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Codworm – a possible biological indicator of the degree of mixing of Greenland and Iceland cod stocks

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During a quantitative survey of the infestation of North Atlantic cod stocks with larvae of the codworm, *Terranova decipiens* Krabbe, considerable differences between the infestations of the various populations were observed. In particular, larvae were virtually absent from cod at Greenland and abundant in those at Iceland. However, on the spawning grounds off southwest Iceland, a reduction in the characteristic level of infestation of Iceland cod was noted. This was thought to be due to the immigration of uninfested cod from Greenland waters. An examination of the infestation in relation to the age of the host further supported this theory. The evidence suggests that the relative abundance of codworm might be used as a biological indicator, providing an aid to the determination of the relative proportions of Iceland and Greenland components of the cod population on the spawning grounds at southwest Iceland.

Introduction

The codworm, *Terranova decipiens* Krabbe, 1878, is an anisakine nematode, parasitic as an adult in the stomachs of pinnipeds, especially the Grey seal, *Halichoerus grypus* (Young, 1972). The life cycle of this nematode, summarized in Figure 1, includes a larval stage which is encysted in the flesh of a demersal fish. Because of consumer reaction and the possible pathogenic effects of the worm on man (Suzuki et al., 1972; Little and MacPhail, 1972), there has been increasing concern about the occurrence of codworm larvae in the cod, *Gadus morhua*. In order to quantify and improve our knowledge of the incidence of this nematode, a survey of the North Atlantic and Arctic cod stocks was undertaken by the former Fisheries Helminthology Unit. During this survey, considerable geographical variation in the *T. decipiens* infestation was observed (Platt, 1975). The variation in infestation within the cod stocks occurring in Iceland and Greenland waters is of particular interest.

Quantitative studies of the parasite fauna of marine fish have increasingly shown differences between distinct stocks of several species, and may be particularly useful as natural biological indicators of fish migrations and the mixing of stocks. Previous workers have suggested several criteria which should ideally be met before a parasite may be considered suitable as a biological indicator (Kabata, 1963; Sindermann, 1961). These may be summarized as follows:

1. The parasite should be common in one population of the studied host species and rare or absent in another.
2. The infestation should be of reasonably long duration, at least several years.
3. The parasite should not bring about the death of its host.
4. The incidence of the parasite should remain relatively stable during the period of the study.
5. The parasite should preferably include in its life cycle only that host species which is being studied.
6. The environmental conditions in the areas studied should be within the physiological range of the parasite.

However, not all of these criteria can consistently be fulfilled in real situations.

The only criterion not satisfied by the codworm infestation in the Greenland and Iceland cod stocks is that the parasite should include in its life cycle only that host species which is being studied. As Kabata (1963) explained, this does not preclude the

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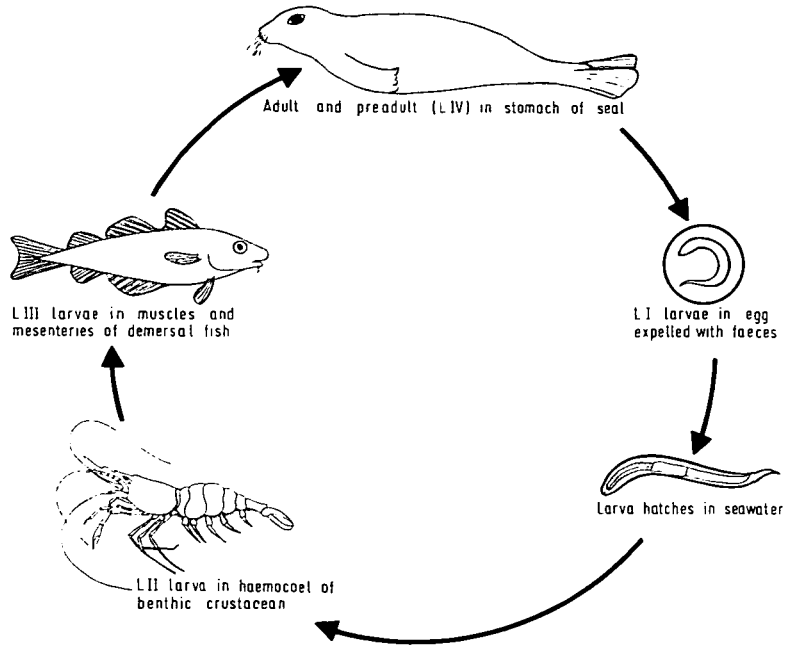

Figure 1. The life cycle of *Terranova decipiens*.

use of the parasite as a biological tag. He remarks that parasites with complex life cycles require wider study than those with single life cycles, because the occurrence and abundance of a parasite depends on the distribution and abundance of the populations of all its hosts. However, the first criterion requires that the parasite should be rare or absent in one of the host populations being studied, and this should essentially be the case for satisfactory quantitative work on the host populations. In order to satisfy this condition it may be necessary for one or both of the last two criteria to remain unfulfilled since the absence of a parasite in a host population suggests that there is a break in the life cycle through one cause or another.

Migration studies have shown that a component of the spawning population of cod on the Icelandic spawning grounds is of Greenland origin (Harden Jones, 1968). These fish are thought to be recruited to the Iceland stock after spawning (Anon, 1973). The nematode survey revealed that codworm was virtually absent from cod at Greenland, but abundant in those from Iceland waters. However, the infestation of cod in the region of the spawning grounds off the southwest coast of Iceland (area 3, Fig. 2) was significantly less than in any other region at Iceland. It was thought that this lower infestation might result from the immigration of an uninfested component of mature cod from Greenland to spawn at Iceland. If this is the case, comparison of the degree of infestation of the various groups of cod may provide an additional means of quantifying the proportion of Iceland to Greenland cod on the spawning grounds off southwest Iceland. Thus, a further analysis of the data obtained during the survey was undertaken, special emphasis being placed on changes in the degree of infestation with increasing age of the cod.

Methods

Approximately 3100 cod, taken from Iceland and Greenland waters, were examined between 1 February 1971 and 30 April 1973. Samples were obtained from the landings of the British distant water trawling fleets of Fleetwood, Grimsby and Hull, during research cruises of the Ministry of Agriculture, Fisheries and Food's RV "Cirolana", and during a cruise of a research vessel of the Icelandic Marine Research Institute, Reykjavik.

Those samples which were obtained from commercial landings consisted of 30 to 65 kg of cod and codling. The fish were packed in crushed ice and sent to the laboratory overnight by road. The grounds from which the fish were taken were deter-

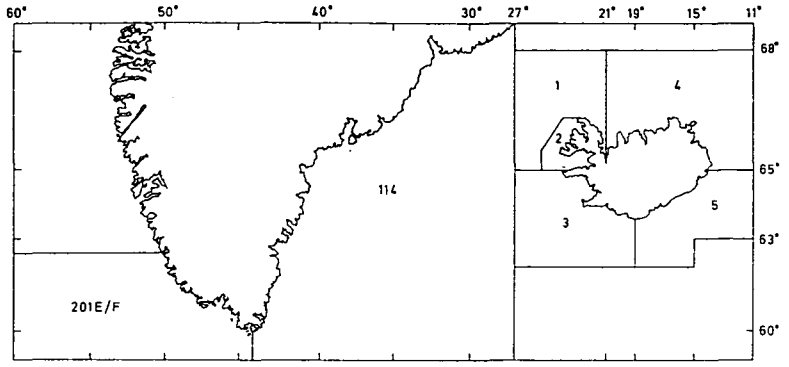

Figure 2. The geographical areas sampled during the survey.

mined by interview and samples obtained from a vessel which had trawled in more than one area were excluded from the analysis of the data. The samples taken during research cruises were either examined on board or deep frozen and examined on return to the laboratory.

The total length of each fish was measured to the centimetre below and its weight determined to the nearest 50 g. The sagittal otoliths were removed for age determination. For the purpose of determining their age, fish were assumed to have been spawned on 1 January.

The cod were filleted and each fillet divided into two portions, the *flap*, that part of the flesh which surrounds the body cavity, and the *fillet*, the remainder of the body musculature. Each portion was examined by slicing the flesh over a candling table fitted with four 20 watt fluorescent light tubes, producing an intensity of 75 foot candles at the working surface. The number and identity of the nematodes found in each portion was recorded. At first, the identification was checked by microscopic examination, the worms having been killed and fixed in hot 70% alcohol or cold glacial acetic acid, preserved in 70% alcohol and cleared in lactophenol (Berland, 1961). Later, they were identified by eye alone, microscopic examination being used only when there was any doubt. The descriptions in Berland (1961) and Grainger (1959) were used as an aid to identification.

Results

The distribution of sampling is shown in Table 1. It has been suggested that the East Greenland and South-west Greenland (ICNAF Division 1E–F) cod may be considered a single stock, based on the results of tagging experiments (Anon, 1973). Thus the data from these areas have been grouped and are given in Table 2. Of the 364 cod examined from Greenland waters only five fish, of which two were of mature age, were found to be infested with *Terranova decipiens* larvae.

The degree of infestation of Iceland cod with *T. decipiens* larvae, recorded as the percentage of cod infested within each age class, is shown in Figure 3. In view of the seasonal variation in fishing between the grounds around Iceland, it has not been possible

Table 1. The distribution of sampling

Geographical Area (see Fig. 2)	Number of fish examined
East Greenland 114	83
South-west Greenland 201 E/F	281
Iceland 1	831
Iceland 2	297
Iceland 3	294
Iceland 4	828
Iceland 5	482

Table 2. The degree of infestation of cod with *Terranova decipiens* larvae in Greenland waters

Age	2	3	4	5	6	7	8	9	10	11	12	13	14
No. examined	4	3	39	33	29	24	86	96	31	13	3	1	2
No. infested	0	0	1	0	2	0	1	1	0	0	0	0	0

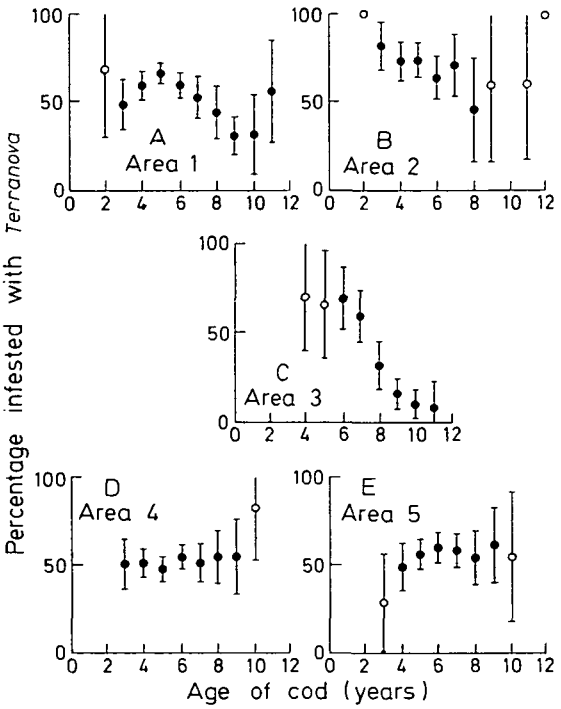

Figure 3. The variation in *Terranova decipiens* infestation of cod in Icelandic waters with increasing age of the host. ○, 5 to 10 cod in age class sample; ●, more than 10 cod in age class sample. The 95% confidence limits are shown.

to sample every area in each season of the year. Thus the data presented in Figure 3 are the sum of the results obtained from Icelandic waters during the whole sampling period.

It will be seen from Figure 3 that the relationship between the proportion of cod infested and the age of the host differs in the areas studied. Cod from areas 4 and 5 (Fig. 2) have similar infestations which gradually increase with the age of the host from around 45% at age 3 years to 60% at 9 years. The infestation of cod in area 2, in the region of Breidafjordur, is the greatest. Between 60% and 80% of the fish from this area were infested and the infestation appears to fall gradually with increasing age to a level similar to that observed in areas 4 and 5, though there were really insufficient examples of older fish for a general statement about their degree of infestation to be made, a point borne out by the great range of the 95% confidence limits (Fig. 3B). The infestation of cod from areas 1 and 3 increases with age in the younger fish, but at about 7 years of age this increase in the proportion of the population infested with codworm is reversed and, particularly in fish from area 3, the region of the spawning grounds to the southwest of Iceland, there is a sharp drop in the degree of infestation (Fig. 3C).

Discussion

In view of the present knowledge of spawning migrations of cod in Greenland and Iceland waters (Harden Jones, 1968), the rapid fall in the level of *Terranova decipiens* infestation observed in mature cod on the spawning grounds off southwest Iceland might reasonably be expected to be caused by the immigration of uninfested mature cod from Greenland. That the majority of the specimens obtained from this area were obtained during the spawning period lends further support to this interpretation. These immigrants are believed to be recruited to the Iceland cod stock (Anon, 1973) and can be expected to move with the native cod population to feeding grounds on the Icelandic continental shelf. An examination of the *T. decipiens* infestation of cod from the northwest of Iceland, area 1, revealed a relationship with age which reflects the rapid fall in infestation which was observed in the older cod on the spawning grounds, but is not quite so extreme. This observation further supports the idea that Greenland cod are recruited to the Icelandic stock and, as the majority of specimens were obtained from the area during the three months immediately following the spawning season, further suggests that the post-spawning recovery grounds are located in this area. That the degree of infestation of the older age classes was greater than on the spawning grounds indicates that the previously uninfested Greenland component of the stock is now exposed to infestation by *T. decipiens* whilst feeding. It is not known how long it will take for this Greenland component to attain the infestation levels of the native component as the sampling effort was necessarily seasonal and insufficient fish were obtained from this area during the winter months.

The situation observed in area 2, off Breidafjordur, is rather anomalous since it also happens to be the region in which the main breeding concentrations of Grey seals, the definitive hosts to *T. decipiens*, are located (Smith, 1966). Thus as one might expect, the infestation of cod in this area is greater than elsewhere at Iceland. This is particularly evident in the case of the younger fish, where there is a slightly greater degree of infestation than in older cod. It is likely that these immature fish do not move far from their feeding grounds, thus allowing the infestation to build up in this section of the population. The mature fish, however, will tend to mix with those

Table 3. The proportion of Iceland to Greenland cod on the spawning grounds off south-west Iceland. The numbers of fish examined are in parentheses

Age class (years)	% Cod infested			Percentage origin of cod	
	at Greenland	at Iceland Area 4 & 5	on spawning ground	Iceland	Greenland
8.....	1·16 (86)	55·17 (87)	31·82 (44)	57%	43%
9.....	1·04 (96)	58·54 (41)	16·46 (79)	27%	73%
10.....	0 (31)	69·23 (13)	11·11 (63)	16%	84%
11.....	0 (13)	– (1)	8·33 (12)	–	–

from other areas during their migrations and their infestations will consequently tend to become representative of the stock as a whole.

In addition to a qualitative description of the spawning migration of cod from Greenland to southwest Iceland and its subsequent recruitment to the Iceland stock, a quantitative estimation of the codworm infestations of the various components of the spawning stock should enable the proportions of Iceland and Greenland cod on the spawning grounds to be determined. This calculation is based on the level of infestation of each component stock, determined by examining fish in their home waters, and on the change in the level of infestation when they mix on the Icelandic spawning ground. Jamieson and Jónsson (1971), who studied haemoglobin types in cod blood, suggest that the genetic composition of the spawning population at southwest Iceland changes throughout the season, presumably due to stock movements. They also suggest that a mosaic effect of genetic isolates is demonstrable within the spawning stock. Thus, when sampling the spawning population, a far greater geographical and temporal coverage than was possible during this survey would be required for an accurate assessment of the composition of the spawning cod population. However, with the reservations that the samples of the spawning fishery were small and gave neither adequate temporal nor geographical coverage, the proportions of mature cod of Iceland and Greenland origin were determined for age classes 8, 9 and 10 years (Table 3). It is immediately apparent that these proportions are of a very different order to those calculated by the ICES North Western working group in 1970 using data obtained from an examination of otolith types, meristic characters and tagging experiments (Anon, 1971). However, it is believed that the use of codworm infestation as a biological indicator would be a valuable aid to the assessment of the inter-relationships of the cod populations at Iceland and Greenland.

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