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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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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

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.

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.

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

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 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 north of Misaine Bank (Feb.)	≤45	20	30	0.45(3)	56	1.12	10	0.10(1)
	46-50	22	41	0.55(3)	100	1.67	23	0.50(7)
	51-55	27	52	0.81(2)	86	1.69	48	0.59(3)
	56-60	34	41	1.44(20)	92	2.38	47	1.47(14)
	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 Shoal, Banquereau Bank (May)	≤40	32	34	0.53(3)	100	3.34	16	0.25(3)
	41-45	23	61	1.39(7)	94	5.89	48	1.26(8)
	46-50	32	56	1.03(4)	100	3.09	56	2.16(16)
	51-55	21	67	1.52(5)	94	3.12	52	1.48(8)
	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 Banquereau Bank (Aug.)	≤35	36	19	0.22(2)	88	1.62	56	0.86(4)
	36-40	29	34	0.52(3)	100	2.63	55	0.90(7)
	41-45	28	36	0.79(5)	100	3.02	54	0.96(8)
	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 Banquereau Bank (Sept.)	≤35	33	21	0.33(2)	100	2.61	58	1.24(5)
	36-40	29	41	0.83(6)	100	4.68	48	0.86(5)
	41-45	21	38	0.52(4)	100	2.11	48	0.76(3)
	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 Hole (Apr.)	≤30	22	5	0.14(3)	100	2.79	5	0.05(1)
	31-35	25	44	0.88(7)	95	7.37	12	0.16(2)
	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 Bank (July)	≤30	33	3	0.06(2)	100	0.82	6	0.09(2)
	31-35	23	35	0.48(3)	82	3.35	22	0.26(2)
	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	≤30	39	41	1.03(6)	95	13.19	13	0.15(2)
Bank (Off	31-35	21	62	1.81(7)	95	14.23	48	0.71(4)
East Bar)	36-40	30	63	4.57(61)	93	23.66	43	0.83(8)
(Sept.)	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	≤35	32	22	0.38(3)	100	3.61	13	0.13(1)
Island Bank	36-40	24	58	1.83(11)	93	10.20	50	1.04(5)
(June)	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	≤35	17	18	0.24(2)	100	2.11	24	0.24(1)
Bank	36-40	14	43	1.21(4)	94	5.95	29	0.36(2)
(July)	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	≤35	16	13	0.25(2)	-	1.98	19	0.19(1)
Western	36-40	19	32	1.11(6)	100	5.77	42	0.84(4)
Bank	41-45	34	74	2.03(8)	96	7.34	56	1.91(15)
(Sept.)	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	≤30	10	50	0.50(1)	100	7.94	0	0
4W-4X	31-35	24	38	1.13(7)	93	9.19	8	0.29(6)
Chebucto	36-40	23	57	1.39(10)	97	8.03	17	0.26(2)
Head	41-45	28	68	2.07(9)	97	8.81	18	0.54(10)
(March)	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≤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 $P \leq 0.05$*, ≤ 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 abuncance 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).

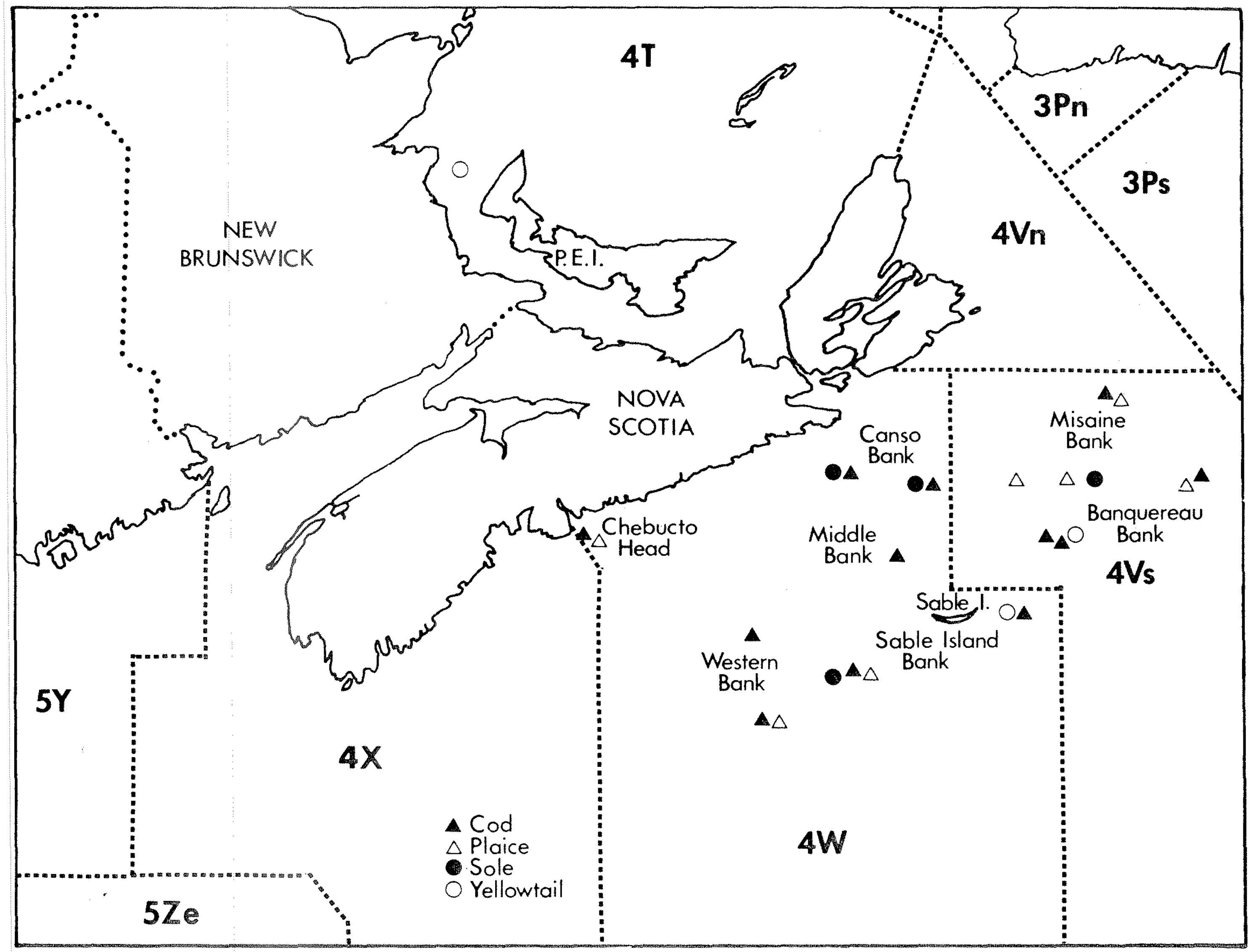

FIG. 1. Sampling locations.

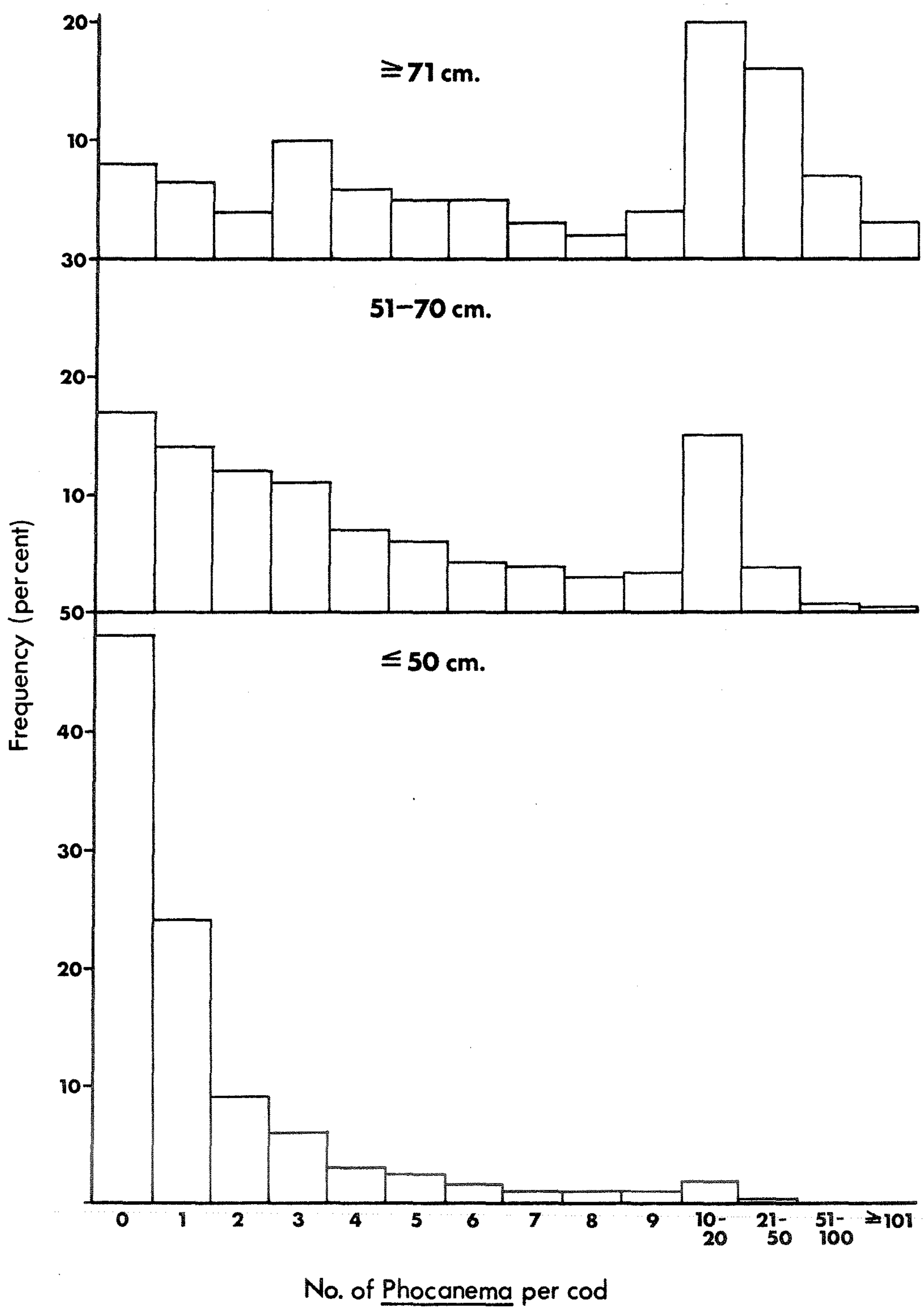

FIG. 2. Frequency distributions of sealworm counts from individual cod for combined 4Vs and 4W cod samples. (Sample from East Bar, Sable Island Bank, omitted; cod stratified into ≤50-cm, 51-cm to 70-cm, and ≥71-cm length groups.)

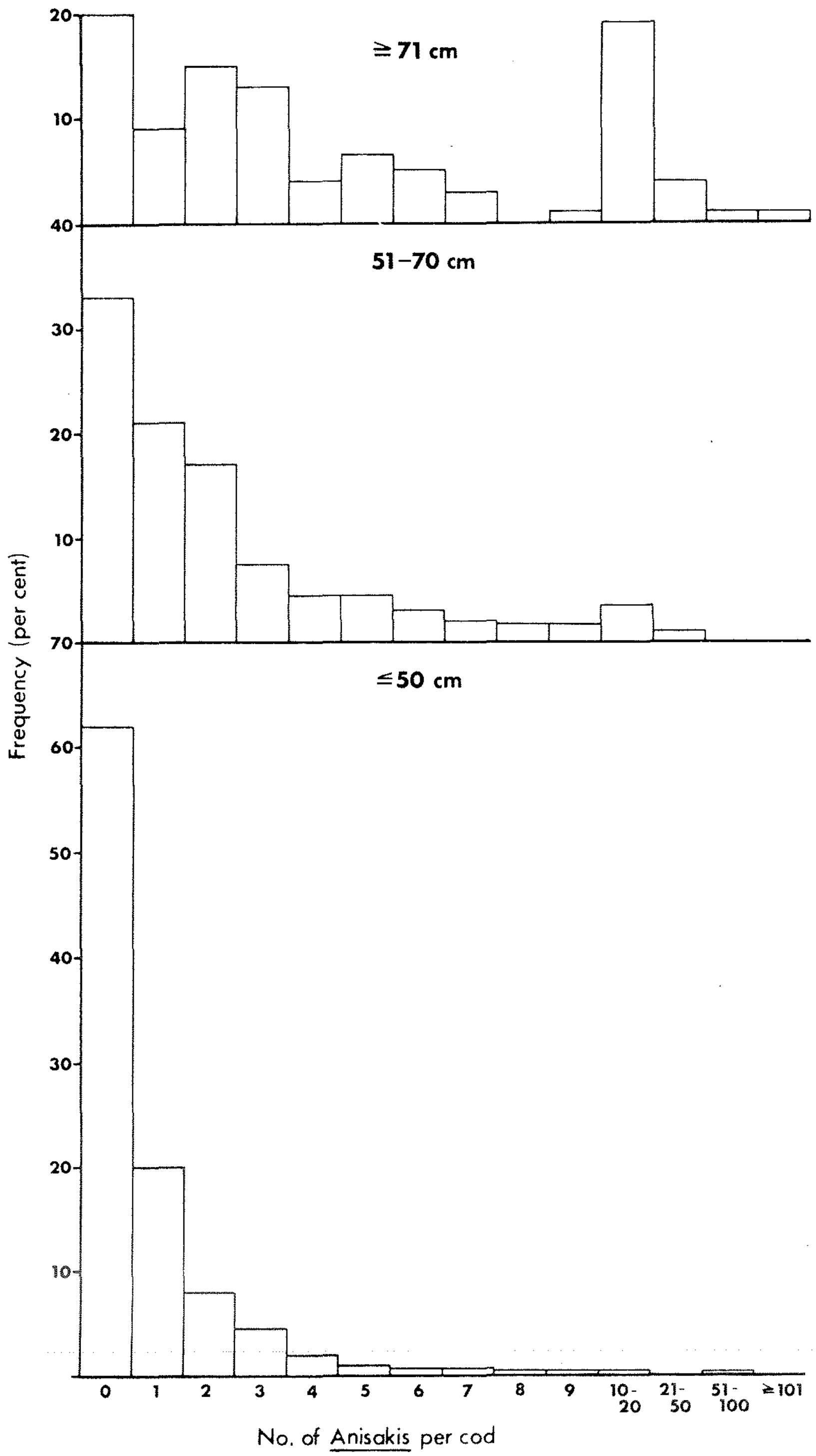

FIG. 3. Frequency distributions of larval Anisakis counts from individual cod for combined 4Vs and 4W cod samples. (Sample from East Bar, Sable Island Bank, omitted. Cod stratified into ≤50-cm, 51-70-cm, and ≥71-cm length groups.)

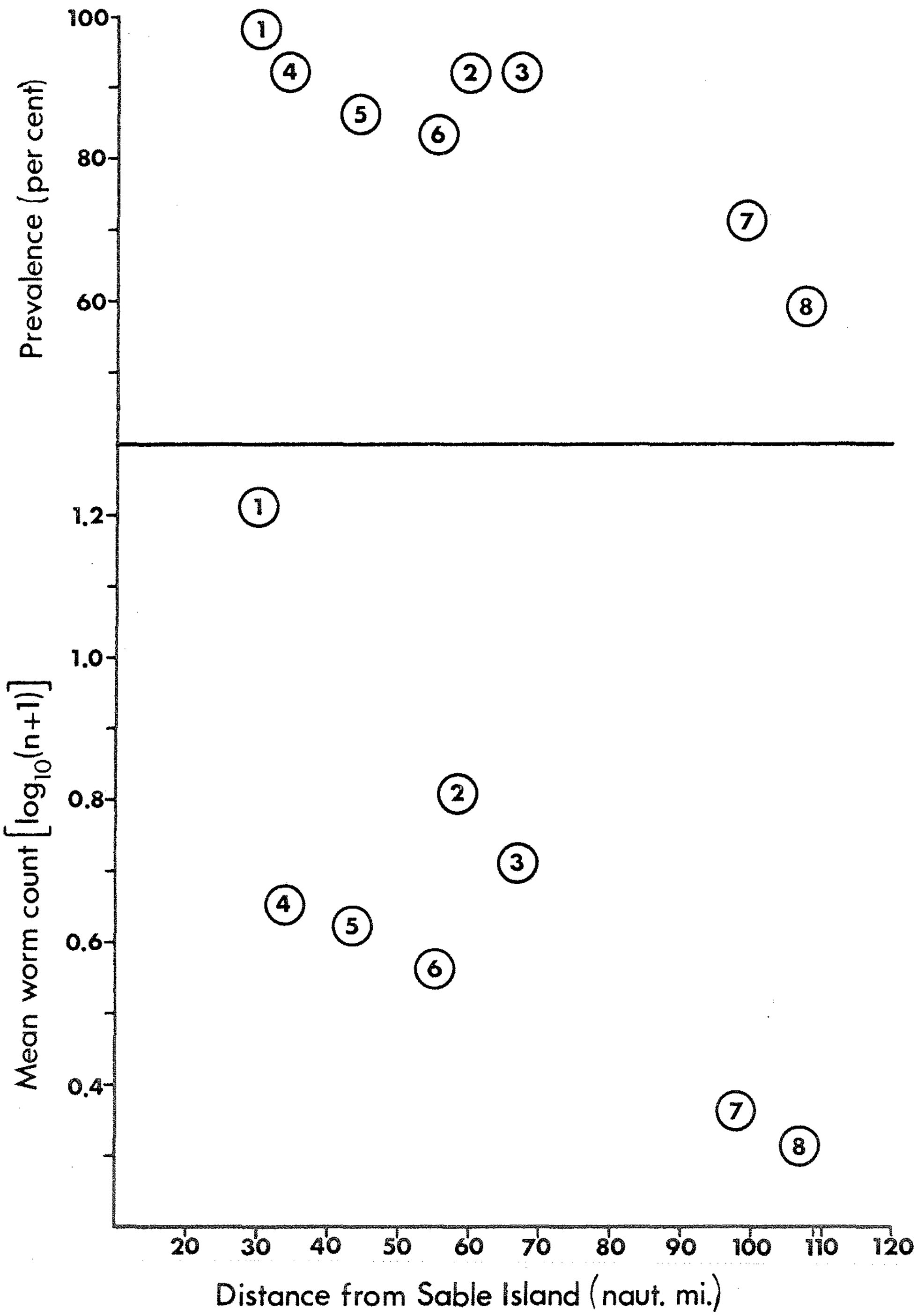

FIG. 4. Prevalence and abundance of sealworm infection in Scotian Shelf (4Vs and 4W) cod, 51-70 cm in length, versus distance from Sable Island. (1. Sable Island Bank, 2. Western Bank, 3. Edge of Western Bank, 4. Middle Bank, 5. West Banquereau Bank, 6. Canso Bank, 7. East Banquereau Bank, 8. Misaine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

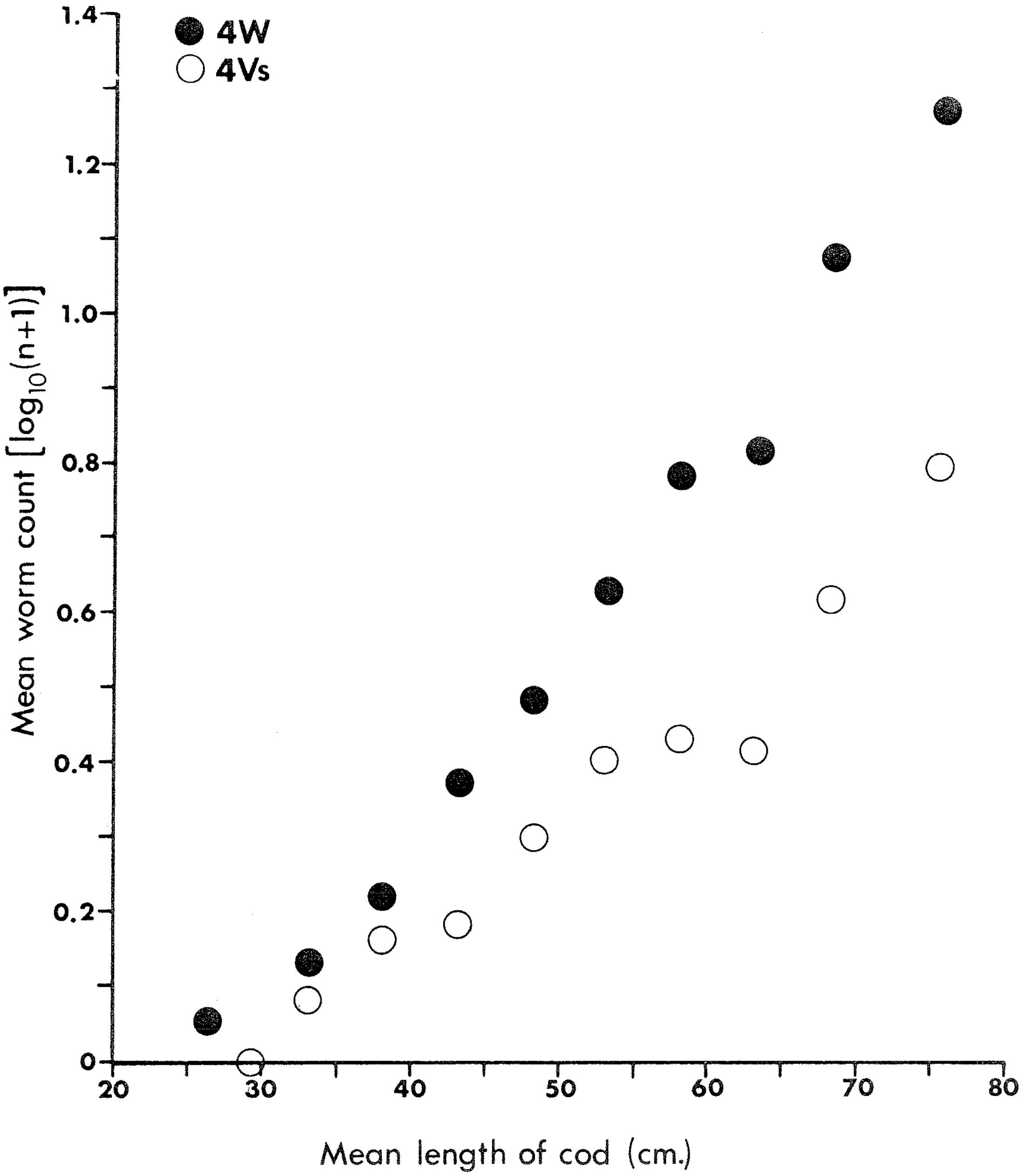

FIG. 5. Mean transformed sealworm count versus mean host length for 5-cm length strata of 4Vs and 4W cod; comparison of worm counts in 4Vs and 4W samples. (Sample from East Bar, Sable Island Bank, omitted.)

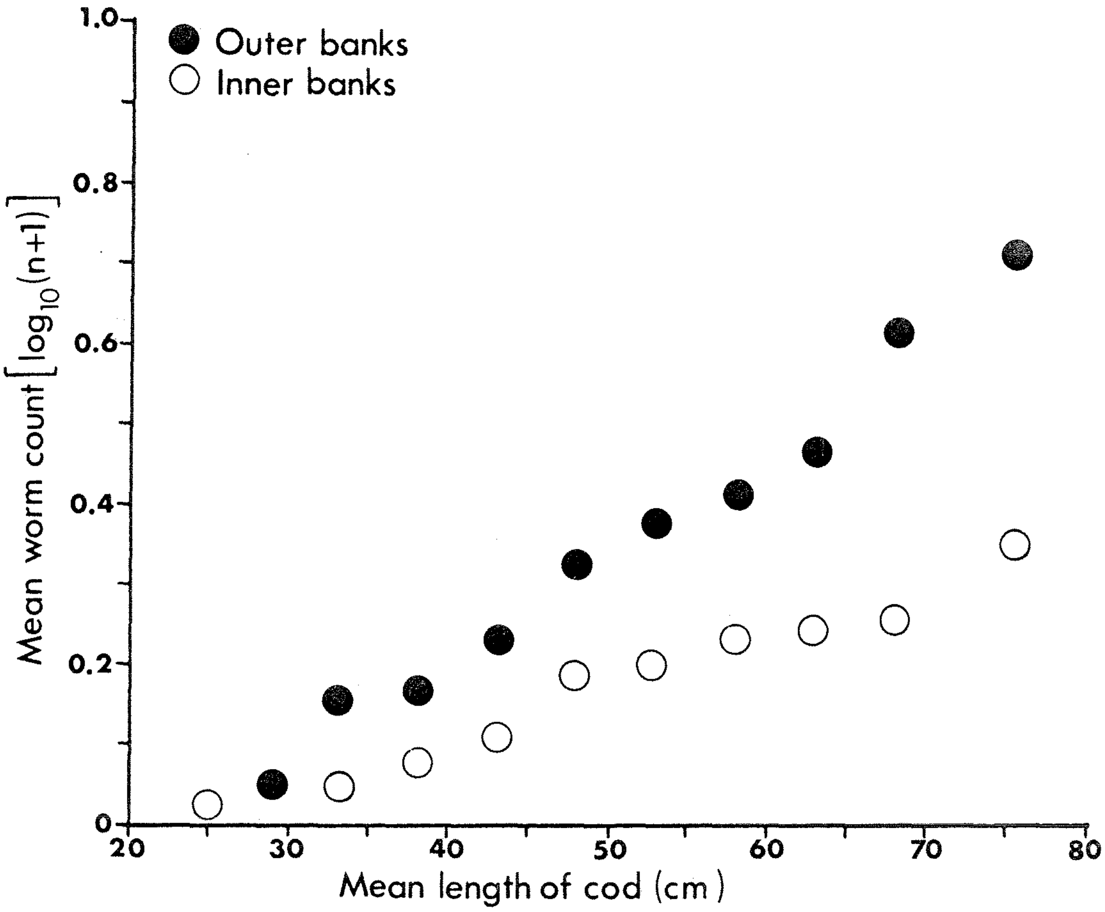

FIG. 6. Mean transformed Anisakis counts versus mean host lengths for 5-cm length strata of 4Vs and 4W cod; comparison of worm counts in "outer" bank (Banquereau, Sable Island, and Western banks) and "inner" bank (Misaine, Canso, and Middle banks) samples.

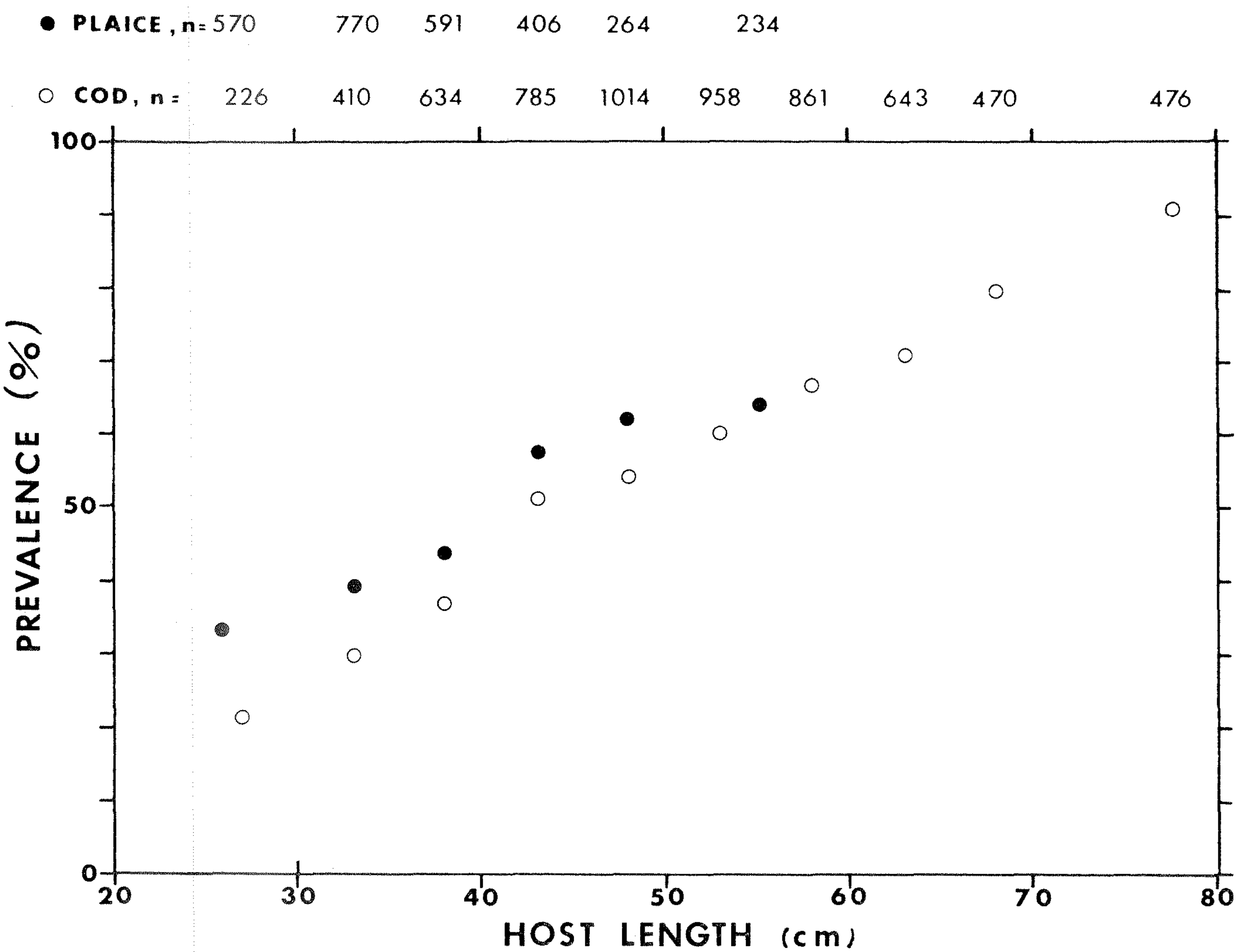

FIG. 7. Prevalence of sealworm infection versus mean host length for 5-cm length strata of 4T, 4V and 4W cod and plaice.

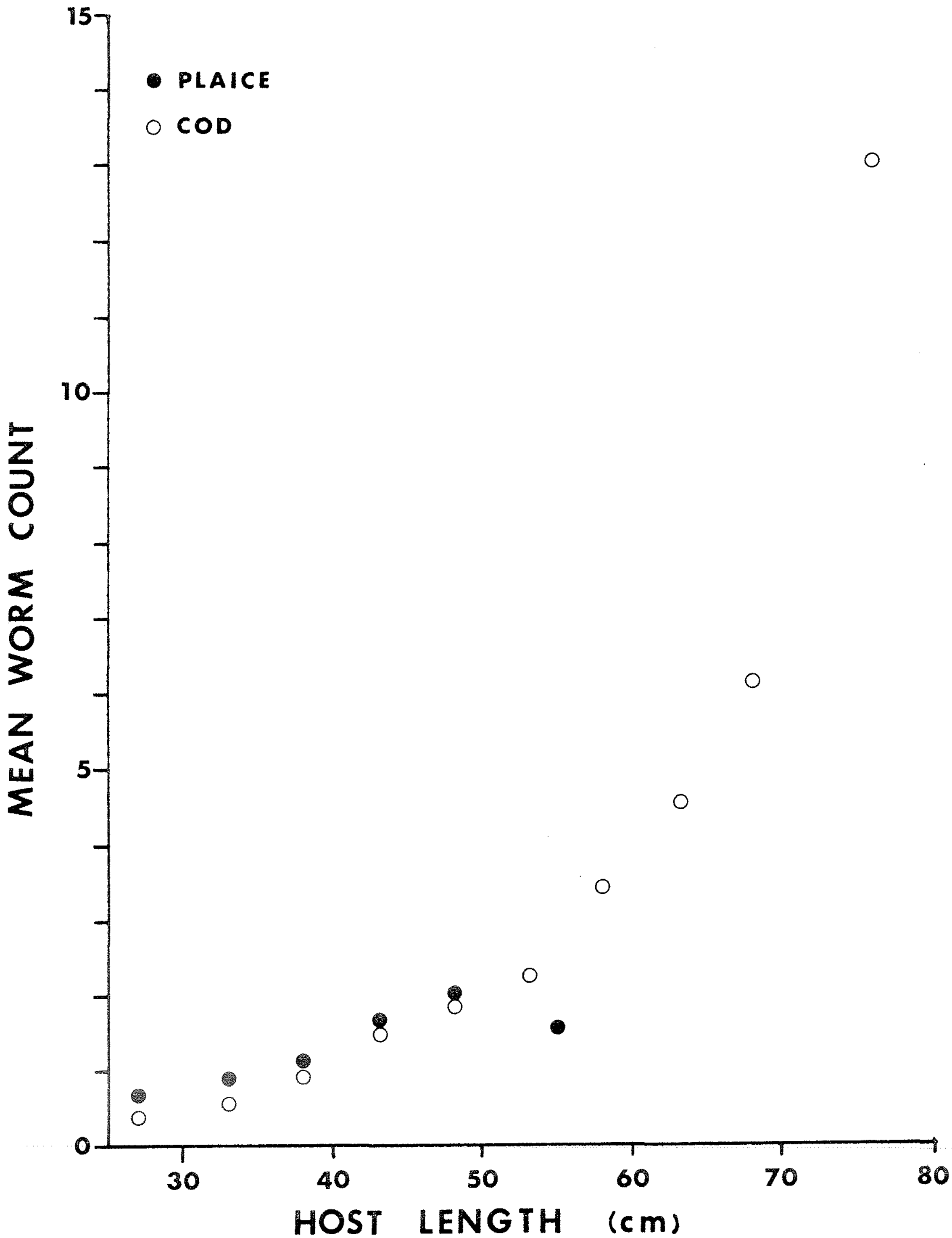

FIG. 8. Abundance of sealworms versus mean host length for 5-cm length strata of 4T, 4V and 4W cod and plaice.

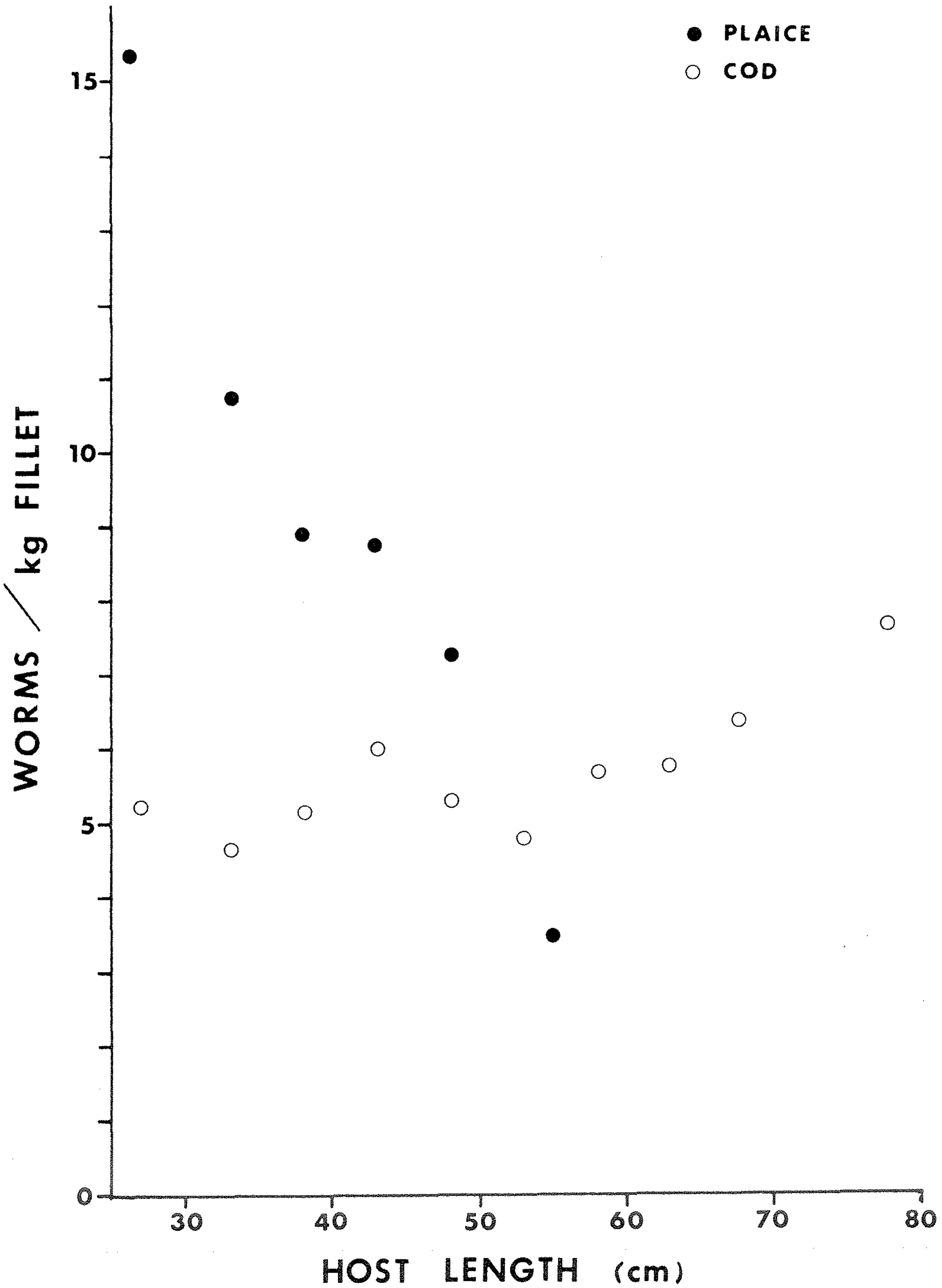

FIG. 9. Sealworm per unit fillet weight versus mean host length for 5-cm length strata of 4T, 4V and 4W cod and plaice.

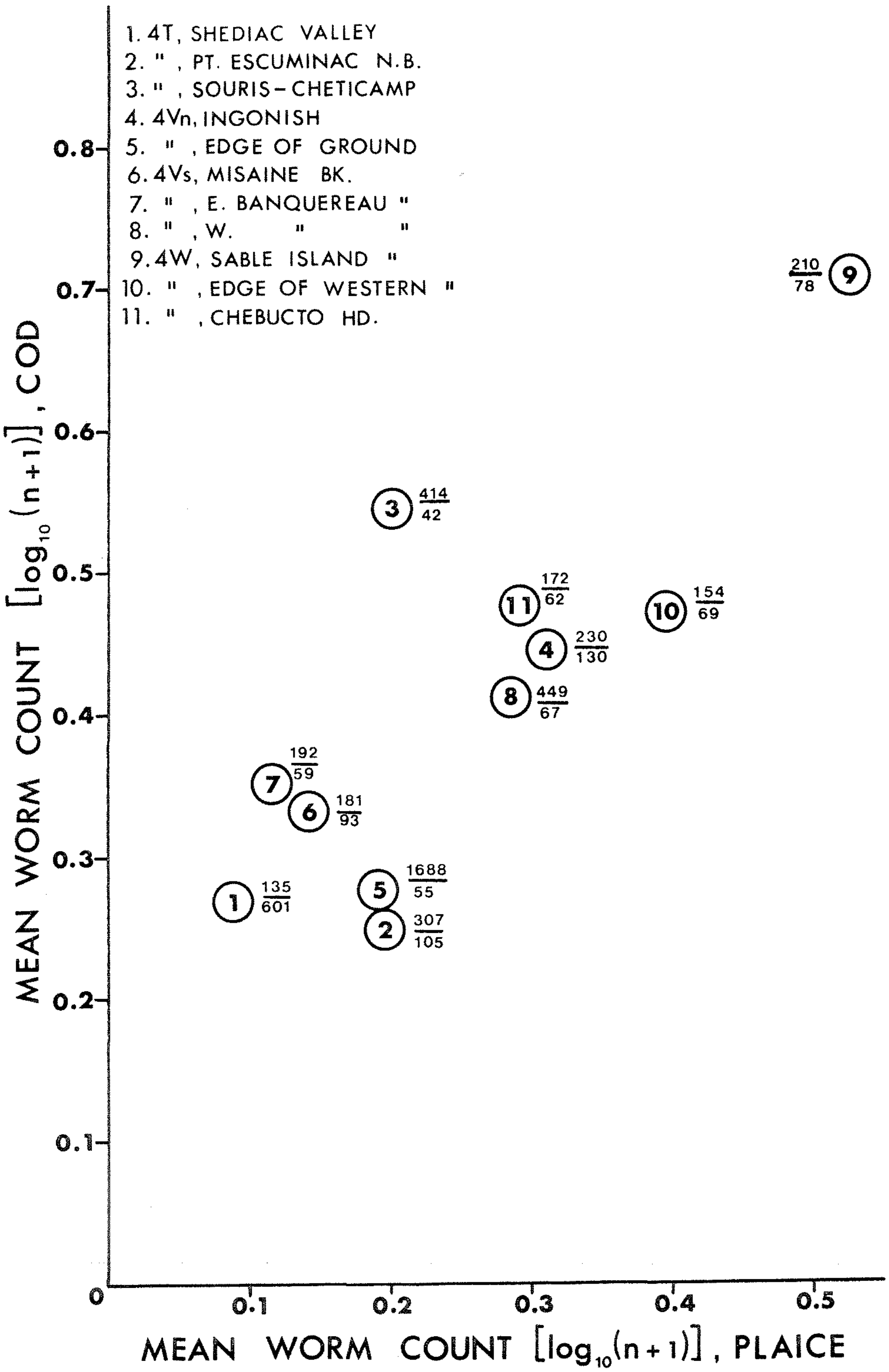

FIG. 10. Mean transformed sealworm counts in cod versus mean transformed worm counts in plaice in corresponding locations. (Cod represented by numerator and plaice, denominator. Frequencies indicated next to points.)

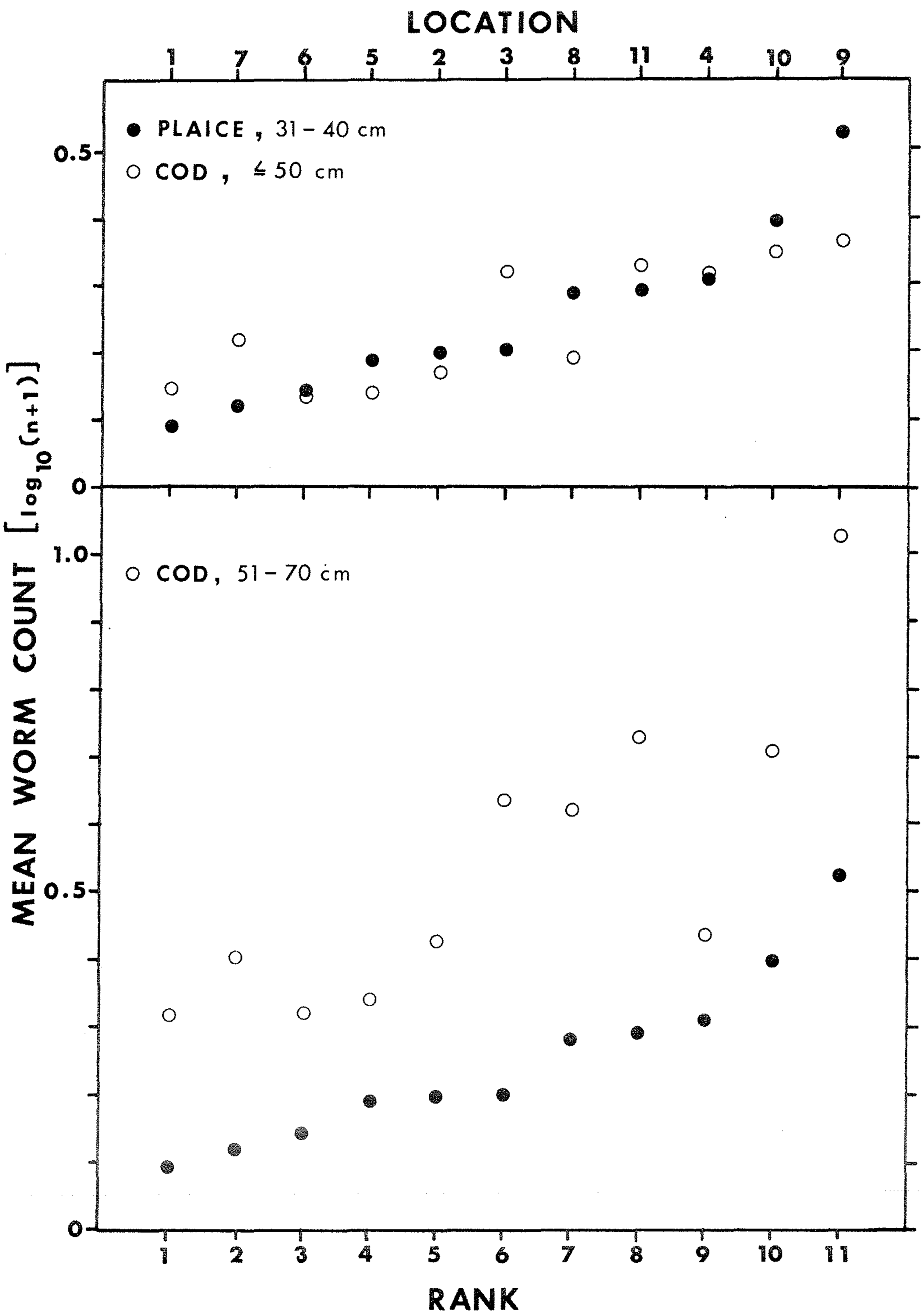

FIG. 11. Mean transformed sealworm counts in cod and plaice versus rank of sampling location. (Sampling locations ranked in ascending order of mean transformed worm counts in plaice.)

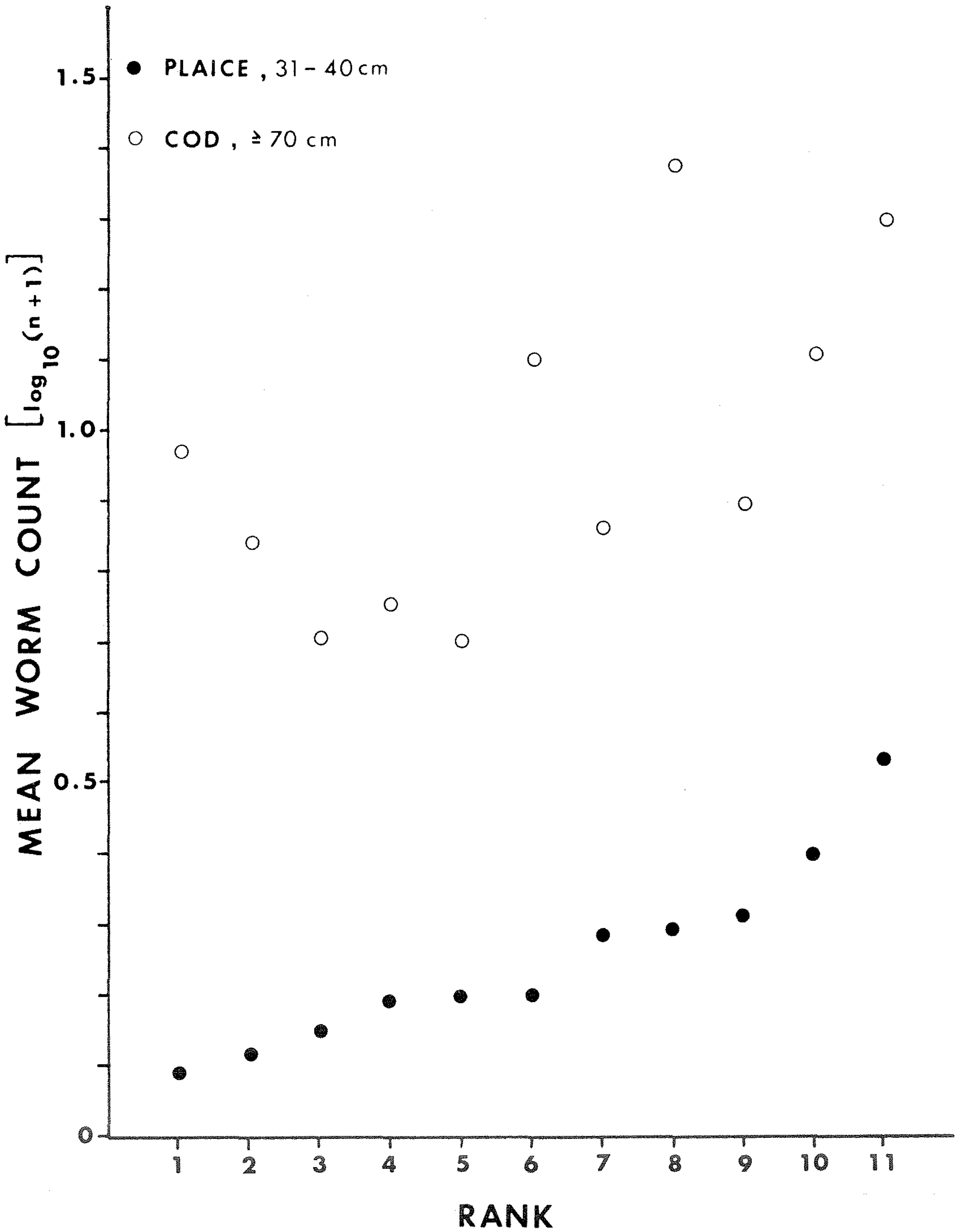

FIG. 11. Continued.

REFERENCES

Appy, R.G. 1978. Parasites of cod, Gadus morhua L., in the northwestern Atlantic Ocean. Ph.D. Thesis, U.N.B.

Armitage, P. 1971. Statistical methods in medical research. Blackwell Scientific Publications, Oxford: xv + 504 p.

Bjorge, A.J., I. Christensen and T. Oritsland. 1981. Current problems and research related to interactions between marine mammals and fisheries in Norwegian coastal and adjacent waters. ICES Marine Mammal Committee C.M. 1981/N:18.

Fruend, R.J. and R.C. Littel. 1981. SAS for linear models. A guide to the ANOVA and GLM procedures. SAS Institute Inc., Cary, North Carolina.

Mansfield, A.W. and B. Beck. 1977. The grey seal in eastern Canada. Environment Canada, Fish. Mar. Serv. Tech. Rep. 704.

Martin, W.R. and Y. Jean. 1964. Winter cod taggings off Cape Breton and on offshore Nova Scotia banks, 1959 to 1962. J. Fish. Res. Board Canada. 21:215-238.

McClelland, G. 1980a. Phocanema decipiens: molting in seals. Experimental Parasitol. 49:128-136.

McClelland, G. 1980b. Phocanema decipiens: growth, reproduction and survival in seals. Experimental Parasitol. 49:175-187.

McClelland, G. 1980c. Phocanema decipiens: pathology in seals. Experimental Parasitol. 49:405-419.

McClelland, G. 1982. Phocanema decipiens (Nematoda:Anisakinae): experimental infections in marine copepods. Can. J. Zool. 60:502-509.

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.

Pälsson, J. 1979. Larval ascaridoid nematodes in young cod (Age Classes 0-III) from Icelandic waters. M.Sc. Thesis, University of Southern Mississippi.

Pitt, T.K. 1969. Migrations of American plaice on the Grand Bank and in St. Mary's Bay, 1954, 1959 and 1961. J. Fish. Res. Board Canada. 26:1301-1319.

Platt, N.E. 1975. Infestation of cod (Gadus morhua L.) with larvae of codworm (Terranova decipiens) and herring worm, Anisakis sp. (Nematoda:Ascaridata) in North Atlantic and Arctic waters. J. Appl. Ecol. 12:437-450.

Power, H.E. 1961. Slicing of fillets as an aid in detection and removal of codworms from Atlantic cod fillets. J. Fish. Res. Board Canada. 18:137-140.

Powles, P.M. 1965. Life history and ecology of American plaice (Hippoglossoides platessoides F.) in the Magdalen Shallows. J. Fish. Res. Board Canada. 22:565-598.

SAS. 1982. SAS user's guide: Statistics. SAS Institute Inc., Cary, North Carolina.

Scott, D.M. 1953. Experiments with the harbour seal, Phoca vitulina, a definitive host of a marine nematode, Porrocaecum decipiens. J. Fish. Res. Board Canada. 10:539-547.

Scott, D.M. and W.R. Martin. 1957. Variation in the incidence of larval nematodes in Atlantic cod fillets along the southern Canadian mainland. J. Fish. Res. Board Canada. 14:975-996.

Scott, D.M. and W.R. Martin. 1959. The incidence of nematodes in the fillets of small cod from Lockeport, Nova Scotia, and the southwestern Gulf of St. Lawrence. J. Fish. Res. Board Canada. 16:213-221.

Snedecor, G.W. and W.G. Cochran. 1980. Statistical methods. Iowa State University Press, Ames, Iowa: xvi + 507 p.

Templeman, W., H.J. Squires and A.M. Fleming. 1957. Nematodes in the fillets of cod and other fishes in Newfoundland and neighbouring areas. J. Fish. Res. Board Canada. 14:831-897.

Underwood, A.J. 1981. Techniques of analysis of variance in experimental marine biology and ecology. Oceanogr. Mar. Biol. Ann. Rev. 19:513-605.

Wiles, M. 1968. Possible effects of the harbour seal bounty on codworm infestations of Atlantic cod in the Gulf of St. Lawrence, the Strait of Belle Isle, and the Labrador Sea. J. Fish. Res. Board Canada. 25:2749-2753.

Young, P.C. 1972. The relationship between the presence of larval anisakine nematodes in cod and marine mammals in British home waters. J. Appl. Ecol. 9:459-485.

Zwanenburg, K., B. Beck and S.J. Smith. 1981. Eastern Canadian grey seal (Halichoerus grypus) research report and 1980 stock assessment. CAFSAC Res. Doc. 81/81.