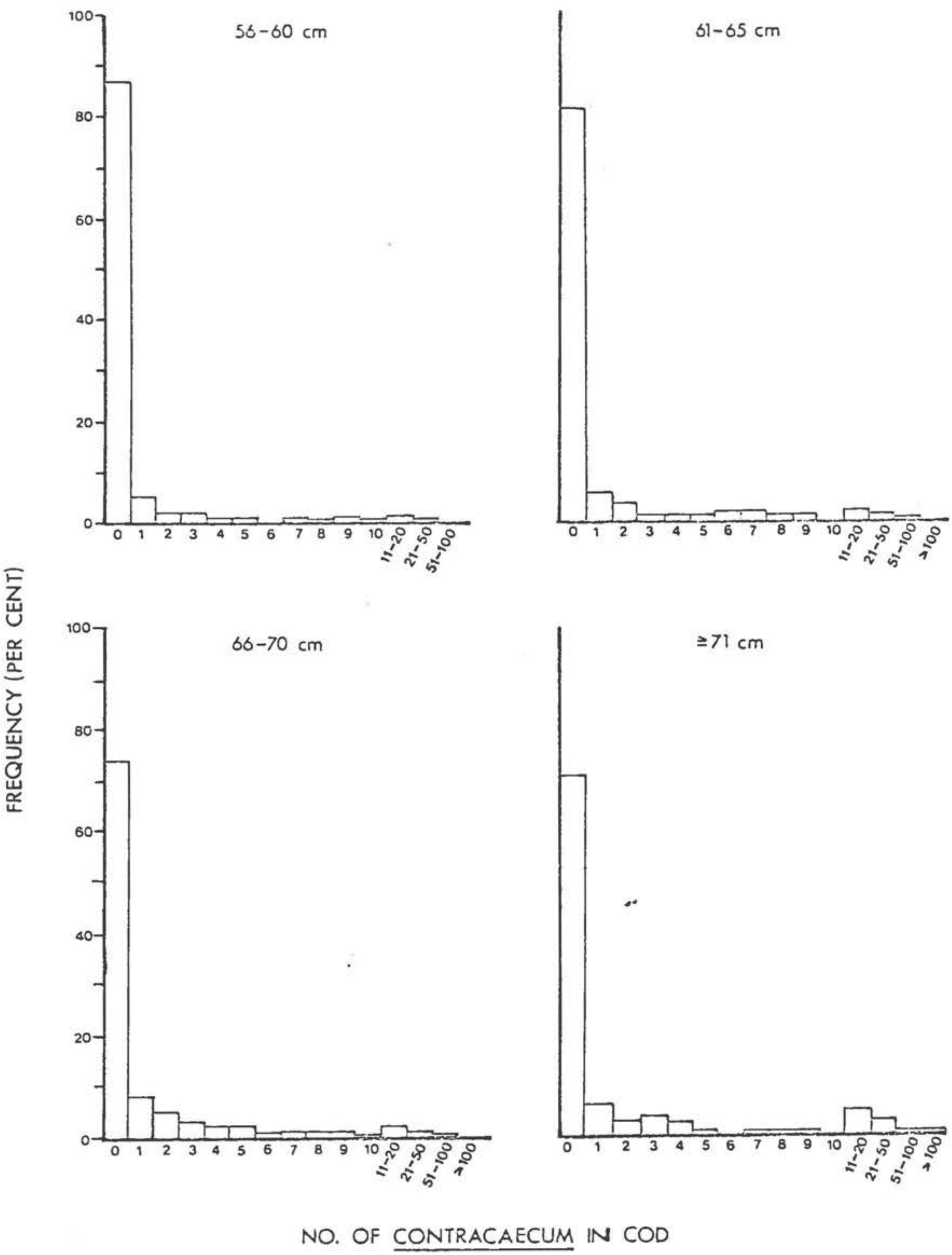

FIG. 4. Continued.

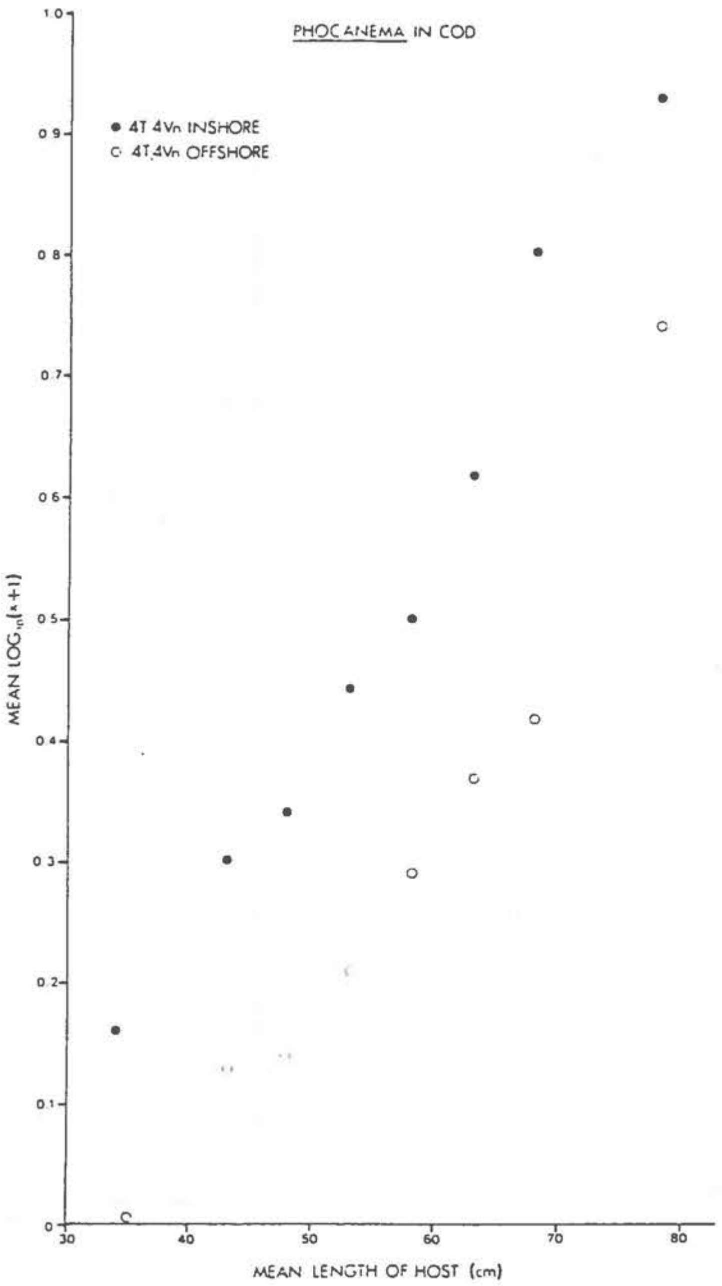

FIG. 5. Mean transformed counts of Phocanema decipiens versus mean host length in 5-cm length groups of 4T and 4Vn cod.

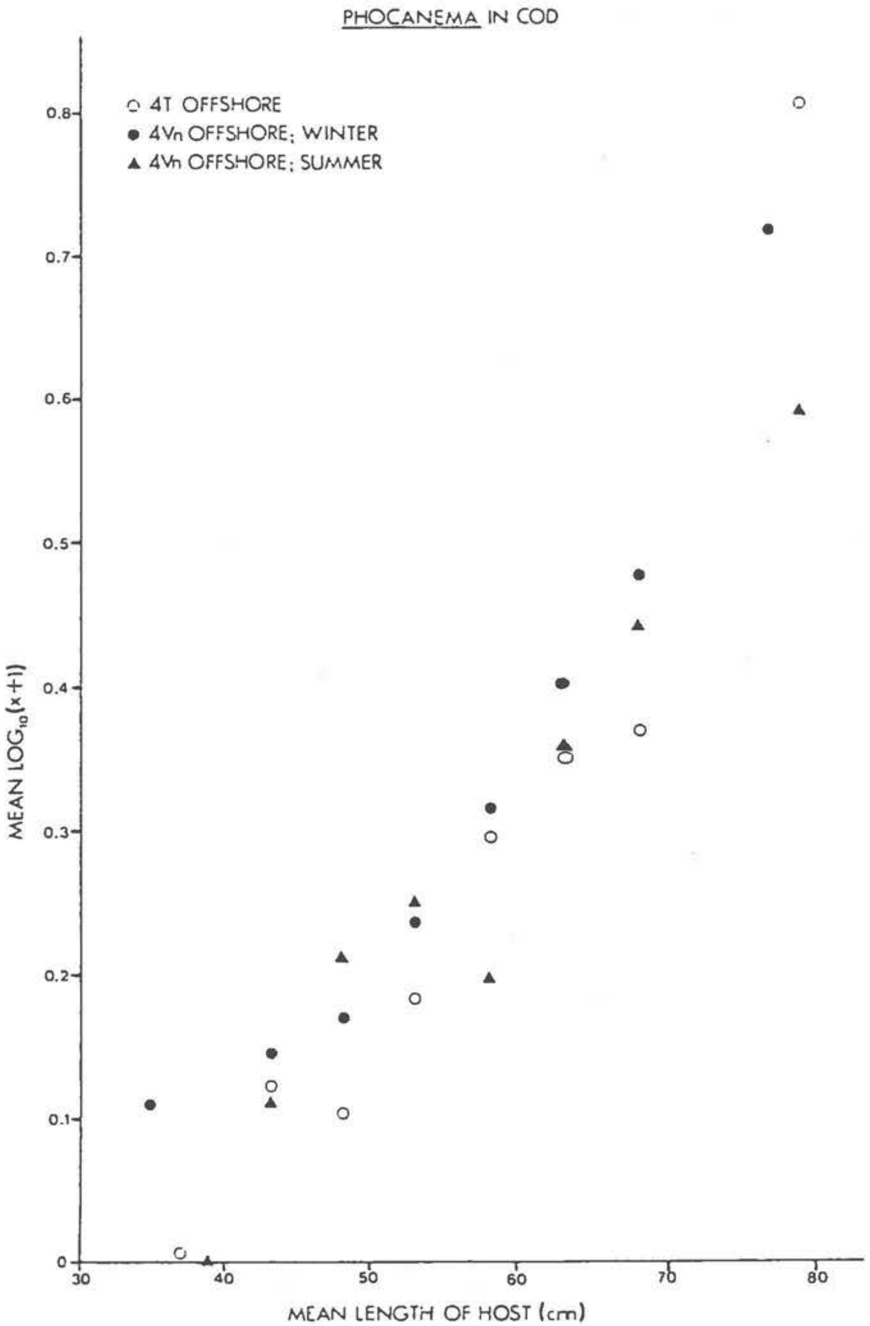

FIG. 5. Continued.

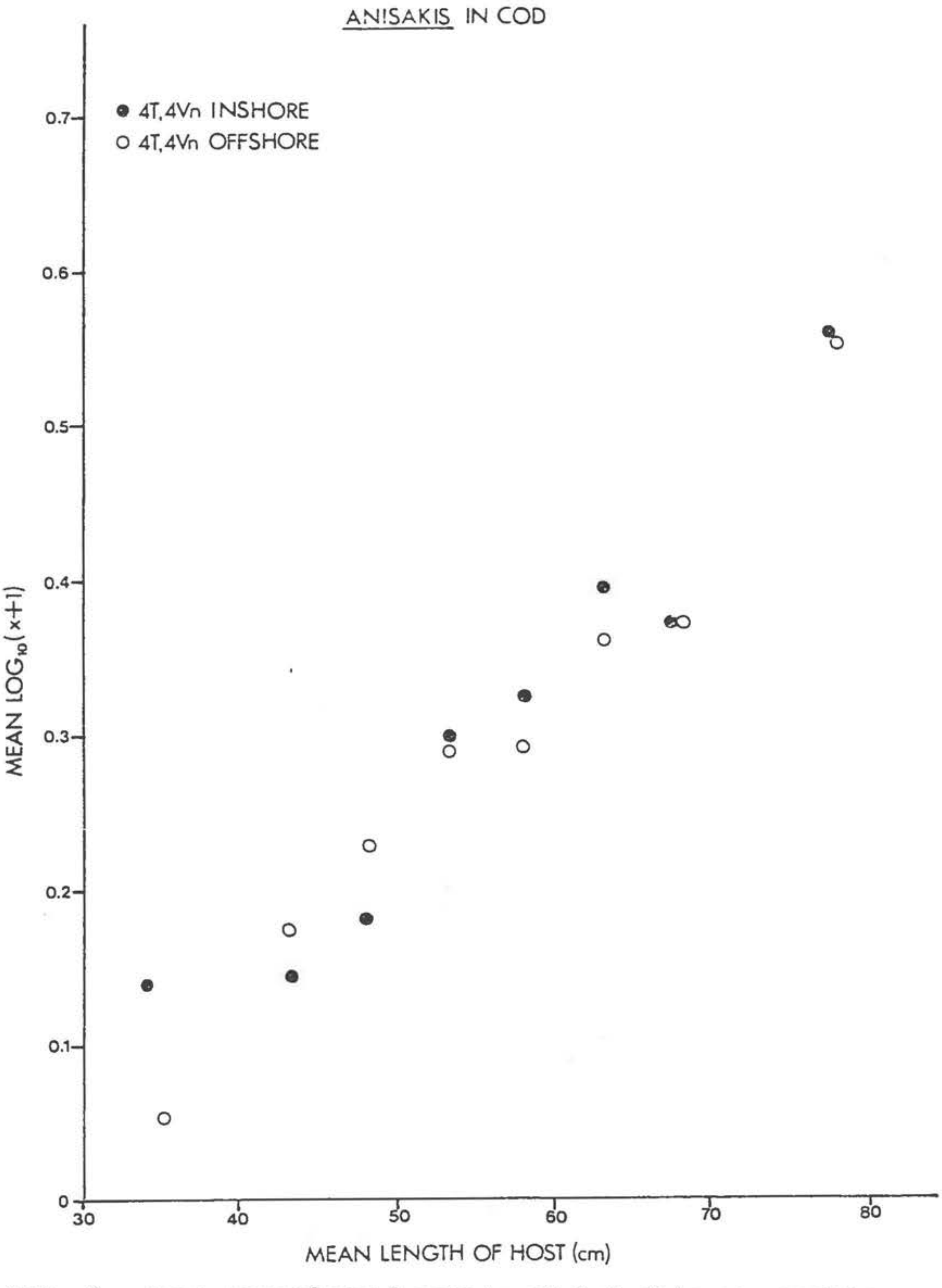

FIG. 6. Mean transformed counts of Anisakis sp. versus mean host length in 5-cm length groups of 4T and 4Vn cod.

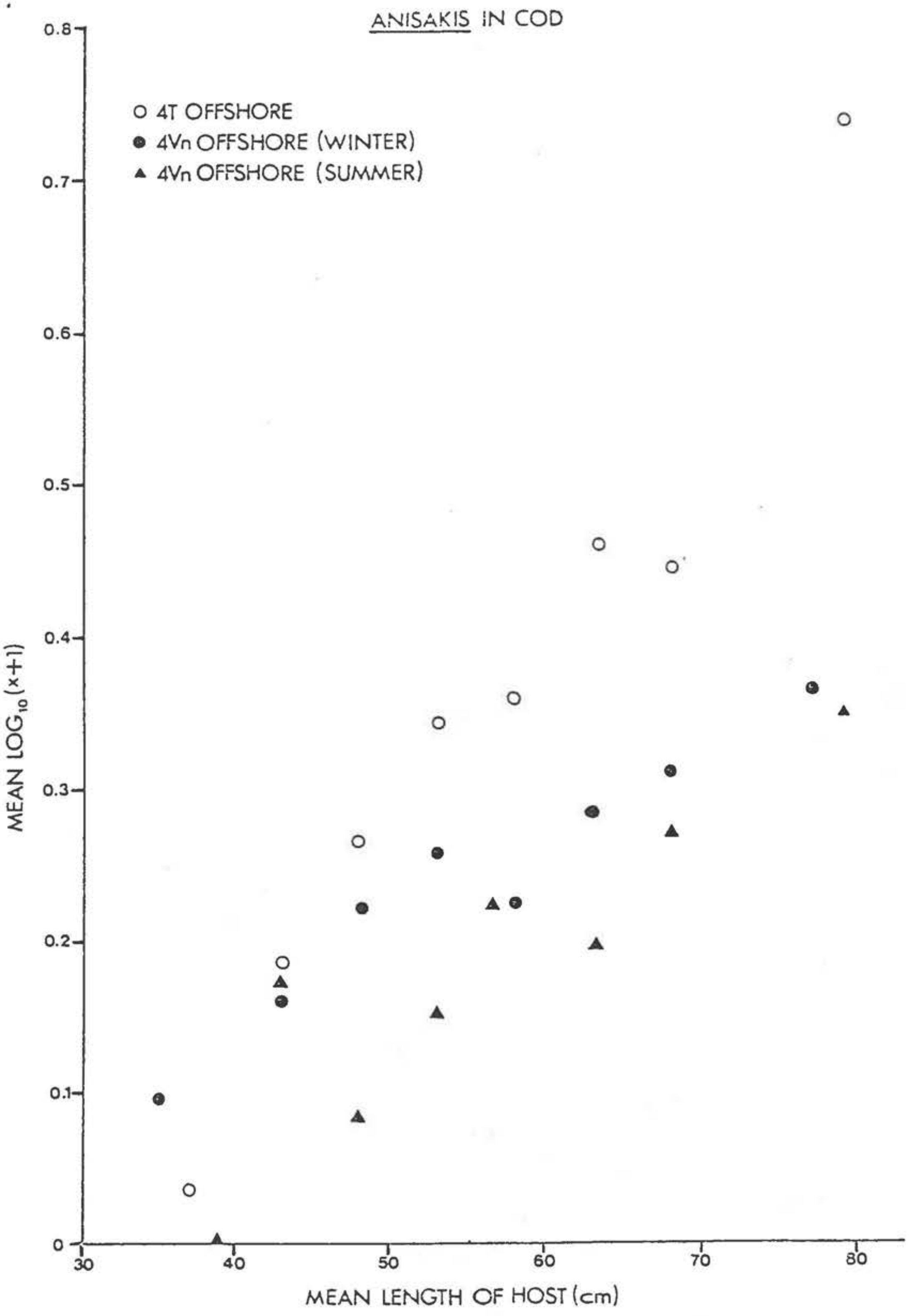

FIG. 6. Continued.

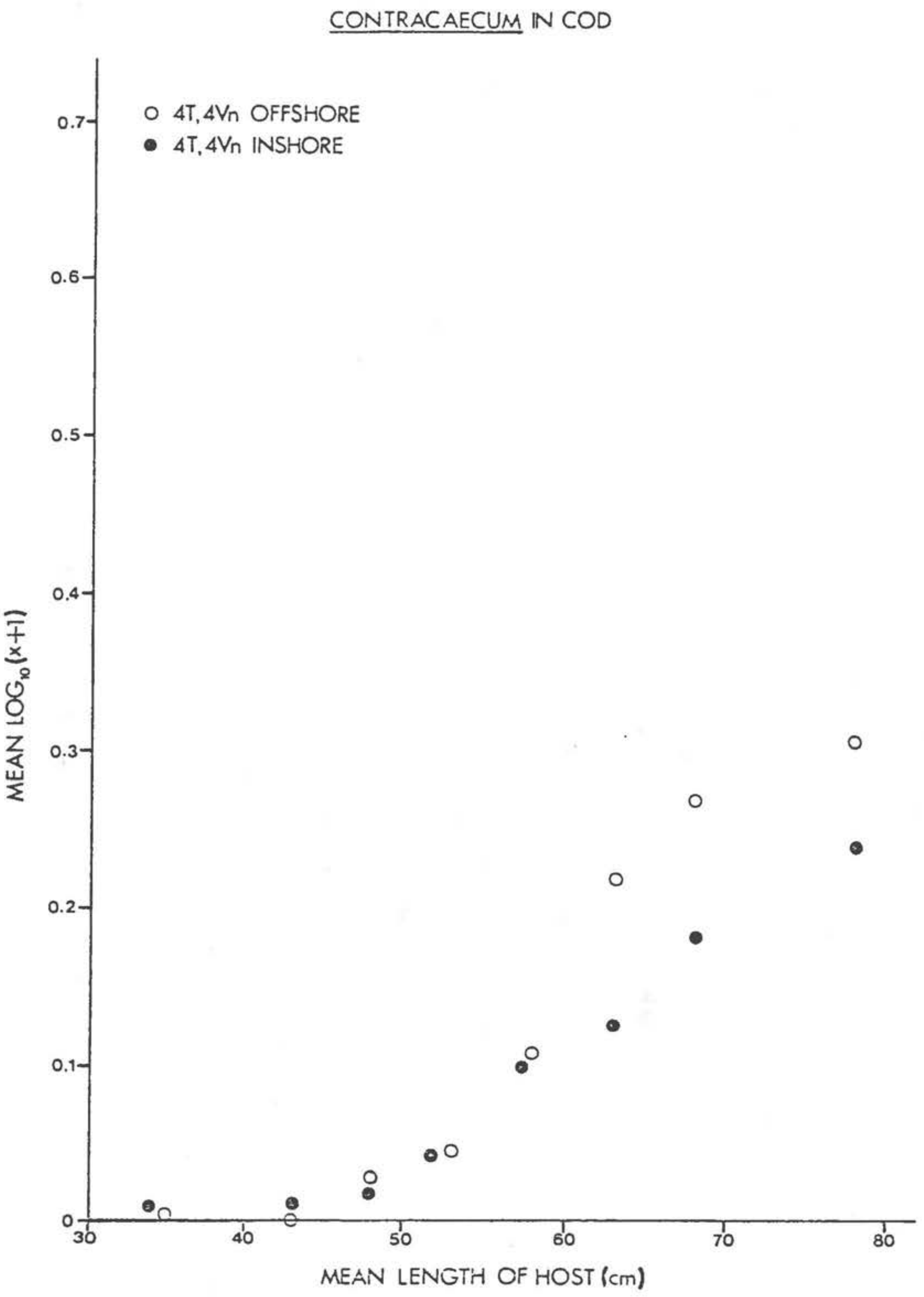

FIG. 7. Mean transformed counts of Contracaecum (Phocascaris) sp. versus mean host length in 5-cm length groups of 4T and 4Vn cod.

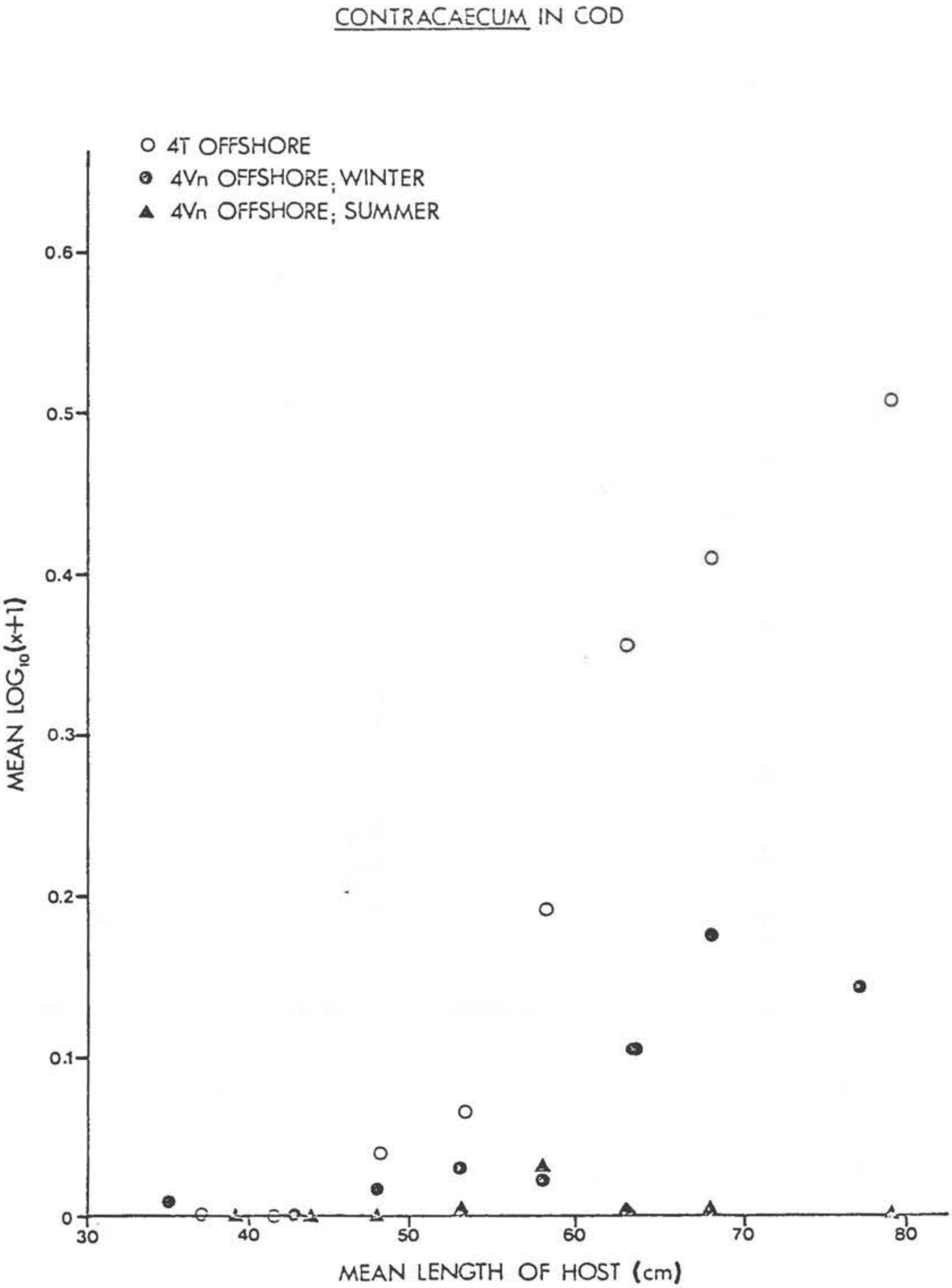

FIG. 7. Continued.

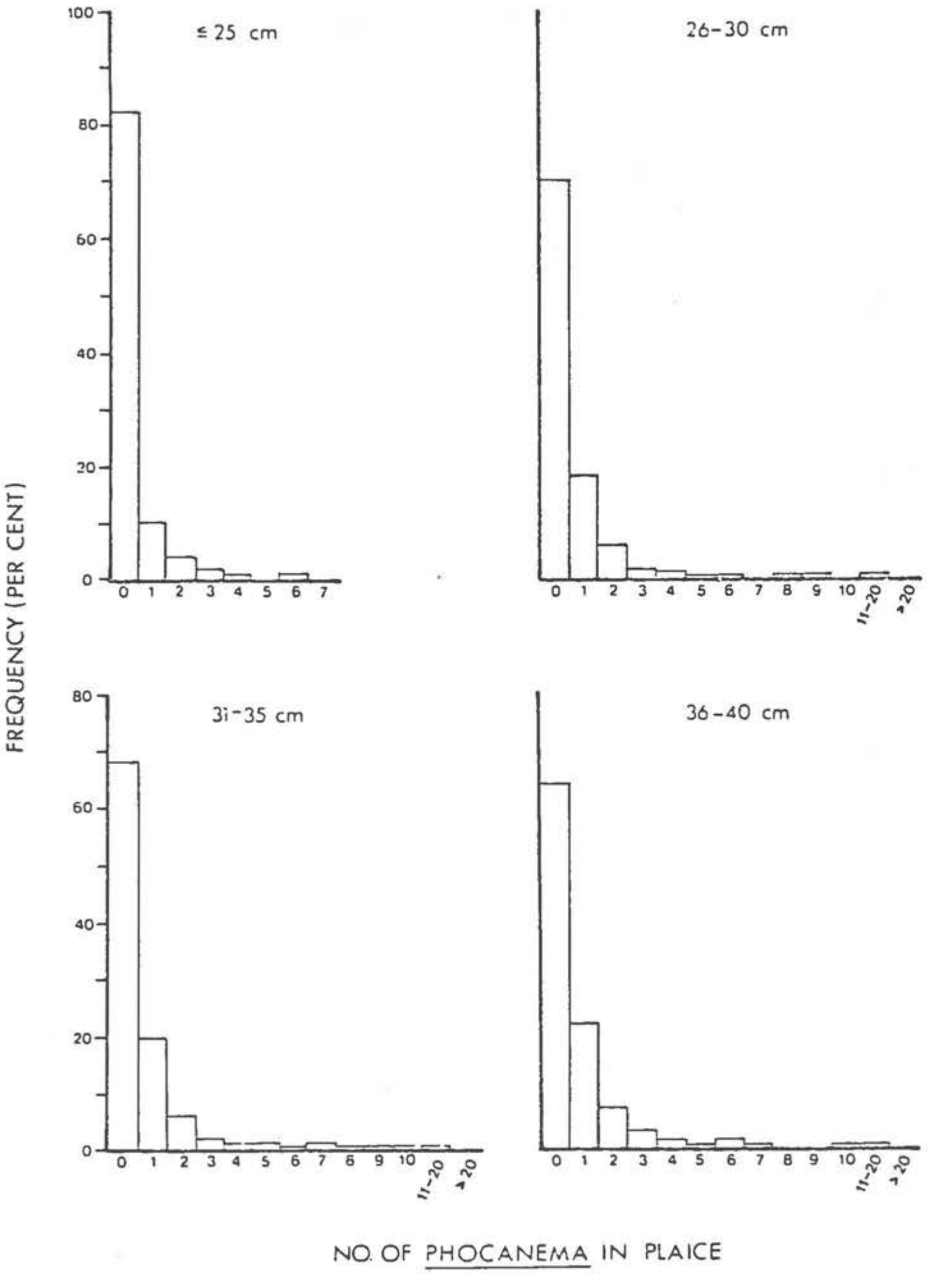

FIG. 8. Frequency distributions of worm counts for <u>Phocanema decipiens</u> in 4T and 4Vn plaice: plaice stratified into 5-cm length groups.

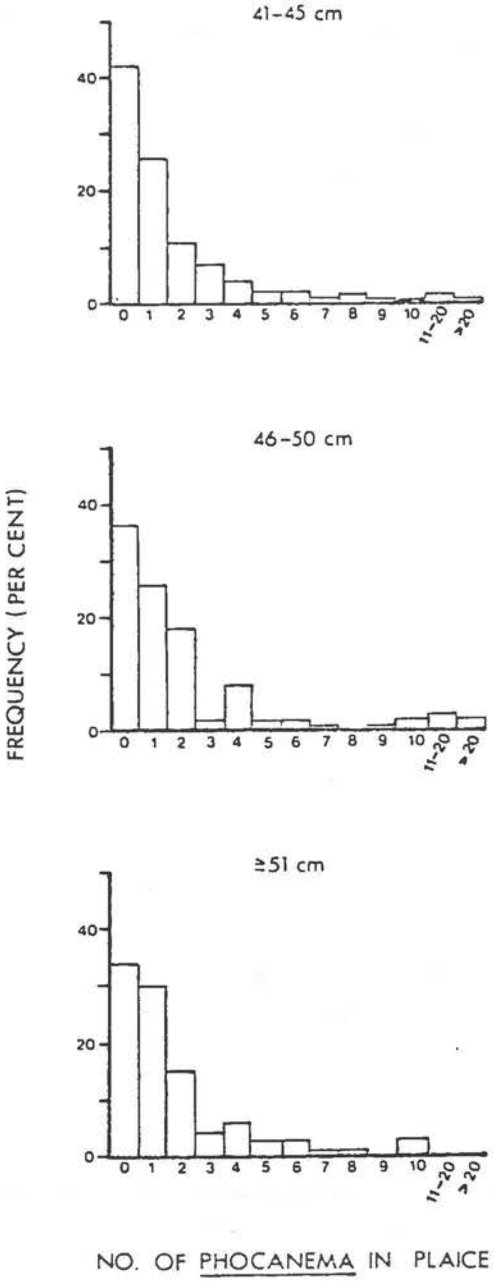

FIG. 8. Continued.

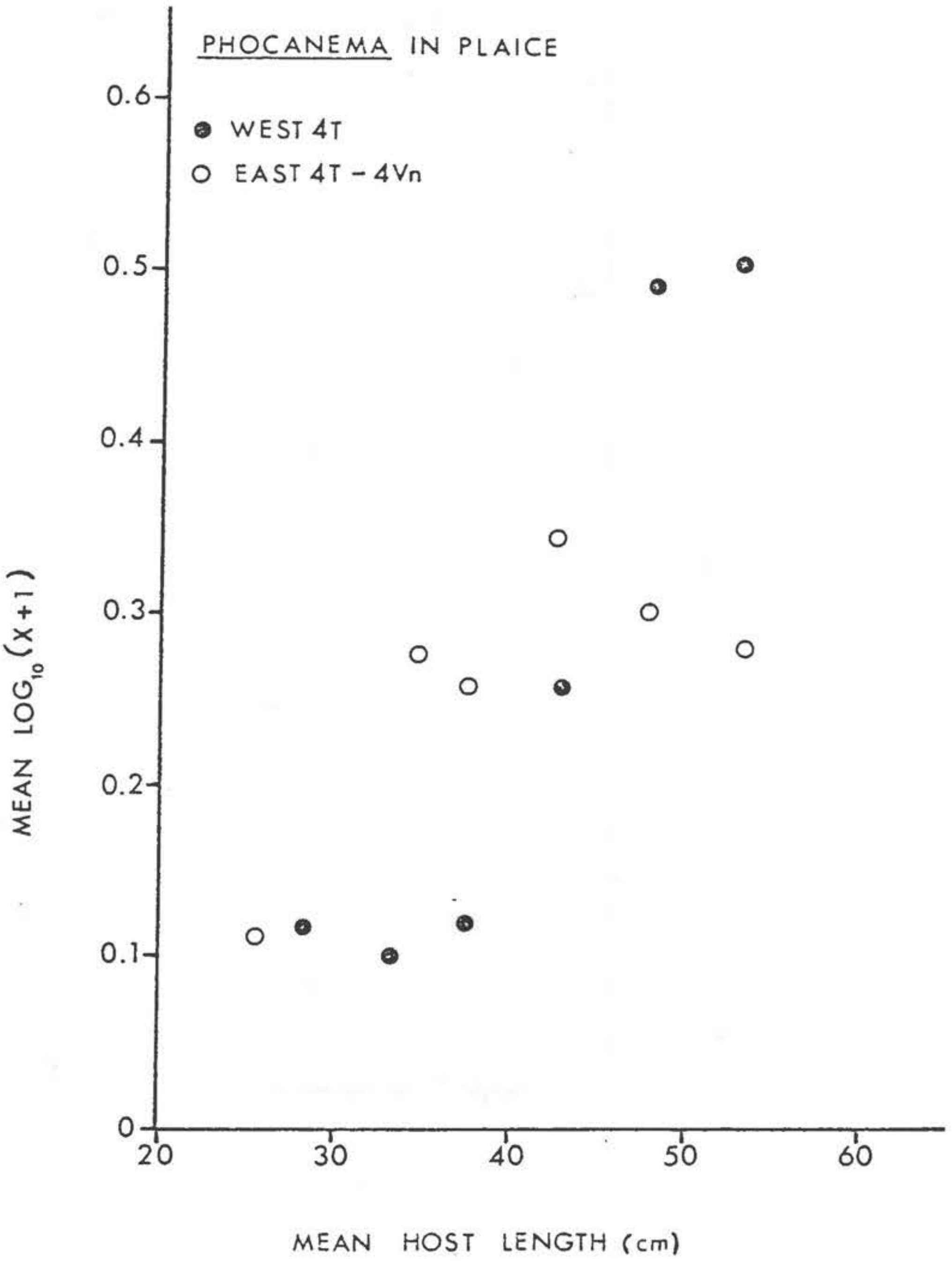

FIG. 9. Mean transformed counts of Phocanema decipiens versus mean host length in 5-cm length groups of 4T and 4Vn plaice.

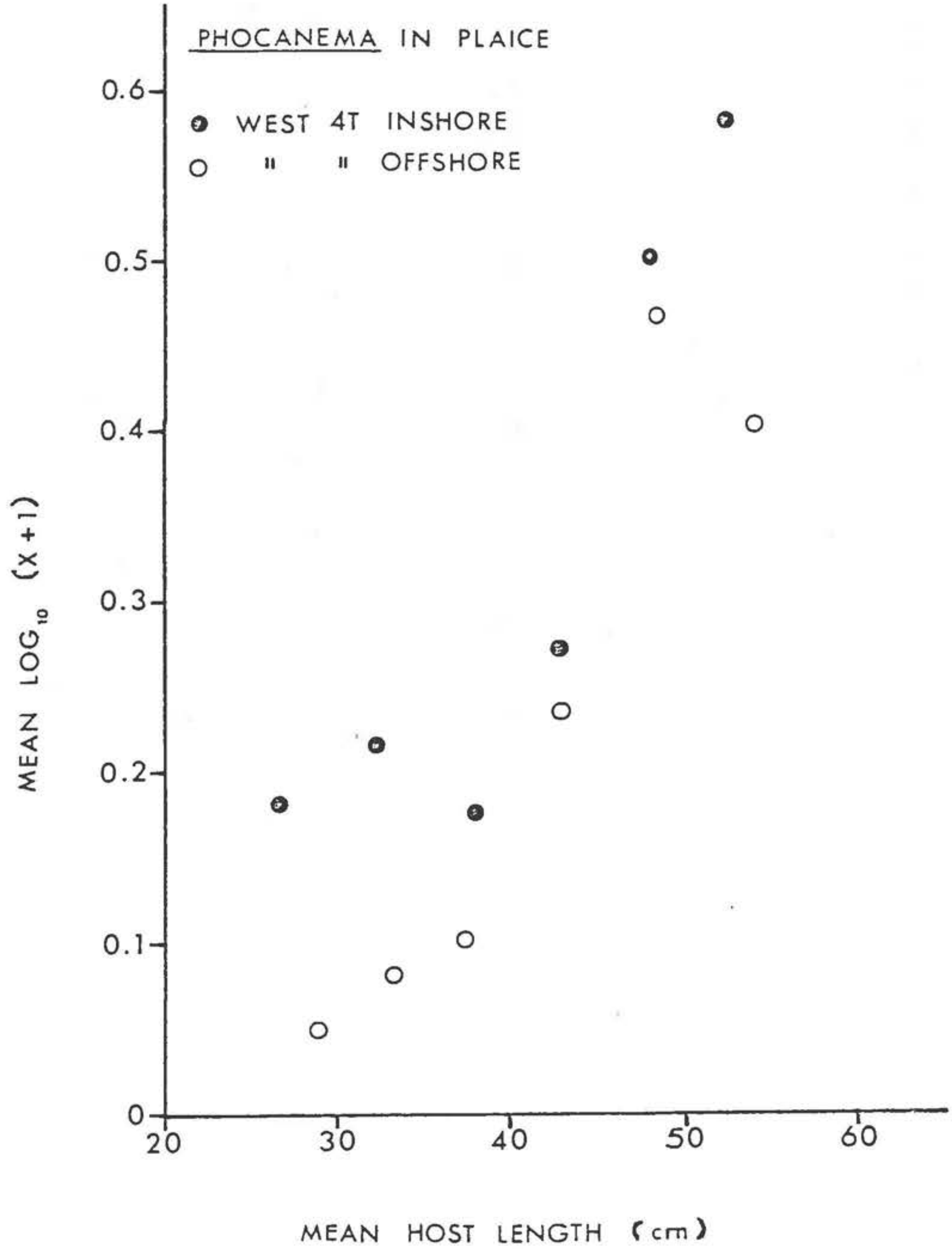

FIG. 9. Continued.

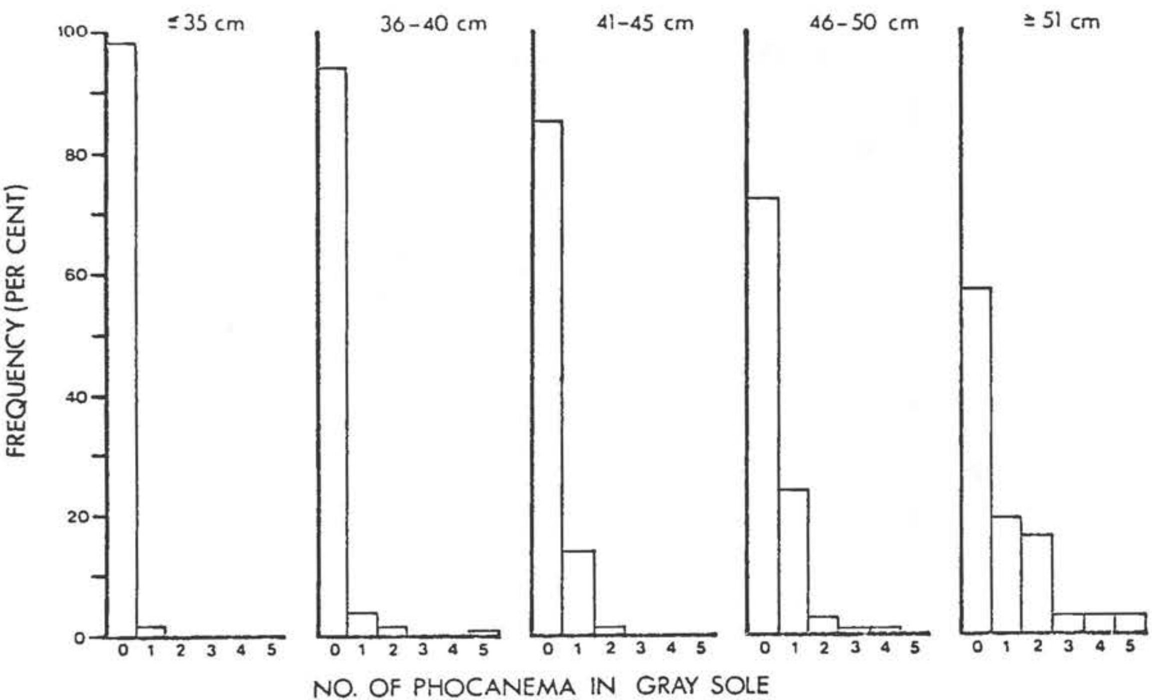

FIG. 10. Frequency distributions of worm counts for *Phocanema decipiens* in 4Vn witch (gray sole): witch stratified into 5-cm length groups.

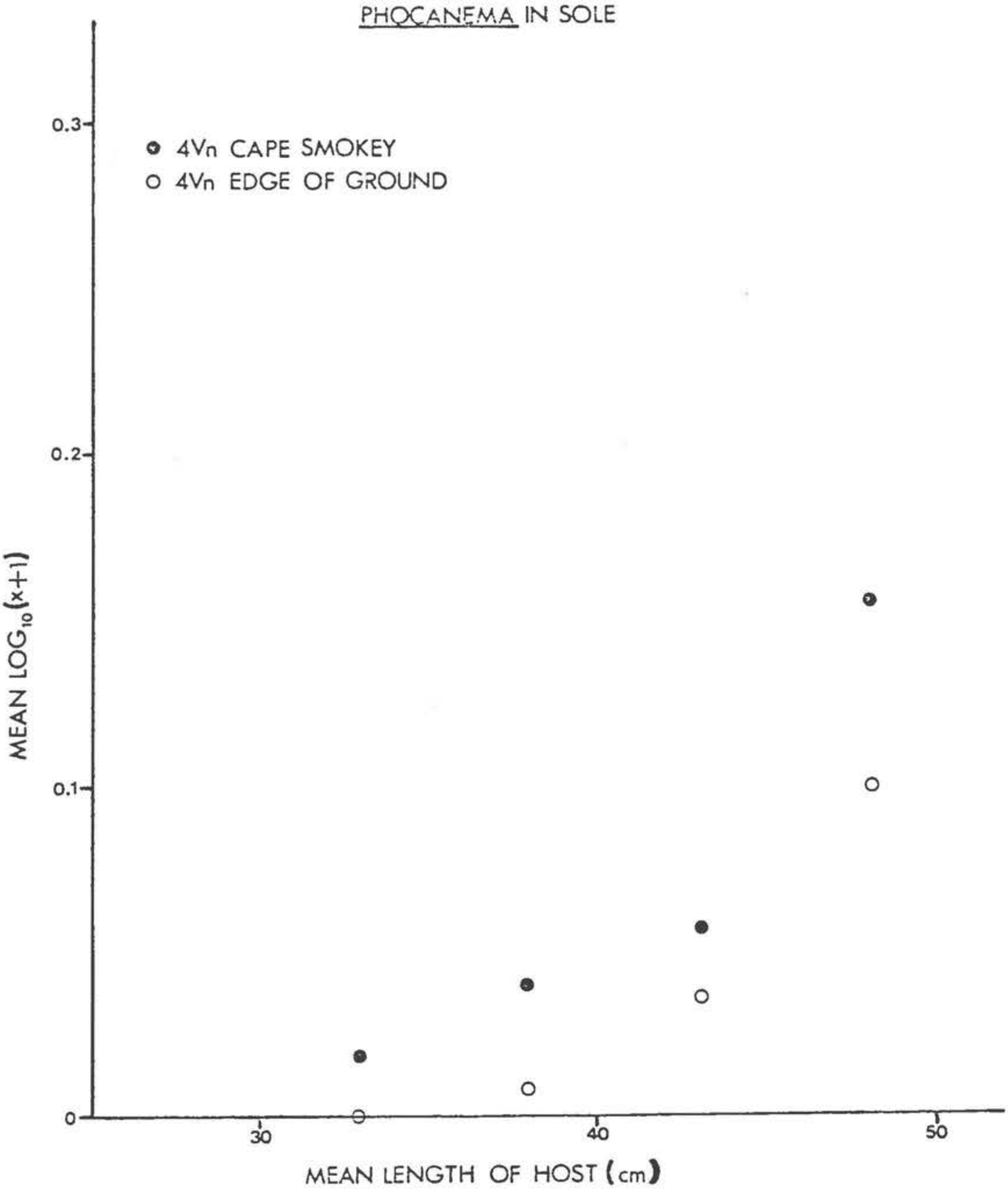

FIG. 11. Mean transformed counts of Phocanema decipiens versus mean host length in 5-cm length groups of 4Vn witch (gray sole).

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VARIATIONS IN ABUNDANCE OF LARVAL ANISAKINES, SEALWORM (PHOCANEMA DECIPIENS) AND RELATED SPECIES IN SCOTIAN SHELF (4Vs and 4W) COD AND FLATFISH

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ABSTRACT

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Larval anisakine infections in Scotian Shelf (4Vs) cod (*Gadus morhua*), plaice (*Hippoglossoides platessoides*), sole (*Glyptocephalus cynoglossus*), and yellowtail (*Limanda ferruginia*) were surveyed between February and November, 1982. Sealworm (*Phocanema decipiens*) occurred primarily in the fillets (86%) of cod, although many were found in the flaps (11%) and body cavity (3%); in flatfish, 98% of the worms occurred in the fillets. *Anisakis* sp. larvae were encysted on the liver and visceral mesenteries, but a few (<3%) were found in the flesh. In most cod and flatfish samples, prevalence and abundance of larval anisakines increased with host length. This trend was not apparent, however, for sealworm infestations in plaice and yellowtail samples from west Banquereau Bank (4Vs) and 4W. Sealworm was more numerous in 4W cod and flatfish than in 4Vs samples; worm abundance increased with proximity to Sable Island. *Anisakis* sp. larvae were most numerous in cod from the "outer" banks (Banquereau, Sable Island, and Western Banks); infestations in 4Vs (Banquereau Bank) samples were, however, similar to those in 4W (Sable Island and Western Bank) samples. Variations in abundance of larval anisakines with host length and geographic origin were highly significant. Geographical variations in sealworm abundance in cod and plaice were similar although the prevalence and abundance in plaice ≤50 cm in length were greater than in cod of similar length. Plaice in this length range had more worms per unit fillet weight than all grades of cod. Sealworm abundances in the 1982 samples were considerably greater than those found in 4Vs and 4W cod and flatfish 25 years ago.

Key words: Sealworm, *Phocanema decipiens*, *Anisakis* sp., nematodes, parasitic, anisakine, cod, *Gadus morhua*, American plaice, *Hippoglossoides platessoides*, gray sole, *Glyptocephalus cynoglossus*, yellowtail flounder, *Limanda ferruginea*, Scotian Shelf, prevalence, abundance, variations, geographic, host length, and host sex.

RÉSUMÉ

McClelland, G., R.K. Misra, and D.J. Marcogliese. 1983. Variations in abundance of larval anisakines, sealworm (*Phocanema decipiens*) and related species in Scotian Shelf (4Vs and 4W) cod and flatfish. Can. Tech. Rep. Fish. Aquat. Sci. No. 1202, ix + 27 p.

Nous avons étudié entre février et novembre 1982 les infestations par nématodes anisakines de morue (*Gadus morhua*), de plie canadienne (*Hippoglossoides platessoides*), de plie grise (*Glyptocephalus cynoglossus*) et de la limande à queue jaune (*Limanda ferruginea*) en provenance du plateau Scotian (4Vs). Le ver de phoque (*Phocanema decipiens*) se rencontre surtout dans les filets de morue (86%), bien qu'on en trouve plusieurs dans les "volets" (11%) et la cavité du corps (3%); chez les poissons plats, 98% des vers se trouvent dans les filets. Les larves d'*Anisakis* sp. sont enkystées sur les mésentères hépatiques et viscéraux, mais quelques-uns (<3%) ont été trouvés dans la chair. Dans la plupart des échantillons de morue et de poissons plats, la prévalence et l'abondance des larves anisakines augmentent en fonction de la longueur de l'hôte. Cette tendance n'est toutefois pas apparente dans la cas d'infestations par vers de phoque dans les échantillons de plie canadienne et de limande à queue jaune recueillis sur le Banquereau (4Vs) et dans 4W. Les vers de phoque sont plus abondants dans les échantillons de morue et de poissons plats de 4W que dans ceux de 4Vs; l'abondance des parasites augmente à mesure qu'on se rapproche de l'Île de Sable. Les larves d'*Anisakis* sp. sont plus abondantes dans la morue des bancs "extérieurs" (Banquereau, Île de Sable et Western); les infestations dans les échantillons de 4Vs (Banquereau) sont toutefois semblables à celles des échantillons de 4W (Île de Sable et banc Western). Il y a corrélation très étroite entre la variation d'abondance des anisakines larvaires et la longueur et l'origine géographique de l'hôte. Les variations géographiques de l'abondance du ver de phoque dans la morue et la plie canadienne sont identiques, bien que la prévalence et l'abondance des parasites dans des plies canadiennes ≤50 cm de long soient supérieures à celles observées chez des morues de même longueur. La plie canadienne, dans cette gamme de longueurs, contient plus de vers par poids unitaire de filet que toutes les catégories de morue. L'abondance des vers de phoque dans les échantillons de 1982 est de beaucoup supérieure à celle de 25 ans passés, dans la morue et les poissons plats de 4Vs et 4W.

INTRODUCTION

A recent survey of larval anisakine infections in cod (Gadus morhua) and flatfish from the southern Gulf of St. Lawrence (4T) and the Breton Shelf (4Vn) revealed that sealworm (Phocanema decipiens) has become increasingly numerous in 4Vn cod, American plaice (Hippoglossoides platessoides), and gray sole (Glyptocephalus cynoglossus) (McClelland et al. 1983). These apparent increases in sealworm abundance were attributed to growth of seasonally occurring populations of grey seals (Halichoerus gryphus) (definitive hosts of the parasite) along Cape Breton and Richmond counties, Nova Scotia, and to increased frequency of migrant grey seals in the Sydney Bight and Cabot Strait areas.

Fishermen and processors interviewed during the above survey stated that sealworm infections in 4T and 4Vn groundfish were relatively light, however, compared to those currently found in Scotian Shelf groundfish. The severity of the worm problem, has caused processors to reject cod from Banquereau (4Vs), Sable Island, and Western banks (4W); and candling is often required in the processing of haddock (Melanogrammus aeglefinus) and other groundfish from these same areas. These allegations were somewhat surprising in light of earlier reports on sealworm abundance in Scotian Shelf fish, which showed that cod were lightly infected and the parasite was rarely found in other fish species (Scott and Martin 1957; Templeman et al. 1957).

Again, the most likely explanation for the increasing severity of the sealworm problem in Scotian Shelf fisheries would appear to be the growth of the grey seal population. The grey seal breeding colony located on Sable Island (4W) has grown by more than tenfold over the past two decades (Mansfield and Beck 1977; Zwanenburg et al. 1981), and several thousand seals now congregate on or near the Island throughout the year (Zwanenburg, pers. comm.[1]). The Scotian Banks lie on the seals' migratory routes from Sable Island to the Nova Scotian mainland, Cape Breton, the Gulf of St. Lawrence and Newfoundland. Further, seals based on Sable Island may spend much time feeding on adjacent banks.

The primary objectives of the present study were to document current abundances of sealworm and related species of parasitic nematode in Scotian Shelf (4Vs and 4W) cod and flatfish, and to show distribution of the parasites in host tissues and variations in their abundance with host length and geographic origin. Alleged increases in sealworm infestations in Scotian Shelf groundfish would then be investigated by comparison of our records with earlier reports (Scott and Martin 1957; Templeman et al. 1957). The impact of the Sable Island grey seal colony on the worm problem in Scotian Shelf fisheries might be examined by analyzing variations in worm abundance in Scotian Bank groundfish with proximity to Sable Island.

MATERIALS AND METHODS

COLLECTION AND EXAMINATION OF FISH SAMPLES

Cod and flatfish samples were collected from commercial draggers and from the E.E. Prince during Department of Fisheries and Oceans scientific cruises (Fig. 1). A forced orthogonal sampling design was employed where the fish were stratified into 5-cm length groups containing equal numbers of fish. Ideally, cod would be stratified into ten (≤30-cm, 31-cm to 35-cm, 36-cm to 40-cm...≥71-cm) and flatfish into six (≤30-cm, 31-cm to 35-cm... ≥51-cm) length categories. However, because of inaccuracies of measurement at sea and scarcities of fish in certain length categories, efforts to conform to the sampling design were only partially successful.

Samples were inspected in the fresh condition when time permitted or stored at -17° C and examined later. The fish were measured, weighed, gutted, sexed and filleted. The fillets and flaps (hypaxial musculature of the abdomen) were inspected by systematic destruction of the flesh (Power 1961; Wiles 1968). All nematodes found in the flesh and on the visceral organs and mesenteries were identified and counted.

STATISTICAL ANALYSIS

Frequency distributions of worm counts which were positively skewed to varying degrees (Figs. 2 and 3) were brought close to normality by a $\log_{10}(x + 1)$ transformation (Platt 1975). Variations in transformed worm counts related to host length, sex and sampling were analyzed by three- and two-way ANOVAs using the GLM procedure (SAS 1982); because of our inability to conform to an orthogonal design (above), Type III ANOVAs were employed (Fruend and Littel 1981). Cells with zero frequency were eliminated from analyses of cod parasites by including all fish ≤40 cm in length and those ≥66 cm in length in single length strata and by deleting one sample (East Bar, Sable Island Bank) lacking cod ≥ 51 cm in length. For the same reason, gray sole ≤35 cm were grouped in a single length stratum. Because of a scarcity of male plaice ≥41 cm in length, ANOVAs involving variations in worm counts with host sex were computed for three host length strata, ≤30-cm, 31-cm to 35-cm, and 36-cm to 40-cm. All six length strata, ≤30-cm to ≥51-cm inclusive, were used, however, in two-way analyses of variance related to sampling or length of plaice. Where blank cells persisted in spite of the above precautions, their influence on the results were investigated by repeating analyses with Type IV ANOVAs.

Data from a survey of 4T and 4Vn cod and flatfish (McClelland et al. 1983), together with those from the present study, were used in a comparison of geographical variations in sealworm abundance in cod and plaice. Because of disparities in sample and cell sizes (Fig. 10), direct analyses of geographical correlations in worm abundance in these host species were not possible and the following approach was employed. Plaice samples were ranked in ascending order of mean transformed worm counts and, following the example of Snedecor and Cochrane (1980), significance of regressions of weighted mean worm counts on rank were tested. Analyses of worm count/rank regressions were repeated for cod, with the samples being assigned

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[1] Marine Fish Division, Department of Fisheries and Oceans, Bedford Institute of Oceanography.

the same ranks as plaice samples from corresponding locations. As variances for cod and plaice regressions were dissimilar, regression coefficients were compared by a χ^2 method (Armitage 1971).

RESULTS

LARVAL ANISAKINES IN 4Vs and 4W COD

Two species of larval anisakine nematode, sealworm (*P. decipiens*) and *Anisakis* sp., were found in great *abundance in 4Vs and 4W cod* (Table 1). A few (one to four) larvae of a third anisakine species, *Contracaecum* (*Phocascaris*) sp., were found in samples *from Misaine, Canso and* Sable Island banks but this parasite was not detected in the remaining samples.

Sealworm occurred primarily in the fillets (86%), although significant numbers were also found in the flaps (11%) and in the coelomic cavity (3%) (Table 2). Infections in the flaps and coelom were most common in large market and steak cod, particularly in specimens with heavy infections in the fillets. *Anisakis* sp. larvae, which closely resemble *A. simplex* (Palsson 1979), were usually encysted *on the surface* of the liver (60%) and on the mesenteries surrounding the pyloric caecae; they were found infrequently in the flaps (1.5%) and fillets (1.3%).

Prevalence and abundance of sealworm and *Anisakis* invariably increased with host length (*Table 1*; Figs. 5 and 6). In most samples, market and steak cod $\geq$61 cm in length had the greatest number of sealworm per unit fillet weight. The influence of host length on worm abundance was highly significant ($P \leq 0.0001$) both as a main effect and in interaction with sampling effects (Tables 3, 4 and 5). Worm abundance did not vary significantly, however, with host sex (Table 3).

As shown by fixed-factor design - a priori contrasts (Tables 4 and 5), geographical variations in worm abundance were highly significant ($P \leq 0.0001$). The distributions of sealworm and *Anisakis* in 4Vs and 4W offshore cod, however, *differed*. Sealworm abundance increased with proximity to Sable Island (Fig. 4). The parasite was least abundant in Misaine and east Banquereau cod (4Vs) and most abundant in cod from Sable Island Bank (4W); 4W cod were more heavily infected by far than 4Vs cod ($P \leq 0.0001$) (Table 4; Fig. 5). *Anisakis* sp. larvae, on the other hand, were more *abundant in* cod from the "outer" (Banquereau, Sable Island and Western) banks of 4Vs and 4W, ($P \leq 0.0001$) than in cod from the "inner" (Misaine, Canso and Middle) banks (Table 5; Fig. 6). *Anisakis* counts in 4Vs (Banquereau Bank) *samples* and 4W (Sable Island and Western banks) samples did not differ significantly.

LARVAL ANISAKINES IN 4Vs and 4W FLATFISH

American plaice, gray sole, and yellowtail flounder collected from 4Vs and 4W were heavily infected with sealworm (*P. decipiens*) but the parasite was more abundant *in plaice* than in the other two hosts (Table 6). Almost all of the worms (98%) were found in the fillets. As shown for cod (above), worm abundance in offshore samples of flatfish increased with proximity to Sable Island, and abundance in 4W samples were significantly greater ($P \leq 0.0001$) than those found in 4Vs samples (Tables 7 and 8).

In gray sole samples, and in plaice samples from Misaine and east Banquereau, prevalence and abundance of sealworm increased with host length. This trend was not, however, evident in west Banquereau and 4W plaice samples or in yellowtail samples. As indicated by a two-way ANOVA (Table 7), variations in sealworm abundance with length of plaice were not highly significant ($P \leq 0.05$). Significant numbers of *Anisakis* sp. larvae were found in large plaice *from east* Banquereau Bank; in this sample, the prevalence of infection was 20%, abundance, 0.61 for plaice $\geq$ 46 cm in length (n = 91). As this parasite occurred less frequently in the remaining flatfish samples (prevalence < 5%), however, variations in its abundance were not analysed.

COMPARISON OF SEALWORM ABUNDANCES IN 4T, 4V and 4W COD AND PLAICE

A comparison of cod and plaice samples from the southern Gulf of St. Lawrence (4T) and the Breton Shelf (4Vn) (McClelland et al. 1983) and those collected from the Scotian Shelf (4Vs and 4W) in the present study shows that plaice $\leq$50 cm in length have a greater prevalence and abundance of sealworm than cod of similar length (Figs. 7 and 8). Plaice in this length range have considerably more worms per unit fillet weight than all grades (scrod, market and steak) of cod (Fig. 9).

These distinctions aside, geographical variations in sealworm abundance in the two hosts appear to be similar (Fig. 10). Comparison of worm count/rank regressions indicates that the geographic distribution of the parasite in plaice, 31-40 cm in length, did not differ significantly from those found in scrod, market and steak cod (Table 9; Figs. 10 and 11). Distributional similarities were not apparent, however, when sampling locations were ranked according to ascending order of mean worm counts in 41-50 cm plaice. Under the latter circumstances, worm count/rank regressions for cod were not significant.

DISCUSSION

Comparison of our records with earlier reports (Scott and Martin 1957; Templeman et al. 1957) shows that sealworm (*P. decipiens*) is far more abundant in Scotian Bank (*4Vs and 4W*) cod and flatfish than it was 25 years ago (Table 10). Worm counts in our cod and plaice samples from Misaine and east Banquereau banks (4Vs) were similar to those found in 4T and 4Vn offshore samples (McClelland et al. 1983) while abundances of the parasite in our west Banquereau (4Vs) and 4W samples were significantly greater. The great disparities between current and past records may be attributable, in part, to variations in season or location of sampling, inconsistencies in age or length structures of samples or to differences in examination procedures (McClelland et al. 1983). The magnitudes of the disparities are so great, however, there can be little doubt that the parasite has become more abundant in Scotian Shelf groundfish in recent years. For example, sealworm abundances in the fillets of steak cod ($\geq$71 cm in length) collected in 1982 were insome cases more than 100 times greater than previously reported.

In the past, candling would not have been required in the processing of 4Vs and 4W cod and flatfish; but at present, worm infestations greatly exceed the government standard for maximum numbers permitted in processed fillets (five per 15-pound block or 0.73 per kg fillet). Efficiencies of commercial procedures for detection and removal of worms from fillets have been estimated at less than 50% (Power 1961) and, obviously, more rigorous inspection would be necessary in order to bring infestations in the fillets of 4Vs and 4W cod and plaice to acceptable levels.

Increases in abundance of sealworm in Scotian Bank groundfish shown here clearly coincide with the growth of the Sable Island grey seal colony (Mansfield and Beck 1977; Zwanenburg et al. 1981). Sealworm matures and reproduces in the gastro-intestinal tract of seals and, in the North Atlantic, the grey seal appears to be the most important definitive host of this parasite (Scott 1953; Young 1972; Platt 1975; Mansfield and Beck 1977; McClelland 1980a, b and c; Bjorge et al. 1981). While they may not be the most numerous seal species in a given locale, grey seals usually support the greatest numbers of mature *P. decipiens*, on an individual and collective basis. Grey seals seem to develop a tolerance for *P. decipiens* as they become reinfected with successively greater numbers of worms as they mature but exhibit little or no inflammatory response (McClelland 1980b and c). A typical adult grey seal may support several hundred mature females of *P. decipiens*, each of which may produce progeny numbering in the hundreds of thousands.

The relationship of sealworm abundance in Scotian Shelf groundfish to the Sable Island grey seal population is implied not only by the coincident growth of both seal and parasite populations in recent years but also by the geographical distribution of the parasite. As shown here, sealworm abundance in cod and flatfish increases significantly with proximity to Sable Island. Although sealworm has been perceived as a problem occurring primarily in inshore fish (Templeman et al. 1957; Scott and Martin 1959; Young 1972; Appy 1978), worm counts in our cod and plaice samples from Sable Island and Western banks, 150 km to 200 km offshore, exceeded those found in 4T and 4Vn inshore samples (McClelland et al. 1983). Notably, the distribution of sealworm in Scotian Bank cod differed from that of *Anisakis* sp. larvae. *Anisakis* larvae, which presumably mature and reproduce in cetaceans, were more numerous in cod from the "outer" banks (Banquereau, Sable Island and Western banks) of 4Vs and 4W than in cod from the "inner" banks (Misaine, Canso and Middle banks). Abundances of *Anisakis* in Banquereau Bank (4Vs) samples, however, did not differ significantly from those found in Sable Island Bank and Western Bank (4W) samples.

The full extent of the worm problem currently being experienced in eastern Canadian fisheries remains to be defined. Grey seals have become more numerous, not only in the Sable Island area but throughout eastern Canada (Zwanenburg et al. 1981). Fishermen and processors interviewed here stated that sealworm was becoming a problem in groundfish off southwestern Nova Scotia (4X), southern Newfoundland (3P) and the northern Gulf of St. Lawrence (4R and 4S). Evidently, *Anisakis* sp. larvae have also become more numerous in the flesh of northern Gulf, southern Newfoundland and Labrador cod. In view of these developments, the survey of larval anisakines, which has been completed for southern Gulf (4T), Breton (4Vn) and Scotian shelves (4Vs and 4W), should be extended to the remaining eastern Canadian fisheries.

As our studies show, it may be more convenient to determine geographic distribution of sealworm through surveys of American plaice rather than cod. The greatest advantage to using plaice in such surveys is logistical. Since they are much smaller than cod, plaice samples are easier to transport, require less storage space and can be examined more quickly. While significant numbers of sealworm are found in the flaps and viscera of cod, the parasite occurs almost exclusively in the fillets of plaice and examinations of other tissues would not be necessary. Cod are heavily infected with related species of ascaridoid nematode (*Anisakis* and *Contracaecum* sp. and *Hysterothylacium aduncum*), and microscopic examinations are needed in order to identify and separate these species from sealworm (McClelland et al. 1983). These other species of nematode, however, rarely occur in the fillets of plaice.

American plaice is widely distributed along the east coast of North America from Hamilton Inlet, Labrador, to Cape Cod; they occur inshore and offshore, in shallow and deep water (Powles 1965). While some populations migrate to deeper water in winter (Powles 1965), seasonal or longer-term migrations of plaice (Pitt 1969) are not as extensive as those undertaken by cod (Martin and Jean 1964). It would be less difficult, then, to interpret geographical origins of sealworm infections by surveying plaice.

The influence of host length on worm abundance is less significant in plaice than in cod. Hence, in surveys of plaice it may be safe to ignore this source of variation and select samples of limited length range. According to our comparison of sealworm infections by 4T, 4V and 4W cod and plaice, geographical variations in abundance of the parasite in plaice 31 cm to 40 cm in length are most similar to those found in cod. Plaice in this length range have a greater abundance of sealworm than scrod and carry more worms per unit fillet weight than scrod, market or steak cod.

We have shown in present and earlier studies (McClelland et al. 1983) that sealworm abundances in plaice can be defined for limited geographic areas. But before we can establish a relationship between larval sealworm abundances and the distribution and densities of seal host populations, more information is required on:

1) densities of local seal populations and seasonal variations in these densities.

2) geographical and seasonal variations in abundance of mature sealworm in the gastro-intestinal tract of seals.

3) regulation of hatching and developmental rates of the parasite (in poikilothermic hosts) over the range of enviromental temperatures.

TABLE 1. Larval anisakines in round 4Vs and 4W cod, 1982.

Host			*P. decipiens*				*Anisakis* sp. larvae	
Location	Length range (cm)	n	Prevalence[a] (%)	Abundance[b] (maximum no.)	% in fillets	No. per kg fillet	Prevalence (%)	Abundance (maximum no.)
4Vs, deeps	≤45	20	30	0.45(3)	56	1.12	10	0.10(1)
north of	46-50	22	41	0.55(3)	100	1.67	23	0.50(7)
Misaine	51-55	27	52	0.81(2)	86	1.69	48	0.59(3)
Bank	56-60	34	41	1.44(20)	92	2.38	47	1.47(14)
(Feb.)	61-65	26	62	2.19(14)	89	2.96	54	0.96(6)
	66-70	26	88	4.42(24)	96	5.09	50	1.27(9)
	≥71	26	81	11.00(75)	69	5.80	62	1.54(10)
	Total	181	57	3.04(75)	80	3.83	43	0.98(14)
4Vs, Eastern	≤40	32	34	0.53(3)	100	3.34	16	0.25(3)
Shoal,	41-45	23	61	1.39(7)	94	5.89	48	1.26(8)
Banquereau	46-50	32	56	1.03(4)	100	3.09	56	2.16(16)
Bank	51-55	21	67	1.52(5)	94	3.12	52	1.48(8)
(May)	56-60	28	64	1.82(6)	96	2.89	71	1.64(14)
	61-65	24	79	2.25(5)	94	2.68	67	2.04(16)
	66-70	17	76	4.18(15)	86	3.90	71	3.71(17)
	≥71	15	87	11.07(56)	79	5.86	87	6.13(28)
	Total	192	63	2.38(56)	88	3.85	55	2.02(28)
4Vs, West	≤35	36	19	0.22(2)	88	1.62	56	0.86(4)
Banquereau	36-40	29	34	0.52(3)	100	2.63	55	0.90(7)
Bank	41-45	28	36	0.79(5)	100	3.02	54	0.96(8)
(Aug.)	46-50	35	71	2.11(12)	100	5.85	71	2.46(13)
	51-55	20	85	3.25(8)	99	7.02	80	2.95(15)
	56-60	32	81	4.47(22)	92	6.35	84	3.50(12)
	61-65	27	78	4.46(21)	92	4.48	85	2.78(9)
	66-70	20	95	6.35(16)	92	6.03	85	4.20(19)
	≥71	28	96	10.50(40)	85	7.33	86	6.57(24)
	Total	255	64	3.35(40)	91	5.76	72	2.67(24)
4Vs, West	≤35	33	21	0.33(2)	100	2.61	58	1.24(5)
Banquereau	36-40	29	41	0.83(6)	100	4.68	48	0.86(5)
Bank	41-45	21	38	0.52(4)	100	2.11	48	0.76(3)
(Sept.)	46-50	28	71	2.50(13)	97	7.02	57	1.14(8)
	51-55	28	89	5.35(17)	93	7.59	68	2.00(7)
	56-60	25	84	5.48(17)	95	9.13	80	2.04(7)
	≥61	30	93	5.77(22)	90	6.16	93	4.53(41)
	Total	194	62	2.75(22)	94	6.49	65	1.84(41)
4W, Canso Bank	≤30	22	5	0.14(3)	100	2.79	5	0.05(1)
Hole	31-35	25	44	0.88(7)	95	7.37	12	0.16(2)
(Apr.)	36-40	27	37	1.30(23)	94	7.14	26	0.33(2)
	41-45	20	60	1.45(7)	100	6.20	20	0.50(5)
	46-50	24	67	2.00(15)	92	5.61	25	0.38(3)
	51-55	24	79	4.50(26)	88	9.47	33	0.63(5)
	56-60	23	78	2.61(10)	83	3.84	65	1.04(3)
	61-65	21	86	5.10(16)	79	5.81	57	0.95(4)
	66-70	7	100	8.57(20)	82	7.98	43	1.57(7)
	≥71	12	100	19.08(54)	76	11.85	75	3.17(13)
	Total	205	60	3.42(54)	83	7.33	33	0.69(13)
4W, Middle	≤30	33	3	0.06(2)	100	0.82	6	0.09(2)
Bank	31-35	23	35	0.48(3)	82	3.35	22	0.26(2)
(July)	36-40	26	35	0.58(4)	100	2.71	19	0.23(2)
	41-45	26	62	1.81(15)	92	6.83	42	0.69(3)
	46-50	23	70	2.30(11)	95	6.50	65	1.32(8)
	51-55	25	84	2.68(15)	91	5.67	60	1.76(16)
	56-60	24	96	5.46(13)	86	8.74	50	1.08(5)
	61-65	11	100	10.27(21)	81	13.19	64	1.73(6)
	Total	205	56	2.30(21)	88	7.03	40	0.84(16)

TABLE 1. (cont'd).

Host			*P. decipiens*				*Anisakis* sp. larvae	
Location	Length range (cm)	n	Prevalence[a] (%)	Abundance[b] (maximum no.)	% in fillets	No. per kg fillet	Prevalence (%)	Abundance (maximum no.)
Sable Island Bank (Off East Bar) (Sept.)	≤30	39	41	1.03(6)	95	13.19	13	0.15(2)
	31-35	21	62	1.81(7)	95	14.23	48	0.71(4)
	36-40	30	63	4.57(61)	93	23.66	43	0.83(8)
	41-45	33	91	7.85(29)	95	29.67	76	3.21(14)
	46-50	24	96	14.21(54)	94	41.87	83	4.88(33)
	Total	147	69	5.54(61)	95	28.73	50	1.82(33)
West Sable Island Bank (June)	≤35	32	22	0.38(3)	100	3.61	13	0.13(1)
	36-40	24	58	1.83(11)	93	10.20	50	1.04(5)
	41-45	22	68	3.09(16)	97	13.55	59	1.14(7)
	46-50	30	87	4.63(11)	92	13.35	83	3.17(12)
	51-55	18	94	9.61(39)	93	20.59	78	2.78(15)
	56-60	26	100	12.19(43)	91	18.95	85	6.00(31)
	61-65	22	95	16.27(93)	85	18.79	86	4.95(28)
	66-70	20	100	27.15(114)	80	24.55	95	7.75(28)
	≥71	16	88	41.81(183)	70	26.02	81	6.88(26)
	Total	210	76	11.06(183)	82	19.68	67	3.45(31)
Western Bank (July)	≤35	17	18	0.24(2)	100	2.11	24	0.24(1)
	36-40	14	43	1.21(4)	94	5.95	29	0.36(2)
	41-45	29	72	2.24(18)	92	8.07	41	0.86(9)
	46-50	31	81	3.81(23)	98	10.91	48	0.81(6)
	51-55	32	94	5.84(31)	96	12.38	63	1.19(4)
	56-60	40	90	8.13(24)	87	11.98	45	0.83(5)
	61-65	20	90	10.35(46)	85	11.82	55	1.95(9)
	66-70	8	100	11.88(18)	85	11.64	88	6.63(21)
	≥71	13	100	34.54(173)	71	17.73	85	17.77(156)
	Total	204	79	7.19(173)	84	12.27	48	2.21(156)
Edge of Western Bank (Sept.)	≤35	16	13	0.25(2)	-	1.98	19	0.19(1)
	36-40	19	32	1.11(6)	100	5.77	42	0.84(4)
	41-45	34	74	2.03(8)	96	7.34	56	1.91(15)
	46-50	35	86	3.29(13)	91	8.53	60	1.60(9)
	51-55	28	93	4.04(9)	96	8.24	79	2.64(10)
	56-60	15	87	7.67(45)	84	11.27	80	2.40(9)
	≥61	7	100	14.43(35)	86	14.32	86	4.86(13)
	Total	154	71	3.49(45)	91	8.91	59	1.83(15)
Boundary 4W-4X Chebucto Head (March)	≤30	10	50	0.50(1)	100	7.94	0	0
	31-35	24	38	1.13(7)	93	9.19	8	0.29(6)
	36-40	23	57	1.39(10)	97	8.03	17	0.26(2)
	41-45	28	68	2.07(9)	97	8.81	18	0.54(10)
	46-50	32	81	2.91(15)	97	8.49	41	2.53(61)
	51-55	21	90	7.52(49)	92	15.43	67	2.10(8)
	56-60	13	100	10.92(28)	92	17.33	69	3.08(14)
	≥61	21	90	13.81(142)	67	7.74	86	7.33(53)
	Total	172	72	4.68(142)	84	10.19	37	2.02(61)

[a] Percent of fish infected.

[b] Mean no. of nematodes per fish.

TABLE 2. Distribution of larval anisakines in the tissues of 4Vs and 4W cod.

Host		Larval anisakines		Percent of nematodes in				
Length range (cm)	n	Species	n	Fillet	Flap	Liver	Pyloric caecae	Other
≤ 30	131	*P. decipiens*	59	96.6	1.7	1.7	-	-
		Anisakis sp.	15	6.7	-	93.3	-	-
31-35	208	*P. decipiens*	130	93.8	3.1	-	-	3.1
		Anisakis sp.	111	1.8	0.9	75.7	14.4	7.2
36-40	248	*P. decipiens*	358	95.0	4.2	0.8	-	-
		Anisakis sp.	150	2.7	-	86.7	6.0	4.7
41-45	281	*P. decipiens*	666	95.0	4.4	-	-	0.6
		Anisakis sp.	338	2.1	1.2	69.5	16.9	10.4
46-50	330	*P. decipiens*	1,128	95.1	4.3	0.2	0.1	0.3
		Anisakis sp.	630	1.7	1.6	69.2	18.7	8.7
51-55	245	*P. decipiens*	1,033	93.0	5.7	0.3	0.2	0.8
		Anisakis sp.	430	0.9	1.2	66.0	27.2	4.7
56-60	261	*P. decipiens*	1,476	89.6	9.8	0.1	0.1	0.5
		Anisakis sp.	575	1.2	1.0	60.9	30.4	6.4
61-65	179	*P. decipiens*	1,172	86.0	13.1	0.1	0.1	0.8
		Anisakis sp.	430	-	0.2	60.5	33.3	6.0
66-70	115	*P. decipiens*	1,127	84.5	13.8	0.3	0.1	1.4
		Anisakis sp.	448	0.4	0.4	55.8	37.7	5.6
≥71	123	*P. decipiens*	2,369	72.9	18.1	1.5	2.4	5.1
		Anisakis sp.	876	1.7	3.4	41.0	41.8	12.1
Total	2,121	*P. decipiens*	9,518	86.1	10.9	0.5	0.7	1.8
		Anisakis sp.	4,003	1.3	1.5	60.0	29.2	8.0

TABLE 3. Three-way ANOVA for variations in abundance of larval anisakines with sex, sample and body length of host, 4Vs and 4W cod.

Source of variation range (cm)	Nematode sp.	Degrees of freedom	Mean square	F^a
Main effects				
Host sex	*Phocanema*	1	0.020	0.19
	Anisakis	1	0.053	0.68
Host length	*Phocanema*	6	9.733	90.95****
	Anisakis	6	3.260	41.72****
Host sample	*Phocanema*	9	3.117	29.13****
	Anisakis	9	1.489	19.06****
Two-way interactions				
Sex x length	*Phocanema*	6	0.095	0.89
	Anisakis	6	0.041	0.52
Sex x sample	*Phocanema*	9	0.096	0.90
	Anisakis	9	0.159	2.03
Length x sample	*Phocanema*	54	0.276	2.58****
	Anisakis	54	0.159	2.03****
Three-way interaction				
(Sex x Length x Sample)	*Phocanema*	53	0.089	0.84
	Anisakis	53	0.081	1.03
Error	*Phocanema*	1,833	0.107	
	Anisakis	1,833	0.078	

[a] Significance at $P \leq 0.05$*, ≤ 0.01**, ≤ 0.001***, and ≤ 0.0001****.

TABLE 4. Two-way ANOVAs for variations in abundance of *Phocanema decipiens* with sample and length of host 4Vs and 4W cod and constrasts of samples.

Contrast	Sample means		Host length		Sample means x host length	
	d.f.	F[a]	d.f.	F[a]	d.f.	F[a]
Two-way ANOVA	9	32.50****	6	94.31****	54	2.80****
4Vs vs. 4W	1	145.32****	-	-	6	6.22****
East Banquereau vs. West Banquereau	1	14.45****	-	-	6	3.84***
Misaine - East Banquereau vs. West Banquereau - Canso - Middle Bank	1	52.40****	-	-	6	4.40***
Sable Island - Western Banks vs. West Banquereau - Canso - Middle Bank	1	63.65****	-	-	6	3.10**
Sable Island vs. Western Bank	1	10.06**	-	-	6	1.19
Sable Island - Western Bank vs. Chebucto Head	1	7.52**	-	-	6	5.00****

[a] Significance at P≤0.05*, ≤0.01**, ≤0.001***, and ≤0.0001****.

TABLE 5. Two-way ANOVAS for variations in abundance of *Anisakis simplex* with sample and length of host 4Vs and 4W cod and constrasts of samples.

Contrast	Sample means		Host length		Sample means x host length	
	d.f.	F[a]	d.f.	F[a]	d.f.	F[a]
Two-way ANOVA	9	20.39****	6	41.73****	54	2.21****
4Vs vs. 4W	1	0.36	-	-	6	0.47
Misaine - Canso - Middle Bank vs. East Banquereau - West Banquereau - Sable Island - Western Bank	1	66.24****	-	-	6	0.84
East Banquereau - West Banquereau Bank vs. Sable Island - Western Bank	1	0.78	-	-	6	1.01
Sable Island - Western Banks vs. Chebucto Head	1	2.02	-	-	6	1.50

[a] Significance at P≤0.05*, ≤0.01**, ≤0.001***, and ≤0.0001****.

TABLE 6. Larval *Phocanema decipiens* in 4Vs and 4W flatfish, 1982.

Host				*P. decipiens* larvae		
Species	Location	Length range (cm)	n	Prevalence[a] (%)	Abundance[b] (maximum no.)	No. per kg fillet
Plaice	Holes north of Misaine Bank 4Vs (Feb.)	≤35	46	33	0.35(2)	4.41
		36-40	52	35	0.85(10)	6.75
		41-45	35	43	0.49(2)	2.81
		46-50	46	50	1.63(24)	6.76
		≥51	31	71	1.94(6)	5.20
		Total	210	44	1.01(24)	5.48
Plaice	Eastern Shoal, Banquereau Bank, 4Vs (May)	≤35	44	32	0.43(3)	4.44
		36-40	21	33	0.62(6)	4.44
		41-45	25	24	0.56(7)	2.78
		46-50	27	44	0.93(8)	3.30
		≥51	64	58	1.31(7)	2.54
		Total	181	42	0.86(8)	2.85
Plaice	Misaine Channel, 4Vs (July)	≤30	34	50	0.82(4)	16.40
		31-35	36	67	2.19(10)	26.96
		36-40	31	39	0.65(3)	5.00
		41-45	30	50	1.00(7)	5.43
		46-50	11	64	0.82(2)	2.96
		≥51	16	56	0.94(3)	2.04
		Total	158	53	1.15(10)	7.37
Plaice	Sable Island Bank 4W (July)	≤30	19	89	3.11(9)	43.31
		31-35	36	78	2.64(8)	30.16
		36-40	42	95	3.69(18)	26.88
		41-45	35	89	2.91(8)	15.25
		46-50	37	78	2.16(10)	8.26
		≥51	26	77	1.92(14)	4.71
		Total	195	85	2.77(18)	14.51
Plaice	Edge of Western Bank, 4W (Sept.)	≤25	24	8	0.08(1)	5.36
		26-30	30	43	0.83(5)	19.13
		31-35	35	69	2.14(9)	27.31
		36-40	34	76	2.18(10)	17.44
		41-45	24	75	1.67(4)	8.61
		46-50	16	63	1.31(4)	4.86
		≥51	16	50	0.56(2)	1.14
		Total	179	56	1.37(10)	9.63
Plaice	Chebucto Head, 4W (March)	≤20	34	9	0.12(2)	9.62
		21-25	45	40	0.69(6)	22.14
		26-30	90	42	0.77(8)	16.53
		31-35	47	53	1.17(9)	13.06
		36-40	15	67	3.20(17)	24.62
		≥41	17	65	2.12(7)	8.43
		Total	248	42	0.98(17)	14.99
Gray sole	Misaine Channel, 4Vs (Nov.)	≤30	12	8	0.08(1)	2.58
		31-35	11	9	0.09(1)	1.14
		36-40	22	5	0.05(1)	0.37
		41-45	21	33	0.43(3)	2.31
		46-50	27	15	0.15(1)	0.62
		≥51	22	32	0.32(1)	1.01
		Total	115	18	0.20(3)	1.06

TABLE 6. (cont'd).

Host				*P. decipiens* larvae		
Species	Location	Length range (cm)	n	Prevalence[a] (%)	Abundance[b] (maximum no.)	No. per kg fillet
Gray sole	Canso Bank Hole, 4W (Nov.)	≤ 20	16	0	0 ( )	0
		21-25	14	0	0 ( )	0
		26-30	24	4	0.04(1)	0.89
		31-35	24	8	0.08(1)	1.19
		36-40	9	11	0.11(1)	1.08
		41-45	6	17	0.17(1)	1.04
		46-50	12	42	0.75(3)	3.35
		≥ 51	17	76	1.06(3)	3.36
		Total	122	19	0.26(3)	2.40
Gray sole	Sable Island Bank, 4W (June)	≤ 40	22	27	0.27(1)	2.42
		41-45	41	34	0.51(3)	3.50
		46-50	44	43	0.68(5)	3.21
		≥ 51	15	73	1.27(3)	4.81
		Total	122	41	0.62(5)	3.94
Yellowtail	West Banquereau Bank, 4Vs (Sept.)	31-35	91	24	0.40(4)	4.19
		36-40	73	23	0.37(6)	2.54
		41-45	22	27	0.36(2)	2.06
		Total	186	24	0.38(6)	3.08
Yellowtail	East Sable Island Bank, 4W (Sept.)	≤ 25	44	20	0.30(2)	13.73
		26-30	45	49	0.76(6)	14.33
		≥ 31	35	34	0.57(4)	6.48
		Total	124	35	0.54(6)	10.55
Yellowtail	Pt. Escuminac,[c] N.B. (4T) (June '81)	≤ 25	16	0	0 ( )	0
		26-30	99	5	0.05(1)	1.28
		≥ 31	54	15	0.17(2)	1.81
		Total	169	8	0.08(2)	1.20

[a] Percent of fish infected.

[b] Mean number of nematodes per fish.

[c] Collected during earlier survey (McClelland et al. 1983).

TABLE 7. Three- and two-way analyses of variations in abundance of *Phocanema decipiens* with sex, sample and length of host, 4Vs and 4W plaice.

Source of variation	Degrees of freedom	Mean square	F[a]
THREE-WAY ANOVA[b]			
Main effects			
Host sex	1	0.170	2.72
Host length	2	0.461	7.38***
Host sample	5	0.785	12.58****
Two-way interaction			
Sex x length	2	0.026	0.42
Sex x sample	5	0.065	1.05
Length x sample	10	0.210	3.37***
Three-way interaction			
Sex x length x sample	9	0.176	2.82**
Error	663	0.062	
TWO-WAY ANOVA			
Main effects			
Host length	5	0.173	2.61*
Host sample	5	1.94	29.22****
Two-way interaction			
Sample x length	25	0.280	4.22****
Error	1,118	0.066	
Contrast			
4Vs vs. 4W (Sample)	1	4.554	68.58****
4Vs vs. 4W (Length x sample interaction)	5	0.204	3.07**

[a] Significance at P≤0.05*, ≤0.01**, ≤0.001***, and ≤0.0001****.
[b] Restricted to plaice ≤40 cm.

TABLE 8. Three- and two-way analyses of variations in abundance of *Phocanema decipiens* with sex, sample, and length of host, 4Vs and 4W gray sole.

Source of variation	Degrees of freedom	Mean square	F[a]
THREE-WAY ANOVA			
Main effects			
Host sex	1	0.000	0.00
Host sample	2	0.097	4.36*
Host length	4	0.040	1.79
Two-way interaction			
Sex x length	2	0.057	2.56
Sex x sample	4	0.033	1.46
Sample x length	8	0.054	2.42*
Three-way interaction			
Sex x sample x length	5	0.022	1.00
Error:	332	0.022	
TWO-WAY ANOVA			
Main effects			
Host length	2	0.185	8.32***
Host sample	4	0.254	11.42****
Two-way interaction			
Sample x length	8	0.063	2.83**
Error	344	0.022	
Contrast			
4Vs vs. 4W (Sample)	1	0.334	15.00****
4Vs vs. 4W (Length x sample interaction)	4	0.094	4.20**

[a] Significance at $P \leq 0.05$*, ≤ 0.01**, ≤ 0.001***, and ≤ 0.0001****.

TABLE 9. Comparisons of weighted regressions for geographic variation of sealworm intensity in 4T, 4V and 4W cod and plaice.

	Plaice[a]			Cod[b]		$b_1 = b_2$	
	b_1[c]			b_2			
Length range (cm)	Transformed worm counts vs. rank		Length range (cm)	Transformed worm counts vs. rank		χ^2	P
	F	P		F	P		
31-40	134.62	0.0000	≤50	17.76	0.0023	0.8305	0.6347
31-40	134.62	0.0000	51-70	16.26	0.0030	2.9658	0.0811
31-40	134.62	0.0000	≥71	6.71	0.0283	0.3903	0.5397
31-40	134.92	0.0000	Total	14.30	0.0044	0.2411	0.6293
41-50	44.36	0.0000	≤50	0.0082	0.9271	-	-
41-50	44.36	0.0000	51-70	0.0086	0.9253	-	-
41-50	44.36	0.0000	≥71	0.0152	0.9003	-	-

[a] Samples ranked in ascending order of mean worm count (see Figs. 10 and 11).
[b] Ranks of sampling locations correspond to those for plaice.
[c] Regression coefficient.

TABLE 10. Comparison of sealworm abundances in Scotian Shelf (4Vs and 4W) cod and flatfish: current and earlier records.

Host			1982[a]				1946-56[b]				
Species	Location	Length range (cm) or grade	n	Prevalence	Abundance	No./kg fillet	n	Prevalence	Abundance	No./kg fillet	Worms/kg fillet ('80-'82) / Worms/kg fillet ('46-'56)
Cod	4Vs, Misaine Bank[c]	31-50	42	36	0.50	1.48	-	-	-	-	-
		51-70	113	59	2.14	3.25	100	11	0.18	0.28	13.59
		≥71	26	81	11.00	5.80	-	-	-	-	-
Cod	4Vs, Banquereau Bank[c]	31-50	326	49	0.98	3.98	150	6	0.18	0.44	9.05
		51-70	266	82	3.89	5.39	2,950	11	0.16	0.20	26.95
		≥71	49	94	10.02	6.45	1,150	14	0.36	0.18	35.85
Cod	4W, Canso Bank[c]	≤30	22	5	0.13	2.79	-	-	-	-	-
		31-50	96	51	1.40	6.35	-	-	-	-	-
		51-70	75	83	4.47	6.37	50	8	-	0.10	63.70
		≥71	12	100	19.92	12.53	-	-	-	-	-
Cod	4W, Middle Bank[c]	≤30	33	3	0.06	0.82	-	-	-	-	-
		31-50	112	53	1.39	5.62	200	12	0.18	0.29	19.38
		51-70	60	92	5.18	8.56	1,300	8	0.12	0.15	57.07
		≥71	-	-	-	-	800	11	0.20	0.09	-
Cod	4W, Western Bank[c]	≤30	10	10	0.10	1.17	-	-	-	-	-
		31-50	185	63	2.23	7.92	250	11	0.14	0.29	27.31
		51-70	148	92	7.53	11.42	3,500	11	0.16	0.20	57.10
		≥71	15	100	31.80	16.93	2,100	12	0.24	0.11	153.89
Cod	4Vs and 4W[d]	≤30	82	7	0.17	2.39	40	8	0.08	-	-
		31-50	848	52	1.53	6.12	226	15	0.20	0.90	6.80
		51-70	748	83	5.91	8.39	350	18	0.36	0.75	11.19
		≥71	118	92	18.31	10.68	41	10	0.12	0.09	118.67
Plaice	4Vn and 4Vs[d]	≤30	52	20	0.62	11.54	214	2	0.02	1.17	9.86
		31-40	404	45	1.21	11.29	61	3	0.07	0.68	16.60
		41-50	381	52	1.75	8.05	31	3	0.03	0.13	61.92
		≥51	173	61	1.42	3.22	18	0	0	0	-
Gray sole	4V and 4W[d]	≤30	83	4	0.04	0.56	12	0	0	0	-
		31-40	358	7	0.08	0.82	40	3	0.03	0.39	2.10
		41-50	561	23	0.29	1.68	91	2	0.02	0.14	12.00
		≥51	90	43	0.73	2.48	44	2	0.02	0.07	35.43

[a] Prevalence and abundance based on nematodes in fillets, flaps and viscera: prevalence = percent of fish infected;
abundance = mean no. of nematodes per fish.

[b] Prevalence and abundance for fillets only.

[c] Records for 1946 to 1956 from Scott and Martin (1957): $n = \frac{\text{no. of fillets examined}}{2}$;
Prevalence = 1.5 x percent of fillets infected;
Abundance = 2 x average no. of worms per fillet.

[d] Records for 1946 to 1956 from Templeman et al. (1957).

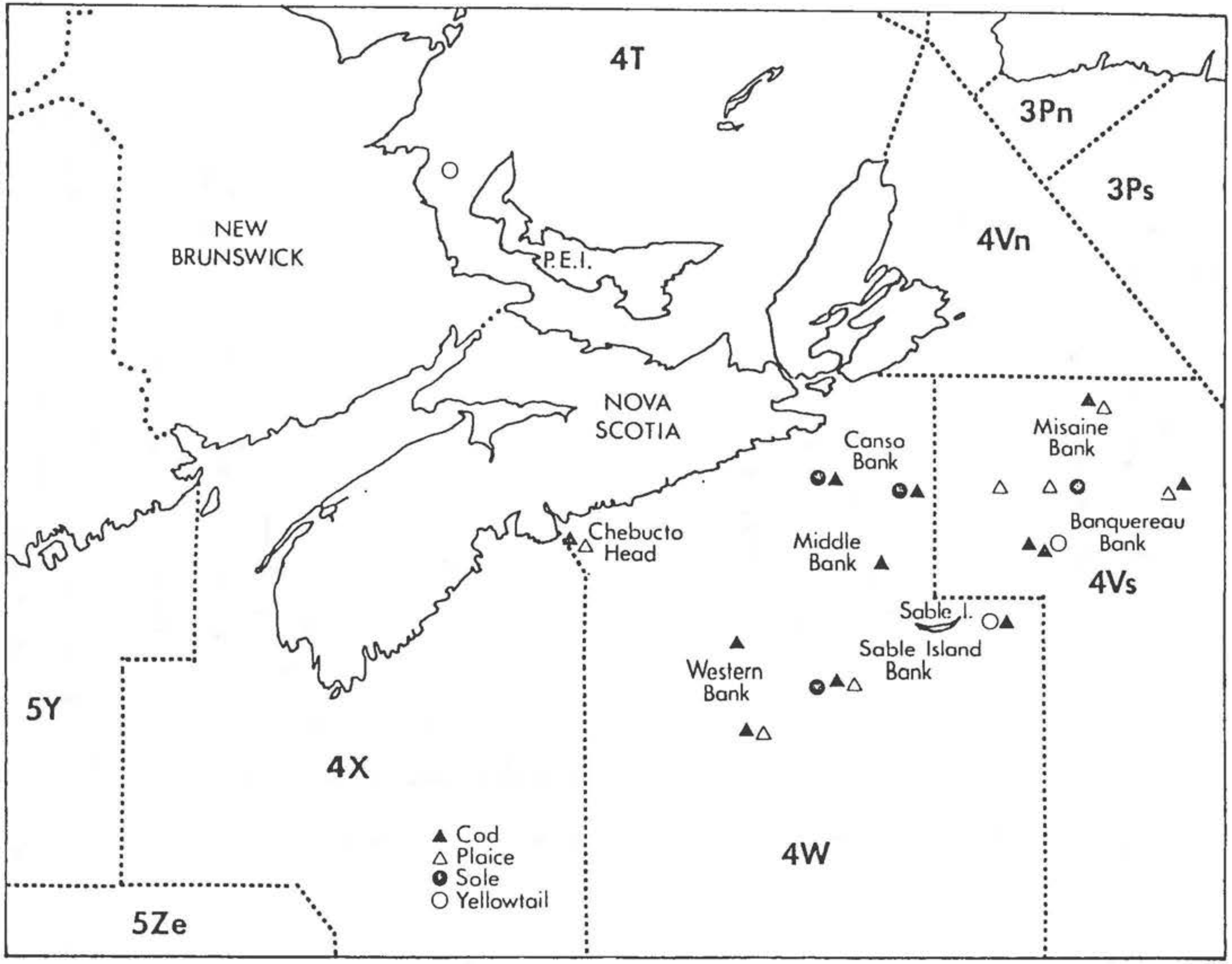

FIG. 1. Sampling locations.

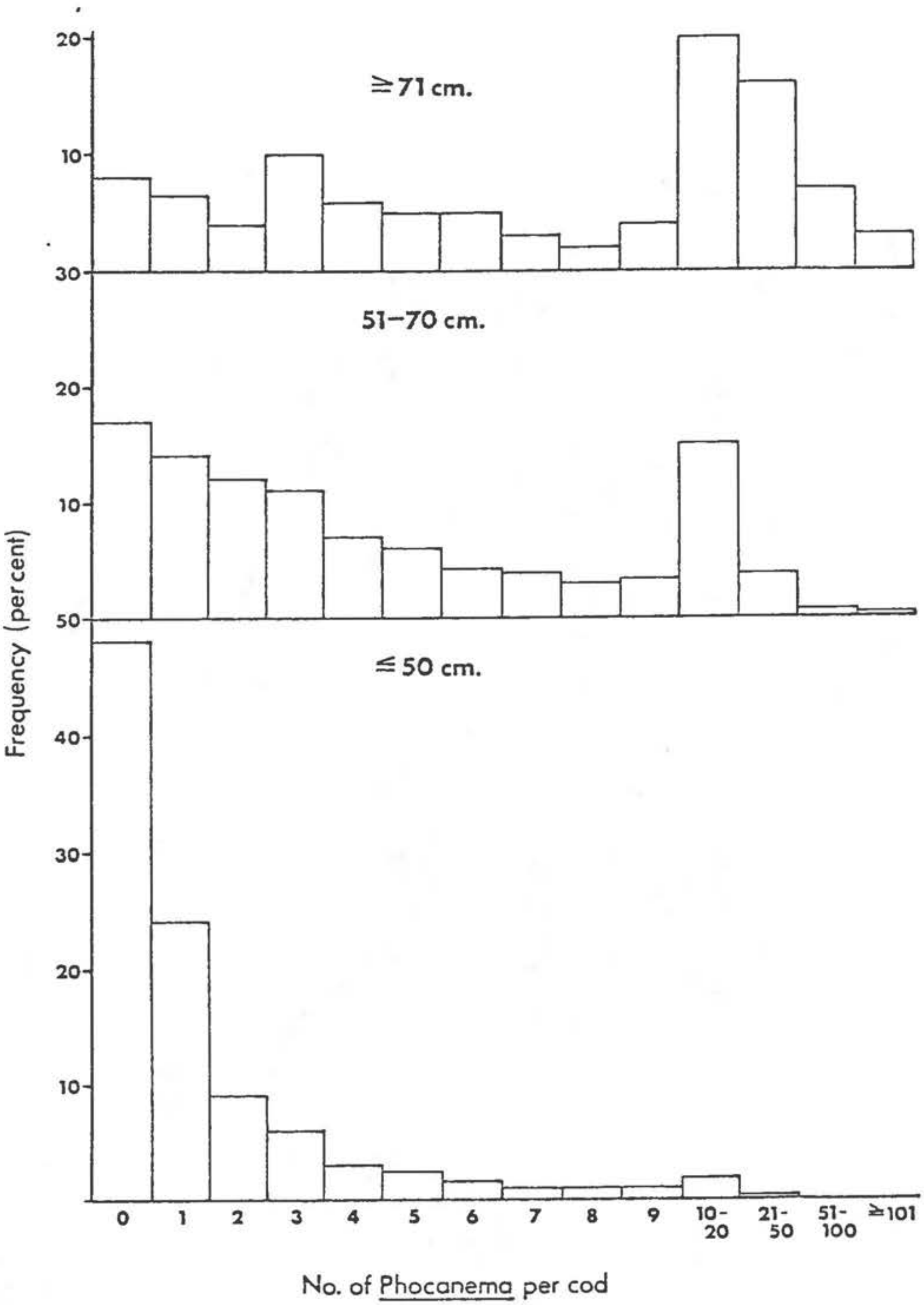

FIG. 2. Frequency distributions of sealworm counts from individual cod for combined 4Vs and 4W cod samples. (Sample from East Bar, Sable Island Bank, omitted; cod stratified into ≤50-cm, 51-cm to 70-cm, and ≥71-cm length groups.)

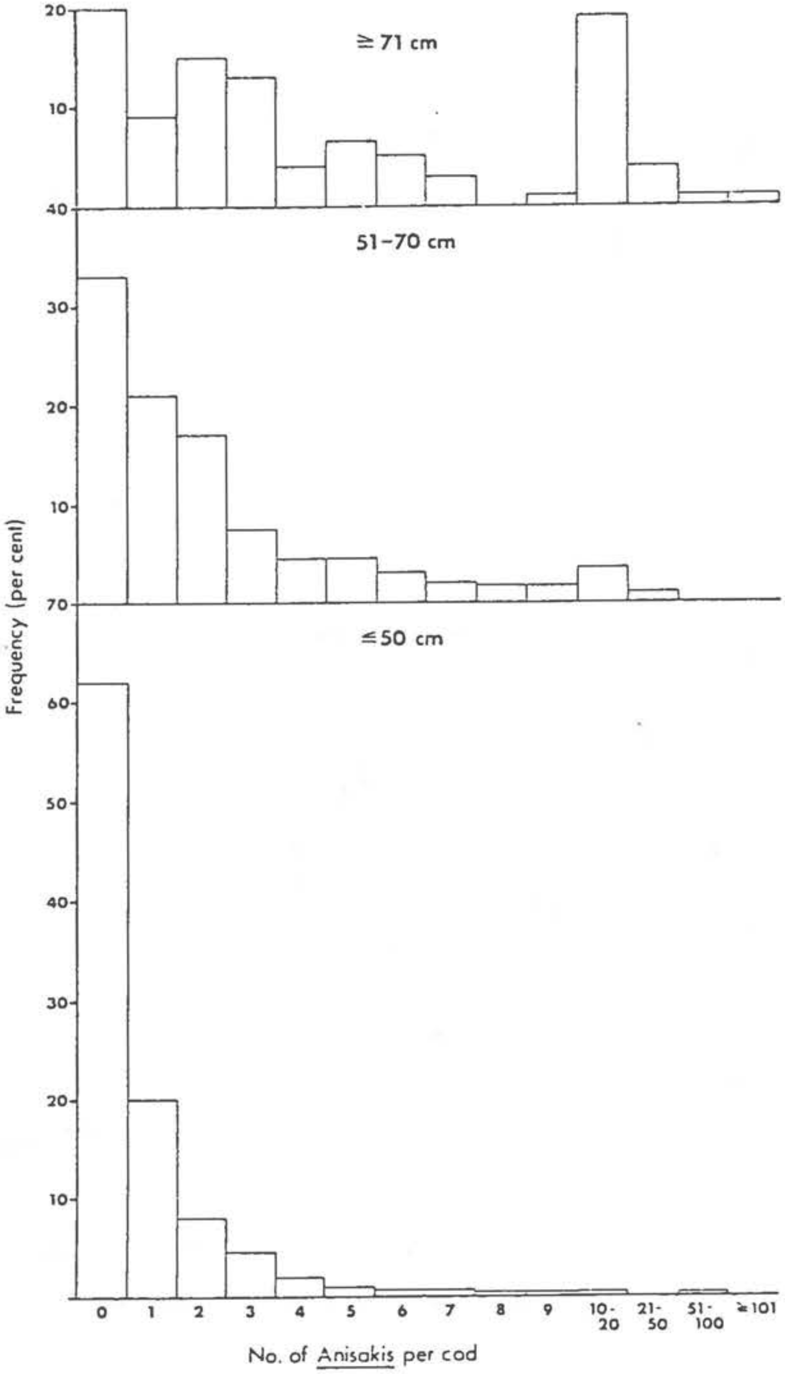

FIG. 3. Frequency distributions of larval Anisakis counts from individual cod for combined 4Vs and 4W cod samples. (Sample from East Bar, Sable Island Bank, omitted. Cod stratified into ≤50-cm, 51-70-cm, and ≥71-cm length groups.)

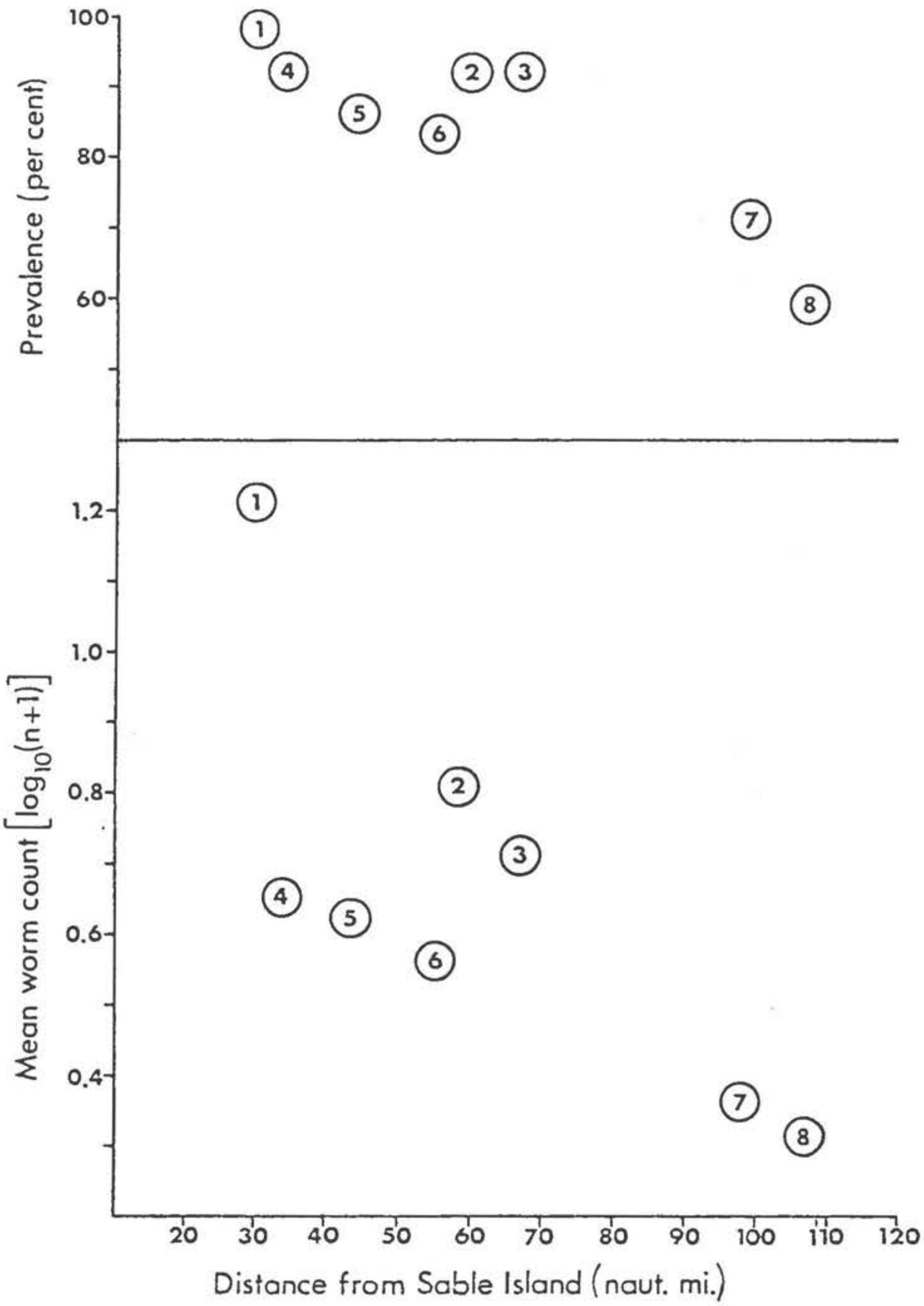

FIG. 4. Prevalence and abundance of sealworm infection in Scotian Shelf (4Vs and 4W) cod, 51-70 cm in length, versus distance from Sable Island. (1. Sable Island Bank, 2. Western Bank, 3. Edge of Western Bank, 4. Middle Bank, 5. West Banquereau Bank, 6. Canso Bank, 7. East Banquereau Bank, 8. Misaine Bank.)

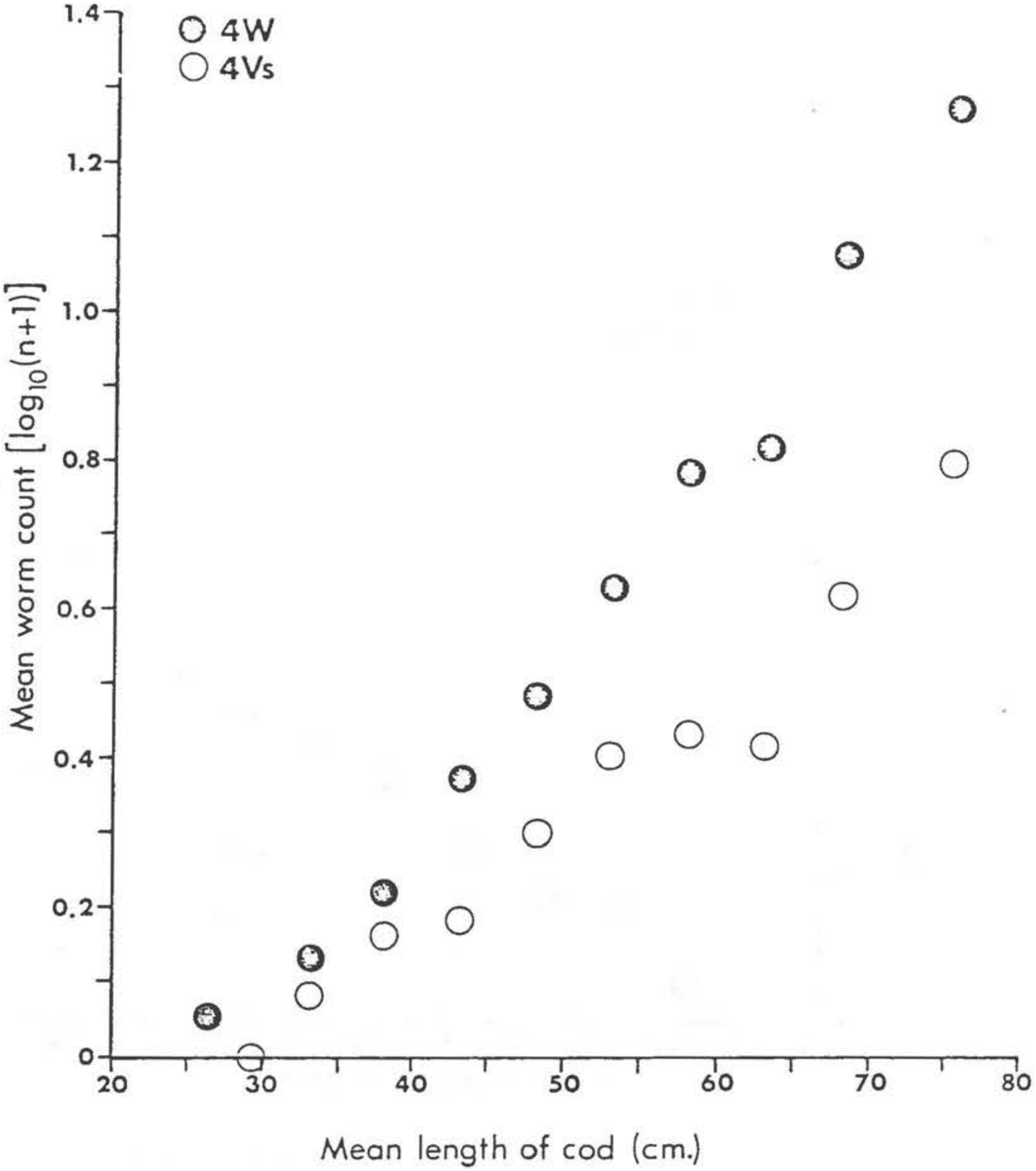

FIG. 5. Mean transformed sealworm count versus mean host length for 5-cm length strata of 4Vs and 4W cod; comparison of worm counts in 4Vs and 4W samples. (Sample from East Bar, Sable Island Bank, omitted.)

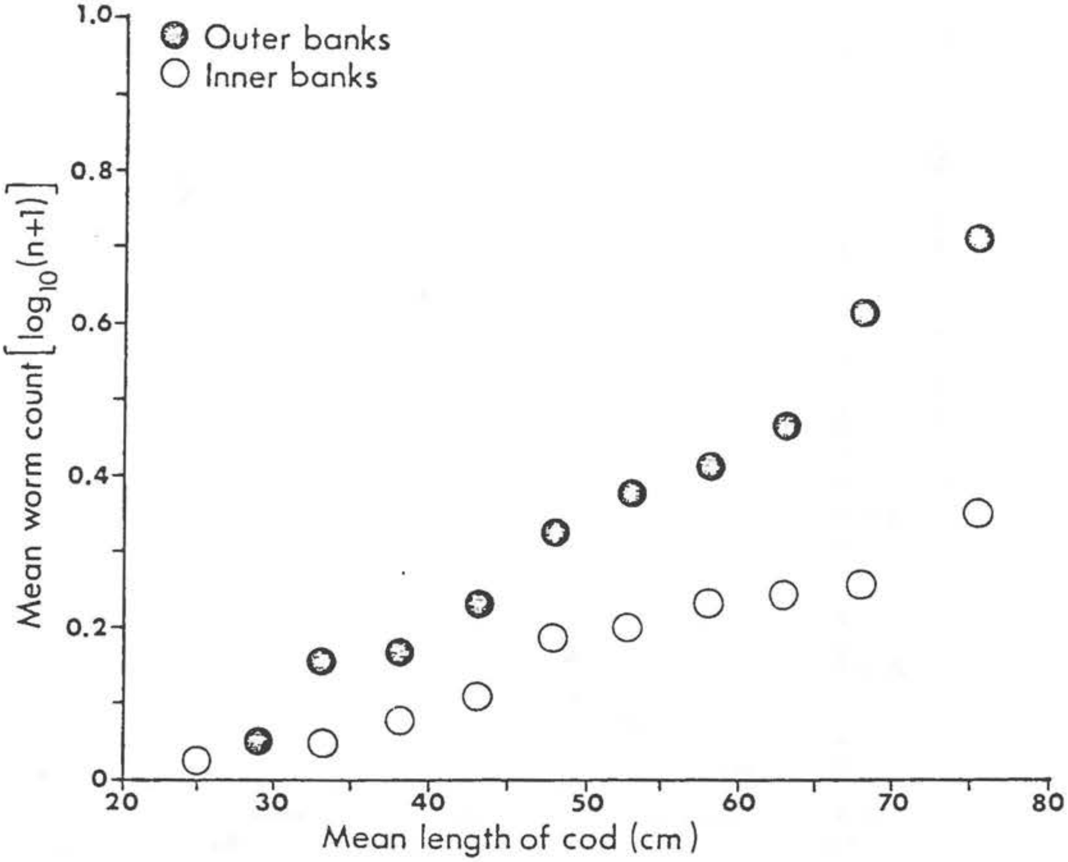

FIG. 6. Mean transformed Anisakis counts versus mean host lengths for 5-cm length strata of 4Vs and 4W cod; comparison of worm counts in "outer" bank (Banquereau, Sable Island, and Western banks) and "inner" bank (Misaine, Canso, and Middle banks) samples.

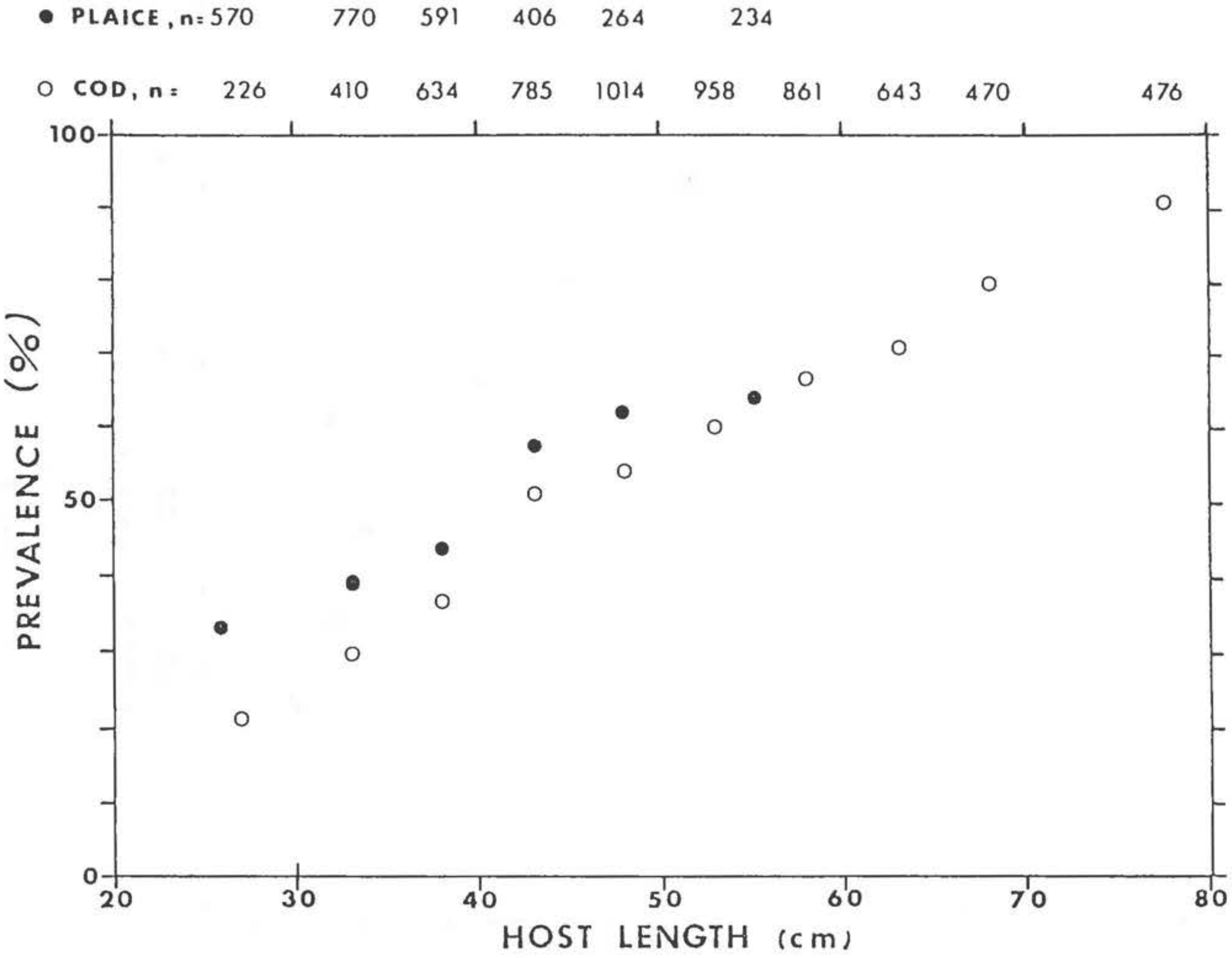

FIG. 7. Prevalence of sealworm infection versus mean host length for 5-cm length strata of 4T, 4V and 4W cod and plaice.

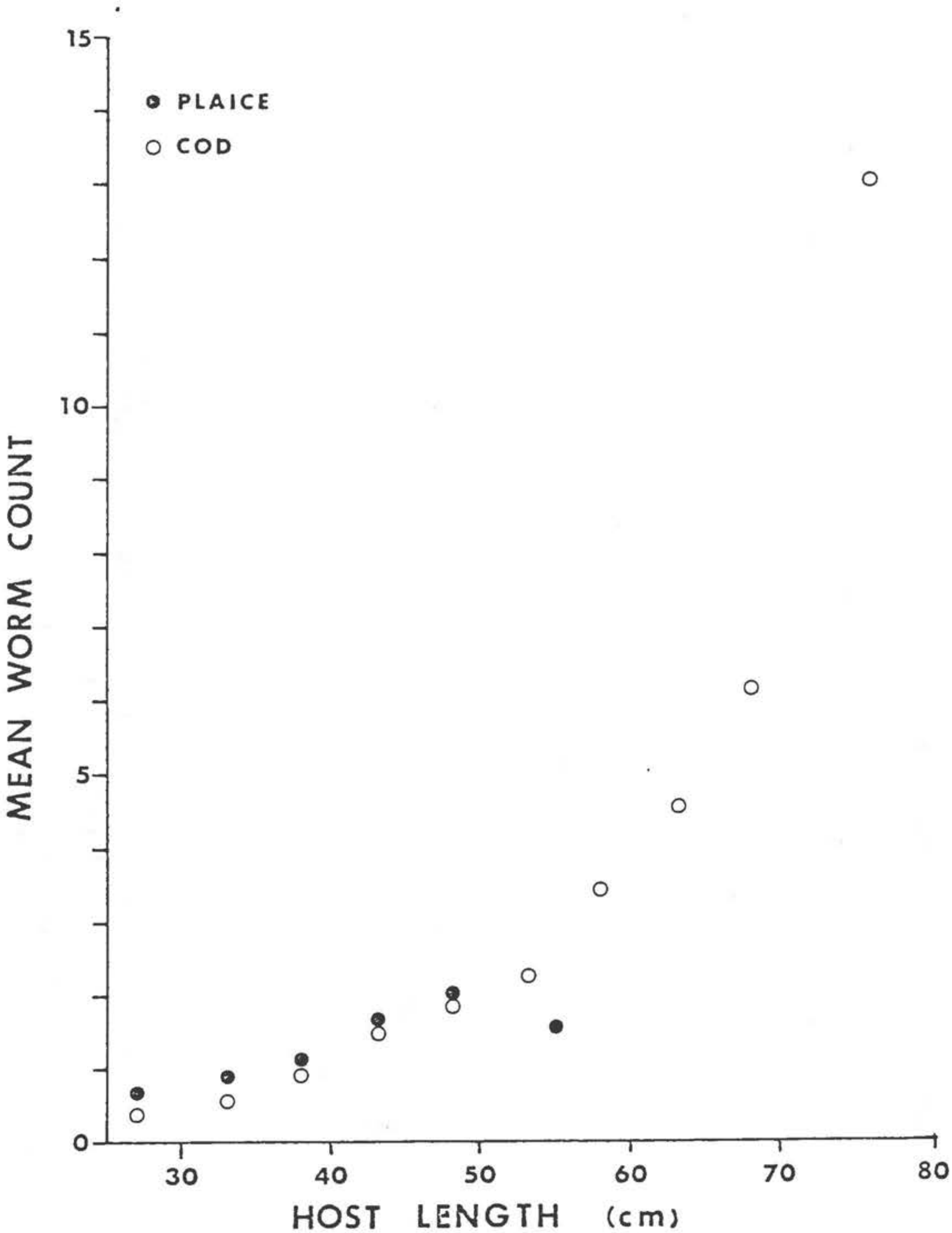

FIG. 8. Abundance of sealworms versus mean host length for 5-cm length strata of 4T, 4V and 4W cod and plaice.

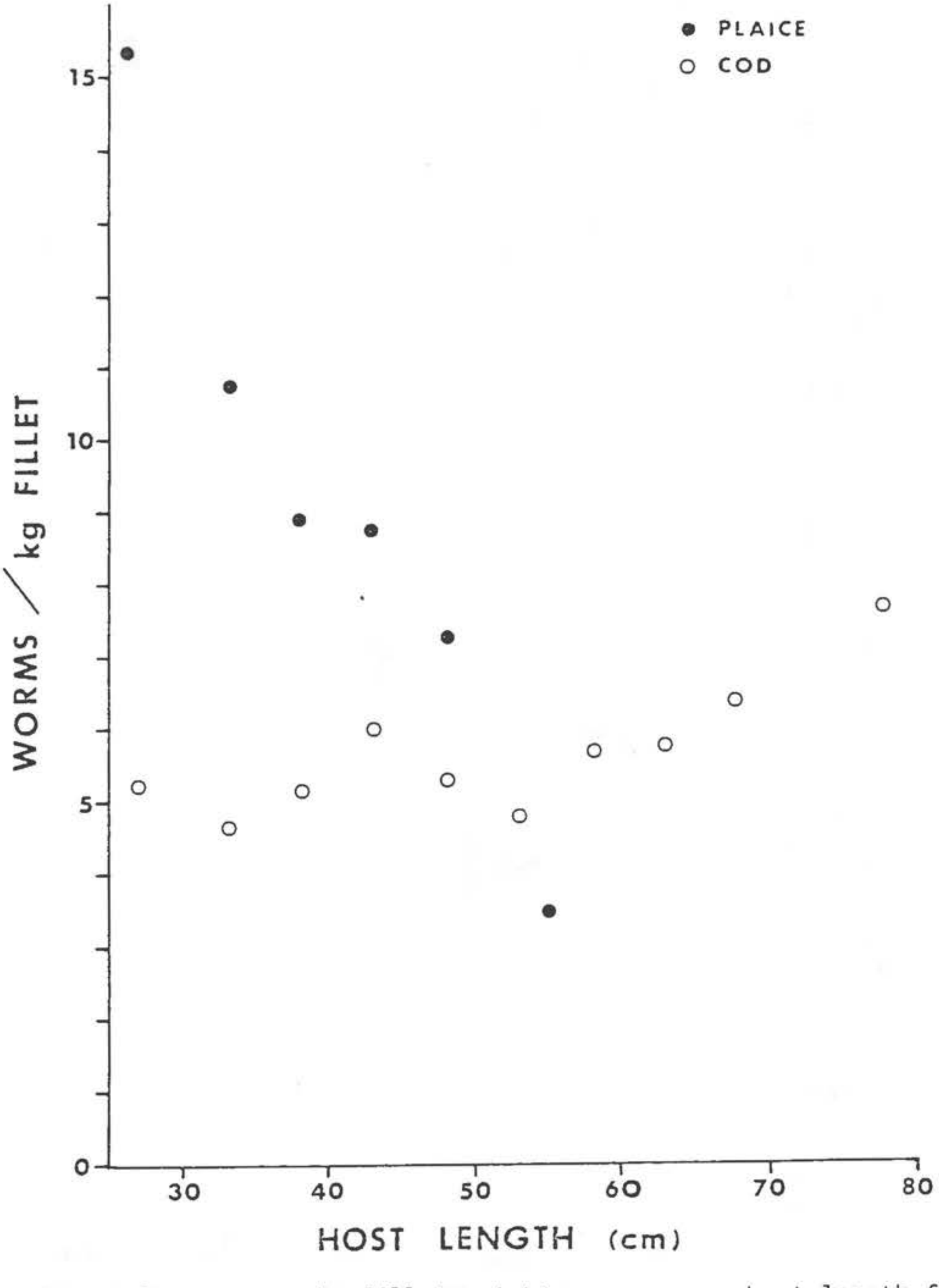

FIG. 9. Sealworm per unit fillet weight versus mean host length for 5-cm length strata of 4T, 4V and 4W cod and plaice.

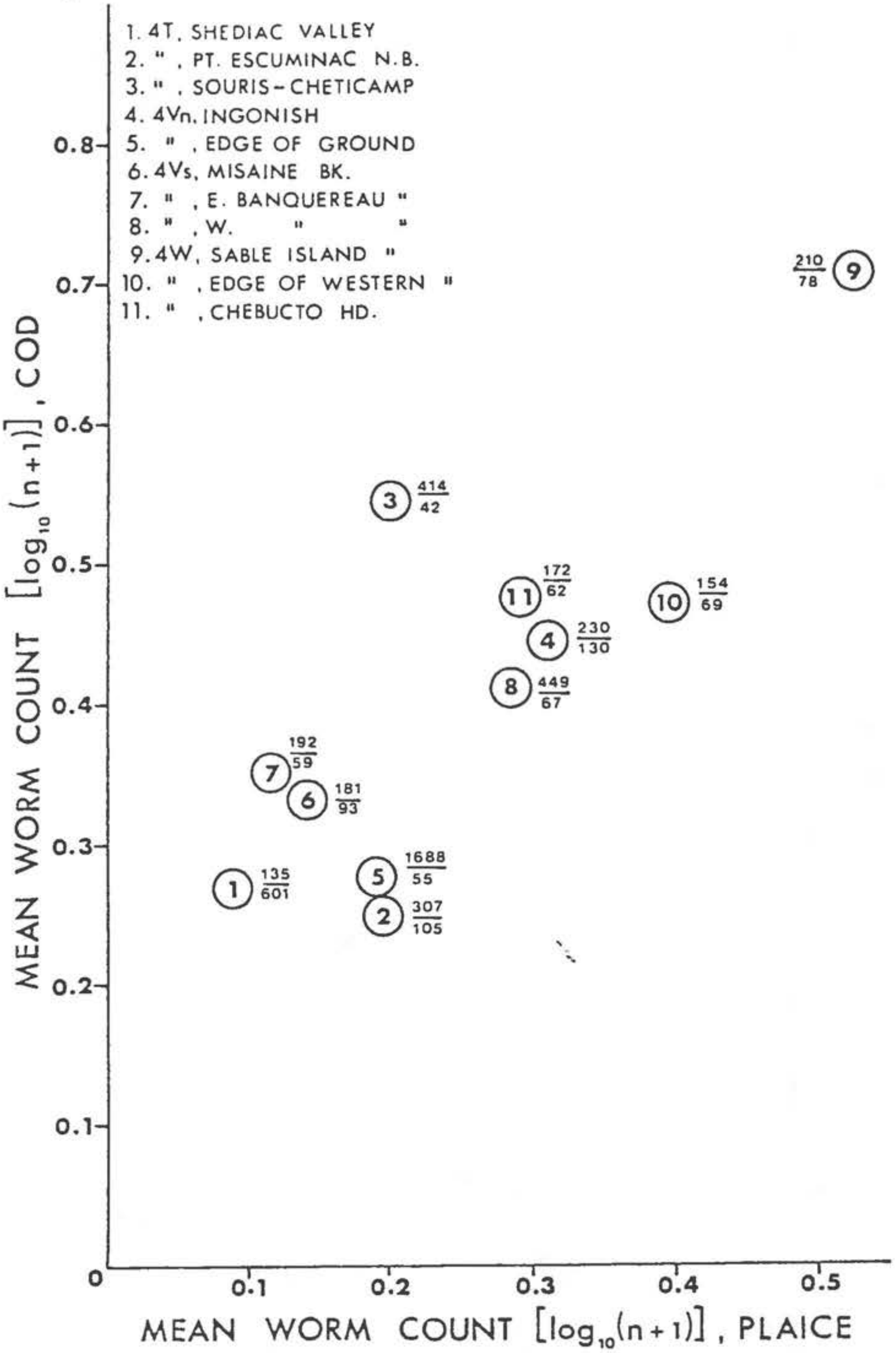

FIG. 10. Mean transformed sealworm counts in cod versus mean transformed worm counts in plaice in corresponding locations. (Cod represented by numerator and plaice, denominator. Frequencies indicated next to points.)

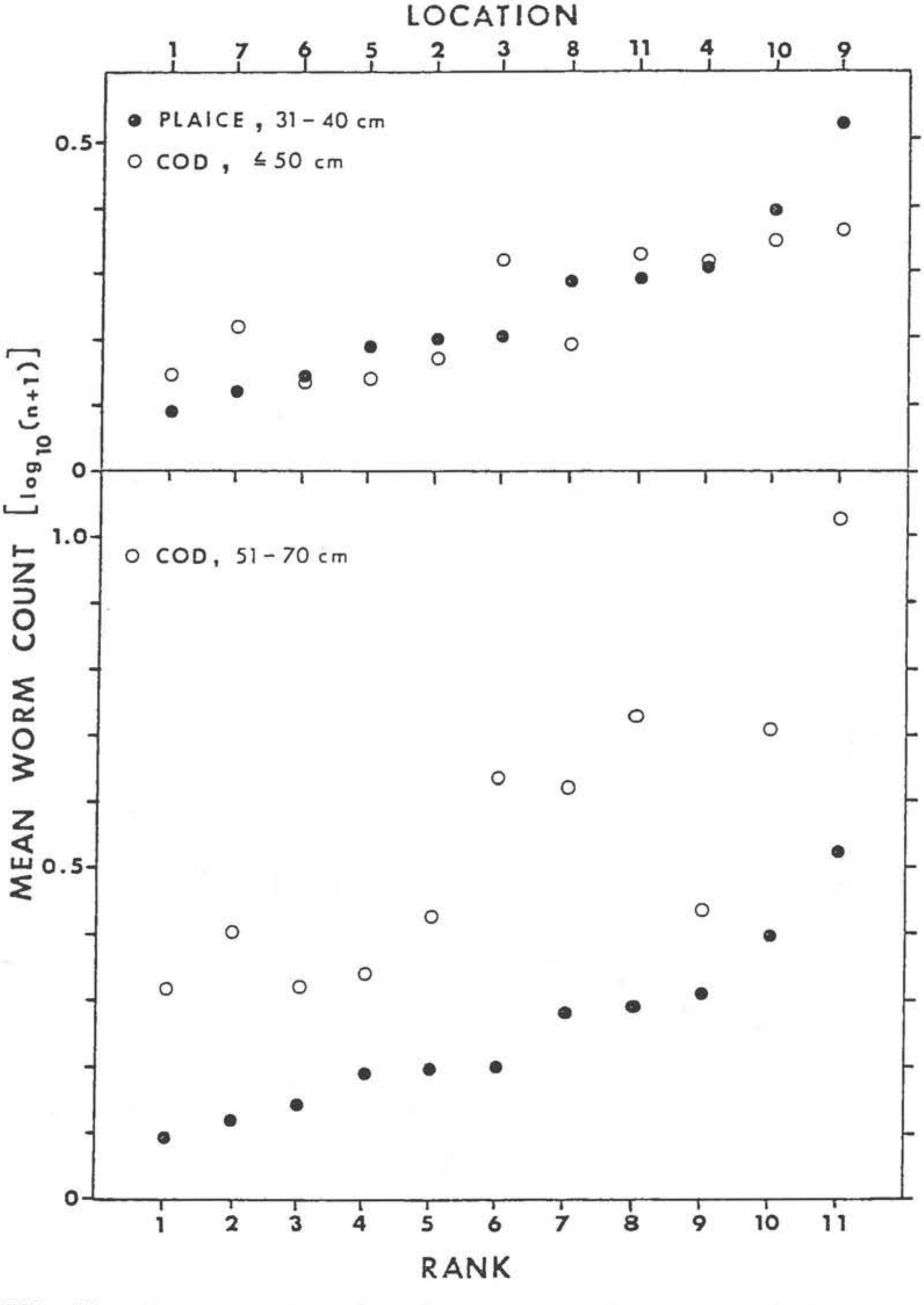

FIG. 11. Mean transformed sealworm counts in cod and plaice versus rank of sampling location. (Sampling locations ranked in ascending order of mean transformed worm counts in plaice.)

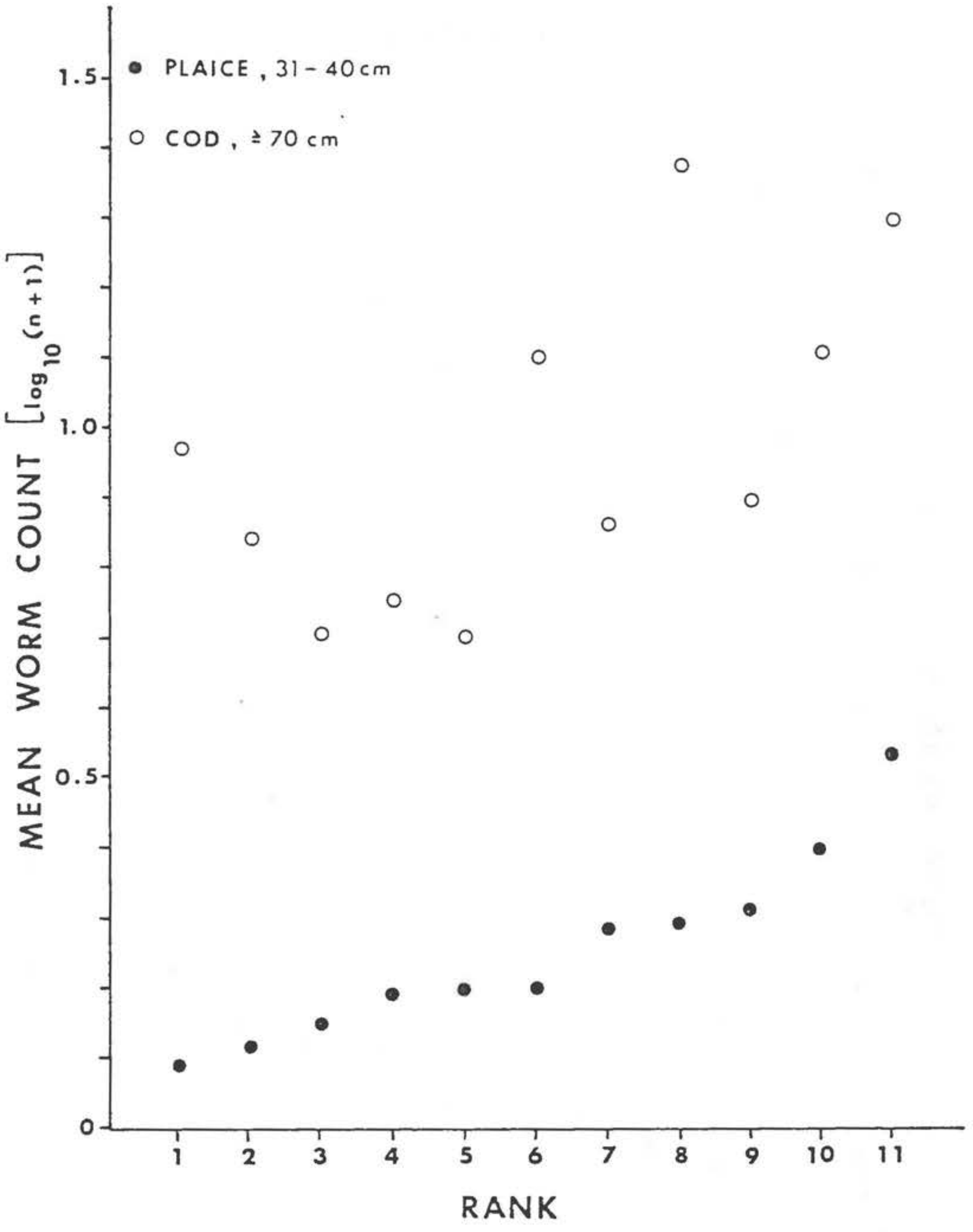

FIG. 11. Continued.

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APPENDIX LIX

TASK FORCE ON SEAL BORNE PARASITES

REPORT

October 25, 1983

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INTRODUCTION

In response to concerns raised by the Atlantic fishing industry, the ADM, Atlantic Fisheries Service, established a task force to analyze and plan means to reduce the problems faced by the industry due to the infestation of commercially important fish stocks by the nematode parasite Phocanema decipiens whose primary host is the grey seal. The task force was directed to examine thoroughly the questions of how to reduce the level of infestation of the parasite in fish stocks and how to improve the efficiency and effectiveness of means of removing the parasite from fish fillets. The task force was asked to consider an increased cull of grey seals in 1983 and beyond as a means of reducing infestation rates in fish stocks in the long-term.

The task force was requested to develop alternative plans for reducing the abundance of grey seals in Atlantic Canada and report on the risks to the Canadian fishing industry associated with alternative culls. Further, the task force was requested to report on means of improving the procedures for removal of the parasite from fish fillets and to propose a plan to monitor the effects of any proposed cull on future parasite infestation levels. Advice was also sought on opportunities to improve the biological basis for management of grey seals associated with any proposed cull.

Economic Considerations

There is no doubt that for fish caught in sub-area 4VW there has been a dramatic increase in the level of parasitic infestation. This problem is spreading into different areas such as southern Newfoundland. Two of the costs to the processing industry have been quantified, i.e. reduced yield and labour to remove parasites (candling). These were estimated as being in excess of $29 million for cod only for 1982. This does not include reduced revenues due to pack downgrading. More information on this is included in the section on economies.

Biological Background

Distribution and Infestation Rates of Phocanema decipiens in Groundfish

Phocanema decipiens is a nematode (worm) parasite found in a number of groundfish species. In The Northwest Atlantic, cod, American plaice, witch flounder and yellowtail flounder are all intermediate hosts. The parasite is also sometimes found in haddock and has been reported in over 30 fish species. The range of distribution in the Northwest Atlantic is from Labrador to Cape Cod. Within that area, the highest levels of incidence are in NAFO Divisions 3P, 4T, 4V, 4W and to a lesser extent, 4X. P. decipiens are also common in groundfish in the Northeast Atlantic, especially in Scotland, Norway and Iceland.

Recent study of the incidence of this parasite indicates that it has become far more abundant (in some cases 100 times greater) in cod in the Eastern Scotian Shelf area and Sidney Bight (4Vs and 4W) than it was 25 years ago. American plaice in Subdivision 4Vn, which were rarely infested 25 years ago, are now subject to heavy infestation. Infestation levels in plaice and other flatfish in Subdivision 4Vs and Division 4W are significantly greater than found 25 years ago and increase with proximity to Sable Island. There is not sufficient evidence to conclude that the current infestation rate of the worm in cod in Division 4T differs from that 25 years ago.

Life Cycle of Phocanema decipiens

Eggs are passed with the faeces of the seal host, settle to the bottom and adhere to the substrate. The development time to hatching is dependent on water temperature and ranges from 8 days at 20°C to 52 days 5°C. Upon hatching, the larvae anchor themselves to the subtrate until they either die, or are ingested by copepods. The larval forms then move through a series of invertebrates in the food chain eventually entering a broad range of fish species. Once in the fish, the worms penetrate the stomach or gut wall and migrate to the musculature where they continue to grow to lengths of up to 60 mm and become encapsulated by host connective tissue.

When an infested fish is consumed by a seal, the parasite escapes from the tissue and partially embeds itself in the stomach wall of the seal. P. decipiens reach sexual maturity after 15-25 days in the seal. Adult worms may grow to 104 mm in length; adult females may contain 200,000 - 500,000 eggs and lay several thousand eggs a day. The average life span in the seal is approximately 35 days, the maximum approximately 75 days.

The grey seal appears to be the main definitive host (host in which the nematode matures) in the North Atlantic. The average infestation rate in grey seals is about 10 times that in harbour seals and is, on average, several hundred worms per stomach in some seasons. The infestations found in the lower Bay of Fundy, however, are probably related to harbour seals. The intensity of infestation in harp seals is quite low (<10 worms per seal). Seals do not appear to develop a resistance to re-infection by sealworm, rather they appear to adapt to its presence and support progressively heavier infestations as they get older. There appears to be a strong correlation between the distribution of grey seals and heavy infestations of P. decipiens in cod on both sides of the North Atlantic.

Geographical Distribution and Abundance of the Grey Seal

Grey seals are found from Labrador to Cape Cod with the greatest numbers found in NAFO Division 3P and Sub-area 4 which consist of the south coast of Newfoundland, the Gulf of St. Lawrence and the Scotian Shelf. The most important breeding areas are on Sable Island and on drifting ice in Northumberland Strait and St. Georges Bay.

Estimates of the abundance of grey seals in the Northwest Atlantic are derived by relating estimates of pup production to the population aged one and older using a life table and maturity schedule. Pup production estimates are obtained from the results of several large scale mark-recapture experiments carried out between 1977 and 1983 on Sable Island and in the Gulf of St. Lawrence. On this basis, CAFSAC has concluded that the 1983 abundance of grey seals aged one and older in the Northwest Atlantic was likely between 60,000 and 130,000. Extensive direct observation and marking has shown that the pup production on Sable Island has been increasing at a rate of 12% per year and that the number of pups increased from 350 in 1962 to 6,000 in 1983. The overall Northwest Atlantic grey seal population has also been increasing steadily, but the actual rate of increase is not known.

ECONOMIC CONSIDERATIONS

1. Introduction

The purpose of this chapter is to document processing costs attributable to parasites Phocanema decipiens and Anisakis simplex (where possible) and consider the impact parasites have on the market value of Canadian groundfish production. It should be noted that Phocanema is a fairly well-documented problem. Anisakis, on the other hand, has only recently been identified as a problem which must sooner or later be addressed by the Canadian fishery. While the focus in this chapter is on Phocanema, Anisakis is included where data permits.

The following sections deal with incremental processing costs and decreased market value caused by parasites in groundfish. First, however, an examination of prevalence is undertaken.

2. The Parasite Problem: Prevalence

The terms prevalence and incidence are generally interchangeable. They mean the percentage of fish possessing at least one parasite. The term abundance means the number of parasites per unit of fish (per fish, per pound fillet weight, etc.). Because Departmental officials have examined the prevalence of parasites, we will not try to duplicate their work in this paper. Rather, this section presents an industry estimate of prevalence.

Whereas the Phocanema problem was once confined to cod in limited geographical areas, the problem has now spread to other species and a much broader area.

Flounder is as heavily infested as cod. Greysole, haddock and catfish are becoming targets on the Scotian Shelf. DFO's Inspection Service has conducted extensive tests of finished product in Atlantic Canada to determine performance measured against the proposed final product grade standards. From the 1982/83 summary information[1], it is apparent parasite infestation leads to significant quality degradation of Canadian fish

Of the information presented at the June 22, 1983 meeting, the following serves to demonstrate the severe nature of the parasite problem: From 1980 to 1982, of steak cod sampled from NAFO area 4VsW had a mean worm count per fish of 18.31, and the mean worm count per kilogram was 10.68.

Whereas the Phocanema problem was once confined to the Gulf of St. Lawrence and Sydney Bight, the problem is now much more widespread. The Gulf of St. Lawrence offshore and southern Gulf

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[1] Distributed to Members of the Working Group on Fresh and Frozen Groundfish, July 4, 1983.

inshore fisheries show stable parasite infestation. A relatively newer problem is reported by processors on the Gulf side of Cape Breton. Evidence indicates prevalence in the Sydney Bight area is three to ten times the prevalence during the 1950's. In NAFO area 4W, parasite abundance falls off as distance from Sable Island increases. There is evidence, however, that fish in 4X is infested: recent product inspection checks in South West Nova Scotia have revealed unacceptable high levels of parasites.

The infestation rate in South Coast of Newfoundland and the Newfoundland Gulf has increased in alarming proportions in the last five years. General estimates indicate infestation has increased four to six fold in that time. Phocanema is reported from the inshore and offshore 3Ps and 3Pn cod, but is more restricted to inshore cod in 4RS. With respect to the rest of Newfoundland, Phocanema seems to be prevalent in the area west of and including 3Ps and in recent years has spread east to areas 3L and 3NO.

Anisakis is generally confined to the Northern cod stock because of the areas inhabited by its hosts.

Based on aggregated corporate data made available from which the general observations made in this section are extracted, we believe it is accurate to summarize the Phocanema and Anisakis problem in Table 1.

Table 1

1982 Parasite Prevalence

A. Cod

Parasite	NAFO Area	Round Weight	Finished Product Weight[1,2]	
		Pounds	Pounds	No. per lb.
Phocanema	4Vs-Vn-W	164,022,000	54,127,000	2.50
"	3Pn, 4RST	340,831,000	112,474,000	1.50
"	3Ps	70,528,000	23,274,000	.40
Anisakis	2J,3KL[3]	215,024,000	70,958,000	.22
B. Flounders				
Phocanema	4VWX[4]	24,182,000	7,013,000	2.00

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[1] Assumes 33% yield for cod; 29% yield for flounders.

[2] Finished product weight means weight following cutting but before trimming.

[3] Vessels over 100 ft. caught 97,561 mt.

[4] Major problem at present does not extend beyond 4VWX.

3. Incremental Costs to Fish Processors due to Parasites in Cod.

Parasites in cod cost fish processors money. Incremental costs to processors are caused primarily by decreased yields and additional labour (primarily candling and trimming).

Yields

The act of removing a parasite from fish flesh involves cutting the flesh of the fish. The removal of a single parasite results in decreased yield. When cutting fish with a significant level of infestation, processors often cut away the nape because of parasite concentration in that area. Disposal of the nape reduces yield 3.5 points or about 10 percent of finished produce weight.

Napes are approximately discarded from approximately 25 percent of Northern cod due to Anisakis. It is estimated that napes are discarded from 40 percent of cod caught on the Scotian Shelf due to Phocanema. In the Gulf, Phocanema claims 35 percent of the napes.

The cost of parasites in terms of decreased yield can be approximated by calculating the cost of discarded napes. The following steps form this calculation:

1. The approximate weighted average market price for Canadian cod products in 1982 was $1.63[1]. This is calculated by summing the products of pack type (such as premium) and pack type market price for major pack types.
2. Of 2J,3KL cod, 25 percent of the napes are discarded due to Anisakis. The cost is: 215,024,000 pounds x 25% discarded napes x 3.5% yield loss x $1.63/lb. weighted average market price, or $3,067,000.
3. Of 4Vs-Vn-W cod, 40 percent of the napes are discarded due to Phocanema. The cost is: 164,022,000 pounds x 40% discarded napes x 3.5% yield loss x $1.63/lb weighted average market price, or $3,743,000.
4. Of 3Pn, 4RST and 3Pn cod, 35 percent of the napes are discarded due to Phocanema. The cost is: 411,359,000 pounds x 35% discarded napes x 3.5% yield loss x $1.63/lb. weighted average market price, or $8,214,000.

The total cost of parasites due to lost yield was $15,024,000 in 1982

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[1] $1.63 is $U.S. 1.33 at 1.23 exchange rate.

Candling and Trimming Labour

The major direct cost for fish processors caused by parasites is the incremental labour cost for candling and trimming. There is a cost attributed to the capital outlay for candling tables and the potential costs caused by modification to a plant to accommodate candling tables. It may also be necessary to include additional costs for training and supervision related to incremental candling and trimming labour. For the purpose of this paper, however, only the incremental direct labour costs of searching for and removing parasites are identified.

These costs for cod are identified in Table 2.

Table 2

Incremental Candling and Trimming Costs to Fish Processors due to Parasites in Cod

Parasite	NAFO Area	Finished Product Weight		Labour Cost[1]	Industry Cost[3]
		Pounds	No. per lb.		
Phocanema	4Vs-Vn-W	54,127,000	2.50	$.094	$ 5,088,000
"	3Pn, 4RST	112,474,000	1.50	.072	8,098,000
"	3Ps	23,274,000	.40	.035	814,000
Anisakis	2J,3KL	70,958,000	.22	.0035[2]	248,000
				Total	$14,248,000

[1] 1982 incremental labour cost per pound given approximate average infestation level.

[2] $.0035 is actual incremental cost per pound of napes ($.035).

[3] Industry cost is labour cost per pound x total finished product weight at given level of incidence.

Table 2 reveals an expenditure of over $14 million in 1982 for direct labour to remove parasites in cod. This can only increase because the life cycle of the parasites means that even with immediate action, no reduction of the growth of the parasite problem can be expected to place over the next few years.

Incremental processing costs of cod in 1982 are:

1. yield	$15,024,000
2. labour	14,248,000
	$29,272,000

4. Incremental Costs due to Parasites in Flounders

Table 1 revealed that the abundance of parasites in flounders is approximately 2.0 per finished pound of fillets. Research and data collected to date has not focused on the cost to processors of parasites in flounders. It appears the cost of detection and removal in terms of additional labour is not as great as it is for cod. This is because flounder fillets are relatively thinner, so parasites are easier to detect and remove.

The other major point, however, is that the abundance of parasites in flounders is a severe problem but so far it is restricted geographically. The concern of processors is that the abundance will increase, and in addition, it will become a generalized east coast problem. For instance, the Phocanema incidence in flounders off Newfoundland approaches that currently in existance on the Scotian Shelf, the magnitude of the Phocanema problem in flounders would approach that of the Phocanema problem in cod.

5. Decreased Market Value

Parasites decrease the market value fish processors receive for their products. Decreased market value is caused primarily by downgrading of product and rejections. This subject will be addressed qualitatively rather than quantitatively.

Downgrading of Product

Deworming can only reliably remove approximately 75 percent of the parasites in fish. In fish fillets thicker than 5/8 inch, it becomes very difficult to see some parasites (even under ideal conditions). With heavily infested fish, the common industry practice is to "strip" or cut the fillet longitudinally in order to decrease the thickness of the flesh and make parasites more readily visible. Even with stripping, only about 80 to 85 percent of the parasites are likely to be removed.

The upper limit to parasite removal means there is a certain raw material infestation level beyond which the final product will automatically be downgraded. For example, if the customer specification permits no more than four parasites per 20 pounds, the raw material can have no more than 16 parasites per 20 pounds (4 divided by .75). For all cases where the parasite level exceeds 16 per 20 pound sample, the processor cannot meet that customer's specification.

Thus, there can be certain raw material which is diverted to lower value packs because it is known removal of parasites cannot be accomplished without incremental costs exceeding incremental revenue. This is an example of downgrading caused directly by parasites.

Downgrading is also caused indirectly. If parasitic fish is being processed, the volume of production decreases. To the extent raw material is held longer before production because of the time taken to remove parasites, other quality problems which contribute to downgrading arise. For instance, texture will deteriorate while raw material is held prior to processing.

On the south coast of Newfoundland particularly in 3Ps, parasitic infestation in the fillet has reached the point where high grade premium packs such as Long John Silver are not attainable. This is due to the removal process which downgrades the product. Cod from 4Vn is regularly packed as block pack, whereas in 3Ps and 4RS, 3Pn, 50 percent of the pack, which would normally be prime pack, is downgraded to block pack.

Rejections

Increasingly the buyers of Canadian fish products are using parasites as a bargaining lever to decrease the price for Canadian fish. Many major buyers have a specification calling for no parasites. They also have no tolerance. Thus, these buyers are able, at any time, to reject product because it does not meet the specification and demand a lower price. Because the practice has increased dramatically during the current recession, we believe the rejections reflect a desire for lower priced product more than an increased prevalence of parasites. In any event, these rejections do decrease the market value of Canadian fish.

6. Conclusion

This chapter has examined costs absorbed by fish processors due to parasites. It was possible to estimate costs for reduced yield and incremental labour for cod based on 1982 at over $29 million per year. It was not possible to quantify estimated costs for processors due to reduced market value because downgrading and rejections are more often due to a variety of factors rather than parasites in isolation and industry estimates of the impact of parasites varied widely.

There can be no doubt that processors consider the costs of parasites onerous and cannot afford to neglect the problem. Processors support a grey seal cull to confine and hopefully reduce the Phocanema problem. The processing industry supports further research not only into Phocanema and grey seals but also into Anisakis and its hosts.

Before remedial action is implemented and the beneficial effects of a grey seal cull are felt, processors will still be faced with the costs of parasites. To some processors, plant closures may well be the optimal response to the problem. Others may adjust their buying practices - through something such as dockside grading - to more accurately reflect the true value of the raw material.

There is considerable risk if a "no-action" decision is taken with respect to the size of the grey seal herd. Processors will be faced with escalating costs to deal with an increasing parasite problem. This fact cannot be disputed. As well, a decision to postpone taking action for a period of say five years could result in grey seals and any proposed cull being the exclusive target of some groups. Although these have implications for processors' costs. They are difficult to quantify at this point. They should be kept in mind and an attempt at quantification made should the Department consider a "no-action" decision.

PARASITE REMOVAL

1. Introduction

The purpose of this chapter is to examine the current technology used to locate and remove parasites and speculate about future technological developments in this field. The current technology is common industry practice. Future technologies which can be developed for the fishery deserve more thought than the current timetable allows.

Prior to dealing with technologies, it is useful to explain the parasite regulations in place at present.

2. Parasite Tolerances

Current government policy allows a maximum of 5 parasites in 15 pounds of fish products. If the number of parasites exceeds 5 in 15 pounds, the product is deemed unwholesome. Product can be unwholesome because of 1) bacteria, 2) toxic substances, or if it is 3) aesthetically offensive. While there is some debate about whether or not parasites contribute to unwholesome because they are toxic, there seems to be agreement that parasites are aesthetically offensive. Unwholesome product can, of course, be detained by the Department of Fisheries and Oceans.

As noted in the Economics Chapter, customer specifications can be for no parasites and no tolerance. This, of course, is virtually impossible to meet. Large customers are inclined to use parasites as a lever to negotiate price reductions.

3. Current Technology

It is assumed that readers are familiar with candling tables in use in fish plants in Atlantic Canada. There is a problem caused by the intensity of light above the candling tables because the minimal illumination required to light the fish plant provides too much background light to properly view the parasites in the fish flesh.

A series of candling tables can be made available outside the normal production area. This allows for a particularly bad quality of fish to be candled a second time - it does not slow down production. This second candling area, however, cannot be accommodated in some plants due to size constraints.

At the H.B. Nickerson and Sons Canso plant, relatively new candling tables are in use. These provide new table position and a unique system for separating candled products.

In the realm of production management, various techniques (such as team management whereby work functions alter regularly) can be used to ensure the candling effort obtains maximum results.

Current Technology

A second major aspect of current technology involves buying practices. By grading fish at dockside, it is possible to predict quite accurately the anticipated parasite removal problem and adjust production planning accordingly. It is also possible to establish a price mechanism which penalizes the landings of fish containing parasites.

4. New Technology

New technology can be in one of two areas: 1) detection, or 2) removal.

A variety of methods to improve detection of parasites are in various stages of development. First, a complete review of current candling techniques focusing on optimum illumination is required. There is also a development in the U.S. which should be followed closely. This is the utilization of sound frequencies to identify if fillets contain worms. This detection equipment could be linked to a mechanical separator such as an electric eye to physically separate fillets with parasites from those with none. This development would allow candling effort to concentrate on those fillets with a known infestation problem. Third, lasers are being investigated in Japan.

In the area of removal, a number of techniques new to Canada should be evaluated. First, there may be value in determining if Phocanema's sensitivity to extremes of hot and cold can be used to incourage parasites to leave the flesh of fish. There are unconfirmed reports that the technique is used in Scandinavian countries to rid fish flesh of parasites. This should be investigated. Second, Baader Corporation is reported to be conducting an investigation in Germany into a new technique which identifies fillets containing worms, locates the worms, and mechanically removes the worm. This technique is reported to combine ultra sound technology with computer video equipment.

5. Conclusions and Recommendations

Because the incremental costs fish processors face as a result of the Phocanema problem are not anticipated to decrease in the foreseeable future - even with a grey seal cull - and because the benefits of a grey seal cull are anticipated only in the long term, there is an urgent need for the examination or review of new technologies and the establishment of research and development projects to create and adapt new technologies to the detection and removal of parasites in fish.

The time constraints in the current Task Force exercise prohibited generation of more complete data. It is recommended consultants be retained to conduct work in this area and report back to the Department on an urgent basis. The work undertaken by consultants should include:

Conclusions and Recommendations

1) An examination of technologies currently available for the detection and removal of parasites in the fisheries and other industries;

2) A field study of processing costs based on current industry practices to determine the optimal techniques (including both equipment requirements and operational methologies) for parasite detection and removal, and;

3) An evaluation of new techniques to determine effectiveness and cost of various alternatives ranging from industry adoption of optimal current techniques to novel techniques (such as lasers, ultra sound, etc.) ready for adoption by the Canadian fishing industry;

4) An estimation of time required to implement either modified current techniques or novel techniques.

RISK ASSESSMENT

1. Introduction

The purpose of this chapter is to assess the risk associated with a major cull on the grey seal population on the east coast of Canada. "Risk", in this case, refers to the potential negative impact on various industry sectors and on government resulting from anticipated publicity and pressures created by interest groups opposed to the killing of marine mammals. The assessment will identify "targets" of adverse publicity, and state the major variables affecting the degree or level of negative impact. An attempt will be made to assess the probability of significant negative impact on the Canadian fishing industry related to boycott activities by protest groups and to a heightened awareness of consumers and buyers of parasites in Canadian fish products.

2. "Targets" of Adverse Publicity

Potential "targets" of adverse publicity generated by interest groups opposed to the proposed culling of grey seals include:

(A) The Canadian Fishing Industry

The fact that the fishing industry in Canada would be the major promoter of a culling operation would make it a primary target of protest groups. This, combined with the leverage provided the protest groups through the commerical threat of a boycott of fish products, places the Canadian fishing industry in a position of being a MAJOR target. Targetable products would be those labelled as "Product of Canada". Therefore, the products most vulnerable would be retail products. The main products sold in the major retail markets outside Canada would include: canned salmon to Europe and Australia; canned herring and sardines to the U.S.; lobster frozen in brine to the U.S.; canned crab to France and the U.S.; canned lobster to the U.S.; and various groundfish packs to the U.S.

The primary objective of the industry in supporting the culling of the grey seal herd is a reduction in prevalence of the seal worm. It is logical to assume that this rationale would become public knowledge and further activities of various interest groups may heighten the awareness that there are parasites in Canadian fish products. This heightened awareness may result in:

(a) reduced consumption of fish products generally;
(b) redirecting purchases towards competitive suppliers, eg. Iceland, therefore a loss of market share;
(c) pressures to reduce prices leading to reduced margins.

This risk element will be borne entirely by the Canadian fishing industry. Suppliers of fresh and frozen groundfish products to Canadian and U.S. markets will be most vulnerable.

(B) The Canadian Government

The Government of Canada, particularly the Department of Fisheries & Oceans, will be a MAJOR target of protest groups as being responsible for both the decision for and the implementation of a major culling operation. The Government would be placed under pressure to protect its international image. This would come primarily through the media, although there could also be some political pressure in the form of questioning by opposition parties. Any defense of a management decision to cull the grey seal herd would be more difficult given the inconclusive scientific evidence with respect to the size of the population as well as the correlation between the population and prevalence of parasites. An effective pre-planned communications strategy would be a prerequisite to a major culling operation. While it would be risky for the fishing industry to take a high profile position in support of Government (due to the potential reaction of consumers in response to a focus on the parasite problem), it is considered necessary for industry to provide visible support.

(C) The Canadian Seal Hunt

While there is no direct connection between the commercial seal hunt in Canada and a culling of the grey seal population, any protest of a grey seal cull would have an impact on the commercial hunt. A cull would revitalize protest activity against all sealing, for whatever reason, and complicate efforts to re-establish the seal pelt trade in Europe. Although this risk is acknowledged, it is suggested that, in relative terms, the impact on the commerical seal hunt would not be major.

(D) Miscellaneous Sectors Involved in International Trade

It is conceivable that sectors such as the tourism industry and various export industries may be affected as a result of international protest. It is the opinion of this Task Force that fish products would be the "best" focal point from the point of view of protestors organizing boycott action. It is unlikely that there would be any impact on other industries.

3. Variables in Assessing Risk

It is difficult to provide precise estimates of risk or damage associated with adverse reaction to a major culling operation. It is useful to identify the major variables which would influence the level of risk or damage.

(a) Level of money and effort expended by protest groups in organizing a boycott of Canadian fish products.

(b) Level of publicity given to the link between the culling operations and the problem of parasites in fish and fish products.

(c) Effectiveness of Government/Industry communications strategy.

(d) Effectiveness and duration of culling operation.

4. Boycott

This section addresses the probability of a signigicant negative impact resulting from boycott activities organized by protest groups. The chart outlined below attempts to quantify the risk measured on a scale of 0 (very low risk) to 10 (high risk). Due to the variables identified in Section 3, no attempt has been made to attach a "value" to lost sales if any.

Canadian Market

Retail . . . . 0 1 [✓ 2 3] 4 5 6 7 8 9 10
Food Service . . . . 0 [✓ 1 2] 3 4 5 6 7 8 9 10

United States Market

Retail . . . . 0 1 2 3 [✓ 4 5] 6 7 8 9 10
Food Service . . . . 0 1 [✓ 2 3] 4 5 6 7 8 9 10
Processor . . . . [✓ 0 1] 2 3 4 5 6 7 8 9 10

European Market

Retail . . . . 0 1 2 3 4 5 6 [✓ 7 8] 9 10
Processor . . . . 0 [✓ 1 2] 3 4 5 6 7 8 9 10

Japanese Market . . . . [✓ 0 1] 2 3 4 5 6 7 8 9 10

From the above, it would appear that boycott activities would be most successful in the retail markets in Europe and the United States. While the "risk" with respect to the retail market in the U.S. is significant, the major impact, should it occur, would likely be in the retail market in Europe. Communications strategies should thus be developed to focus on these market segments.

5. Heightened Awareness of Parasite Problem

This section addresses the probability of a significant negative impact resulting from heightened consumer/buyer awareness of parasites in Canadian fish products. The chart outlined below attempts to quantify the risk measured on a scale of 0 (very low risk) to 10 (high risk). No attempt has been made to attach a "value" to lost sales if any.

Canadian Market

Retail . . . . 0 1 2 3 4 5 6 [✓ 7 8] 9 10
Food Service . . . . 0 1 2 3 4 5 6 [✓ 7 8] 9 10

United States Market

Retail . . . . 0 1 2 3 4 5 6 [✓ 7 8] 9 10
Food Service . . . . 0 1 2 3 4 5 6 [✓ 7 8] 9 10
Processor . . . . 0 1 2 3 [✓ 4 5] 6 7 8 9 10

European Market

Retail . . . . 0 1 [✓ 2 3] 4 5 6 7 8 9 10
Processor . . . . [✓ 0 1] 2 3 4 5 6 7 8 9 10

Japanese Market . . . . [✓ 0] 1 2 3 4 5 6 7 8 9 10

The major risk associated with increased consumer/buyer awareness of parasites in Canadian fish products is with the retail and food service markets in both Canada and the United States. Any impact would most likely be manifested in reduced fish consumption generally. Loss of market share would be more or less a factor depending on the effective communications program with the clear message that the parasite problem is not uniquely a Canadian problem, i.e. competing suppliers also have this problem. Pressures to reduce prices would be felt in the processor market in the United States. This market segment is relatively sophisticated and buyers will use the occurance of parasites as a price lever in any event.

CULL PROGRAM

Introduction

The task force examined several alternatives for reducing the abundance of grey seals, including ways of also reducing the abundance of the nematode parasite propagated by the grey seals. These alternatives included the present cull, and expanded cull, the current bounty program, an expanded bounty and various other possible programs such as anti-fertility drugs, hiring of professional hunters on a contract basis. Lengthy discussions took place on all these alternatives. The administration of anti-fertility drugs to the breeding females would be a humane approach; however, it has several disadvantages:

a) The technique is not proven.

b) The logistics of adminsitering it to most adult females are almost impossible.

c) Even if successful, it would merely stabilize the size of the herd at its present level until natural mortality reduced the numbers, thereby not addressing the parasite problem.

The deworming technique is presently not effective for a lengthy period of time (in excess of four months) and the problem of locating all the animals, including the bulls, to administer the drug is almost insurmountable.

Following discussions, it was concluded that the most practical way of reducing the grey seal population involves a combination of the cull and the bounty program.

Departmental Cull

The Department, using fishery officers, operating in concert with professional sealers employed by K. Karlsen Shipping Ltd. has been carrying out a controlled cull program every year since 1967. The program has operated in four areas, three islands off the coast of Nova Scotia; Amet Island, Basque Island, and Camp Island, as well as the ice in Northumberland Strait and Georges Bay. The results of this program are summarized in the following table.

Table 1: Controlled Cull[1]

Year	Male	Female	Total Adult[2]	Pups	Total
1967	14	3	17	212	229
1968	16	2	18	134	152
1969	3	19	189	589	778
1970			125	520	645
1971			122	743	865
1972	22	110	132	599	731
1973	4	35	64	558	622
1974	17	109	126	1042	1168
1975	54	480	534	1619	2153
1976	13	83	96	545	641
1977	150	192	342	1046	1388
1978	59	88	147	569	716
1979	15	30	45	269	314
1980	46	165	211	921	1132
1981	119	277	396	1212	1608
1982	140	578	718	1009	1846
1983	136	527	663	1627	2385

Note (1) Includes seals killed by others and found during the cull.

(2) Not all adults sexed so total may be different from males plus females.

This cull has not been successful in controlling the population increase of grey seals. It should be pointed out, however, that the cull's effectiveness has been reduced because of the effort expended in salvaging the animals' pelts. One can surmise, however, that without it the population increase would have been even more dramatic.

There is an expanding breeding colony of grey seals on Sable Island. No cull program has been carried out on Sable; however, we have been carrying out research on pup production and movements since 1962. These show a steady increase in pup production (see Table 2). Tagging experiements have shown that there is some intermixing of the Sable Island colony with the mainland population. The Sable Island colony is one of the largest known breeding colonies of grey seals that can be culled, and since there are no other know significant ones, except possible for the spring ice in Northumberland Strait, any major effort to reduce the seal populations will have to involve Sable Island. There is a possibility that some colonies may exist in the Gulf. of St. Lawrence. Efforts should be intensified to locate additional colonies in the Gulf during the pupping season since the key to population reduction may depend on this.

The task force examined various options for increasing the cull, including culling the maximum number of seals possible and a number of alternatives which would permit the tagging of seals for scientific studies. Scientists have specifically requested that pup escapement from Sable Island be tagged and requested that no culling operations be conducted in the Gulf for one year to permit a large scale tagging operation.

Table 2: Actual Pup Production on Sable Island.

Year	Number of Pups[1]
1962	350
1963	400
1964	500
1965	660
1966	No data
1967	580
1968	750
1969	836
1970	930
1971	1060
1972	982
1973	1226
1974	1278
1975	No data
1976	2006
1977	2181
1978	2687
1979	2937
1980	3600
1981	3600
1982	4500
1983	6000

(1) Estimates based on counts from Mansfield and Beck, 1977, 1978, 1979, 1980 from B. Beck.

(2) It is estimated that there is approximately a 14% pup mortality which would mean a lower escapement figure that those indicated.

OPTION 1

Option one is a tabulation of the maximum numbers of seals that could be obtained through the most intensive cull program possible. Anticipated results are summarized below:

Location	Pups	Adult Females	Adult Males	Total
1. Sable Island	6000	3000	600	9600
2. Amet Island	500	200	40	740
3. Camp Island	250	50	10	310
4. Basque Island	80	20	-	100
5. Anticosti Island (Summer Cull)	-	150	150	300
6. Magdalen Islands	60	20	-	80
7. Northumberland Strait Ice	3000	2000	600	5600
8. Sable Island (Summer Cull)	-	150	150	300
TOTALS	9890	5590	1550	17030

OPTION 2

Option two is similar to option one except that it allows the escapement of a number of pups from Sable Island. This pup escapement would permit continued population assessments. However, it reduces total removals, and would mean a longer program to achieve the target population level. The cost of option two does not significantly vary from option one. The estimated cull would then be:

Location	Pups	Adult Females	Adult Males	Total
1. Sable Island	4000	3000	600	7600
2. Amet Island	500	200	40	740
3. Camp Island	250	50	10	310
4. Basque Island	80	20	-	100
5. Anticosti Island (Summer Cull)	-	150	150	300
6. Magdalen Islands	60	20	-	80
7. Northumberland Strait Ice	3000	2000	600	5600
8. Sable Island (Summer Cull)	-	150	150	300
TOTALS	7890	5590	1550	15030

OPTION 3

Option three provides for the escapement of the seals on the Northumberland Strait ice, Amet Island and Magdalen Islands. The scientists state that this is necessary if we are to firm up our population estimates for the Gulf component of the herd. It should be noted that this option reduces the number of adult females being taken and consequently reduces the effectiveness of the cull, more so than option two. The estimated cull would then be:

Location	Pups	Adult Females	Adult Males	Total
1. Sable Island	6000	3000	600	9600
2. Amet Island	-	-	-	-
3. Camp Island	250	50	10	310
4. Basque Island	80	20	-	100
5. Anticosti Island	-	150	150	300
6. Magdalen Islands	-	-	-	-
7. Northumberland Strait Ice	-	-	-	-
8. Sable Island (Summer Cull)	-	150	150	300
TOTALS	6330	3370	910	10610

OPTION 4

Option four combines options two and three. The revised totals would be as follows. This option would meet all the scientific request, but it is doubtful if we could achieve a significantly reduced population within a reasonable period of time.

	Location	Pups	Adult Females	Adult Males	Total
1.	Sable Island	4000	3000	600	7600
2.	Amet Island	-	-	-	-
3.	Camp Island	250	50	10	310
4.	Basque Island	80	20	-	100
5.	Anticosti Island (Summer Cull)	-	150	150	300
6.	Magdalen Island	-	-	-	-
7.	Northumberland Strait Ice	-	-	-	-
8.	Sable Island (Summer Cull)	-	150	150	300
	TOTALS	4330	3370	910	8610

OPTION 5

A concentrated cull is to be carried out in the Gulf removing maximum grey seals regardless of age and sex and allowing for only natural escapement. In addition, only the "adults" on Sable Island are to be culled. This, however, would leave the pup population susceptable to slow starvation. The grey seal cull in other areas would continue as in previous years. This would remove approximately 10,700 grey seals and leave a Sable Island pup population of 6000+ with a higher than normal (14%) mortality.

The following table provides the positive and negative features associated with each of the above options:

	Positive Features	Negative Features
OPTION 1	- Results in largest number of animals killed. - Results in largest number of adult females killed and therefore the greatest impact on grey seal population growth. - Would be supported by industry in preference to other options if other options do not provide sufficient population reduction.	- Eliminates the basis for estimating the grey seal population. - Maximum risk for protest activity because of kill on Sable Island (particularly killing of pups).
OPTION 2	- Allows for continued, but reduced, scientific population estimation.	- Killing on Sable Island would generate strong protest as any killing or cull, options 1-5. - Does not improve scientific knowledge. - Reduces the overall rate of population reduction.
OPTION 3	- Partially meets scientific tagging requirements in the Gulf.	- Weakens the ability to establish population estimates. - Protest movements will react. - Slows rate of population reduction.
OPTION 4	- Of all the options, provides the optimum scientific advice for population estimates and population intermixing.	- Removals from total population reduced to questionable level as to effectiveness and the duration of the cull. - Protest movements will react.
OPTION 5	- Would allow some pup escapement for Sable Island for population estimates. - Possibly not generate as much negative publicity re the Gulf as this is an ongoing cull.	- Would generate considerable adverse comment if the Sable Island pups were deemed to be starved to death. - Asthetic effect on the ice would raise concerns. - Of questionable scientific value. - Would slow down the population reduction program.

The culling program could take place during the month of January and early February of each year and during the summer on Sable and Anticosti Islands. The exact timing of the winter cull would depend on the start of pupping and on the weather and ice conditions.

The seals will be killed using firearms whenever possible. The lower jaw will be retrieved for scientific purposes provided that this does not detract from the killing operation. On Sable Island the carcasses would be left for natural scavengers or burned. Consideration was given to salvaging the meat and the pelts, but the pelt market is very depressed and the costs of removing the carcasses and transporting them to the mainland outweigh the revenue to be obtained from the sale. Similarly, burying the carcasses or removing them with a tractor would upset the ecology of the Island.

No more than six departmental personnel would be involved in the cull. Scientific staff would also be requested to retrieve jaws. An estimate of costs is included later in this report.

Recommendations

Of the five options presented, it is recommended that 3 and 5 be rejected. Option 5 was supported only by the representative from COSS and would most certainly lead to industry withdrawing its public endorsement of the program if adopted. Option 3 received no specific support from any task force member.

While Option 1 would bring about the greatest and quickest reduction in the seal population, it would be the least defensible from a scientific and resource management point of view. It would seriously impair the Department's ability to conduct stock assessments and could lead to accusations that the Department's intent was to eliminate grey seal stocks entirely.

Options 2 and 4 provide the best balance of reducing the grey seal population while respecting programs to scientifically assess population levels.

Should it be deemed to be asthetically important, up to five weapons, similar to those that have been field tested by Mr. T. Hughes, would be made available for culling under whatever option the cull is carried out.

Subsequent Years

Estimations of the numbers to be culled in subsequent years is of some concern as, at this time, insufficient scientific information is presently available. As to the effect of the removals under the various options given, using the present estimates, for example in Option 2, the Sable Island population would possibly support a cull of 3000 pups, 2000 females, 400 males for two (3) to three (3) years, allowing for immature females reaching breeding age to return to the breeding colonies: A possible effect of the implementation of Option 1 and Option 4 is being presently compiled to indicate the possible effects utilizing the minimum and maximum present population estimates of 60,000 to 130,000 (CAFSAC estimates).

BOUNTY PROGRAM

The current level of bounty kills is approximately 300 per year. The bounty program was commenced in 1976 and the initial payments were twenty-five dollars for an adult and ten dollars for a juvenile (less than one year old). In 1979, this was increased to fifty dollars for adults and twenty-five dollars for juveniles. The lower jaw of the seal must be submitted to the Department as proof of the kill. The initial aim of the bounty program was to kill or drive away those seals who have learned to rob fishermen's gear for food. The money was to provide an incentive for action and to compensate for lost or damaged gear and catches. The returns provided necessary scientific information on the age composition and age distribution of the herds.

Following an initial jump in 1979 when the bounty was increased, the numbers of bounty kills have gradually been declining although the seal population has been increasing.

There are several arguments against the bounty program:

a) It has been widely criticized as being inhumane because seals are often not killed quickly.

b) It is ineffective as a population control measure.

c) Fishermen do not appear to be greatly interested in it.

Arguments in favour of the bounty include:

a) It permits those affected, i.e. fishermen, to have a hand in solving their own problem.

b) It is the only means of obtaining a random age sample of the population for stock assessment purposes.

c) It deals with seals who rob fishing gear.

The present bounty level in Canada is lower than that paid in Norway and Iceland, i.e. approximately $75.00 in Iceland in 1982 and $60.00 in Norway. It is evident that the present bounty program is ineffective as a population control measure (declining returns) and it has been subject to fairly heavy criticism as being inhumane.

A recent survey indicates that fishermen would participate far more actively if the payments were doubled to $100.00 for adults and $50.00 for juveniles and also if hunting were permitted starting on February 15th instead of March 1st. Fishermen surveyed also estimated that they recovered up to 75% of the animals they shot.

There are three options available:

<u>OPTION 1</u>: Terminate the bounty program.

<u>OPTION 2</u>: Maintain the current program.

<u>OPTION 3</u>: Double the payment levels and undertake a low key publicity campaign to encourage more fishermen to participate with an objective of removing 1500 adults and 500 juveniles.

Recommendation:

Option three is recommended.

Cost Estimates

Bounty Program

The estimated yearly cost of the enhanced bounty program would be $175,000 (Recent costs $10,000 approximately). In year one, there would be an additional cost of $5,000 for a low key promotion, mainly postable.

Cull Program

The estimates of cost for the various cull options was determined on the basis of the operation requiring six Fishery officers for 45 days (two for Sable Island, two for Northumberland Strait and islands, and two for Anticosti and Magdalen Islands).

YEAR 1

ITEMS	OPTION 1	OPTION 2	OPTION 3	OPTION 4
Ammunition	10,000	10,000	6,500	6,500
Helicopter	(70 hrs) 30,000	(70 hrs) 30,000	(20 hrs) 7,500	(20 hrs) 7,500
Fixed Wing	(20 hrs) 6,300	(20 hrs) 6,300	--	--
Accommodation	7,200	7,200	1,000	1,000
Transportation (Sable/Anticosti Islands)	10,000	10,000	10,000	10,000
Comp. Allowance	9,045	9,045	5,200	5,200
TOTAL	72,545	72,545	30,200	30,200

Should alternative flying services be made available, i.e. Provincial aircraft, costs to the Department could be reduced by between $21,300 and $3,750.

Ammunition costs would be maintained at $10,000 as pups may be clubbed should the "experimental" gun not be used.

In addition to the expenses under the various options, an additional $7,000 would be required to purchase equipment and rifles for six officers; equipment such as thermal underwear, protective clothing, emergency supplies, etc. Therefore, the maximum costs would be $79,545 to carry out the grey seal cull in the Scotia-Fundy/Gulf Regions.

The advice in relation to the buying or removal of the grey seal carcasses from Sable Island was that the cutting open of the carcasses, and allowing for the natural decomposition and scavaging of gulls, would effectively remove the majority of the carcass; other remains would subsequently be covered by drifting sand.

To endeavor to bury the carcasses by utilizing a plough would be ineffective as (1) the composition of the sand would hamper the operation of a plough and tractor, and (2) most importantly the use of tractor and plough would be considerably more detrimental to the terrain of Sable Island than the effect of the decomposition of the seal carcasses.

MONITORING AND SCIENTIFIC INFORMATION

The task force was requested to propose a plan to monitor the effects of any proposed cull on future parasite infestation levels and advise on opportunities to improve the biological basis for management of grey seals associated with any proposed cull.

DFO is implementing in 1983 a program to monitor *P. decipiens* in samples of American plaice and Atlantic cod in Atlantic Canadian waters. Attention has been focused on American plaice as an indicator species of the parasite in the marine environment since they are relatively sedentary, easy to sample at sea, easy to examine for worms, have a weaker relation of infestation rates to fish length than cod and are widely distributed in the area to be monitored. It should be noted that this program is presently being carried out under contract. A long-term commitment of resources (2PY O & M) may be required to ensure the viability of this program. The extent of the present program should be examined to ensure that the south coast of Newfoundland is included.

This program will provide a baseline for measuring future trends in abundance of the nematode. Repetition of the program in future years at the same level of coverage will permit detection of changes of 25% or less in incidence and infestation rates of American plaice in a NAFO Division or Sub-division. Given the time lags associated with the life cycle of the parasite, the monitoring program need not be repeated every year. This program could be complemented by comprehensive survey of processors to determine the extent to which the problem affects their operations.

CAFSAC has indicated that the ability to estimate grey seal abundance in future depends on continued large scale tagging of pups and sampling of the population of animals aged one and older via a bounty program or equivalent means. It was noted that increased tagging of pups in the Gulf of St. Lawrence is particularly important. The task force also recommends that further aerial surveys in the Gulf of St. Lawrence be carried out. In order for a tagging program in the Gulf of St. Lawrence to provide meaningful results, all pups escaping from Sable Island should be tagged.

Collection of jaws and the recording of brand numbers and/or letters, as well as an estimate of sure kills and possible kills should be part of any culling program.

The task force also noted the present lack of resources dedicated to grey seal research and recommended the assignment of 2PY's and appropriate O & M to this program.

COMMUNICATIONS STRATEGY

The proposed communications strategy is premised on an anticipated negative public reaction to an increased grey seal cull. Anti-sealers in North America and Europe can be expected to react vigorously, targeting their activity, inter alia, on consumers of Canadian fish products.

Because it is highly improbable that any communications plan can prevent such a reaction, the proposed strategy, as defined below, is to give the cull the lowest possible profile. Presentation of information in support of the cull should appear rational, reasonable and factual, and involve key people from government and industry.

The strategy contemplates close cooperation with officials of the Department of External Affairs, since they will have to handle the anti-sealers' propaganda in the U.S.A. and Europe, and facilitate movement of expert personnel as required.

Following are recommendations on subject areas and issues which should be addressed in a long-term communications strategy.

1. No announcement of increase in cull

A decision to increase the cull should be implemented as quietly as possible, without any public announcement. The importance of this approach should be impressed on others involved (e.g. processors, fishermen, provincial governments).

2. Information package

Straightforward, factual background data should be assembled for an information package directed at both the general public and the news media. This should focus on the existing cull and include information on the grey seal, sealworm and fishing industry as follows:

(a) History of grey seal cull to date, including culling methods numbers, within the context of Canadian policy on management of marine mammals; it should be noted there is no trade in grey seal products.

(b) Grey seal population trend, research being conducted, impact of cull on population.

(c) Role of grey seal as vector for sealworm in various fish species and stocks (fish consumption by grey seal could be noted).

(d) Relationship of grey seal population to worm infestation; lead time necessary to study the impact of culling on parasite abundance in fish.

(e) Outline of studies into alternative methods of grey seal population control.

(f) Identification of other seal culls, species culled, numbers taken and reasons for the cull: this would permit comparisons and show that Canada does not stand alone.

(g) Statement on impact of cull on ecosystem of Sable Island "sanctuary".

(h) Cost to fish processors of removing sealworm; product loss; downgrading. Resulting cost to Canadian consumers should be estimated.

(i). Statement addressing health fear/concern which consumers may raise as a result of publicity regarding parasites in fish, and emphasizing that Canadian fish inspection procedures ensure that fish are safe for consumption.

3. <u>Communicators</u>

To cope with the image problem which is anticipated and the attendant need for people, rather than paper, to respond, it is recommended that key personnel be designated to handle the issue. They must be capable of projecting, through the media, the genuine concerns of those employed in the fishing industry. They must be available to respond (often on short notice) to media requests in what could be antagonistic situations.

In line with this, it is further recommended that there be up front public participation by the Fisheries Council of Canada and fishermen's organizations to identify the issue as a problem for the working person in the fishing industry.

Statements of support from sources outside the fishing industry (e.g. municipal councils, community organizations, prominent individuals) should also be identified and utilized.

4. <u>Anticipated Cost</u>

The cost of communications activities resulting from an increased grey seal cull can be placed in two categories:

(a) Publishing costs: DFO preparation of information kits (est. $40 per 1,000). This would include approximately 10 pages of information in "fact sheet" format similar to that produced on the harp seal hunt, plus copies of the Underwater World booklet on grey seals;

(b) Travel costs: This is extremely difficult to forecast, and would depend on the nature and location of protest action, and personnel available to react.

CONCLUSIONS & RECOMMENDATIONS

It is evident from recent studies that with respect to NAFO Sub-Divisions 4VW AND 3Ps, the parasite problem is getting worse both in level of infestation and species affected. The most recent scientific information indicates that there has been a continuing increase of the grey seal population.

This task force concluded that a culling program is the only presently feasible means of reducing the population of grey seals. It should start in 1984 and continue for at least five years. This program will have industry support provided that it achieves significant population reduction. Coupled with the cull program there should be increased scientific research to provide detailed information on the status of the grey seal population and the effects of the culling program on both population size and parasite infestation. Information should be available to provide a review in three years. There must also be increased research into technological improvements to parasite removal techniques since the parasite problem as it exists today will remain at this level or worse for several years.

In conjunction with the culling program, the task force recommends an increased level of bounty payments to encourage increased activity with an objective of a minimum of 2,000 removals per year.

The proposed communications strategy recommended is reactive - i.e. no prior announcement, respond to criticism with fact sheets, statements that culling has been ongoing and that one scope and emphasis has changed. As well, responses should be both by government and industry personnel.

APPENDIX LX

Number of grey seals taken in DFO research bounty, and cull programs.

	1967	1968	1969	1970	1971	1972	1973	1974	1975
Research	-	66	140	305	-	-	-	-	118
Bounty	-	-	-	-	-	-	-	-	-
Cull	229	152	778	645	865	731	622	1168	2153

	1976	1977	1978	1979	1980	1981	1982	1983
Research	-	-	-	-	-	-	208	256
Bounty	734	613	650	961	952	735	496	610
Cull	641	1388	716	314	1132	1608	1846	2385

APPENDIX LXI

[illegible]

[illegible]

INTERIM CONVENTION ON CONSERVATION OF NORTH PACIFIC FUR SEALS

Note: The Interim Convention was signed in Washington on February 9, 1957, on behalf of the Governments of Canada, Japan, the Union of Soviet Socialist Republics, and the United States of America. The Interim Convention came into force on October 14, 1957, and has since been amended as follows:

By a Protocol which was signed in Washington on October 8, 1963, and entered into force on April 10, 1964. The 1964 Protocol extended the term of the Convention for six years and affected several changes in the scientific research programs to be carried out by the Party Governments;

By an exchange of notes among the Party Governments which became effective on September 3, 1969, and which extended the term of the Convention, as amended, for an additional period of six years;

By a Protocol which was signed in Washington on May 7, 1976, and entered into force on October 12, 1976. The 1976 Protocol extended the term of the Interim Convention for a period of four years, and made several changes in the scientific research programs to be carried out by the Party Governments and in the duties of the North Pacific Fur Seal Commission.

The text of the Interim Convention, as amended, is as follows:

The Governments of Canada, Japan, The Union of Soviet Socialist Republics, and the United States of America,

Desiring to take effective measures towards achieving the maximum sustainable productivity of the fur seal resources of the North Pacific Ocean so that the fur seal populations can be brought to and maintained at the levels which will provide the greatest harvest year after year, with due regard to their relation to the productivity of other living marine resources of the area,

Recognizing that in order to determine such measures it is necessary to conduct adequate scientific research on the said resources, and

Desiring to provide for international cooperation in achieving these objectives,

Agree as follows:

Article I

1. The term "pelagic sealing" is hereby defined for purposes of this Convention as meaning the killing, taking, or hunting in any manner whatsoever of fur seals at sea.

(Printed - Nov. 1976)

2. The words "each year", "annual" and "annually" as used hereinafter refer to Convention year, that is, the year beginning on the date of entry into force of the Convention.

3. Nothing in this Convention shall be deemed to affect in any way the position of the Parties in regard to the limits of territorial waters or to the jurisdiction over fisheries.

Article II

1. In order to realize the objectives of this Convention, the Parties agree to coordinate necessary scientific research programs and to cooperate in investigating the fur seal resources of the North Pacific Ocean to determine:

(a) what measures may be necessary to make possible the maximum sustainable productivity of the fur seal resources so that the fur seal populations can be brought to and maintained at the levels which will provide the greatest harvest year after year; and

(b) what the relationship is between fur seals and other living marine resources and whether fur seals have detrimental effects on other living marine resources substantially exploited by any of the Parties and, if so, to what extent.

2. The research referred to in the preceding paragraph shall include studies of the following subjects:

(a) size of each fur seal herd and its age and sex composition;

(b) natural mortality of the different age groups and recruitment of young to each age or size class at present and subsequent population levels;

(c) with regard to each of the herds, the effect upon the magnitude of recruitment of variations in the size and the age and sex composition of the annual kill;

(d) migration routes of fur seals and their wintering areas;

(e) numbers of seals from each herd found on the migration routes and in wintering areas and their ages and sexes;

(f) relationship between fur seals and other living marine resources, including the extent to which fur seals affect commercial fish catches, the damage fur seals inflict on fishing gear, and the effect of commercial fisheries on the fur seals;

(g) effectiveness of each method of sealing from the viewpoint of management and rational utilization of fur seal resources for conservation purposes;

(h) quality of sealskins by sex, age, and time and method of sealing;

(i) effects of man-caused environmental changes on the fur seal populations; and

(j) other subjects involved in achieving the objectives of the Convention, as determined by the Commission established under Article V, paragraph 1.

3. In furtherance of the research referred to in this Article, the Parties agree:

(a) to continue to mark adequate numbers of pups;

(b) to devote to pelagic research an effort which, to the greatest extent possible, should be similar in extent to that expended in recent years, provided that this shall not involve the annual taking by all the Parties combined of more than 2,500 seals in the Eastern and more than 2,200 seals in the Western Pacific Oceans, unless the Commission, pursuant to Article V, paragraph 3, shall decide otherwise; and

(c) to carry out the determinations made by the Commission pursuant to Article V, paragraph 3.

4. Each Party agrees to provide the Commission annually with information on:

(a) number of black pups tagged for each breeding area;

(b) number of fur seals, by sex and estimated age, taken at sea and on each breeding area; and

(c) tagged seals recovered on land and at sea;

and, so far is practicable, other information pertinent to scientific research which the Commission may request.

5. The Parties further agree to provide for the exchange of scientific personnel; each such exchange shall be subject to mutual consent of the Parties directly concerned.

6. The Parties agree to use for the scientific pelagic research provided for in this Article only government-owned or government-chartered vessels operating under strict control of their respective authorities. Each Party shall communicate to the other Parties the names and descriptions of vessels which are to be used for pelagic research.

Article III

In order to realize the purposes of the Convention, including the carrying out of the coordinated and cooperative research, each Party agrees to prohibit pelagic sealing, except as provided in Article II, paragraph 3, in the Pacific Ocean north of the 30th parallel of north latitude including the seas of Bering, Okhotsk, and Japan by any person or vessel subject to its jurisdiction.

Article IV

Each Party shall bear the expense of its own research. Title to sealskins taken during the research shall vest in the Party conducting such research.

Article V

1. The Parties agree to establish the North Pacific Fur Seal Commission to be composed of one member from each Party.

2. The duties of the Commission shall be to:

(a) formulate and coordinate research programs designed to achieve the objectives set forth in Article II, paragraph 1;

(b) recommend these coordinated research programs to the respective Parties for implementation;

(c) study the data obtained from the implementation of such coordinated research programs;

(d) recommend appropriate measures to the Parties on the basis of the findings obtained from the implementation of such coordinated research programs, including measures regarding the size and the sex and age composition of the seasonal commercial kill from a herd and regarding a reduction or suspension of the harvest of seals on any island or group of islands in case the total number of seals on that island or group of islands falls below the level of maximum sustainable productivity; provided, however, that due consideration be given to the subsistance needs of Indians, Ainos, Aleuts, or Eskimos who live on the islands where fur seals breed, when it is not possible to provide sufficient seal meat for such persons from the seasonal commercial harvest or research activities, and

(e) study whether or not pelagic sealing in conjunction with land sealing could be permitted in certain circumstances without adversely affecting achievement of the objectives of the Convention, and make recommendations thereon to the Parties at the end of the twenty-first year after entry into force of the Convention.

3. In addition to the duties specified in paragraph 2 of this Article, the Commission shall, subject to Article II, paragraph 3, determine from time to time the number of seals to be marked on the rookery islands, and the total number of seals which shall be taken at sea for research purposes, the times at which such seals shall be taken and the areas in which they shall be taken, as well as the number to be taken by each Party, taking into account any recommendations made pursuant to Article V, paragraph 2 (d).

4. Each Party shall have one vote. Decisions and recommendations shall be made by unanimous vote. With respect to any recommendations regarding the size and the sex and age composition of the seasonal commercial kill from a herd, only those Parties sharing in the sealskins from that herd under the provisions of Article IX, paragraph 1 shall vote.

5. The Commission shall elect from its members a Chairman and other necessary officials and shall adopt rules of procedure for the conduct of its work.

6. The Commission shall hold an annual meeting at such time and place as it may decide. Additional meetings shall be held when requested by two or more members of the Commission.

7. The expenses of each member of the Commission shall be paid by his own Government. Such joint expenses as may be incurred by the Commission shall be defrayed by the Parties by equal contributions. Each Party shall also contribute to the Commission annually an amount equivalent to the value of the sealskins it confiscates under the provisions of Article VI, paragraph 5.

8. The Commission shall submit an annual report of its activities to the Parties.

9. The Commission may from time to time make recommendations to the Parties on any matter which relates to the fur seal resources or to the administration of the Commission.

Article VI

In order to implement the provisions of Article III, the Parties agree as follows:

1. When a duly authorized official of any of the Parties has reasonable cause to believe that any vessel outfitted for the harvesting of living marine resources and subject to the jurisdiction of any of the Parties is offending against the prohibition of pelagic sealing as provided for by Article III, he may, except within the territorial waters of another State, board and search such vessel. Such official shall carry a special certificate issued by the competent authorities of his Government and drawn up in the English, Japanese, and Russian languages which shall be exhibited to the master of the vessel upon request.

2. When the official after searching a vessel continues to have reasonable cause to believe that the vessel or any person on board thereof is offending against the prohibition, he may seize or arrest such vessel or person. In that case, the Party to which the official belongs shall as soon as possible notify the Party having jurisdiction over the vessel or person of such arrest or seizure and shall deliver the vessel or person as promptly as practicable to the authorized officials of the Party having jurisdiction over the vessel or person at a place to be agreed upon by both Parties; provided, however, that when the Party receiving notification cannot immediately accept delivery of the vessel or person, the Party which gives such notification may, upon request of the other Party, keep the vessel or person under surveillance within its own territory, under the conditions agreed upon by both Parties.

3. The authorities of the Party to which such person or vessel belongs alone shall have jurisdiction to try any case arising under Article III and this Article and to impose penalties in connection therewith.

4. The witnesses or their testimony and other proofs necessary to establish the offense, so far as they are under the control of any of the Parties, shall be furnished with all reasonable promptness to the authorities of the Party having jurisdiction to try the case.

5. Sealskins discovered on seized vessels shall be subject to confiscation on the decision of the court or other authorities of the Party under whose jurisdiction the trial of a case takes place.

6. Full details of punitive measures applied to offenders against the prohibition shall be communicated to the other Parties not later than three months after the application of the penalty.

Article VII

The provisions of this Convention shall not apply to Indians, Ainos, Aleuts, or Eskimos dwelling on the coast of the waters mentioned in Article III, who carry on pelagic sealing in canoes not transported by or used in connection with other vessels, and propelled entirely by oars, paddles, or sails, and manned by not more than five persons each, in the way hitherto practiced and without the use of firearms; provided that such hunters are not in the employment of other persons or under contract to deliver the skins to any person.

Article VIII

1. Each Party agrees that no person or vessel shall be permitted to use any of its ports or harbors or any part of its territory for any purpose designed to violate the prohibition set forth in Article III.

2. Each Party also agrees to prohibit the importation and delivery into and the traffic within its territories of skins of fur seals taken in the area of the North Pacific Ocean mentioned in Article III, except only those taken by the Union of Soviet Socialist Republics or the United States of America on rookeries, those taken at sea for research purposes in accordance with Article II, paragraph 3, those taken under the provisions of Article VII, those confiscated under the provisions of Article VI, paragraph 5, and those inadvertently captured, which are taken possession of by a Party; provided, however, that all such excepted skins shall be officially marked and duly certified by the authorities of the Party concerned.

Article IX

1. The respective Parties agree that, of the total number of sealskins taken commercially each season on land, there shall at the end of the season be delivered a percentage of the gross in number and value thereof as follows:

By the Union of Soviet Socialist Republics	to Canada	15 percent
	to Japan	15 percent
By the United States of America	to Canada	15 percent
	to Japan	15 percent

2. Each Party agrees to deliver such sealskins to an authized agent of the recipient Party at the place of taking, or at some other place mutually agreed upon by such Parties.

3. The respective Parties will seek to ensure the utilization of those methods for the capture and killing and marking of fur seals on land or at sea which will spare the fur seals pain and suffering to the greatest extent practicable.

Article X

1. Each Party agrees to enact and enforce such legislation as may be necessary to guarantee the observance of this Convention and to make effective its provisions with appropriate penalties for violation thereof.

2. The Parties further agree to cooperate with each other in taking such measures as may be appropriate to carry out the purposes of this Convention, including the prohibition of pelagic sealing as provided for by Article III.

Article XI

The Parties agree to meet in the twenty-second year after entry into force of the Convention to consider the recommendations in accordance with Article V, paragraph 2(e) and to determine what further agreements may be desirable in order to achieve the maximum sustainable productivity of the North Pacific fur seal herds.

Article XII

Should any Party consider that the obligations of Article II, paragraphs 3,4, or 5 or any other obligation undertaken by the Parties is not being carried out and notify the other Parties to that effect, all the Parties shall, within three months of the receipt of such notification, meet to consult together on the need for and nature of remedial measures. In the event that such consultation shall not lead to agreement as to the need for and nature of remedial measures, any Party may give written notice to the other Parties of intention to terminate the Convention and, notwithstanding the provisions of Article XIII, paragraph 4, the Convention shall thereupon terminate as to all the Parties nine months from the date of such notice.

Article XIII

1. This Convention shall be ratified and the instruments of ratification deposited with the Government of the United States of America as soon as practicable.

2. The Government of the United States of America shall notify the other signatory Governments of ratifications deposited.

3. This Convention shall enter into force on the date of the deposit of the fourth instrument of ratification.

4. The Convention shall continue in force for twenty-two years and thereafter until the entry into force of a new or revised fur seal convention between the Parties, or until the expiration of one year after such period of twenty-two years, whichever may be the earlier; provided, however, that the Convention shall terminate one year from the day on which a Party gives written notice to the other Parties of an intention of terminating the Convention.

5. At the request of any Party, representatives of the Parties will meet at a mutually convenient time within ninety days of such request to consider the desirability of modifications of the Convention.

6. The original of this Convention shall be deposited with the Government of the United States of America, which shall communicate certified copies thereof to each of the Governments signatory to the Convention.

IN WITNESS WHEREOF the undersigned, being duly authorized by their respective Governments, have signed this Convention.

DONE in Washington this ninth day of February 1957, in the English, Japanese, and Russian languages, each text equally authentic.

FOR THE GOVERNMENT OF CANADA:

A. D. P. Heeney

G. R. Clark

FOR THE GOVERNMENT OF JAPAN

Masayuki Tani

FOR THE GOVERNMENT OF THE UNION OF SOVIET SOCIALIST REPUBLICS:

G. Zaroubin

FOR THE GOVERNMENT OF THE UNITED STATES OF AMERICA:

William C. Herrington

Arnie J. Suomela

1980 PROTOCOL AMENDING THE INTERIM CONVENTION ON CONSERVATION OF NORTH PACIFIC FUR SEALS

The Governments of Canada, Japan, the Union of Soviet Socialist Republics and the United States of America, Parties to the Interim Convention on Conservation of North Pacific Fur Seals, signed at Washington on February 9, 1957, as amended, hereinafter referred to as the Convention,

Desiring to amend the Convention,

Have agreed as follows:

Article I

The Convention shall be applied as amended by this Protocol as from the date of its entry into force.

Article II

In Article V, paragraph 2(e) of the Convention, "twenty-first" shall be replaced by "twenty-fifth".

Article III

In Article VI, paragraph 1 of the Convention, "except within the territorial waters of another State" shall be replaced by "except within the areas in which another State exercises fisheries jurisdiction".

Article IV

In Article XI of the Convention, "twenty-second" shall be replaced by "twenty-sixth".

Article V

In Article XIII, paragraph 4 of the Convention, "twenty-two" shall be replaced by "twenty-six".

Article VI

1. This Protocol shall be subject to ratification or acceptance. Instruments of ratification or acceptance shall be deposited with the Government of the United States of America as soon as possible.

2. A signatory Government which intends to ratify or accept this Protocol, may notify the Government of the United States of America that it will apply this Protocol provisionally in accordance with its laws and regulations pending fulfillment of domestic constitutional requirements for ratification or acceptance.

3. The Government of the United States of America shall notify the other signatory Governments of ratifications or acceptances deposited and of notifications of provisional application made.

4. This Protocol shall enter into force provisionally on the date on which instruments of ratification or

acceptance have been deposited or the notifications of provisional application as referred to in paragraph 2 above have been made by all the signatory Governments. It shall continue in force provisionally until the date on which it enters into force definitively in accordance with the provisions of paragraph 5.

5. This Protocol shall enter into force definitively on the date on which instruments of ratification or acceptance have been deposited by all the signatory Governments.

6. The original of this Protocol shall be deposited with the Government of the United States of America, which shall communicate certified copies thereof to each of the Governments signatory to this Protocol.

IN WITNESS WHEREOF the undersigned, being duly authorized by their respective Governments, have signed this Protocol.

Done at Washington, this fourteenth day of October, nineteen hundred and eighty, in the English, French, Japanese, and Russian languages, each text equally authentic.

R THE GOVERNMENT OF CANADA:
OUR LE GOUVERNEMENT DU CANADA:
カナダ政府のために：
ОТ ИМЕНИ ПРАВИТЕЛЬСТВА КАНАДЫ:

FOR THE GOVERNMENT OF JAPAN:
POUR LE GOUVERNEMENT DU JAPON:
日本国政府のために：
ОТ ИМЕНИ ПРАВИТЕЛЬСТВА ЯПОНИИ:

Yoshio Hatano

FOR THE GOVERNMENT OF THE UNION OF SOVIET SOCIALIST REPUBLICS:
POUR LE GOUVERNEMENT DE L'UNION DES REPUBLIQUES SOCIALISTES SOVIETIQUES:
ソビエト社会主義共和国連邦政府のために：
ОТ ИМЕНИ ПРАВИТЕЛЬСТВА СОЮЗА СОВЕТСКИХ СОЦИАЛИСТИЧЕСКИХ РЕСПУБЛИК:

А. Добрынин
(с заявлением).

FOR THE GOVERNMENT OF THE UNITED STATES OF AMERICA:
POUR LE GOUVERNEMENT DES ETATS-UNIS D'AMERIQUE:
アメリカ合衆国政府のために：
ОТ ИМЕНИ ПРАВИТЕЛЬСТВА СОЕДИНЕННЫХ ШТАТОВ АМЕРИКИ:

WD Busby

I CERTIFY THAT the foregoing is a true copy of the 1980 Protocol Amending the Interim Convention on Conservation of North Pacific Fur Seals signed at Washington on October 14, 1980, the original of which, in the English, French, Japanese and Russian languages, is deposited in the archives of the Government of the United States of America.

IN TESTIMONY WHEREOF, I, Edmund S. Muskie, Secretary of State of the United States of America, have hereunto caused the seal of the Department of State to be affixed and my name subscribed by the Acting Authentication Officer of the said Department, at the city of Washington, in the District of Columbia, this seventeenth day of October, 1980.

Edmund S. Muskie
Secretary of State

By Annie R. Maddux
Acting Authentication Officer
Department of State

in h another State exercises fisheries jurisdic-

tic

[8/29/84]

1984 PROTOCOL AMENDING THE INTERIM CONVENTION ON CONSERVATION OF NORTH PACIFIC FUR SEALS

The Governments of Canada, Japan, the Union of Soviet Socialist Republics, and the United States of America, Parties to the Interim Convention on Conservation of North Pacific Fur Seals, signed at Washington on February 9, 1957, as amended and applied, hereinafter referred to as the Convention,

Desiring to amend the Convention,

Have agreed as follows:

Article I

The Convention shall be applied as amended by this Protocol as from the date of its entry into force.

Article II

In Article V, paragraph 2(e) of the Convention, "at the end of the twenty-fifth year after entry into force of the Convention" is replaced by "by October 13, 1986".

Article III

In Article XI of the Convention, "in the twenty-sixth year after entry into force of the Convention" is replaced by "within the one year period prior to October 14, 1987".

Article IV

In Article XIII of the Convention, paragraph 4 is replaced by the following: "4. The Convention shall continue in force until October 13, 1987 and thereafter until the entry into force of a new or revised fur seal convention between the Parties, or until October 13, 1988, whichever may be the earlier; provided, however, that the Convention shall terminate one year from the day on which a Party gives written notice to the other Parties of an intention of terminating the Convention."

Article V

1. This Protocol shall be subject to ratification or acceptance. Instruments of ratification or acceptance shall be deposited with the Government of the United States of America as soon as possible.

2. A signatory Government which intends to ratify or accept this Protocol may notify the Government of the United States of America that it will apply this Protocol provisionally in accordance with its laws and regulations pending the fulfillment of domestic constitutional requirements for ratification or acceptance.

3. The Government of the United States of America shall notify the other signatory Governments of ratifications or acceptances deposited and of notifications of provisional application made.

the date on which instruments of ratification or acceptance have been deposited with or the notifications of provisional application as referred to in paragraph 2 above have been made to the Government of the United States of America by all the signatory Governments. It shall continue (in force) to be applicable provisionally until the date on which it enters into force definitively in accordance with the provisions of paragraph 5.

5. This Protocol shall enter into force definitively on the date on which instruments of ratification or acceptance have been deposited with the Government of the United States of America by all the signatory Governments.

6. The original of this Protocol shall be deposited with the Government of the United States of America, which shall communicate certified copies thereof to each of the Governments signatory to this Protocol.

IN WITNESS WHEREOF, the undersigned, being duly authorized by their respective Governments, have signed this Protocol.

Done at Washington this day of , 1984, in the English, French, Japanese, and Russian languages, each text being equally authentic.

APPENDIX LXII

Appendix LXII. The Baffin Region Inuit Association's estimated seal harvest levels for 1981 to 1983.

Community	Year	Ringed Seals	Bearded Seal	Harp Seal	Hooded Seal	Harbour Seal	Total
Arctic Bay	1981	1560	20	41	0	0	1621
	1982	1820	48	86	0	0	1954
	1983	2458	60	86	0	0	2604
Broughton Island	1981	5700	110	92	0	0	5902
	1982	4370	59	97	2	0	4528
	1983	3699	38	348	3	1	4089
Cape Dorset	1981	2190	234	6	0	3	2433
	1982	2220	211	6	0	3	2440
	1983	1802	177	21	0	2	2002
Clyde River	1981	3730	60	28	1	0	3819
	1982	2565	17	8	0	0	2590
	1983	3148	32	15	0	0	3195
Frobisher Bay	1981	2170	87	168	5	29	2459
	1982	2130	79	153	0	1	2363
	1983	1360	36	74	0	0	1470
Grise Fiord	1981	771	27	207	0	0	1005
	1982	776	11	115	0	0	902
	1983	723	23	185	0	0	931
Hall Beach	1981	891	83	1	0	0	975
	1982	361	76	0	0	0	437
	1983	969	154	11	0	6	1140
Igoolik	1981	1330	68	1	0	0	1399
	1982	1270	71	6	0	0	1347
	1983	1559	133	14	1	5	1712
Lake Harbour	1981	1910	121	22	3	4	2060
	1982	1210	83	6	0	12	1311
	1983	1461	89	14	0	1	1565
Nanisivik	1981	480	4	0	0	0	484
	1982	440	8	3	0	0	451
	1983	352	3	7	0	0	362
Pangnirtung	1981	5180	131	4630	1	0	9942
	1982	5320	54	4580	3	0	9957
	1983	4310	84	1658	5	1	6058
Pond Inlet	1981	2010	20	7	4	0	2042
	1982	4070	27	56	5	0	4158
	1983	N/A	N/A	N/A	N/A	N/A	N/A

Appendix LXII. The Baffin Region Inuit Association's estimated seal harvest levels for 1981 to 1983. (Continued)

Community	Year	Ringed Seals	Bearded Seal	Harp Seal	Hooded Seal	Harbour Seal	Total
Resolute Bay	1981	188	7	0	0	0	195
	1982	233	4	3	0	0	239
	1983	249	16	0	0	0	265
Sanikiluag	1981	2890	139	0	0	0	3029
	1982	2110	138	0	0	3	2251
	1983	2093	40	0	0	2	2135
Outpost camps[2]	1981	5000	168	1060	0	53	6281
	1982	3240	78	730	2	15	4065
	1983	N/A	N/A	N/A	N/A	N/A	N/A
Total	1981	36000	1279	6263	14	96	43645
	1982	32135	963	5849	12	33	38992
	1983[3]	24183	885	2433	9	39	27528

[1] Excludes women in 1981

[2] There was 26 in 1981, 25 in 1982

[3] Excludes Pond Inlet and outpost camps

(Sources: 85, 86; Pattimore <u>pers</u>. <u>comm</u>. for 1983 estimated harvests)

APPENDICES LXIII AND LXIV

Appendix LXIII. Estimated harvest of seals in the Keewatin Region, Northwest Territories.

Community	Period	Estimated Number	Harvest Period	Number
Baker Lake	Nov. /81-Sept./82	-	Nov. 82-Sept. 83	1
Chesterfield Inlet	Jan., Feb., Aug., & Sept. 82	48	Oct. 82-Sept. 83	137
Coral Harbour	Oct. 81-Sept. 82	977	Oct. 82-Sept. 83	-
Eskimo Point	Oct. 81-Sept. 82	448	Oct. 82-Sept. 83	278
Rankin Inlet	Nov. 81-Sept. 82	465	Oct. 82-Sept. 83	469
Repulse Bay	Oct. 81-Sept. 82	836	Oct. 82-Sept. 83	360
Whale Cove	Oct. 81-Sept. 82	134	Oct. 82-Mar. 83	57

(Source: 87)

Appendix LXIV. Reported harvest of seals in the Kitikmeot Region, Northwest Territories.

Community	Reported Harvest[1]	Hunter Response[2] (mean % + S.D.)	Time Period (Year/Month)
Bay Chimo/Bathurst Inlet	26	95 ± 8.6	83/01 - 83/12
Cambridge Bay	112	79 ± 20.4	82/10 - 83/11
Coppermine	549	55 ± 20.3	83/02 - 83/12
Gjoa Haven	371	52 ± 17.6	82/09 - 83/11
Holman Island	1,665	71 ± 22.3	82/10 - 83/11
Pelly Bay	339	89 ± 13.5	82/10 - 83/11
Spence Bay	1,044	85 ± 20.8	82/09 - 83/11

[1] Estimated harvest not available

[2] Percentage of hunters contacted each month

(Source: 88)

APPENDIX LXV

Appendix LXV. Estimated seal harvests by Northern Québec Inuit Communities* between 1976 and 1980.

Community	Year	Ringed Seal	Bearded Seal	Harp Seal	Harbour Seal	Total	Average Annual Estimatec Harvest
Kuujjuarapik	1976	3,276	107	2	1	3,386	
(Poste-de-la-Baleine)	1977	2,114	66	2	0	2,182	
(Great Whale River)	1978	1,282	42	0	2	1,326	1,986.6
	1979	1,375	92	8	1	1,476	
	1980	1,452	111	5	0	1,563	
Inukjuak	1976	2,833	198	11	9	3,051	
	1977	2,671	194	3	0	2,868	
	1978	1,281	71	0	22	1,374	2,283.2
	1979	1,776	204	12	3	1,995	
	1980	1,842	285	11	0	2,128	
Akulivik	1976	956	101	3	0	1,060	
(Cape Smith)	1977	842	63	2	0	907	773.2
	1978	210	59	1	0	270	
	1979	839	143	11	0	993	
	1980	530	105	1	0	636	
Salluit	1976	2,591	180	43	0	2,814	
(Sugluk)	1977	2,623	95	23	2	2,743	
	1978	787	71	8	0	866	1,905.2
	1979	1,264	138	25	0	1,427	
	1980	1,482	155	39	0	1,676	
Kangiqsujuaq	1976	4,740	213	58	6	5,017	
(Maricourt)	1977	2,624	92	61	0	2,777	
(Waleham Bay)	1978	1,313	64	27	1	1,390	2,813.0
	1979	2,451	98	15	1	2,565	
	1980	2,195	95	18	8	2,316	
Quaqtaq	1976	1,117	64	8	5	1,194	
(Koartac)	1977	725	49	14	0	788	
	1978	281	11	1	0	293	665
	1979	499	39	9	0	547	
	1980	462	37	4	0	503	
Kangiqsuk	1976	781	124	7	0	912	
(Bellin)	1977	495	122	2	0	619	
(Payne Bay)	1978	243	71	2	0	316	507.6
	1979	246	92	1	0	339	
	1980	239	90	23	0	352	

Appendix LXV. Estimated seal harvests by Northern Québec Inuit Communities* between 1976 and 1980. (continued)

Community	Year	Ringed Seal	Bearded Seal	Harp Seal	Harbour Seal	Total	Average Annual Estimated Harvest
Aupaluk (Hopes Advance Bay)	1976	278	37	4	0	319	200.6
	1977	125	15	0	0	140	
	1978	106	18	0	0	124	
	1979	258	37	1	1	297	
	1980	106	17	0	0	123	
Tasiujaq (Leaf-Bay)	1976	481	56	0	1	544	247.2
	1977	209	25	0	4	224	
	1978	122	21	0	3	146	
	1979	92	18	1	0	111	
	1980	184	26	0	1	211	
Kuujjuaq (Fort Chimo)	1976	706	119	2	3	830	584.2
	1977	718	131	1	3	852	
	1978	318	58	4	1	381	
	1979	414	36	4	1	455	
	1980	303	86	2	12	403	
Kangiqsualujjuaq (Port-Nouveau-Québec) (George River)	1976	1,446	127	34	6	1,613	794
	1977	772	62	20	2	856	
	1978	374	35	1	5	415	
	1979	363	93	0	1	456	
	1980	502	91	6	31	630	
Killiniq (Port Burwell)	1976	652	70	100	6	828	789
	1977	530	40	178	2	750	
Fort-George (Chisasibi)	1976	2	0	0	0	2	9
	1977	0	0	0	0	0	
	1978	20	2	0	0	22	
	1979	21	0	0	0	21	
	1978	0	0	0	0	0	
TOTAL	1976	19,865	1,396	272	37	21,570	13,402.4
	1977	14,448	954	306	13	15,721	
	1978	6,337	523	44	34	6,938	
	1979	9,598	990	89	8	10,685	
	1980	9,297	1,098	109	52	10,556	

* The members of the communities of Povungnituk and Ivujivik, and approximately half of the members of the Salluit community did not take part in the survey.

(Sources: 80, 90. 91)

APPENDIX LXVI

Appendix LXVI. Estimated annual seal harvest by Northern Québec Cree Communities from 1975 to 1979.

Community	1975-76	1976-77	1977-78	1978-79	Annual Average Harvest
Kuujjuarapik (Great Whale River)	224	175	130	50	144.75
Chiaasibi (Fort George)	252	212	257	156	175.4
Wemindji	62	91	83	69	61
Eastmain	0	11	13	2	6.5
Fort Rupert	2	1	0	0	1

(Sources: 92, 93, 94, 95)

APPENDIX LXVII

Appendix LXVII. Average annual harvest listed by seal species and community for the Northwest Territories, 1973 to 1982.

REGION PINNIPEDS

Baffin	Harp	Ringed	Other
Arctic Bay	29.6 [9]	813.9 [10]	145.4 [9]
Broughton Island	214.0 [8]	4,932.0 [9]	550.6 [9]
Cape Dorset	8.5 [6]	836.2 [9]	428.6 [9]
Clyde River	18.9 [7]	2,379.3 [9]	516.0 [8]
Frobisher Bay	115.4 [9]	1,117.7 [10]	379.4 [9]
Grise Fiord	68.0 [9]	257.0 [9]	81.9 [7]
Hall Beach	29.1 [7]	205.1 [9]	101.6 [7]
Igoolik	8.0 [7]	1,391.3 [9]	304.9 [9]
Lake Harbour	13.3 [8]	1,103.3 [9]	154.5 [9]
Pangnirtung	2,531.3 [9]	7,318.4 [9]	985.5 [9]
Pond Inlet	16.3 [8]	892.8 [9]	193.5 [8]
Resolute Bay	0.5 [6]	66.5 [8]	14.0 [7]
Sanikiluaq	0.4 [5]	351.4 [9]	57.8 [8]
Port Burwell+	25.2 [4]	165.2 [4]	6.5 [4]
Subtotal	3,078.5	21,830.1	3,920.2
Keewatin			
Chesterfield Inlet	2.5 [6]	45.3 [6]	77.8 [9]
Repulse Bay	30.5 [6]	760.0 [8]	213.5 [8]
Coral Harbour	21.6 [7]	516.5 [8]	206.3 [9]
Rankin Inlet	0	18.0 [8]	41.4 [8]
Eskimo Point	1.0 [7]	87.0 [9]	67.4 [8]
Whale Cove	0 [5]	35.3 [6]	60.2 [9]
Subtotal	55.6	1462.1	666.6
Kitikmeot			
Bathurst Inlet	0 [5]	34.7 [6]	0.2 [6]
Cambridge Bay	1.6 [5]	50.6 [7]	27.4 [8]
Pelly Bay	0.2 [6]	210.7 [9]	113.5 [8]
Spence Bay	0.2 [5]	310.6 [8]	58.6 [9]
Baker Lake	0 [6]	0.9 [8]	49.9 [8]
Gjoa Haven	9.2 [6]	110.9 [9]	63.0 [8]
Coppermine	3.5 [6]	1,606.7 [10]	127.6 [8]
Holman Island	3.2 [6]	2,543.5 [10]	246.4 [7]
Subtotal	18	4,868.6	686.6
Inuvik			
Aklavik	0 [3]	18.8 [4]	4 [4]
Inuvik	0 [3]	1 [4]	0 [3]
Paulatuk	0 [3]	43 [5]	27.3 [4]
Sachs Harbour	0 [3]	73.6 [5]	62.3 [4]
Tuktoyaktuk	0 [3]	12.6 [5]	14.7 [6]
Subtotal	0	149.0	108.3
GRAND TOTAL	3,152.1	28,309.8	5,381.7

+ Port Burwell was moved in 1980.

[#] indicates number of years averaged.

APPENDIX LXVIII

Appendix LXVIII. Number of seal pelts to the Hudson's Bay Company in the Western, Central and Eastern Arctic from 1941 to 1984.

Year	Western	Central	Eastern	Eastern Arctic % of Total	Grand Total
1941		24	5,549	99.5	5,573
1942			2,101	100.0	2,101
1943			1,825	100.0	1,825
1944			4,178	100.0	4,178
1945			4,500	100.0	4,500
1946			3,434	100.0	3,434
1947	86	326	9,290	95.7	9,702
1948	13	461	12,378	96.3	12,852
1949	34	745	9,683	92.5	10,462
1950	299	910	4,578	79.1	5,787
1951	409	184	3,900	86.8	4,493
1952	96	309	4,952	92.4	5,357
1953	541	479	6,017	85.5	7,037
1954	619	659	8,380	86.7	9,658
1955	425	604	10,112	90.7	11,141
1956	236	480	10,331	93.5	11,047
1957	926	640	10,326	86.8	11,892
1958	702	988	9,898	85.4	11,588
1959	391	837	12,084	90.7	13,312
1960	626	1,051	11,689	87.4	13,366
1961	1,521	1,815	14,989	81.7	18,325
1962	1,354	1,121	16,370	86.8	18,845
1963	6,471	6,147	36,902	74.5	49,520
1964	14,390	9,471	43,213	64.4	67,074
1965	16,514	9,207	46,595	64.4	72,316
1966	9,087	5,475	37,384	71.9	51,946
1967	4,713	3,880	23,485	73.2	32,078
1968	2,838	1,589	19,351	81.3	23,778
1969	7,829	6,840	35,281	70.6	49,950
1970	6,923	4,228	27,262	70.9	38,413
1971	7,592	3,993	25,855	69.0	37,439
1972	5,495	3,516	20,129	69.0	29,140
1973	5,814	4,143	25,214	71.6	35,171
1974	5,362	3,935	28,693	75.5	37,990
1975	3,486	3,770	34,809	82.7	42,065
1976	2,897	2,284	29,408	85.0	34,589
1977	2,068	1,350	28,987	89.4	32,405
1978	3,230	1,846	21,327	80.7	26,403
1979	4,841	1,255	22,838	78.9	28,934
1980	6,041	2,281	26,632	76.1	34,954
1981	4,980	1,458	22,382	77.6	28,820
1982	1,717	504	15,519	87.5	17,740
1983	1,154	184	9,422	87.5	17,760
1984	372	23	4,097	91.2	4,492

(Source: Hudson's Bay Company, December 27, 1984)