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STUDIES ON THE GENUS DIPHYLLOBOTHRIUM

A REVISION OF THE FINNISH FINDS OF DIPHYLLOBOTHRID PLEROCERCOIDS

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INTRODUCTION

Our present interest in Diphyllobothrid plerocercoids was aroused when one of us was confronted with several types of Diphyllobothrid larva which could not be distinguished from larvae of *Diphyllobothrium latum* according to the special literature available (Finnish authors, SCHÄPERCLAUS, FIEBIGER, HOFER, etc.). Both the morphological differences and the differences in cyst formation and location of the plerocercoids were too great to make it probable that all these larvae belonged to the same species. Some Finnish research workers familiar with tapeworm larvae were questioned, but no assistance could be obtained. The situation changed at once when the excellent works of KUHLOW (1953 a, b, c, and 1955) were seen. KUHLOW is the first to give a differential diagnosis of four *Diphyllobothrium* species which makes it possible to identify these at the plerocercoid stage. Thus it was confirmed that the different plerocercoid types do in fact belong to different species.

It was immediately obvious that the Finnish literature on Diphyllobothrid plerocercoids contained many errors due to the tendency of the authors to identify every plerocercoid as belonging to *D. latum*.

As is well known, the human population in Finland is heavily infested with the fish tapeworm (cf. p. 7). It is therefore of outstanding importance to know which fish species are the second intermediary or transport hosts of the fish tapeworm and to what degree the fish populations of at least some lakes are infected with plerocercoids. The authors hope to be able to perform investigations on this problem. The first work to be done seems, however, to be a revision of the earlier finds of *Diphyllobothrium* plerocercoids. In 1950

HUHTALA has reviewed the present state of tapeworm research in Finland, but his data on plerocercoids are very incomplete and they are not, of course, reviewed in the critical sense here applied.

IDENTIFICATION OF DIPHYLLOBOTHRID PLEROCERCOIDS

There exist a large number of species of the genus *Diphyllobothrium*. It is difficult to distinguish between many of them even in the adult stage. Hence it must be assumed that the difficulties in making correct species determinations at the larval stages are very great.

Working with material derived from fish from Soviet Karelia, PETRUSCHEWSKY and TARASSOW (1933) showed experimentally that not all those plerocercoids which had been suspected of belonging to *D. latum* developed to the adult worm in man. As mentioned above, KUHLOW (op.c.) gives for the first time a reliable specific diagnosis of four species of *Diphyllobothrium* which allows a distinction between these even at the plerocercoid stage. It is obvious that much further research remains to be done in this field, but KUHLOW's works afford a reliable basis for further investigations. In the present state of knowledge of Diphyllobothrid plerocercoids it seems, however, indispensable to make infection experiments before any conclusive deductions regarding the species specificity of the plerocercoids can be made. (It may, for instance, be mentioned that according to WARDLE (1935) eleven per cent of the burbot (*Lota lota maculosa*) in Lake Winnipeg harbour a plerocercoid very similar to that of *D. latum*, but that infection experiments were negative.)

The four species with which KUHLOW's works deal are: *Diphyllobothrium dendriticum* Nitzsch 1824, *D. osmeri* (v. Linstow 1878), *D. vogeli* Kuhlow 1955, and *D. latum* Linnaeus. As adults the three first-mentioned species are parasites of birds, especially of Laridae. The differential diagnosis cannot be cited here in full. Only those characters are given which have to do with external and easily recognisable characters, such as those usually mentioned in the literature.

D. dendriticum (fig. 1a) was found free in the coelom of *Gasterosteus*. Its maximal length (relaxed) was 4.8 cm. The plerocercoids are contracted and the cuticle is folded into numerous regular deep folds. The scolex is mostly extruded and laterally compressed. The colour is white. The body of the plerocercoids is covered with cuticular bristles 4—10 μ long.

D. osmeri (fig. 1b). The plerocercoids occur in the smelt in cysts which usually lie around the ventricle. The body is somewhat transparent, bluish-white in colour, and always without folds. The length varied within 8—16 mm. The scolex is extruded and rounded. Both the body and the scolex are provided with cuticular bristles 14—18 μ long.

D. vogeli (fig. 1c). This species was found in the liver of *Gasterosteus*. It resembles *D. osmeri*, but is smaller (10 mm.). The caudal end is pointed and cannot be contracted

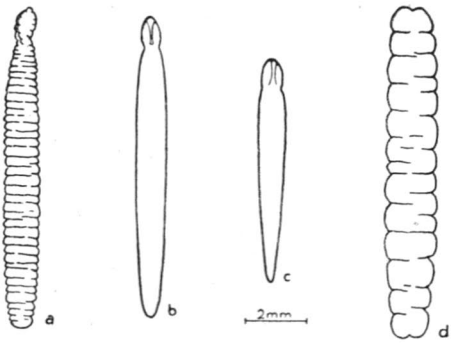

Fig. 1. Reproduction of the figures given by KUHLOW (1953a) of the plerocercoids of *Diphyllobothrium dendriticum* (a), *D. osmeri* (b), *D. vogeli* (c), and *D. latum* (d).

into the body. The scolex and the bothrids are short. The body surface is covered with long bristles (18—35 μ).

D. latum (fig. 1d). KUHLOW found the plerocercoids of this species in burbot (*Lota vulgaris*) and perch (*Perca fluviatilis*). In burbot the larvae were found subperitoneally on the ventricle and the appendices pylores. In perch they lived in the body muscles. The plerocercoids were not encysted. They are deeply folded and strongly contracted. Both the scolex and the caudal end of the body are withdrawn into the body. The larvae are nontransparent, and white. The largest observed specimen measured 4.5 cm. (relaxed). Usually the plerocercoids are much smaller. The cuticle lacks bristles.

The figure given by KUHLOW of the plerocercoid of *D. latum* does not in our experience fully correspond with the majority of cases found by us (cfr. figs. 3 and 4).

One character very important in the following discussion may be especially pointed out. According to the literature it seems to be convincingly proved that the plerocercoids of *D. latum* are not encysted, i.e. surrounded by a wall of connective tissue formed by the host. WARDLE writes: »It may be taken as certain, however, that any plerocercoid that is enclosed in a cyst is not *Diphyllobothrium latum*.» Our own observations are in full accordance with this statement.

Furthermore, some interesting observations by KUHLOW (1955) on the life history of *D. latum* may be summarized here.

In infection experiments with procercoids positive results were obtained on feeding procercoids to ruff (*Acerina cernua*), ten-spined stickleback (*Gasterosteus pungitius*), pike (*Esox lucius*) and perch. The plerocercoids were found chiefly in the musculature. Negative results were obtained with eel (*Anguilla vulgaris*), three-spined stickleback (*Gasterosteus aculeatus*) and tench (*Tinca vulgaris*). The numbers of fish used in the experiments were, however, relatively small.

In infection experiments with plerocercoids a penetration of these through the gut of the hosts was shown in all the fish species used, *viz.* ruff, pike, perch, rainbow-trout (*Trutta shasta*), and roach (*Leuciscus rutilus*). The plerocercoids were located partly in the coelom and partly in the muscles. Thus ruff, perch and pike can serve as both second intermediary and transport hosts. Plankton-feeding fishes can also serve as transport hosts in spite of the fact that they are obviously immune to infection with procercoids.

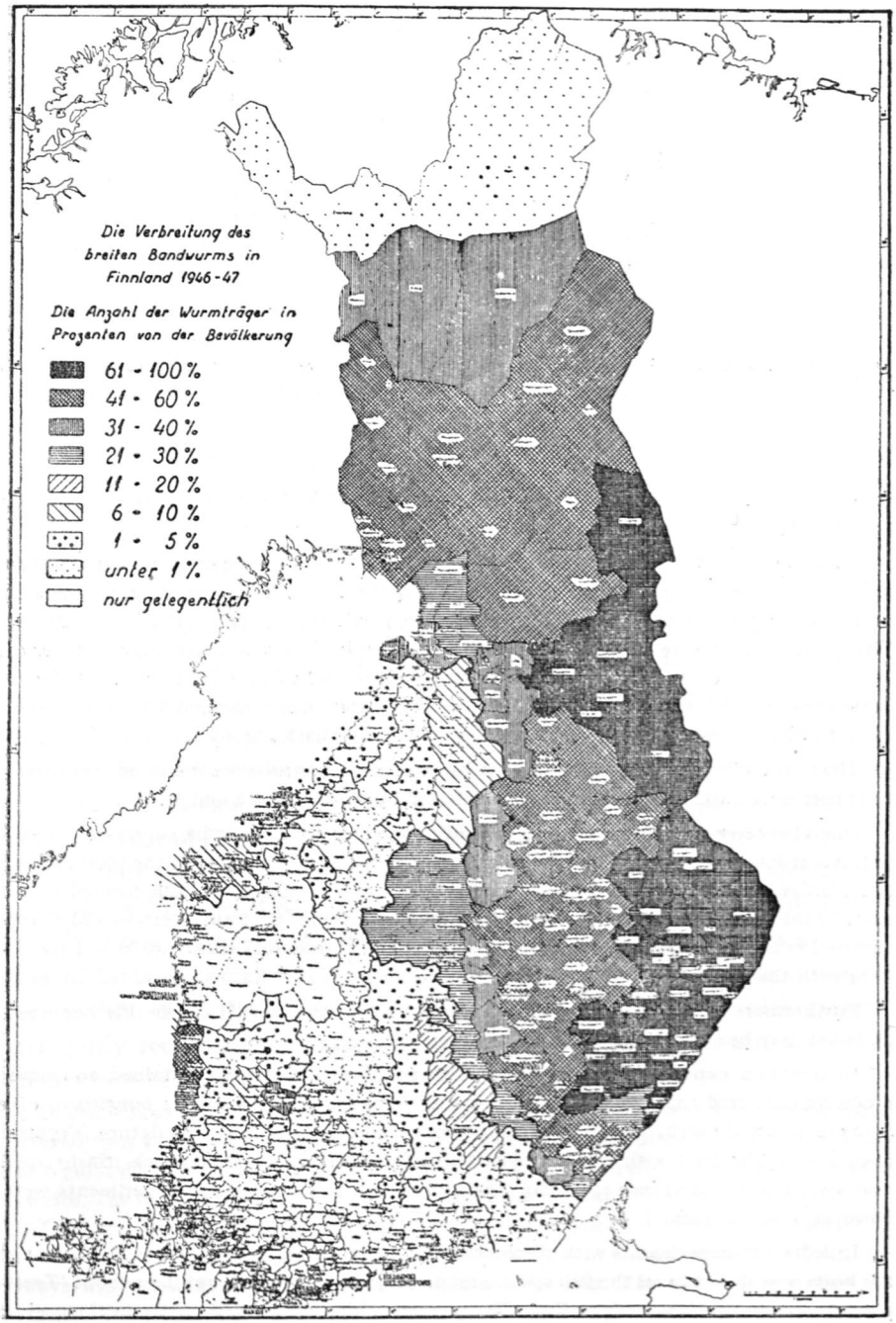

Fig. 2. The distribution of the adult fish tapeworm in Finland according to HUHTALA (1950).

THE DISTRIBUTION OF THE FISH TAPEWORM

The distribution of the fish tapeworm in Finland has been studied by SIEVERS (1905), EHRSTRÖM (1926), SEPPÄ (1927), OLLILAINEN (1943), TÖTTERMAN (1944), GYLLING (1949), and HUHTALA (1950).

The material of SIEVERS, EHRSTRÖM and HUHTALA consists of information given by physicians in different parts of the country regarding findings of worm ova in faeces of patients. SEPPÄ, OLLILAINEN and TÖTTERMAN have studied the occurrence of the broad tapeworm in hospital patients. GYLLING's work is based on data taken from case reports. HUHTALA's paper also includes a summary of the previous investigations in this field.

The material collected by SIEVERS was quite small. The chief conclusion was that the broad tapeworm is distributed all over the country. The eastern and central parts of Finland were shown to be most strongly infested, and especially heavily infested areas were those around the water-systems of Pielisjärvi—Saimaa and Keitele—Päijänne. The southwest parts of the country and southern Ostrobothnia were not so heavily infested.

Twenty years later EHRSTRÖM made a new and larger inquiry among about 500 physicians and showed that the most strongly infested areas lay in the eastern districts, along the coasts of Lake Ladoga and in the water-system of the Vuoksi. Strong infection was also recognised in the large inland lake district except for its westernmost parts (Tavastlandia). EHRSTRÖM suggests that the weak infection in Tavastlandia depends upon the fact that the people in this district do not usually eat raw or insufficiently salted fish. This same fact had already been mentioned by SIEVERS.

SEPPÄ's material is based on patients examined in the military hospital at Viipuri. The patients came from nearly all parts of the country, but the majority were from the eastern districts of Savonia and Karelia. Infection with the broad tapeworm was discovered in 11.8 per cent of 3937 persons examined. According to SEPPÄ the strongest infection occurred in the wilds of Kainuu and Kuusamo, on the coasts of Lake Ladoga and around the towns of Pieksämäki, Uusikaupunki and Pori. The lake districts of Tavastlandia and Southern Ostrobothnia were almost free from tapeworm infection. OLLILAINEN chiefly investigated soldiers from North Finland and again the Kainuu area proved to be exceptionally strongly infested. TÖTTERMAN's investigation was performed on patients of a military hospital situated on the north coast of Lake Ladoga. Both soldiers and civilians were examined. The civilians were found to harbour the broad tapeworm to a much higher degree than the soldiers.

GYLLING worked through 14 631 case reports which included mentions of tapeworm infection. Areas with a high degree of infection were the easternmost

districts and the neighbourhood of the lake Oulunjärvi. A similar infection occurred in some districts in North Finland.

HUHTALA re-examined the above-mentioned investigations and obtained supplementary information. He was able to show clearly the pronounced easterly distribution of the broad tapeworm. The real *Diphyllobothrium* district lies east of the line Oulu—Kotka (fig. 2.).

Most of the above-mentioned authors have calculated the total degree of infection of the nation. The figures given are: SEPPÄ about 14 per cent, GYLLING about 18 per cent, TÖTTERMAN about 14.5 per cent and HUHTALA about 20 per cent. In an official verdict MUSTAKALLIO (1940) also reckons a total degree of infection of 20 per cent.

FINNISH FINDS OF DIPHYLLOBOTHRID PLEROCERCOIDS

The previous finds of plerocercoids have been listed and discussed below. For the sake of completeness it seems desirable to give fairly extensive citations of the definitions given by different authors. It seems desirable to treat the finds from the fish species pike, burbot, perch and ruff separately from those from Coregonids and other fish species.

FINDS FROM PIKE, BURBOT, PERCH AND RUFF

Since the works of BRAUN (1882), it has been known that larvae of the broad tapeworm occur in pike and burbot. SCHRÖDER (1895, 1896) found them in perch. KUHLOW (1955) has shown that the ruff is among the species which can serve as both intermediary and transport host. Investigating fish from Soviet Karelia PETRUSCHEWSKY (1931) found a heavy infection with plerocercoids obviously belonging to *D. latum* in all these fish species (*Acerina cernua* 98 %, *Lota vulgaris* 91.6 %, *Esox lucius* 88.8 %, *Perca fluviatilis* 53.3 %). Even if, perhaps, other *Diphyllobothrium* plerocercoids than those belonging to *D. latum* can occur in these fish (cf. p. 4), it seems likely that plerocercoids which lie free in the coelom or in the peritoneal membranes or in the musculature of pike, burbot, perch and ruff do in fact belong to *D. latum*.

The first finds of *D. latum* plerocercoids from pike seem to be those made by SCHNEIDER (1901). In two out of nine pike caught in brackish waters at Esbo —Kyrkslätt he found *D. latum* larvae in the coelom. One of these pike contained two plerocercoids, the other only one. LEVANDER (1902) dissected five pike from the same waters and found a larva »on the surface of the ventricle» of one fish. In this same year LUTHER found numerous larvae of *D. latum* in the mesenteries and gut of pike from Lake Keitele. SCHNEIDER (1902), in

studying 12 pike from coastal waters (Tvärminne), found plerocercoids of *D. latum* in two pike but only one specimen in each fish (in the coelom and the ovary). In 1903 SCHNEIDER further reported that one out of four pike investigated showed a fairly severe infection with plerocercoids of *D. latum*. E. W. SUOMALAINEN (1909) wrote that he knew of the occurrence of *D. latum* plerocercoids in pike, ruff, whitefish and trout in the lake Kallavesi without, however, giving any evidence in support of his statement. In 1909 LEVANDER reported plerocercoids in eight out of 41 pike (coastal waters). JÄÄSKELÄINEN (1911) reported finds of 32 plerocercoids in the coelom and ovaries of a pike caught in Lake Ladoga. In pike from the lake Kuolimonjärvi KAJAVA (1913) observed plerocercoids in five out of six specimens. He also studied six pike from Lake Saimaa and three of these were infected with plerocercoids. JÄÄSKELÄINEN (1915) observed plerocercoids in 18 out of 21 pike investigated (Lake Ladoga). The larvae were found on the surface of the ventricle, in the pancreas and the spleen, in the liver and the gonads of both sexes, free in the coelom, in the walls of the gut and in one specimen within the gut (distal part), and further in the musculature. BROFELDT (1917) reported unconfirmed finds of *D. latum* plerocercoids in two out of 13 pike from the lake Längelmävesi. JÄRNEFELT (1921), studying a large number of pike from the lake Tuusulanjärvi, found *D. latum* larvae in 39.4 per cent. (cf. also BROFELDT 1915). Further, BROFELDT (1925) shortly reported finds in pike from the lakes Ylimmäinen and Alimmainen Rautjärvi (Evo). The plerocercoids were situated in the musculature, and the liver, on the surface of the viscera, in the mucosa of the mouth, and in the gonads.

In 1913 JÄÄSKELÄINEN reported having found four plerocercoids of *D. latum* in one pike out of nine from Kemi River.

Plerocercoids from burbot have been observed as follows:

LEVANDER (1906) found four small plerocercoids in the liver of a burbot caught in Rautunselkä (the lake Vanajavesi). KAJAVA (1913) dissected about 20—30 burbot from the lakes Kuolimonjärvi and Saimaa and discovered numerous plerocercoids in all specimens. The larvae were located in the musculature, below the peritoneal membranes and in the gonads. JÄÄSKELÄINEN (1915) observed plerocercoids in eight out of 30 burbot investigated (Lake Ladoga). The plerocercoids were located in the liver, the peritoneal membranes and the outer wall of the ventricle. The musculature was investigated in only a few cases. BROFELDT (1915) reported finds from two burbot caught in the lake Tuusulanjärvi (musculature and surface of viscera) and in a burbot purchased at Tampere (very numerous larvae in the liver and musculature) JÄRNEFELT (1921) mentioned plerocercoids in some burbot from the lake Tuusulanjärvi. BROFELDT (1925) reported finds from the lakes Alimmainen, Keskimmäinen and Ylimmäinen Rautjärvi, and Savijärvi. The plerocercoids were

situated in the musculature, in the liver and on the viscera. In some cases there were hundreds of them in one fish. WIKGREN (1955) reported finds in burbot from the lakes Immolanjärvi and Päijänne (larvae in nearly all parts of the body).

The finds of Diphyllobothrid plerocercoids from perch are fewer. LEVANDER (1902) reported larvae in the dorsal musculature in four out of 32 perch caught in coastal waters. He wrote: »I cannot doubt that this larva is the young stage (plerocercoid) of the broad tapeworm of man (*Bothriocephalus latus*) since in its shape it fully resembles as far as I can see the figures and descriptions which are to be found in the literature». Later LEVANDER (1909) was unable to find plerocercoids in perch again. SCHNEIDER (1903) searched for plerocercoids in perch and found one larva in one perch. This specimen closely resembled those derived from pike; it was one centimetre long and situated in the mesentery close to the spleen. Investigating the parasites of the fish of Lake Ladoga JÄÄSKELÄINEN (1915) found plerocercoids in two out of 21 perch dissected. The plerocercoids were situated in the liver and in the peritoneal membranes. BROFELDT (1925) found plerocercoids in perch from the lake Ylimmäinen Rautjärvi. He mentions that they were located in the mucosa of the mouth. According to JÄÄSKELÄINEN (1921), finds of Diphyllobothrid plerocercoids from perch caught in the lake Pyhäjärvi (S.W. Finland) have been made by JÄRNEFELT.

There seem to exist only four records of plerocercoids belonging to *D. latum* from the ruff. In 1902 LEVANDER was the first to observe two Diphyllobothrid plerocercoids in one ruff out of 11 dissected (coastal waters). One of the larvae was found in the coelom, the other in the dorsal musculature. LEVANDER was convinced that at least the larva in the musculature belonged to *D. latum*. In 1909 LEVANDER again reported a find of one *D. latum* plerocercoid (2 cm. long) in the dorsal musculature of a ruff caught near Helsinki. JÄÄSKELÄINEN (1915) reported finds of plerocercoids in 4 out of 31 ruff investigated. The plerocercoids were situated on the outer wall of the gut, in the peritoneal membranes, free in the coelom, and in the musculature. Further finds have been reported by E.W. SUOMALAINEN (1900).

Summarizing the finds of Diphyllobothrid plerocercoids from the fish species mentioned above, it becomes apparent that the pike and the burbot are especially heavily infested. The data available on the numbers of plerocercoids per fish show that usually fewer larvae are present in fish caught in coastal waters compared with fish from inland waters. In spite of the incompleteness of the reports there is ample reason to assume that plerocercoids do not occur to the same extent in perch. Thus, for instance, JÄÄSKELÄINEN (1915) found plerocercoids in 18 out of 21 pike, but in only two out of as many perch investigated. It may also be remembered that the investigations of SCHNEIDER

(1902), LUTHER (1902), KAJAVA (1913), BROFELDT (1915, 1917), and JÄRNEFELT (1921) included material of a large number of fish species, but that plerocercoids were not found in perch. From the data given by PETRUSCHEWSKY (1931) it also appears that the degree of infection of perch is lower than that of the other species. The ruff has been so little studied that no conclusions can be based on the informations available. A heavy infection of ruff must be expected.

SOME OBSERVATIONS ON THE PLEROCERCOIDS OF *D. latum* L.

The morphology of the Diphyllobothrid plerocercoids will be dealt with in a later paper. Here only some data are given.

In connection with fishery biological investigations one of us (B. W.) has found plerocercoids obviously belonging to *D. latum* in pike and burbot caught in the lake Vanajavesi and in the lakes Rautavesi and Liekovesi and in the river Kokemäenjoki. Plerocercoids have also been observed in burbot from the lake Pyhäjärvi (S.W. Finland). Only a part of the material is worked through, but it seems as if both these fish species are strongly infected. Plerocercoids have been found both on and in the inner organs and in the musculature. They often lie close below the peritoneal membrane without being enclosed in any recognisable cyst. Plerocercoids have also been found in the gonads of both sexes.

Fig. 3. Drawing of a plerocercoid of *D. latum* from a burbot caught in the lake Pyhäjärvi (S. W. Finland). (orig.)

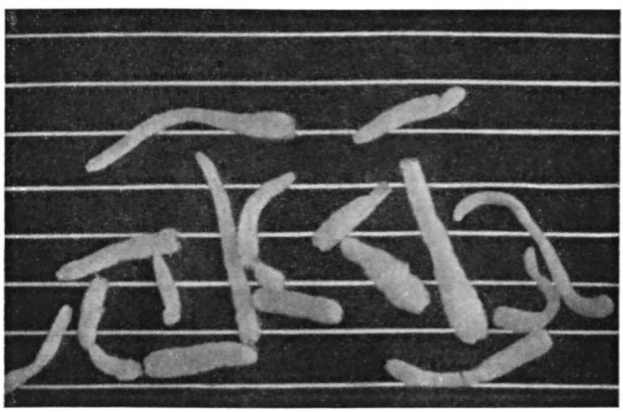

Fig. 4. Photo showing plerocercoids of *D. latum* taken from a pike from the lake Liekovesi. The plerocercoids had been fixed in formaldehyde. Distance between lines 2 mm. (orig.)

The shape of the plerocercoids (figs. 3 and 4) differs slightly from that pictured by KUHLOW. The anterior end is usually broader than the rest of the body, the larvae often being club-shaped in outline. They are of pure white colour. Both ends are tucked within the body. The cuticle lacks bristles. Some measurements on a few specimens (living): thickness of the cuticle: 3.2—6.5 μ, breadth of the lime corpuscle—free zone: about 10 μ, lime corpuscles: 15 μ × 19 μ. The average length of 56 specimens preserved in dilute formaldehyde is 5.2 mm and the limiting values are: 2—11 mm.

PLEROCERCOIDS FROM COREGONIDS

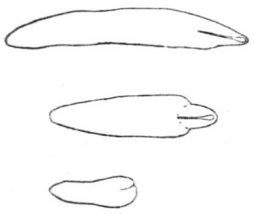

Fig. 5. Reproduction of JÄRVI's (1909) figures of the plerocercoids found in vendace from the lakes Kivijärvi and Keitele.

The question of the true nature of the plerocercoids found in Coregonids is a puzzling one. Physicians have for a long time suggested that the people in the lake districts are most probably infected with the fish tapeworm by eating insufficiently cured vendace (*Coregonus albula*). This belief was supported by the discovery by LÖNNBERG (1892) in Sweden of plerocercoids from vendace and whitefish (*Coregonus lavaretus*). LÖNNBERG described these plerocercoids as belonging to *D. latum*.

In 1908 JÄRVI published an article in which he declared that he had found plerocercoids of *D. latum* in vendace caught in the lakes Kivijärvi and Keitele. The degree of infection was fairly high, varying between 10 and 40 per cent. The number of plerocercoids per fish varied between one and fourteen, but the cases of one or two plerocercoids per fish were in the majority. The figures given by JÄRVI are reproduced in figs. 5 and 6. He gives the following description: »All the plerocercoids seen by me have been located on the outer wall of the ventricle of vendace, where they occur included in rounded, cyst-shaped growths; only twice have I seen them creeping on the walls of the ventricle. I have not found them in the ovaries or the peritoneal membranes in spite of having looked for them there . . . The walls of the cysts were slightly transparent or quite opaque. The walls were not especially hard; with a needle it was easy to make a hole and draw the larva out.» »The plerocercoids of the fish tapeworm found by me were relatively small. In some fish they can grow up to 30 mm., but only very few of those found by me in vendace were longer than 10 mm. The

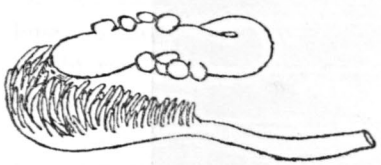

Fig. 6. The location of encysted plerocercoids around the ventricle of the vendace (JÄRVI 1909).

normal length was about 4—8 mm. Put into formaldehyde or spirit they contracted to about 2—5 mm.; the largest specimens being somewhat larger (up to 8 mm.)». In 1921, JÄRVI again mentioned these finds.

It is a remarkable fact that LUTHER (1902) investigating several fish species from Lake Keitele, did not report finds of plerocercoids from vendace. SUOMALAINEN (1909) also claimed to have found *D. latum* plerocercoids in vendace from Lake Kallavesi. Most of these larvae are said to have occurred in the gut, but some were also found on the walls of the coelom and on the swimbladder. KAJAVA (1913) reported having regularly found numerous *D. latum* plerocercoids in vendace from the lakes Kuolimonjärvi and Saimaa. JÄÄSKELÄINEN (1915) reported finds of plerocercoids from vendace from Lake Ladoga. Eight out of 38 fish were infected. The plerocercoids occurred on the ventricle and in the mesenteries. The figure given (cf. fig. 9.) shows plerocercoids which greatly resemble those found by JÄRVI. According to JÄÄSKELÄINEN (1921) Diphyllobothrid plerocercoids have further been found from vendace by HÄNNINEN (from Kuusamo) and by BROFELDT (from Evo). JÄÄSKELÄINEN has not given any references and the papers describing these finds cannot be traced. Perhaps they were not published (at least not referred to in Bibliotheca Zoologica Fennica).

If we accept WARDLE's statement (cf. p. 5) that the plerocercoids of *D. latum* are never encysted and the conclusions of PETRUSCHEWSKY and TARASSOW (1933) that encysted plerocercoids in vendace are not infective to man, it is obvious that the plerocercoids found by JÄRVI do not belong to the broad tapeworm of man. In a personal communication (1955), Professor JÄRVI has also expressed some doubts on his determination in 1908. Further WIKGREN (1955) has shown that the cuticle of these plerocercoids is provided with bristles and that according to KUHLOW's differential diagnosis they pertain to *Diphyllobothrium osmeri* (v. Linstow 1878). On p. 14 a short description is given. The vendace is thus certainly heavily infested with *D. osmeri*. The possibility of infection with *D. latum* cannot, however, be fully excluded. JÄRVI's material obviously consisted of *D. osmeri* only, but the true nature of the finds of SUOMALAINEN, JÄÄSKELÄINEN and KAJAVA is questionable. This point needs further investigation.

The first finds of plerocercoids from whitefish (*Coregonus lavaretus*) which have been claimed to belong to *D. latum* seem to be those made by KAJAVA (1913) in two out of nine whitefish (the lakes Kuolimonjärvi and Saimaa). JÄÄSKELÄINEN (1921) mentions having made finds of *Bothriocephalus* sp. larvae in whitefish from Lake Höytiäinen. ODENWALL (1927) mentions the occurrence of cysts on the outer wall of the gut of whitefish. One such case was shown to Professor K. M. LEVANDER, who claimed these cysts to be caused by larvae of *Bothriocephalus latus*. In 1929 LEVANDER, in an article

entitled »The whitefish as the intermediary host of the broad tapeworm», wrote that hitherto the only reports that whitefish could be infected with plerocercoids of *D. latum* were from Lake Höytiäinen (obviously referring to JÄÄSKELÄINEN). LEVANDER now reported that he had studied a sample consisting of the inner organs of a large whitefish caught in the lake Pyhäjärvi (S. W. Finland) and that he had found numerous plerocercoids which »on satisfactory evidence» could be determined as belonging to *D. latum*. The larvae occurred on the surface of the ventricle in round, protruding cysts 4 mm. in diameter. Some cysts were smaller. The larvae are said to have been 10—15 mm. long. Referring to this article ODENWALL (1930) wrote that it is the whitefish that seems to be the main source of infection to man and he mentions that nearly every whitefish caught in the lake Lappajärvi is infected with tapeworm larvae in cysts on the gut.

A prominent character in the descriptions mentioned above is that the larvae occurred in rounded, protruding cysts chiefly around the ventricle. This eliminates the possibility of a *D. latum* infection. As a curiosity it may be mentioned that in 1906 LEVANDER wrote that the larvae of *D. latum* are small, usually less than one centimetre in length, and do not form (!) cysts around themselves.

Investigating a large sample of whitefish from the lake Pyhäjärvi (S. W. Finland) one of us (B. W.) has found tapeworm plerocercoids in nearly every fish. These plerocercoids occur in cysts quite similar to those described by LEVANDER. They certainly do not belong to *D. latum* and it has been suggested (WIKGREN 1955) that they belong to the genus *Eubothrium*. Plerocercoids of *D. latum* certainly do not occur in whitefish from the lake Pyhäjärvi, but they are present in burbot.

It seems evident that certain finds of plerocercoids of *D. latum* in whitefish have not hitherto been reported in Finland.

PLEROCERCOIDS OF *D. osmeri* (V. LINSTOW 1878)

One of us (B. W.) has investigated Diphyllobothrid plerocercoids from vendace caught from the lakes Vanajavesi and Puulavesi. The plerocercoids lay in rounded cysts, chiefly on the outer wall of the ventricle. The larvae, when dissected out, measured 3—6 mm. in length and about 0.5—1.0 mm in

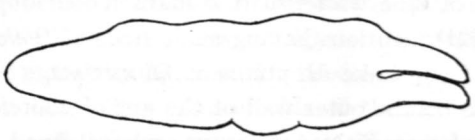

Fig. 7. Drawing of a plerocercoid which obviously belongs to *D. osmeri*. Host: Vendace from the lake Puulavesi. (orig.)

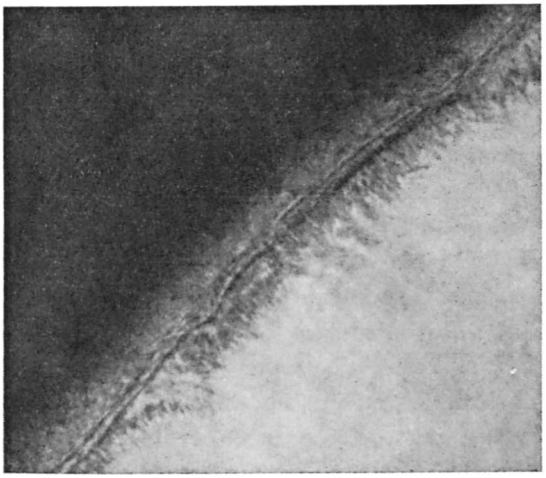

Fig. 8. Photo showing a part of the body cuticle of a plerocercoid of *D. osmeri*. Note the long cuticular bristles. (orig.)

breadth. The colour was whitish, but the larvae were not quite untransparent. Both the scolex and the caudal end were extruded (fig. 7). The cuticle was somewhat folded in the living state; in specimens preserved in formaldehyde the cuticle is unfolded. The body, except perhaps for its cranialmost end, was covered with cuticular bristles 16 μ long (fig. 8). The thickness of the cuticle measured about 13 μ. The bothrids were 0.5—0.7 mm. The lime corpuscle—free zone was about 14 μ broad (measured to the inner lining of the cuticle). The lime corpuscles measured about 10 $\times$ 13 μ.

These plerocercoids most closely resemble the plerocercoids of *D. osmeri* as these have been described by KUHLOW. Hence this name has been adopted until the final determination can be made with the aid of infection experiments.

PLEROCERCOIDS FROM OTHER FISH SPECIES

The data concerning finds of plerocercoids from fish species other than those dealt with above are very few, and most of them have been given by JÄÄSKELÄINEN (1915). This author investigated 27 fish species from Lake Ladoga and found Diphyllobothrid plerocercoids in 13 species. The findings from pike, burbot, perch, ruff and vendace have been cited above. Plerocercoids were further observed in the following species:

1) Three-spined stickleback (*Gasterosteus aculeatus*). Plerocercoids in the liver, the peritoneal membranes and on the walls of the ventricle together with specimens lying free in the coelom. 25 out of 100 fish were infected.

2) Ten-spined stickleback (*Gasterosteus pungitius*). Plerocercoids occurred in the liver. One out of nine fish was infected.

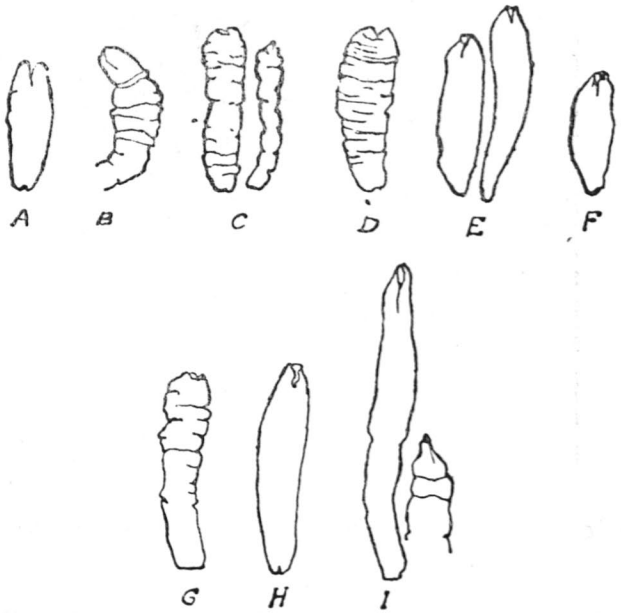

Fig. 9. Reproduction of the figures given by JÄÄSKELÄINEN (1915 and 1921) of the plerocercoids found by him in fish from Lake Ladoga. A. From *Salmo salvelinus*. B. From *Lota vulgaris*. C. From *Esox lucius*. D. From *Perca fluviatilis*. E. From *Gasterosteus aculeatus*. F. From *Petromyzon fluviatilis*. G. From *Thymallus vulgaris*. H. From *Osmerus eperlanus*. I. From *Coregonus albula*.

3) Four-horned Cottus (*Cottus quadricornis*). Larvae in the mesenteries. One out of 25 fish was infected.

4) Smelt (*Osmerus eperlanus*). Plerocercoids were found on the walls of the ventricle and in the liver. 39 per cent were infected.

5) Silver bream (*Abramis blicca*). Plerocercoids in the liver. One out of 21 fish was infected.

6) Char (*Salmo salvelinus*). Plerocercoids within the ventricle. In one out of 12 fish.

7) Grayling (*Thymallus vulgaris*). Plerocercoids occurred in the walls of the gut. Two out of 18 fish were infected.

8) River lamprey (*Petromyzon fluviatilis*). Plerocercoids in the walls of the gut and on the surface of the kidney. In two out of six lampreys.

The figures given by JÄÄSKELÄINEN are reproduced in fig. 9. JÄÄSKELÄINEN himself was convinced of the relation with *D. latum* only for the plerocercoids from char, burbot and pike. Some tentative conclusions can perhaps be drawn:

1) The shape of the plerocercoids from pike, perch and grayling closely correspond to the usual appearance of *D. latum* plerocercoids. The figure of plerocercoid from burbot shows a partially extruded scolex, but obviously

this larva also belongs to *D. latum*. In the char plerocercoids were found only from within the ventricle. Such larvae are probably not comparable with those which have penetrated the gut. It is possible that the larva from the char also belongs to *D. latum*.

2) The other plerocercoids figured, *i.e.* those from the ten-spined stickleback, the smelt, the vendace, and the lamprey, have an unfolded cuticle and do not seem to belong to *D. latum*. Those from the vendace are very similar to those from this same fish species found by WIKGREN.

LEVANDER (1907) writes that he had determined some plerocercoids from a lake trout (*Salmo trutta lacustris*) caught in Lake Saimaa as belonging to *D. latum*. The larger specimens were 7—9 mm. long and 1—2 mm. broad. The larvae were situated on the peritoneal membranes. KAJAVA (1913) mentioned having inspected one salmon (*Salmo salar*) in which some plerocercoids occurred in the peritoneum. According to JÄÄSKELÄINEN (1921) Diphyllobothrid plerocercoids had further been found by RANTANEN in trout (»*Salmo trutta*») from the river Kemijoki and by JÄÄSKELÄINEN in lake trout from Lake Höytiäinen.

It may be mentioned here that LEVANDER (1918) reported finds of tapeworm ova in plankton samples taken at the port of Helsinki. The ova were brownish and of 60 μ length and 50 μ breadth.

THE LOCALITIES OF DIPHYLLOBOTHRID PLEROCERCOID FINDS

The localities of Diphyllobothrid plerocercoid finds are listed below and also mapped in fig. 10. No relations between the occurrence of the adult worm and the plerocercoids can be deduced. This, of course, depends on the paucity of information regarding plerocercoids.

Plerocercoids from pike, burbot, perch and ruff.

Coastal waters:

The coast line Helsinki—Hangö (pike, perch, ruff).

The lakes:

Alimmainen Rautjärvi (Evo) (pike),
Immolanjärvi (burbot),
Kallavesi (pike, ruff),
Keitele (pike),
Keskimmäinen Rautjärvi (Evo) (burbot),
Kuolimonjärvi (pike, burbot),
Ladoga (pike, burbot, perch, ruff) (no longer belongs to Finland),
Liekovesi (pike, burbot),
Längelmävesi (pike),
Pyhäjärvi (S.W. Finland) (burbot, ruff),
Päijänne (burbot),
Rautavesi (pike, burbot),
Saimaa (pike, burbot),
Savijärvi (Evo) (burbot),
Tuusulanjärvi (pike, burbot),
Vanajavesi (pike, burbot),
Ylimmäinen Rautjärvi (Evo) (pike, perch),

and the rivers:

Kokemäenjoki (pike, burbot),
Kemijoki (pike).

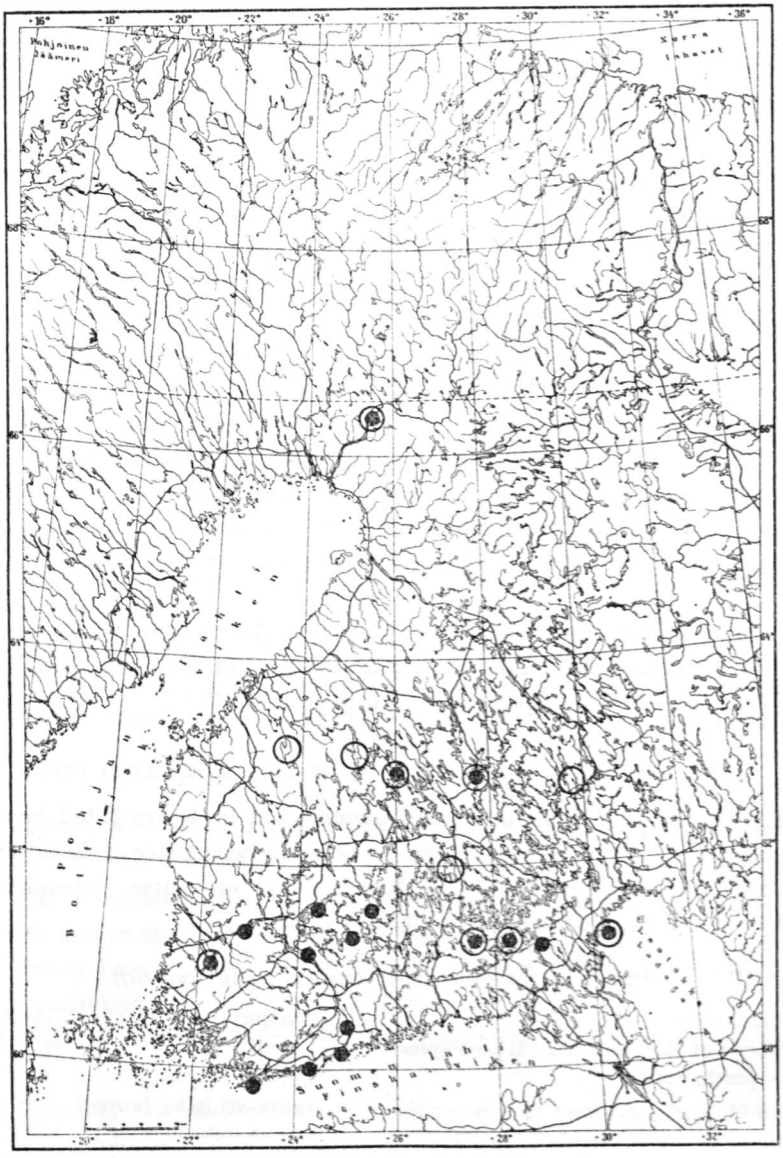

Fig. 10. The localities of Diphyllobothrid plerocercoid finds. Solid rings: finds from pike, burbot, perch and ruff. Open rings: finds from other fish species.

Plerocercoids from Coregonids

The lakes:

Höytiäinen,
Kallavesi,
Keitele,
Kivijärvi,
Kuolimonjärvi,
Ladoga,
Lappajärvi,
Puulavesi,
Pyhäjärvi (S. W. Finland),
Saimaa.

Plerocercoids from other fish species

The lakes:

Höytiäinen,
Ladoga,
Saimaa

and the river

Kemijoki

DISCUSSION

The facts mentioned above warrant only one certain conclusion, *viz* that the occurrence of fish tapeworm plerocercoids in Finland is quite unsatisfactorily known in relation to the importance of the problem. The first work to be done is to accumulate new facts regarding both the geographical distribution of *D. latum* plerocercoids and the occurrence of plerocercoids in different fish species. Simultaneously it will be possible to study the occurrence of plerocercoids of the other *Diphyllobothrium* species.

The problem of the occurrence of plerocercoids in different fish species is especially interesting from several points of view. As was shown, we can only be certain of the relationship with *D. latum* of the plerocercoids from pike, burbot, perch, and ruff, and perhaps also of those from Salmonids. All these species may be infected with procercoids in their early youth when still feeding on plankton. It must, however, be assumed that predatory fish also take over plerocercoids from their prey and that they thus »concentrate» plerocercoids. The most logical conclusion would be that plerocercoids occur in plankton-feeding fish, but on the other hand plankton-feeding fish do not seem to be susceptible to infection with procercoids (cf. p. 5).

If there were a plankton-feeding fish species which was the main source of infection of the predatory fish, this (or these) fish species should be very heavily infested with plerocercoids. According to preliminary investigations made by us and according to the Finnish literature no heavy infection of true plankton- feeding fish has been observed.

The list of host species given by CRAIG and FAUST (1948) include the following species (for Europe): *Esox lucius, Perca fluviatilis, Lota vulgaris, Acerina cernua, Salmo trutta, Coregonus* sp., *Thymallus vulgaris,* and *Anguilla vulgaris.* It is interesting to compare with the corresponding list given by WARDLE and MCLEOD (1952) which is: *Esox lucius, Perca fluviatilis, Lota vulgaris, Salmo salar, Salmo trutta, Salmo trutta lacustris,* and *Thymallus vulgaris.* It may be mentioned that exactly the same list was given by WARDLE in 1935. The list of fish hosts given by PIEKARSKY (1954) is: »*Esox lucius, Perca fluviatilis, Lota vulgaris, Salmo umbla, Trutta vulgaris, Trutta lacustris, Thymallus vulgaris, Coregonus lavaretus, C. albula,* und *Anguilla vulgaris*».

The question of the primary fish host of *D. latum* is thus still unsolved. One hypothetical possibility may be mentioned, *viz.* that larger predatory fish take over plerocercoids only from the smaller predatory fish upon which they prey (cf. HOBMAIER, 1927). Thus, for example, both pike and burbot frequently feed on small perch and ruff which in turn feed on plankton for considerable periods of time.

As was mentioned above, physicians have long suspected the vendace as an important source of *D. latum* infection in man. Even if it now appears as if the dominant species parasitizing vendace is *D. osmeri*, the possibility of infection with *D. latum* must be taken into account. The investigation of ample material of vendace is accordingly one of the most important points of our research programme.

The exact knowledge of the occurrence of fish tapeworm plerocercoids is also of outstanding importance in the campaign against the worm. It cannot be tolerated that at least every fifth Finnish citizen harbours tapeworms.

SUMMARY

1) The state of knowledge of Diphyllobothrid plerocercoids is briefly discussed.

2) The distribution of the fish tapeworm in Finland is summarized according to the literature references available.

3) The Finnish finds of Diphyllobothrid plerocercoids are reviewed. It is assumed that the finds reported from pike, burbot, perch and ruff most probably belong to *D. latum*. Also the plerocercoids found in Salmonids may belong to this species. The true nature of the finds claimed as *D. latum* plerocercoids from Coregonids is questionable. A confusion with finds of other Diphyllobothrid species has certainly occurred. It seems not to be convincingly proved that Coregonids act as carriers of *D. latum* plerocercoids. Plerocercoids have been reported from some other fish species, too.

4) Short descriptions of new finds of plerocercoids of *D. latum* and *D. osmeri* are given.

5) The problem of the first fish host of *D. latum* is discussed. It is provisionally assumed that *D. latum* does not at all pass through true plankton-feeding fish species, but chiefly employs such fish species as ruff and perch as the first fish host.

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REFERENCES

BRAUN, M. 1882. Zur Frage des Zwischenwirtes von *Bothriocephalus latus* Brems. — Zool. Anz. *5*, 39—43, and 194—196.

BROFELDT, P. 1915a. Tuusulan järven kaloista ja kalastusoloista sekä ehdotuksia näiden parantamiseksi. — Suomen Kalatalous *3*, 106—124.

—»— 1915b. Runsaasti ihmisen leveän heisimadon (*Diphyllobothrium latum*) toukkia mateen lihaksissa ja sisälmyksissä. — Suomen Kalastusl. *22*, 36.

—»— 1917. Tietoja järviemme kalastosta. Längelmävesi. — Suomen Kalatalous *4*, 1—42.

—»— 1925. Evon kalastusasemalla tavatuista kalaloisista. — Ibid. *8*, 1—11.

CRAIG, C. F., and FAUST, E. C. 1951. *Clinical Parasitology*. Philadelphia: Lea and Febiger.

EHRSTRÖM, R. 1926. Zur Kenntniss der Darmparasiten in Finnland. — Acta med. scand. *64*, 29—68.

GYLLING, B. 1949. Den geografiska utbredningen av *Diphyllobothrium latum* i Finland. — Finska Läkaresällsk. Handl. *92*, 38—48.

HOBMAIER, M. 1927. Wie kommt die Infektion der Raubfische mit dem Plerocercoid von *Dibothriocephalus latus* zustande? — Zbl. Bact., Parasitenk., Infektionskr. *72*, 268—273.

HUHTALA, A. 1950. Über die Verbreitung des breiten und des schmalen Bandwurms in Finnland. — Ann. Med. Intern. Fenn. *39*, Suppl. 63 p.

JÄRNEFELT, H. 1921. Untersuchungen über die Fische und ihre Nahrung im Tuusulasee. — Acta Soc. F. Fl. Fenn. *52* (1), 160 p.

JÄRVI, T. H. 1908. Muikku leveän heisimadon väli-isäntänä ja levittäjänä. — Suomen Kalastusl. *17*, 248—255.

—»— 1921. Die kleine Maräne, *Coregonus albula* L., im Keitelsee. — Ann. Acad. Sci. Fenn., Ser. A. *14*, 301 p.

JÄÄSKELÄINEN, V. 1911. Suomelle uudet kalaloiset Laatokasta. — Medd. Soc. F. Fl. Fenn. *37*, 34.

—»— 1913. Anteckningar om Kemiälfs fiskfauna. — Finlands Fiskerier *2*, 133—204.

—»— 1915. Leveä heisimato ja Laatokan kalat sen levittäjinä. — Suomen Kalastusl. *22*, 184—188.

—»— 1921. Über die Nahrung und die Parasiten der Fische in Ladogasee nebst einem Verzeichnis der in Finnland bisher konstatierten Fischhelminthen nach ihren Wirten geordnet. — Ann. Acad. Sci. Fenn., Ser. A. *14* (3), 55 p.

KAJAVA, Y. H. 1913. Några iakttagelser rörande den breda bandmaskens (*Bothriocephalus latus*) blåsmask. — Finska Läkaresällsk. Handl. *55*, 700—707.

KUHLOW, F. 1953a. Bau und Differentialdiagnose heimischer Diphyllobothrium-Plerocercoide. — Z. Tropenmed. Parasitol. *4* (2), 186—202.

—»— 1953b. Beiträge zur Entwicklung und Systematik heimischer Diphyllobothrium-Arten. — Ibid. *4* (2), 203—234.

—»— 1953c. Über die Entwicklung und Anatomie von *Diphyllobothrium dendriticum* Nitzch 1824. — Z. Parasitenk. *16*, 1—35.

—»— 1955. Untersuchungen über die Entwicklung des Breiten Bandwurmes (*Diphyllobothrium latum*). — Z. Tropenmed. Parasitol. *6* (2), 213—225.

LEVANDER, K. M. 1902. Havaintoja kalojen ravinnosta ja loismadoista muutamista matalista merenlahdista Kirkkonummen pitäjästä. — Suomen Kalastusl. *11*, 24—34.

—»— 1906. Rakkuloista mateen maksassa. — Suomen Kalastusl. *15*, 97—101.

—»— 1907. Om larver av *Dibothriocephalus latus* (L.) hos insjölax. — Medd. Soc. F. Fl. Fenn. *32*, 196.

—»— 1909. Beobachtungen über die Nahrung und die Parasiten der Fische des Finnischen Meerbusens. — Finnl. hydrogr.-biol. Unters. *5*, 44 p.

LEVANDER, K. M. 1918. Meddelande om Helsingfors hamnplankton. — Medd. Soc. F. Fl. Fenn. *44*, 217—219.

—»— 1929. Siika lapamadon väli-isäntänä. — Suomen kalastusl. *36*, 169.

LUTHER, A. 1902. Anteckningar rörande fiskfaunan i Keitele sjö och några smärre vatten i dess omgivningar. — Fiskeritidskr. Finland *11* (5/6), 1—8.

LÖNNBERG, E. 1892. Über das Vorkommen des breiten Bandwurmes in Schweden. — Zbl. Bact., Parasitenk., Infektionskr. *11*, 189—192.

MUSTAKALLIO, E. 1940. Suomalaisilla tavattavista sisälmysloisista, erikoisesti leveästä heisimadosta (*Bothriocephalus latus*). — Komiteanmietintö No. 5 (1940), 309—319.

ODENWALL, E. 1927. Fiskfaunan i Lappajärvi sjö. — Acta Soc. F. Fl. Fenn. *56* (13), 48 p.

—»— 1930. Siken och binnikemaskens spridning. — Fiskeritidskr. Finland *37*, 14—15.

OLLILAINEN, V. S. 1943. Leveän heisimadon esiintymisestä kenttäarmeijassa. — Sotilaslääket. Aikakausl. *6*, 259—273.

PETRUSCHEWSKY, G. K. 1931. Über die Verbreitung der Plerocercoide von *Diphyllobothrium latum* in den Fischen der Newabucht. — Zool. Anz. *94*, 139—147.

PETRUSCHEWSKY, G. K., and TARASSOW, V. 1933. Versuche über die Ansteckung des Menschen mit verschiedenen Fischplerocercoiden. — Arch. Schiffs-Trop. Med. *37*, 370—372.

PIEKARSKI, G. 1954. *Lehrbuch der Parasitologie*. Würzburg: Springer.

SCHNEIDER, G. 1901. Några statistiska meddelanden angående parasiter i fiskar från Finlands södra skärgård. — Fiskeritidskr. Finland *10*, 143—147.

—»— 1902. Ichthyologische Beiträge. III. Über die in den Fischen des Finnischen Meerbusens vorkommenden Endoparasiten. — Acta Soc. F. Fl. Fenn. *22* (2), 88 p.

—»— 1903. Beiträge zur Kenntnis der Helminthenfauna des Finnischen Meerbusens. — Ibid. *26* (3), 34 p.

SCHRÖDER, V. VON 1895. Noch eine Quelle der Infektion der Bewohner Petersburgs mit Finnen des *Bothriocephalus latus*. — Zbl. Bact., Parasitenk., Infektionskr. *18*, 24.

—»— 1896. Finnen von *Bothriocephalus* aus Barschen in Dorpat. — Ibid. *20*, 621.

SEPPÄ, T. 1927. Leveän heisimadon levinneisyydestä Suomessa ja sen aiheuttaman anemian yleisyydestä. — Duodecim *43*, 101—106.

SIEVERS, R. 1905. Zur Kenntnis der Verbreitung von Darmparasiten des Menschen in Finnland. — Festschrift f. Palmén No. 10, 46 p.

SUOMALAINEN, E. W. 1909. Kaksi eläintieteellistä tiedonantoa. — Medd. Soc. F. Fl. Fenn. *35*, 87—88.

TÖTTERMAN, G. 1944. Anaemia hyperchromica diphyllobothrica. — Sotilaslääket. Aikakausl. *5*, 173—180.

WARDLE, R. A. 1935. Fish-tapeworm. — Biol. Board Canada, Bull. *45*, 25 p.

WARDLE, R. A., and MCLEOD, J. A. 1952. *The zoology of tapeworms*. — Minneapolis: Univ. Minnesota Press.

WIKGREN, B.-J. 1955. Uusia kalatautitapauksia. — Suomen Kalastusl. *62*, 110—112.

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