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Studies on the Helminth Fauna of Alaska. XXI. Taxonomy, Morphological Variation, and Ecology of *Diphyllobothrium ursi* n. sp. Provis on Kodiak Island

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STUDIES ON THE HELMINTH FAUNA OF ALASKA. XXI. TAXONOMY, MORPHOLOGICAL VARIATION, AND ECOLOGY OF *DIPHYLLOBOTHRIUM URSI* N. SP. PROVIS. ON KODIAK ISLAND

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According to Eguchi (1934), two species of salmon (*Oncorhynchus*) serve as a source of human infection by a cesode indentified as *Diphyllobothrium latum* (Linnaeus, 1758), in Japan. The possible role of these fishes in the transmission of cestodes to man and other animals has not been investigated in North America, nor, apparently, on the Eurasian mainland. However, Ward (1930) reported unidentified *Diphyllobothrium*-like plerocercoids from Alaskan salmon; Simms and Shaw (1931) collected plerocercoids identified as *D. cordiceps* (Leidy, 1871) from *Oncorhynchus kisutch* (Walbaum) from lakes in Oregon; and Wardle (1932) reported plerocercoids of *Diphyllobothrium* spp. from *O. kisutch* and *O. nerka* (Walbaum) in western Canada.

Cestodes of the genus *Diphyllobothrium* Cobbold, 1858, are commonly harbored by bears on Kodiak Island, in the Gulf of Alaska. During the months of summer and early fall, these mammals feed largely upon salmon, which spawn in great numbers in the streams of the island. Since fishes of other species are rarely obtainable, with the exception of a herring, *Clupea pallasii* Valenciennes, which spawns along the coast in early spring, the circumstances strongly suggest that the bears are infected through ingesting plerocercoid larvae in salmon.

Five species of *Oncorhynchus* occur in the waters of Kodiak Island, and all are important as human food. Aboriginal methods of preparing fishes for human consumption are such that cestode larvae might remain viable for some time. Localization of plerocercoids in parts of the fish used for food would provide opportunity for human infection.

An investigation of the ecology and taxonomy of the species of *Diphyllobothrium* occurring on Kodiak Island was undertaken by the writer in 1952, the results of which are reported here. Emphasis has been placed on morphological variation in *Diphyllobothrium*.

MATERIALS AND METHODS

Field observations were centered around the Karluk Lake-Uyak Bay region of Kodiak Island (see map). Information on host-parasite relationships was obtained in the Karluk Lake region only. All experimental work was carried on at the laboratory in Anchorage, Alaska.

Adult cestodes were secured at the autopsy of bears, *Ursus arctos middendorffi* Merriam, which had been collected for the purpose or were otherwise available. Of particular importance is the material, consisting of 523 cestodes, taken from a young bear (about 4 years old, 430 lbs.) collected at Karluk Lake on September 10, 1952. This animal (autopsy No. 12062) was shot too late in the evening to permit immediate examination. The viscera were removed at once and exposed overnight at an air temperature of about 10° C. The following day, the living

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cestodes were taken from the intestine, washed in water, and killed individually by abrupt immersion in hot formalin-acetic acid-alcohol solution. Many additional cestodes were secured at the autopsies of other bears on Kodiak Island.

Cestodes to be mounted entire were stained with Semichon's acetic carmine or Ehrlich's acid hematoxylin stains, dehydrated in ethanol, and cleared in terpineol. Representative segments, after staining and dehydration, were cleared in terpineol and partially dissected before mounting. The removal of superficial layers of tissue, including the vitellaria, permitted an unobstructed view of the testes and details of the female genital organs. The dissection of cleared specimens under the low-power microscope seemed to give better results than the paraffin-embedding method of Markowski (1949, p. 108).

In connection with this work, comparative study was made of adult cestodes from naturally-infected Alaskan birds and mammals, which had been collected since 1949. This material was obtained at autopsy of the hosts, except that cestodes from man were eliminated through the use of drugs. Experimental infections of birds and mammals also yielded adult cestodes used in this study.

On Kodiak Island, plerocercoid larvae of *Diphyllobothrium* sp. were collected from spawning or spawned-out red salmon, *O. nerka* (Walbaum). Some of these larvae were fed to experimental animals, and the remainder fixed and preserved for study.

Six young black bears, *Ursus americanus* Pallas, were employed in infection experiments with plerocercoids from red salmon, since attempts to capture brown bear cubs for this purpose were unsuccessful. These bears had been caught in the spring, before weaning, and were maintained in a manner precluding accidental infection by fish-transmitted cestodes. The 6 bears were killed and autopsied after elapse of the desired periods of time following administration of larval cestodes.

Representative series of fishes of other species on Kodiak Island were examined for plerocercoids of *Diphyllobothrium* spp. The occurrence of plerocercoids is discussed further below, under "ecology." Comparative plerocercoid material was taken from steelhead (rainbow) trout, *Salmo gairdnerii* Richardson, from the Kenai Peninsula, southern Alaska.

RESULTS

Nearly all red salmon examined from the streams tributary to Karluk Lake harbored plerocercoid larvae of *Diphyllobothrium* sp., localized in cysts on the serosa of the stomach. Cestodes morphologically identical with those taken from bears on Kodiak Island developed when these larvae were fed to captive black bears. These results support the hypothesis that bears of Kodiak Island are infected with *Diphyllobothrium* sp. by ingesting plerocercoids in red salmon.

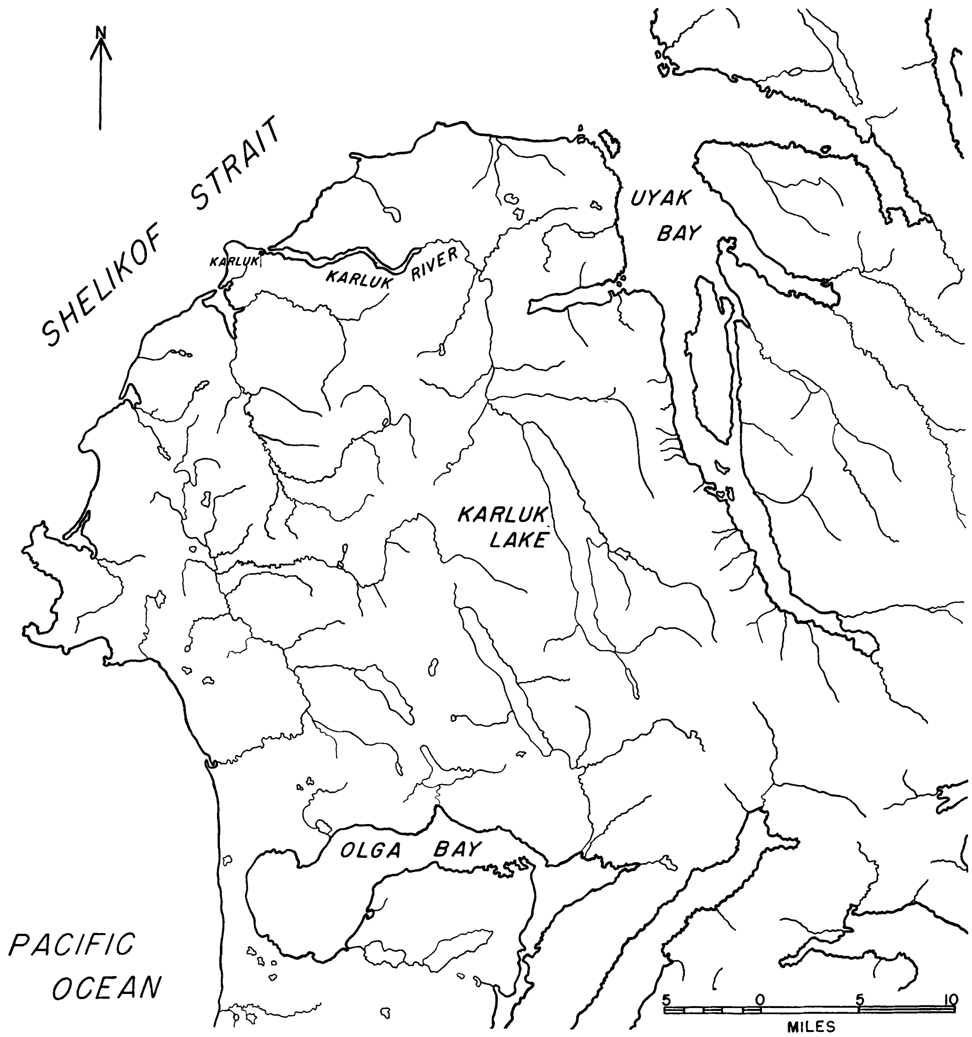
OBSERVATIONS ON MORPHOLOGICAL VARIATION

I. The adult cestode.

Since morphological characters, taken either singly or in combination, are apparently too variable to be relied upon, most of the species of the genus *Diphyllobothrium* are inadequately characterized and consequently difficult to identify with certainty. As pointed out by Stunkard (1949, p. 622), variation in the species of *Diphyllobothrium* is poorly understood, particularly in regard to the possible effect of differences in species of host. In the writer's opinion, the degree of normal mor-

phological variation in members of this genus may be comparable to that seen in certain cyclophyllidean cestodes (Rausch and Schiller, 1949; Rausch, 1952; Schiller, 1952).

The abundant material from bear No. 12062 had unusual value in demonstrating range of morphological variation under the uniform conditions of occurrence in a single host animal. This material has been used as the basis for evaluating characters



Map of northwest end of Kodiak Island, showing Karluk River drainage.

regularly considered in differentiating species of *Diphyllobothrium*. Each feature is discussed separately.

Scolex. The size and shape of the scolex are usually included in any description of a species of *Diphyllobothrium*. Wardle and McColl (1937, p. 164) pointed out that the scolex of *D. latum* may vary greatly in shape and size, as would be expected of such a motile organ. In the writer's material, shape of scolex depended upon the state of expansion or contraction at the time of fixation. Size of scolex

was relatively uniform, irrespective of strobilar size, and it is possible that average dimensions might in some cases have value in differentiating the present form from others. Among recent workers, both Markowski (1949) and Kuhlow (1953b) attached importance to size and shape of the scolex as having specific value.

Neck. The presence or absence of a neck, defined as the unsegmented portion of strobila following the scolex, is important in descriptions of *Diphyllobothrium* spp. In evaluating this character, Markowski (1949, p. 117) stated, "The 'neck' is of systematic value only in so far as it is present or absent, because the length of this part of the body varies considerably, even in the same species, and is in no way constant." Kuhlow (1953c, p. 21), in his detailed study of *D. dendriticum* (Nitzsch, 1824), found a neck to be consistently present. He also (1953b) made use of this character in differentiating other species studied.

The writer's material was unusual. A well-defined neck of variable length is present in young strobilae; however, the undifferentiated zone decreases in length as the cestode becomes older, and eventually disappears. In specimens from the black bears, 10-day-old strobilae had necks up to 5 mm. long. A 61-day-old specimen, measuring more than 3 meters in length, still had a short neck which was being eliminated through the process of segmentation. Old strobilae, without regard to size, were uniformly segmented to the base of the scolex. It is necessary to differentiate between incipient segmentation and transverse striation resulting from contraction in making these observations. This was readily accomplished in the writer's material because internal segmentation could be recognized, and the genital primordia were already visible in very young segments.

Elimination of the neck appears directly related to age of strobila, but not necessarily to its size. In bear No. 12062, strobilae of a great range in size occurred together. The smallest cestodes, some no longer than 500 mm., evidenced age; i.e., apolysis had occurred, normally-developed genital organs were present, and the eggs in the uteri were normal in size and number. Such small specimens showed no undifferentiated zone following the scolex. The same condition was observed in cestodes from other bears.

The persistence of the neck in the 61-day-old strobila was perhaps related to favorable growth conditions. Its host harbored only 2 other cestodes (*Taenia krabbei* Moniez, 1879) and a few ascarids (*Toxascaris* sp.), and had received abundant high-protein food.

Chizhova (1951) observed a similar situation in a cestode parasitizing gulls (*Larus argentatus* Pontoppidan), dogs, and man on Ol'khon Island, Lake Baikal. Although apparently of the same species, specimens with and without necks were found in both gulls and man. In both hosts 2 strobilar forms were observed, probably a manifestation of differences in age. Talyzin (1932, p. 724) stated, regarding the neck in *D. strictum* (Talyzin, 1932), that "Ein gut ausgepraegter Hals ist hier nicht vorhanden, jedoch beginnt die Segmentierung nicht sofort am Koepfchen (wie bei *D. minor*), sondern in einer Entfernung, welche der Laenge des Koepfchens gleicht." Chizhova identified 1 species on Ol'khon Island, though Talyzin recognized 3.

Kuhlow (1953c) did not observe a disappearance of the neck in *D. dentriticum.* Likewise, in the present study, specimens of *Diphyllobothrium* sp. obtained in dogs, foxes, bears, cats, and gulls, after feeding plerocercoids from steelhead (rainbow)

trout, showed in the neck little variation that could be related to strobilar age. These specimens ranged in age up to 100 days.

It appears that the presence of a neck depends upon age of strobila in some species of *Diphyllobothrium*. The undifferentiated zone is gradually eliminated as the cestode becomes older; the lack of a neck may indicate that the strobila is senile and no longer producing segments. It is difficult to evaluate the presence or absence of a neck until more is known of the normal life span and the possible effect of occurrence in different hosts. Possibly, cestodes of a given species of *Diphyllobothrium* are able to persist until they become senile in some hosts, but are eliminated relatively early from others. It is noteworthy that gulls often eliminate cestodes after a few weeks. Additional work on the comparative development of *Diphyllobothrium* spp. in different hosts is required to clarify these points. The presence or absence of a neck has no diagnostic significance in the cestode from Kodiak Island bears.

Size and form of strobila. Extreme differences in size of strobilae have been accepted as serving to distinguish some species of *Diphyllobothrium* from others. One gains the impression that a given species is relatively uniform in length of strobila, or at least that the range in length is not great. Such is often true when only a single species of host is involved, and when only a few cestodes are present.

In bear No. 12062, cestodes ranging in length from less than 500 mm. to more than 10 meters had attained a comparable degree of maturity. Crowding undoubtedly exerts a retarding influence on strobilar growth. This has been observed in certain species of cyclophyllidean cestodes, e.g., *Hymenolepis diminuta* (Rudolphi, 1819), and was demonstrated by Kuhlow (1953c, p. 20) in *D. dentriticum* from gulls. Wardle and Green (1941, p. 246) mentioned a similar observation on *D. latum* in dogs, and believed that superinfected animals soon lost most of their parasites. Petrushevskii and Tarasov (1933) found the strobilar length of *D. latum* in man to be inversely proportional to the number of cestodes comprising a given infection. In the above-mentioned bear, crowding appears to be the cause of the great range in size of strobilae.

It must be assumed that the largest cestodes from bear No. 12062 attained their size without, or despite, crowding. It is possible that they became established early in the summer, when red salmon were scarce, and developed from the first few larvae ingested, or possibly they were maintained over the winter from the previous summer. The former assumption is reasonable, considering that early growth is very rapid, and that strobilae as long as 4.5 meters had not undergone apolysis. Ward (1935) reviewed the literature on longevity of *D. latum* in man, and concluded that most records were unreliable and did not consider the possibility of recurrent infection. Leiper (1936), on the contrary, disagreed with Ward's conclusions and presented evidence gained experimentally that infections may persist for a period of years. Irrespective of the life span of *D. latum* in man, it is likely that bears lose their infections prior to, or during, the period of winter denning. This was first considered by Rush (1932), who concluded that seasonal diet changes preceding denning-time might cause expulsion of the cestodes. Cestodes of the genus *Diphyllobothrium* may be very sensitive to changes in the dietary habits of their host. Kuhlow (1953c, p. 20) observed that experimentally-infected gulls spontaneously lost their cestodes (*D. dendriticum*) during a period of improper

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feeding. The possible seasonal loss of *Diphyllobothrium* infections by bears is discussed further below under "ecology."

Strobilae grow rapidly during early life. A 10-day-old strobila, obtained by feeding plerocercoids from red salmon to a black bear, averaged a daily growth increment of 96 mm., or 62 segments (total length 960 mm., 620 segments). A 61-day-old strobila of the same origin contained 932 segments, with a total length of 3.16 meters. Actual growth could not be determined because apolysis had already taken place, but the minimum growth had averaged 51 mm., or 15 segments per day. Wardle and Green (1941) found that strobilae of *D. latum,* in dogs, averaged a daily increment of 48 mm. for the 6- to 15-day period, and 61.5 mm. for the 15- to 30-day period. Apolysis occurred at about 24 days. For the same species, Petruschevskii and Tarasov (1933) reported an average daily increment of 47 mm. in dogs, and 150 mm. in man for the 6- to 36-day period. Kuhlow (1953b, p. 224) reported an average increase of 200 mm. per day for *D. latum.* Accurate growth data on another species, *D. dendriticum,* were also secured by Kuhlow (1953c). He found, in gulls (*Larus ridibundus* Linnaeus), that a strobilar length of 410 to 610 mm. was attained in 6 days, with a total of 350 to 450 segments. The average daily increase in strobilar length was about 70 to 100 mm., or 58 to 75 segments. The increase in length to the time of maturity averaged about 100 mm. per day. According to Kuhlow, length of strobila increased from the 6th to the 12th day by segment production, and apolysis was observed in the period of the 12th to 16th days.

In cestodes from Kodiak Island bears, growth of individual segments contributed more to attainment of large size than did production of segments. The latter occurred after maturity, but was so restricted as to do little more than balance losses taking place through apolysis. A length of 10 mm. or more was not uncommon for a segment in the larger strobilae. The longest specimen collected measured 11.7 meters, but contained only 1725 segments. Compared with the above-mentioned 61-day-old strobila, this was 3 times the length, but less than twice the number of segments. In some strobilae, width of segments may be great (as much as 23 mm.) without proportional increase in length. There is in all cases a progressive increase in the ratio of length/width as segments become older, but this varies in degree.

Two forms of segmentation, termed "primary" and "secondary," and related to age of the strobila, were described by Wardle and McColl (1937). Their observations were made on cestodes, identified as *D. latum,* from dogs. The primary type was characterized by elongate segments, while the secondary type possessed segments of greater width than length. Kuhlow (1953c) observed 2 strobilar forms in *D. dendriticum,* which he designated as "type A" and "type B," corresponding to the 2 types differentiated by Wardle and McColl. He found that mature examples of *D. dendriticum* could be reared from eggs taken from either strobilar type. Talyzin (1934) recognized 2 strobilar types in *D. minus* Kholodkovskii, 1916; these were designated as "type I" and "type II." Chizhova (1951) defined 2 strobilar types in a species of *Diphyllobothrium* from *Larus argentatus* in the Lake Baikal region; these were designated as "type A" and "type B." From these observations, one may presume that shape of segment is in part related to age of strobila.

Wardle and McLeod (1952, p. 606) stated, "In superinfested animals such

primary segmented worms may persist for several months, but usually within three weeks after the entrance of the plerocercoid larva into the mammalian host secondary segments begin to appear in the neck region, at first linear, three to four times as wide as long." Cestodes having the primary-type segmentation were not observed in "superinfested" bears. Experimentally-obtained 10-day-old strobilae contained some elongate terminal segments, but these were not representative of "primary strobilae" as originally defined.

The writer observed "primary-type" segmentation persisting as long as 100 days in dogs and foxes experimentally infected by feeding plerocercoids from *Salmo gairdnerii.* In gulls (*Larus glaucescens* Naumann), segmentation progressed about as described by Kuhlow (1935c) for *D. dendriticum* in *Larus ridibundus.* In older strobilae, the segments comprising the posterior half were of greater length than width, but there was no evidence of "primary strobilae" as defined by Wardle and McColl, even in the youngest examples. All segments of cestodes from black bears were of greater width than length. This was true also for specimens expelled from man at about 65 days.

The "narrow tapeworm" of man, *D. strictum* Talyzin, 1932, was described on the basis of cestodes having elongate, primary-type segments. The original material was associated with cestodes identified as *D. minus,* already mentioned as existing in 2 strobilar forms, and *D. latum.* Markowski (1949, p. 122) expressed the opinion that *D. strictum* may be a synonym of *D. dendriticum,* on the basis of morphological similarities. Further work has been done in Buriat-Mongolia by Chizhova (1951), who stated that the cestode in gulls and dogs demonstrated 3 forms of strobilae. Two of these corresponded to the 2 types observed in *D. minus* by Talyzin (1934). The third form, designated as "group V," was observed in gulls and found to correspond morphologically with *D. strictum.* Chizhova (1951, p. 219) stated, ". . . the morphological structures of the parasitic worms of the sea gull and of mammals have so much in common that if it were not for such different environments, then they, without doubt, could be referred to one species." Chizhova reared procercoid larvae from eggs of both avian and human origin, and found them morphologically identical, with the same rate of development. Plerocercoids from naturally infected fishes were studied, and it was impossible to confirm the occurrence of a single species. When dogs and gulls were experimentally infected, however, the adult cestodes obtained were morphologically identical.

Present knowledge indicates that differences in host species may influence considerably the strobilar development of a given species of *Diphyllobothrium.* It does not appear to the writer that the primary-type of segmentation takes place during the growth of the cestode of bears on Kodiak Island. The youngest specimens, from naturally infected bears, had all segments of greater width than length, when total length of strobila ranged from 18 to 30 mm. Strobilae 50–60 mm. long were similar, and as length increased the segments were derived from the undifferentiated zone following the scolex. The presence of malformed terminal segments was noted, however, in 10-day-old strobilae ranging in length from 520 to 1050 mm. These are considered anomalous, since some contained the genital components of as many as 3 segments joined in such a way that future separation would undoubtedly be impossible. The significance of such segments is unknown. In reference to similar segments in *Diphyllobothrium* sp., observed in a mammal in Suri-

nam, Baylis (1947, p. 407) stated, "It seems possible that in the present case the host had accidentally acquired an infection with a species which was ill adapted to it, and that in consequence the parasites had developed abnormally." Markowski (1949, p. 112) observed multiple sets of genital organs in a single segment of *D. dendriticum;* he listed as a character common to avian species of *Diphyllobothrium* "very narrow elongate segments, becoming somewhat threadlike, . . . in the posterior region of the body" (p. 120). Kuhlow (1953c, p. 26) stated, "Die jugendliche Gliederkette ist durch das Auftreten schmaler, langer Proglottiden mit mehreren Genitalsaetzen und vielen Missbildungen characterisiert. Sie wird durch die Sekundaerstrobila ersetzt, deren Glieder schneller heranreifen und betraechtlich breiter als lang werden." Similar malformed segments have been described by other workers. These appear to be related in some way, at least in degree of malformation, to species of host in which they occur.

It is concluded that size of strobila *per se* has little diagnostic value. However, if data were available on age of strobila, size of infection, and species of host for the 2 or more species of *Diphyllobothrium* being compared, size of strobila would constitute a good diagnostic character. Such data can be obtained only through experimental infections.

Testes. Regarding the taxonomic value of the testes in species of *Diphyllobothrium,* Markowski (1949, p. 119) stated, "The number of testes is also very unreliable as a systematic criterion because in the same species, and even in a single worm, the maximum number may be twice as great as the minimum." Kuhlow (1953b) concluded that testes distribution in relation to the genital pore had taxonomic value in some species. In the writer's opinion, the situation is about as it is in *Andrya macrocephala* Douthitt, 1915 (see Rausch and Schiller, 1949) ; that is to say, neither number nor distribution of testes can be relied upon as being constant for a given species.

In the cestode from Kodiak Island, the testes ranged in number from about 400 to 1650 per segment. This represents a remarkable range, but it is related to segment size. The larger the segment, the more testes present. Size of testes would seem to have no taxonomic value.

Distribution of the testes is rather constant, there being a tendency for their restriction to 2 lateral, disconnected fields. However, the 2 fields are at times confluent anterior to the genital pore, near the anterior margin of the segment. The testes never extend into the area around the genital pore, and the testicular fields are never confluent posterior to the ovary. Dubinina (1951) found considerable variation in the distribution of the testes in segments from a single strobila of *Diphyllobothrium erinacei-europaei* (Rudolphi, 1819) from cats.

It is concluded that distribution of testes can be relied upon as being fairly uniform for a given species. Number of testes, however, is subject to a wide range of variation.

Ovary. Kuhlow (1953b) regarded shape of ovary to have unusual diagnostic value in the species studied by him. This could not be confirmed in material from Kodiak Island in which the ovary has a reticulate structure, with the 2 lobes connected by a narrow isthmus. Much variation was seen in the form and extent of the posterior and anterior horns of the ovarian lobes. Consequently, no specific shape is defined as being characteristic for this cestode. Aberrant structure was

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also noted, usually in the form of secondary connections between the lobes, posterior to the normal one, and strand-like projections in many specimens extended from the antero-lateral margins of the organ.

Uterine coils. The number and arrangement of the uterine coils have been accepted as characters of importance in differentiating species of *Diphyllobothrium.* Both Markowski (1949) and Kuhlow (1953b) utilized these in defining the species studied by them. The taxonomic value of uterine development and the number of the lateral coils as specific characters has also been discussed in detail by Wardle and McColl (1937).

In the writer's material, the number of uterine coils is not diagnostic. The range in number of lateral coils is the same as in several other species. Variation in the position of the uterine coils results from differences in number of eggs present and in the state of contraction of the segment. It was often impossible to count the coils for this reason. The anterior extension of the uterus beyond the genital pore is important, but this character is not unique, for the Kodiak Island species.

Vitelline glands. In the Kodiak Island cestode, distribution of vitelline glands is basically the same as in other members of the genus. There is variation, however, in the arrangement of these glands around the female genital organs and the genital pore. Frequently they extend medially only as far as do the testes; in other examples, they overlap the uterine coils to a considerable degree. The vitelline glands are confluent anterior to the genital pore in some cases, and when this occurs, it is usually the same dorsally and ventrally. Sometimes dorsal confluence of the glands alone may be seen. The vitelline glands do not extend across the mid-line at the posterior margin of the segment, but they frequently extend farther mediad here than do the testes.

Distribution of the vitelline glands has taxonomic value, but enough material must be available to determine first the range in variation. Since a relationship exists between the distribution of the vitelline glands and the state of contraction of the segment, material to be compared should be handled and fixed uniformly.

Mehlis' gland. Some description of Mehlis' gland is generally included in diagnoses of species of *Diphyllobothrium,* and shape and size of this organ are listed as being diagnostic. Markowski (1949) did not attempt to utilize this character in differentiating avian species of *Diphyllobothrium.* Kuhlow (1953b), on the contrary, believed that the organ had a typical shape in each of the 4 species of *Diphyllobothrium* studied by him in detail.

In the Kodiak Island material, the Mehlis' gland appeared elliptical or crescent-shaped in dorso-ventral aspect, but often was so diffuse as to be hardly visible. Size of this organ has little value as a diagnostic character, and it is doubtful that shape is ever consistent in a given species.

Egg. Size of egg has been regarded as having unusual value in differentiating species of a given genus of cestodes. It has been found that size of eggs may be quite variable in species of cyclophyllidean cestodes (Rausch, 1952). This appears to be correlated with geographical distribution of specimens, rather than with differences in hosts parasitized (see Rausch, 1952; Schiller, 1952). A similar situation may exist with regard to variation in size of eggs of *Diphyllobothrium* spp.

The cestodes from Kodiak Island contained eggs which were fairly uniform in average size and in shape. The area involved was too small to permit reliable observations on variation related to geographical distribution. Eggs from cestodes

collected on the mainland were also uniform in size and shape, and closely resembled those from Kodiak Island. It is of interest that the reported sizes of eggs from various species of cestodes from the northern hemisphere fall within narrow limits.

According to present knowledge, differences of reasonable degrees in size and proportions of eggs may have value in distinguishing species of *Diphyllobothrium*. This can be evaluated only after confirmation of the specific status of the numerous species now regarded as valid (especially, those described by Russian workers).

Other characters. Regarding other characters used in differentiating species of *Diphyllobothrium,* Markowski (1949, p. 120) stated, "Some contemporary authors, *e.g.* Vergeer (1942) and Thomas (1946) introduce into their descriptions new features, among which are the measurements of the ootype, of the receptaculum seminis and of the genital apertures. These features are also of little systematic value. . . ." The writer has not found other characters of value in differentiating the adult cestodes of this genus.

II. The plerocercoid.

As a result of the work of Kuhlow (1953a), it appears possible to differentiate the plerocercoid larvae of certain species of *Diphyllobothrium*. The larvae of many species, however, have not been studied. Four points are worthy of consideration in attempting to characterize these larvae: 1) Localization in the body of the host; 2) Species of host; 3) External morphology; 4) Microscopic anatomy.

Kuhlow's work (1953a) has emphasized that the plerocercoid stages of certain species of cestodes have a characteristic locus in the host. Thus, the larva of *D. dendriticum* is free in the body cavity of the host; that of *D. osmeri* (von Linstow, 1878) occurs in cysts on the serosa of the stomach; the plerocercoid of *D. vogeli* Kuhlow, 1953, is found in peripheral liver tissue; and the larva of *D. latum* usually occurs unencysted in the musculature.

Infective plerocercoids of the Kodiak Island cestode encyst on the serosa of the stomach of the red salmon. In North America, encysted larvae have been reported by several investigators. Linton (1891b) observed encysted larvae in *Salmo clarkii lewisi* (Girard) in Wyoming; Cooper (1921) reported apparently encysted larvae in *Salvelinus marstoni* Garman, from Bernard Harbor, Northwest Territories; Fasten (1922) observed such larvae in *S. clarkii* Richardson, in Washington; Simms and Shaw (1931) reported encysted larvae in *Salvelinus fontinalis* (Mitchill) and *Oncorhynchus kisutch* in Oregon; Wardle (1932) collected encysted larvae from *O. nerka kennerlyi* (Suckley) in British Columbia; and Vergeer (1942) and Thomas (1946) conducted feeding experiments with encysted larvae from *Leucichthys* spp.

In Eurasia, Duguid and Sheppard (1944) and Hickey and Harris (1944) have recently established infections by feeding larvae from *Salmo trutta* Linnaeus. Unsworth (1944) carried on similar studies. Kuhlow (1953a) established infections by feeding to gulls encysted plerocercoids from the stomach of *Osmerus eperlanus* Linn. The investigations of Skvortsov and Talyzin (1940),[1] Petrushevskii and Boldyr (1935), Petrushevskii and Tarasov (1933), Tarasov (1936), and Chizhova (1951) have also been important in establishing relationships of encysted plerocercoids.

[1] Quoted in Chizhova (1951). The writer has not seen the original.

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A high degree of host specificity appears to have been developed by some species. For example, Kuhlow (1953a) found the plerocercoids of *D. osmeri* only in *Osmerus eperlanus;* those of *D. vogeli* ocurred only in the liver of *Gasterosteus* spp., but plerocercoids of *D. dendriticum* occurred in the body cavity of the same species. Plerocercoids of *D. latum* have often been reported from fishes of the genera *Esox, Perca,* and *Lota.* They apparently occur less commonly in salmonids. The larvae of *D. minus* and *D. strictum* are encysted in fishes of the genera *Coregonus* and *Thymallus* (Pavlovskii, 1946; Chizhova, 1951).

Kuhlow (1953a) was able to differentiate plerocercoid stage larvae of 4 species of *Diphyllobothrium* (*D. dendriticum, D. osmeri, D. vogeli,* and *D. latum*) on the basis of their external characteristics. Several characters were useful in this; viz., shape and size of body, presence or absence of cuticular folds, state of scolex (evaginated or not), and, if present, the distribution of cuticular bristles. Plerocercoids of other species have been described, but often there has been no well-founded attempt to correlate this larval stage with the adult. Magath (1929) and Vergeer (1929) wrote extensively of the plerocercoid larva of *D. latum;* Linton (1891a, b) distinguished larvae of 2 forms which were thought to be plerocercoids of *D. cordiceps* (Leidy, 1871); Petrushevskii and Tarasov (1933) described plerocercoids from Karelian fishes; and Vergeer (1942) presented details of the plerocercoid of *D. laruei.* Numerous other descriptions in the literature are of no use at the present time, since it is unlikely that the forms could again be recognized.

The differentiation of *Diphyllobothrium* plerocercoids on the basis of microscopic anatomy has been dealt with by Kuhlow (1953a). Although he was concerned with only 4 species, his method appears to be reliable and should be an important aid in elucidating some of the existing taxonomic problems. He concluded that characteristics of the frontal glands, arrangement of muscle layers, length and disposition of cuticular bristles ("Kutikulaborsten"), and relative thickness of body layers serve to differentiate species of plerocercoids. Kuhlow believed that the cuticular bristles had been overlooked by earlier workers. Linton (1891a, p. 76), in a paper probably not available to Kuhlow, stated in describing the smaller plerocercoid from trout in Wyoming, "The musculature and vascular systems are substantially the same as in the larger specimens. There is, however, an epidermal layer present which was absent from the larger specimens. This epidermis appears in transverse sections as a border of short, curved, hair-like processes springing from a thin basement layer, which separate easily from the cuticle." Subsequent workers failed to take advantage of Linton's observations.

CONCLUSIONS

The Kodiak Island cestode perhaps can be characterized according to structural and ecological peculiarities of both the adult and plerocercoid stages. Our present knowledge renders it impossible to confirm that this form is specifically identical with any previously-described species. Consequently, in order to characterize it and make available a name by which it may be designated, it is provisionally described as a new species. Since the intestine of the brown bear appears to constitute the most favorable habitat, and since maximum development is attained in this host, the name *Diphyllobothrium ursi* n. sp. provisional is proposed.

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Diphyllobothrium ursi n. sp. provis.
(Figs. 1–5 and 7–8)

Diagnosis (adult stage): Strobilar length up to 11 meters; maximum width 23 mm.; maximum number of segments about 1800. Neck absent in mature strobilae. All segments of greater width than length. Anterior segments containing eggs with length/width ratio of about 1:8; older segments approaching square shape, with length/width ratio about 1:1.5. Strobilar margins only slightly serrate. Scolex relatively small and muscular, measuring 1.0 to 1.5 mm. long, by about 0.750 mm. thick; width (lateral view) up to 1.5 mm.; shape variable. Bothria extending full length of scolex. Adjacent part of strobila wider than scolex. Genital pore situated in anterior half of segment, often near anterior margin; surrounded by elevated area covered by papilla-like protrusions. Ovary, situated at posterior margin of segment, consisting of 2 distinct lobes connected by narrow isthmus near middle. Ovarian structure reticulate; anterior and posterior horns of lobes variable in position and degree of development. Vagina running from ovary directly anteriad to genital pore, superficial and ventral until just posterior to genital pore, there turning abruptly dorsad and extending nearly to dorsal wall of segment, then turning abruptly ventrad, paralleling cirrus sac to genital sinus and emptying into floor of sinus just posterior to male opening. Primordia of uterus visible in earliest segments (60 to 80 segments, or as little as 5 mm., from scolex). In mature segments, posterior portion of uterus much coiled; anterior portion, containing fully-developed eggs, consisting of 4 to 8 loops on each side of mid-line; anterior-most loops often extending well beyond genital pore. Pattern of uterus depending upon degree of segmental contraction. Uterine pore situated just posterior to genital pore, on mid-line. Fully-developed eggs elongate, measuring 56 to 69 microns long by 39 to 49 microns wide (av. about 65 by 43 microns). Vitellaria numerous, variable in size; distributed in lateral, disconnected fields, or at times confluent at anterior margin of segment; in latter case, they may be confluent dorsally and separate ventrally, or confluent both dorsally and ventrally. Vitellaria sometimes overlapping uterine coils, depending somewhat upon state of contraction of segment. Vitellaria superficial, with long axes directed dorso-ventrally. Major vitelline ducts variable in number and size, joining to form single, primary duct of relatively large diameter, latter joining oviduct near and dorsal to isthmus of ovary. Mehlis' gland diffuse, of variable size, and usually appearing oval or crescent-shaped when viewed dorso-ventrally. Testes abundant, up to 1650 per segment, of variable diameter, but usually about 150 microns. Testes usually disposed in disconnected lateral fields, or extending across mid-line anterior to genital pore, never extending across mid-line posterior to ovary. Cirrus sac piriform, large, up to 1.3 mm. long by 575 microns wide; distal end directed anteriad; ejaculatory duct coiled. Propulsion vesicle well developed; spherical in shape, measuring up to 650 microns in diameter, and situated just posterior to distal end of cirrus sac. Male genital opening situated in anterior part of floor of genital sinus.

Host: Ursus arctos middendorffi Merriam.

Locality: Kodiak Island, Alaska.

Habitat: Small intestine.

Type: Slides, No. 49355, containing portions of adult strobilae, have been deposited in the Helminthological Collection of the U. S. National Museum.

Diphyllobothrium ursi n. sp. provis. Plerocercoid larva.
(Figs. 6 and 10, 11, 12)

Diagnosis (plerocercoid stage): Excysted larvae 5 to 20 mm. long. Scolex evaginated; about 1.0 mm. wide, and oval to cordate in lateral view, and about 0.5 mm. thick; about same width as adjoining body. Body tapered toward either end, somewhat flattened dorso-ventrally; maximum width anterior to middle about 1.0 mm.; posterior end terminating bluntly. Dorsal and ventral median grooves present. Cuticle showing few folds, or none. Integument of plerocercoid, including scolex, covered with cuticular bristles of uniform length, 8 to 9 microns long. Cuticle about 4–5 microns thick; subcuticular zone about 8 microns thick. Next deeper zone, containing calcareous corpuscles, 24 to 30 microns thick. Calcareous corpuscles spherical, 3 to 4 microns in diameter. Subcuticular muscle fibers arranged singly; muscles of parenchyma arranged in large bundles, about 30–50 microns thick. Frontal glands well developed, arranged in dorsal and ventral masses, connected by thin isthmus; not extending into neck.

Host: Oncorhynchus nerka (Walbaum).

Habitat: In cysts on serosa of stomach.

Slides of entire and sectioned specimens have been deposited in the Helminthological Collection of the U. S. National Museum, No. 49356.

DISCUSSION

Species of *Diphyllobothrium* reported from marine mammals are not considered here. The writer has at hand a fairly representative collection from *Odobenus, Erignathus, Phoca,* and *Eumetopias,* and none of these closely resembles *D. ursi* n. sp. Neither does any described species, including those assigned by some authors to other genera (see Wardle and McLeod, 1952) resemble the present species. Diadromous and anadromous fishes bearing plerocercoids of *D. ursi, D. osmeri,* and possibly of other species, are undoubtedly available to piscivorous marine mammals. Mueller's statement (1937), ". . . it seems rather improbable that the same genus of cestode will be found in both the porpoise and land-dwelling mammals," is not necessarily valid in view of the lack of host specificity demonstrated by some species of *Diphyllobothrium.*

The species described here resembles closely some previously described species of *Diphyllobothrium.* It cannot be differentiated with certainty from some of these, but neither can it be established that they are identical. The following species are compared:

D. latum (Linnaeus, 1758). Parasitic in man, dog, and possibly bear; of circumboreal distribution. *D. ursi* n. sp. can be separated on the basis of larval characters, including morphology, host parasitized, and habitat in the host. The broad range of morphological variation observed in the adult *D. ursi* n. sp. makes its differentiation difficult from the adult of *D. latum.*

D. minus Kholodkovskii, 1916, and *D. strictum* Talyzin, 1932. Parasites of man, obtained from Buriats on Ol'khon Island in Lake Baikal. Although these 2 species were based on differences in strobilar form, they probably constitute a single species. According to a figure in Pavlovskii (1946, p. 290), the plerocercoid of *D. minus* has an everted scolex and a blunt, possibly invaginated posterior end. The body diameter is relatively great in relation to length, and cuticular folds are present. The work of Chizhova (1951) indicates that a single form, capable of infecting man, dogs, and gulls, exists in the region of Ol'khon Island. Additional work is needed to determine its status. Markowski (1949) regarded *D. strictum* as a synonym of *D. dendriticum,* while Kuhlow (1953b) was of the opinion that both *D. minus* and *D. strictum* are dwarfed forms of *D. latum.* The present species is readily differentiated from these forms on the basis of both larval and adult characters.

D. tungussicum Podiapolskaia and Gnedina, 1920. A parasite of man, obtained from Iakuts and Tungus from the lower Tungus and Lena region. This species closely resembles *D. latum,* of which it was thought by Kuhlow (1953b) to be a dwarfed form. A mature segment was figured by Pavlovskii (1946, p. 294). The status of this cestode is indefinite, and *D. ursi* n. sp. as yet cannot be differentiated adequately from it.

D. skrjabini Plotnikoff, 1932. Parasitic in man in the German National Okrug, lower Pechora River, and reported from dogs at Sverdlovsk. According to Pavlovskii (1946, p. 293), this cestode, with a maximum length of only 2.6 meters, has as many as 2700 segments. *D. ursi* n. sp. is differentiated from it on this basis. The life cycle of *D. skrjabini* is not known.

D. nenzi Petrov, 1938. A parasite of man from the lower Pechora River region. The only description available to the writer is that of Pavlovskii (1946, p. 294;

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fig. p. 296). According to this description, no segmentation is visible for as much as 320 mm. posterior to the scolex. The testes extend across the mid-line posterior to the ovary. *D. ursi* n. sp. is distinguished by differences in form of strobila and distribution of testes.

D. giljacicum Rutkevich, 1937. Parasitic in man, from Giliaks of the west coast of Sakhalin. This cestode occurred with *D. latum,* and may be identical with it. With a maximum strobilar length of only 2.6 meters, it possesses as many as 1830 segments. Eggs first appear in the uterus about 980 mm. from the scolex. According to this information, *D. ursi* n. sp. differs in form of strobila, and in rate of maturation. Additional information on *D. giljacicum* is needed before determination of its status.

D. luxi Rutkevich, 1937. A parasite of man, from Iakuts of the eastern shore of Sakhalin. This species resembles *D. nenzi* and *D. giljacicum* in the apparent slow rate of maturation of the genital organs and the relatively great number of segments (1662) for the length of its strobila (1.5 meters). This species may not be valid, but adequate data are lacking. *D. ursi* n. sp. can be differentiated from it, apparently, on the basis of the form of its strobila and rate of maturation.

D. cordiceps (Leidy, 1871). A parasite of gulls, white pelican, and bears, in Wyoming. The only description that is fairly complete is that of Ward (1918, p. 432), which has no value for taxonomic purposes. Through the kindness of Dr. E. W. Price, Animal Disease and Parasite Research Branch, Agricultural Research Service, U. S. Department of Agriculture, the writer had available for study 2 adult strobilae and some plerocercoids designated as *D. cordiceps.* These were from black bear and *Salmo* sp. ("rainbow trout"), respectively, the former from Yellowstone Park and the latter from Oregon.

Skinker (1932, p. 162) concluded that ". . . on the basis of morphology of the material available for study, *D. cordiceps* for the present must be considered a synonym of *D. latum.*" At the same time, Scott (1932, p. 162) concluded that the cestode in Yellowstone Park bears was *D. cordatum* (Leuckart, 1863), but found that eggs were indistinguishable from those of *D. latum,* and that the larvae appeared to be identical. Woodbury (1935) was unable to infect himself by ingesting both free and encysted larvae from *Salmo lewisi* [sic], and concluded that the species represented probably was not *D. latum.* More recently, Markowski (1949) concluded that *D. cordiceps* is a synonym of *D. dendriticum.* Kuhlow (1953b, p. 230) was not willing to agree with Markowski's conclusion, however, and emphasized the need for further study.

Unfortunately, Linton's description of the larvae (1891a, b) does not elucidate the problem, since he apparently was dealing with 2 species. His descriptions were adequate to indicate that he had a long form (up to 15 cm.) which showed transverse striae, and a small, encysted form. The latter was described by Linton (1891b, p. 339) thus: "The smaller larvae up to a centimeter or more in length are lanceolate, flattish, tapering rather abruptly and uniformly to each end." His description of the microscopic anatomy of this form was insufficient for present purposes. In any event, it is certain that a long plerocercoid similar to that of *D. latum* (as described by North American workers) were present, along with a small one similar to that of *D. ursi* n. sp. Feeding experiments involving both forms will be necessary to determine which is the larva of *D. cordiceps.*

From the adult cestode, *D. ursi* n. sp. can be differentiated by its larger, relatively long eggs (av. size in *D. cordiceps*: 56 by 43 microns), and by a more restricted distribution of the vitellaria (see Fig. 9). Other apparent differences cannot be evaluated at the present time.

D. laruei Vergeer, 1942. Described from adult and immature strobilae obtained by feeding dogs and cats encysted plerocercoids from *Leucichthys* spp. in the Great Lakes region. Attempts to infect young gulls were unsuccessful (Vergeer, 1942, p. 373).

Markowski (1949, p. 123) concluded that *D. laruei* is a synonym of *D. dendriticum*. Kuhlow (1953b) regarded *D. laruei* as distinct from *D. dendriticum*, and concluded that *D. oblongatum* Thomas, 1946, probably represents the primary strobila of *D. laruei*. *D. oblongatum* was regarded by Markowski as a synonym of *D. dendriticum*.

The description of the plerocercoid of *D. laruei* by Vergeer (1942) is too incomplete for present needs. Externally, however, it resembles larvae of *D. osmeri*, *D. vogeli*, and of *D. ursi* n. sp. Additional work is needed to determine the status of *D. laruei*.

D. ursi n. sp. differs from the published description of *D. laruei* in having a much larger egg (av. size in *D. laruei*: 47 by 33 microns), and a restricted distribution of the testes, which in *D. laruei* extend across the mid-line posterior to the ovary. Other apparent differences cannot be evaluated at the present time; among these, shape of ovary may be significant.

D. ditremum (Creplin, 1825). Recently studied in detail by Markowski (1949) and Kuhlow (1953b), *D. ditremum* apparently parasitizes only piscivorous birds, particularly colymbiform and pelecaniform species. *D. ursi* n. sp. differs from *D. ditremum* in having larger eggs, many more testes, and much larger strobila. Host species may also be diagnostic.

D. dendriticum (Nitzsch, 1824). Recently studied by Markowski (1949) and Kuhlow (1953a, c), this species is commonly found in gulls, but dogs and other mammals have been experimentally infected. Kuhlow has provided a good knowledge of normal morphological variation in this species.

D. ursi n. sp. is distinguished from *D. dendriticum*, in the adult stage, by its larger eggs, possessing more testes, and larger strobila. However, there is no information on the development of *D. dendriticum* in bears. In the plerocercoid stage, *D. ursi* n. sp. differs in having a relatively smooth cuticle, cuticular bristles over the entire scolex, and in thickness of subcuticular layers.

D. osmeri (von Linstow, 1878). Natural final host not known; thought by Kuhlow (1935b p. 208) to be a marine mammal, since the plerocercoid occurrs in an anadromous fish. Experimentally obtained in gulls.

In the adult stage, *D. ursi* n. sp. differs from *D. osmeri* in having the gravid uterus extending beyond the genital pore, more testes, larger eggs, and a much larger strobila. In the plerocercoid stage, *D. ursi* n. sp. has much shorter cuticular bristles and differently arranged subcuticular muscles.

D. vogeli Kuhlow, 1953. A parasite of gulls in Germany. The adult *D. ursi* n. sp. has more testes, a differently shaped ovary, larger eggs, and a much larger strobila. The plerocercoid stage of *D. ursi* n. sp. has much shorter cuticular bristles, and different relative proportions of the subcuticular layers.

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Diphyllobothrium sp. indet. Adult cestodes were experimentally obtained in gulls and certain species of mammals, including man, by feeding plerocercoids from steelhead (rainbow) trout, *Salmo gairdnerii,* collected on the Kenai Peninsula, southern Alaska. Excepting young trout, up to 150 mm. in length, all were heavily infected with encysted plerocercoids. These larvae closely resembled the plerocercoid of *D. ursi* n. sp. in most details. However, development of the adult stage is greatly influenced by the host. Differences in size, form of strobila, rate of development, and other features do not permit the conclusion that this form and *D. ursi* n. sp. are conspecific. Mature segments from a variety of host species are shown in figs. 13–17. Any decision regarding the 2 forms must await further study of material from experimentally infected animals.

Possibly, the situation in Alaska (and other parts of North America) may be the same as that observed by Chizhova (1951) on Ol'khon Island, where apparently a single species of *Diphyllobothrium* occurs in both birds and mammals, but the considerable morphological variation results in part from differences in hosts.

Whether *D. ursi* n. sp. is capable of infecting man has not yet been determined. It is hoped that this phase of the problem can be investigated on Kodiak Island in the future. It is well known that fish tapeworm infection is epidemic in the lower Kuskokwim River region of Alaska (Hitchcock, 1950), but the species of *Diphyllobothrium* involved cannot be identified as yet. A study of the characters of plerocercoid larvae, with experimental infections of various animals, should clarify this problem. Mature segments of cestodes from man in Alaska are shown in figs. 18–20. On the basis of the strobilar stage, this species cannot be differentiated from *D. ursi* n. sp.

NOTES ON THE ECOLOGY OF *D. ursi* N. SP.

Around Karuk Lake, red salmon make up an important part of the diet of bears during July and August, and to a lesser degree in September. As the salmon become available, the bears congregate along the smaller streams to feed on them. Most of the red salmon eaten by these mammals are spawned-out or already dead, since the more recently arrived individuals are very active and escape by swimming downstream when disturbed. During the several weeks the bears are feeding on red salmon, large numbers of plerocercoids are ingested. These establish themselves in the small intestine of the bears, beginning about 2 meters below the stomach, and rapidly attain sexual maturity.

Depleted portions of strobilae appear in the feces of the bears as early as August 1, but these are seen in increasing quantities as the season progresses. When berries become available [particularly *Sambucus racemosa* L. and *Viburnum edule* (Michx.)] around September 1, the bears leave the streams to feed on vegetation. However, salmon are eaten by them until December; these are either red salmon spawning along the shores of Karluk Lake, or carrion. Late in the fall, large quantities of cestodes are seen in the feces, mixed with the remains of vegetation.

It has not been determined whether *Diphyllobothrium* spp. are capable of overwintering in the intestine of the bear. Rush (1932, p. 275) stated, "The absence of the Russian broad tapeworm in the bears trapped in October at a distance of more than 20 miles from the Lake may indicate one of two conditions, viz: the infestation in the Park may not extend beyond the Lake district, or, the bear may

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have a natural means of ridding themselves of parasites before going into hibernation. There is some evidence that most parasites are very specific in their diet and it seems reasonable that the broad tapeworm could not subsist in the intestines of a bear after it goes on a grass diet, which it does in the fall months." There is some evidence to support the hypothesis that bears and true hibernators lose their helminth parasites in the fall. At the writer's request, Mr. Alf Madsen, an experienced professional guide, examined bears shot by hunters on Kodiak Island during the fall of 1953. He stated that 11 bears killed during September in the vicinity of Karluk Lake and Uganik Bay all harbored cestodes, but 6 animals killed in the same locality after October 20 were negative. On the contrary, an old female bear killed by Mr. Russell R. Hoffman, Biologist, U. S. Fish and Wildlife Service, on December 26 at Karluk Lake, harbored about 500 cestodes. On Kodiak Island, the bears often do not den until December, and sometimes not at all. They usually emerge during April.

Bears killed soon after emergence from the winter den have a rectal obstruction, composed of dehydrated remnants of plant material, which probably has been retained throughout the time of denning. According to Mr. Madsen and others, bears killed in the spring, before elimination of this obstruction, never harbor cestodes.

In June, 1953, the writer attempted to gain further information on survival of cestodes in denning bears. It was assumed that new infections could not take place until the beginning of the salmon runs in July. Five bears, killed along Uyak Bay, were examined, viz. a yearling, 2 two-year-olds, and 2 adults. All were negative for cestodes. Two animals contained a few immature ascarids which had undoubtedly been acquired since emergence from the winter den.

Since red salmon do not spawn in the streams emptying into Uyak Bay, and there is no definite information on the distance individual bears may travel, it is uncertain that these bears were ever exposed to infection through the eating of red salmon. These findings, therefore, were inconclusive. There was no opportunity to obtain bears from around Karluk Lake at the time. The finding of cestodes in bear feces along Sulua Creek, near Olga Bay, several miles from any drainage used by red salmon, seems to indicate that considerable movement of the animals may take place. The greatest activity is seen during the breeding time (May–June).

The writer has been told by Nunamiut Eskimo of northern Alaska that bears lose their parasites in the fall before denning. These people, who are accurate observers, were impressed by the abundance of ascarids in the bears killed in late summer. It was concluded by Dubinin and Leshkovich (1945) that marmots, *Marmota sibirica* Radde, true hibernators, eliminate in the fall the ascarids which they harbor during the warm months. They stated (page 377), "In the beginning of October, the worms left and the marmots went into hibernation." Bears probably lose their cestodes in the fall when they stop feeding. The change in diet from salmon to vegetation may be enough, in itself, to bring this about.

During the time the bears are feeding on salmon, they defecate freely in and along the streams, so that large numbers of cestode eggs reach an environment favorable for development. The eggs themselves, or the coracidia, are carried downstream into Karluk Lake, which has an abundant copepod fauna. The writer has made no observations on this part of the life cycle of *D. ursi* n. sp., but there

is much information on the zooplankton of Karluk Lake as a result of the studies of Juday, Rich, Kemmerer, and Mann (1932).

The red salmon, after hatching, usually spend 3 years in the lake, during which time they feed largely on zooplankton. They would undoubtedly be infected during this time through the ingestion of copepods containing procercoid larvae of *D. ursi* n. sp. The role of copepods in the diet of red salmon fry has been discussed by Foerster (1934). The 3-year-old red salmon leave the fresh water and enter the sea. Here they spend either 2 or 3 years, and then return to spawn in the drainage where they hatched. By the time of their return, they harbor infective plerocercoids which are ingested by the bears.

Four other species of salmon occur in the Karluk River drainage. The king salmon, *O. tschawytscha* (Walbaum) spawns in the Karluk River, as does the dog salmon, *O. keta* (Walbaum). The silver salmon, *O. kisutch,* spawns mainly in the Karluk River and in the lake itself. The pink salmon, *O. gorbuscha* (Walbaum), spawns in the Karluk River and also in some of the tributaries used by the red salmon. Of these, the fry of pink and dog salmon enter salt water immediately upon hatching. The fry of king salmon feed upon copepods, but it is not known to the writer whether this species harbors plerocercoids of *D. ursi* n. sp. The fry of silver salmon do not feed on plankton. It is of interest that Euguchi (1934) obtained plerocercoids regarded as *D. latum* from both *O. gorbuscha* and *O. keta* in Japan. He stated (p. 4149), "The occurrence of plerocercoids is very common in *O. masou* and *O. gorbuscha,* but a rare phenomenon in *O. keta.*" The former species does not occur in North America, but it appears improbable that the fry of *O. gorbuscha* remain long enough in fresh water to become infected from eating fresh-water copepods. An attempt to infect experimentally birds and mammals using larvae from *O. gorbuscha* might be enlightening. Examination of a series of pink salmon disclosed no larvae of *Diphyllobothrium;* however, they were taken from a stream not used by red salmon and not frequented by bears. Further observations on this species and on king salmon are needed.

The examination of series of other fishes from Karluk Lake [viz., *Salvelinus malma* (Walbaum), *O. kisutch, Salmo gairdnerii, Cottus* sp., and *Gasterosteus aculeatus* Linnaeus] gave uniformly negative results. A large series of *S. gairdnerii* was available, and the fact that no plerocercoids were found in them would support the view that *D. ursi* n. sp. is specifically distinct from the cestode occurring on the mainland. To the writer's knowledge, no observations have been reported on the occurrence of *Diphyllobothrium* spp. in bears (*Ursus arctos*) in the regions of northeastern Asia where they also feed on spawning salmon.

CONCLUSIONS

From observations made on cestodes from Kodiak Island bears, it has been found that a wide range of variation is to be expected in morphological characters heretofore used in differentiating species of the genus *Diphyllobothrium* Cobbold, 1858. It is concluded that species cannot be effectively differentiated through use of morphological features of the adult cestodes alone. The following points seem pertinent if adequate information is to be obtained on a given species:

The plerocercoid should be studied in detail, including host-species, habitat, and morphology. An attempt should be made to rear adult cestodes in a variety of

piscivorous birds and mammals, so that comparative material of known age can be obtained. Animals of a given species should be fed uniformly, to avoid any possible effect of changes in diet. Before comparing morphological features, observations should be made on rate of growth of strobila, time required for attainment of sexual maturity, onset of apolysis, and, if possible, normal life span. Kuhlow's (1953c) investigation of *D. dendriticum* could serve as a model for a study of this type.

Data of the kinds stated should eventually permit an evaluation of the named species of *Diphyllobothrium,* many of which can hardly be valid. Cestodes occurring in man fall into 2 main groups: those whose plerocercoid larvae occur encysted in salmonid fishes, and those whose larvae occur non-encysted in fishes of other families. Most of the species of *Diphyllobothrium* in boreal Eurasia and North America, for which the plerocercoid stages are known, fall into the first group. Fishes of the same species occur on both sides of Bering Strait, and it is probable that some of the same species of *Diphyllobothrium* will be recognized in the northern regions of both continents.

It would seem at first that species of *Diphyllobothrium* which occur in marine mammals would be difficult to study, and this is undoubtedly true for some. However, several species of anadromous and diadromous fishes are available to marine mammals. In addition, some fishes move freely between fresh water and salt water. An example of this is a whitefish, *Leucichthys sardinella* (Valenciennes), from which, incidentally, the writer has collected at Point Barrow the plerocercoid stage of a species of *Diphyllobothrium* harbored commonly by seals. Some marine mammals, moreover, enter fresh-water streams. For example, the harbor seal, *Phoca vitulina* Linnaeus, is often seen around river mouths, and the white whale, *Delphinapterus leucas* Pallas, sometimes travels several miles up streams. Further study of these interrelationships should be particularly productive.

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References

Baylis, H. A. 1947 Some roundworms and flatworms from the West Indies and Surinam. II. Cestodes. J. Linn. Soc. London, Zool. **41**: 406–414.

Chizhova, T. P. 1951 O Difillobotriidakh chaek na Baikale. Zool. Zhur. **30**: 217–223.

Cooper, A. R. 1921 Trematodes and Cestodes of the Canadian Arctic Expedition 1913–18. Rep. Canad. Arctic Exped. 1913–18. **9** Parts G-H: 3–27.

Dubinin, V. B. and Leshkovich, L. I. 1945 Zhirovye rezervy tarbaganov i ikh zarazhennost' askaridami pered vpadeniem v spiachku. Zool. Zhur. **24**: 373–378.

Dubinina, M. H. 1951 O biologii i rasprostranenii *Diphyllobothrium erinacei-europaei* (Rud. 1819) Iwata, 1933. Zool. Zhur. **30**: 421–429.

Duguid, J. B. and Sheppard, E. M. 1944 A *Diphyllobothrium* epidemic in trout. J. Path. Bact. **56**: 73–80.

Eguchi, S. 1934 On the secondary intermediate host of *Diphyllobothrium latum* in Japan, with special reference to fishes of the genus Oncorhynchus. Proc. 5th Pacific Sc. Cong. (Canada, 1933), **5**: 4145–4149.

Fasten, N. 1922 The tapeworm infection in Washington trout and its related biological problems. Am. Naturalist **56**: 439–447.

Foerster, R. E. 1934 The importance of Copepoda in the natural diet of sockeye salmon. Proc. 5th Pacific Sc. Cong. (Canada, 1933), **3**: 2009–2016.

Hickey, M. D. and Harris, J. R. 1944 Definitive hosts of a species of *Diphyllobothrium* causing mass infection of trout in reservoirs: Preliminary note. Brit. Med. J. September 2. p. 310.

Hitchcock, D. J. 1950 Parasitological study on the Eskimos in the Bethel area of Alaska. J. Parasit. **36**: 232–234.

Juday, C., Rich, W. H., Kemmerer, G. I. and Mann, A. 1932 Limnological studies of Karluk Lake, Alaska, 1926–1930. U. S. Bur. Fisheries, Bull. 12, **47**: 407–436.

Kuhlow, F. 1953a Bau und Differentialdiagnose heimischer Diphyllobothrium-Plerocercoide. Zeitschr. Tropenmed. u. Parasitol. **4**: 186–202.

———1953b Beiträge zur Entwicklung und Systematik heimischer Diphyllobothrium-Arten. Zeitschr. Tropenmed. u. Parasitol. **4**: 203–234.

———1953c Ueber die Entwicklung und Anatomie von *Diphyllobothrium dendriticum* Nitzsch 1824. Zeitschr. Parasitenk. **16**: 1–35.

Leiper, R. T. 1936 Some experiments and observations on the longevity of Diphyllobothrium infections. J. Helminth. **14**: 127–130.

Linton, E. 1891a On two species of larval Dibothria from the Yellowstone National Park. Bull. (150) U. S. Fish Commission (1889) **9**: 65–79.

———1891b A contribution to the life history of *Dibothrium cordiceps* Leidy, a parasite infesting the trout of Yellowstone Lake. Bull. (164) U. S. Fish Commission (1889) **9**: 337–358.

Magath, T. B. 1929 Experimental studies on *Diphyllobothrium latum*. Amer. J. Trop. Med. **9**: 17–48.

Markowski, S. 1949 On the species of Diphyllobothrium occurring in birds, and their relation to man and other hosts. J. Helminth. **23**: 107–126.

Mueller, J. F. 1937 A repartition of the genus *Diphyllobothrium*. J. Parasit. **23**: 308–310.

Pavlovskii, E. N. 1946 Rukovodstvo po parazitologii cheloveka. Vol. 1. Moscow-Leningrad. 521 p.

Petrushevskii, G. K. and Boldyr, E. D. 1935 Propagation du bothriocéphale (*Diphyllobothrium latum*) et de ses larves plérocercoides dans la région du nord-ouest de l'U.R.S.S. Ann. Parasit. **13**: 327–337.

——— AND TARASOV, V. A. 1933 Versuche über die Ansteckung des Menschen mit verschiedenen Fischplerozerkoiden. Arch. Schiffs-u. Tropenhyg. **37**: 370–372.

RAUSCH, R. 1952 Studies on the helminth fauna of Alaska. XI. Helminth parasites of microtine rodents—taxonomic considerations. J. Parasit. **38**: 415–444.

——— AND SCHILLER, E. L. 1949 A critical study of North American cestodes of the genus *Andrya* with special reference to *A. macrocephala* Douthitt, 1915. (Cestoda: Anoplocephalidae). J. Parasit. **35**: 306–314.

RUSH, W. M. 1932 *Diphyllobothrium latum* in bear. J. Mammal. **13**: 274–275.

SCHILLER, E. L. 1952 Studies on the helminth fauna of Alaska. X. Morphological variation in *Hymenolepis horrida* (von Linstow, 1901) (Cestoda: Hymenolepididae). J. Parasit. **38**: 554–568.

SCOTT, J. W. 1932 *Diphyllobothrium cordatum* (Leuckart, 1863) in bears of Yellowstone Park, Wyoming. J. Parasit. **19**: 162–163.

SIMMS, B. T. AND SHAW, J. N. 1931 Studies of the fish-borne tapeworm *Dibothrium cordiceps* Leidy. J. Am. Vet. Med. Ass. **79**: 199–205.

SKINKER, M. S. 1932 Comparative study of *Diphyllobothrium cordiceps* and *D. latum*. J. Parasit. **19**: 162.

SKUNKARD, H. W. 1949 *Diphyllobothrium stemmacephalum* Cobbold, 1858 and *D. latum* (Linn., 1758). J. Parasit. **35**: 613–624.

TALYZIN, F. F. 1932 *Dibothriocephalus strictus* n. sp. Menschenparasit des Baikalgestades. Zeitschr. Parasitenk. **4**: 722–729.

———1934 Zur Frage der morphologischen Charakteristik der Strobila bei *Diphyllobothrium minus* Chol. Zool. Anz. **106**: 209–215.

TARASOV, V. A. 1936 Expérience acquise par cinq années d'études sur les bothriocéphales dans la partie nord-est de l'U.R.S.S. (1931-1935). Ann. Parasit. **14**: 472–484.

THOMAS, L. J. 1946 New pseudophyllidean cestodes from the Great Lakes region. I. *Diphyllobothrium oblongatum* n. sp. from gulls. J. Parasit. **32**: 1–6.

UNSWORTH, K. 1944 Observations on the life-cycle of a species of *Diphyllobothrium* found parasitizing trout in Great Britain. Ann. Trop. Med. and Parasitol. **38**: 213–219.

VERGEER, T. 1929 The broad tapeworm in America with suggestions for its control. J. Inf. Dis. **44**: 1–12.

———1942 Two new pseudophyllidean tapeworms of general distribution in the Great Lakes Region. Trans. Amer. Mic. Soc. **61**: 373–382.

WARD, H. B. 1918 Parasitic flatworms. (*In* Ward, H. B. and Whipple, G. C. Fresh-water Biology.) John Wiley and Sons. New York and London. 1111pp.

———1930 The introduction and spread of the fish tapeworm. (*Diphyllobothrium latum*) in the United States. De Lamar Lectures, 1929–30. Williams and Wilkins Co., Baltimore. 36 pp.

———1935 The longevity of *Diphyllobothrium latum*. Recueil des Travaux dédié au 25-me Anniversaire Scientifique du Professeur Eugene Pavlovsky 1909–1934. pp. 288–294. Moscow.

WARDLE, R. A. 1932 The Cestoda of Canadian fishes. I. The Pacific Coast region. Contrib. to Canadian Biol. and Fisheries, n.s. **7** Art. 18: 221–243.

——— AND GREEN, N. K. 1941 The rate of growth of the tapeworm *Diphyllobothrium latum* (L.). Canad. J. Research, **19** Sect. D: 245–251.

——— AND MCCOLL, E. L. 1937 The taxonomy of *Diphyllobothrium latum* (Linné, 1758) in western Canada. Canad. J. Research, **15** Sect. D: 163–175.

——— AND MCLEOD, J. A. 1952 The Zoology of Tapeworms. U. Minnesota Press, Minneapolis. 780 pp.

WOODBURY, L. A. 1935 Infectivity of the plerocercoids of *Diphyllobothrium cordiceps* (Leidy) for man. J. Parasit. **21**: 315–316.

Explanation of Plates

Plate I

Fig. 1. *Diphyllobothrium ursi* n. sp., mature segment from naturally infected brown bear, Kodiak Island, Alaska.

Fig. 2. *D. ursi* n. sp., mature segment from naturally infected brown bear.

Fig. 3. *D. ursi* n. sp., scolex of mature cestode from naturally infected brown bear.

Fig. 4. *D. ursi* n. sp., mature segment from naturally infected brown bear.

Fig. 5. *D. ursi* n. sp., sagittal section through mature segment, showing relationships of genital ducts. From naturally infected brown bear.

Fig. 6. *D. ursi* n. sp., plerocercoid larva from red salmon, excysted.

Fig. 7. *D. ursi* n. sp., 10-day-old mature segment from experimentally infected black bear.

Fig. 8. *D. ursi* n. sp., 61-day-old mature segment from experimentally infected black bear.

Plate II

Fig. 9. *D. cordiceps* (Leidy, 1871), mature segment from naturally infected black bear, Yellowstone Park, Wyoming.

Fig. 10. *D. ursi* n. sp., scolex of plerocercoid, lateral view.

Fig. 11. *D. ursi* n. sp., segment of cross-section of plerocercoid; drawn from 5 micron section, stained with hematoxylin-eosin.

Fig. 12. *D. ursi* n. sp., scolex of plerocercoid, dorso-ventral view.

Fig. 13. *Diphyllobothrium* sp., 107-day-old mature segment from experimentally infected arctic fox, *Alopex lagopus* L.

Fig. 14. *Diphyllobothrium* sp., 65-day-old mature segment from experimentally infected man.

Fig. 15. *Diphyllobothrium* sp., 56-day-old mature segment from experimentally infected dog.

Fig. 16. *Diphyllobothrium* sp., 10-day-old mature segment from experimentally infected gull, *Larus glaucescens* Naumann.

Fig. 17. *Diphyllobothrium* sp., 107-day-old mature segment from experimentally infected black bear.

Fig. 18. *Diphyllobothrium* sp., mature segment from naturally infected man, Kotzebue, Alaska.

Fig. 19. *Diphyllobothrium* sp., mature segment from naturally infected man, Nelson Island, Alaska.

Fig. 20. *Diphyllobothrium* sp., mature segment from naturally infected man, Bethel, Alaska.

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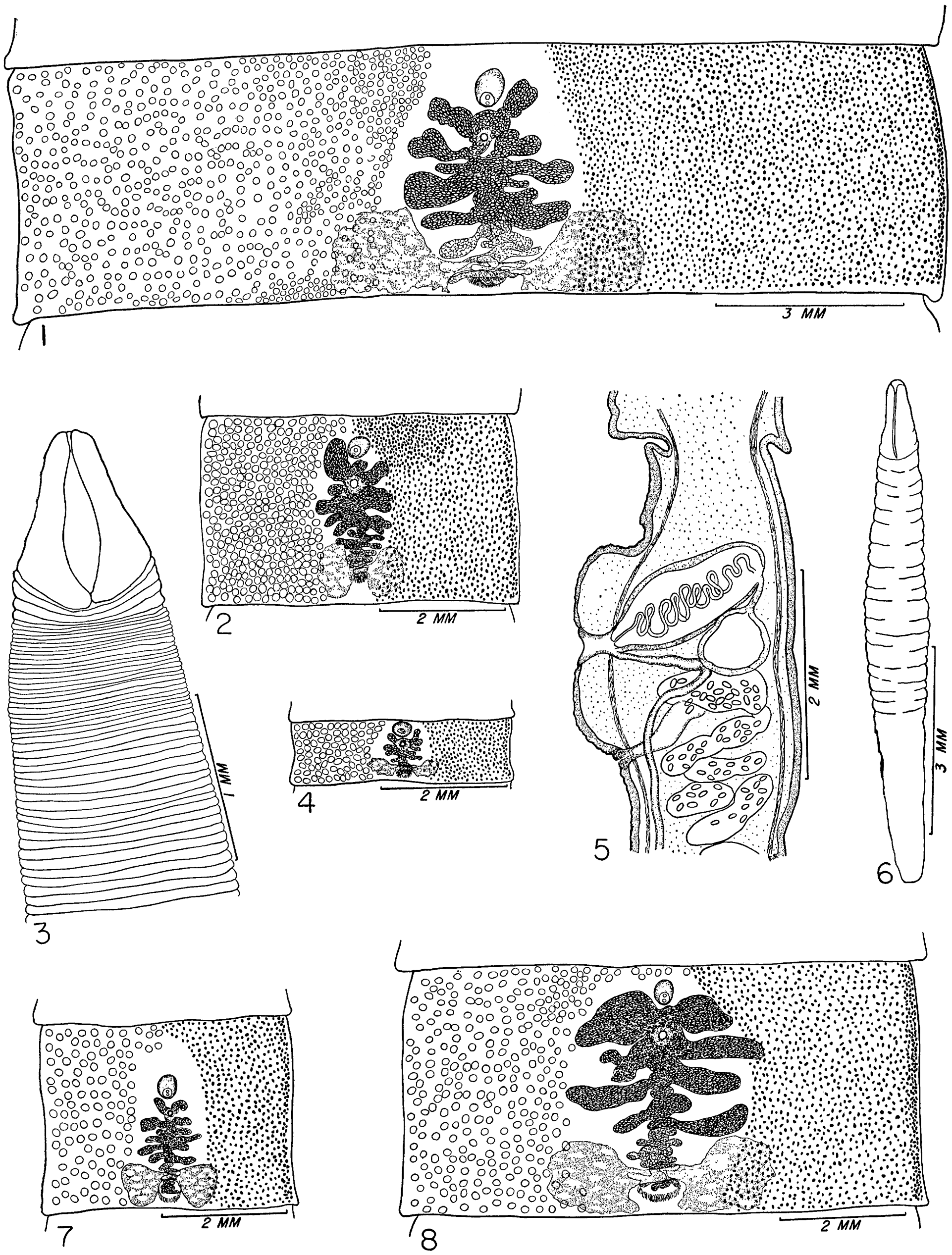
PLATE I



Rausch in Journal of Parasitology (October 1954) v. 40, no. 5, section 1.

PLATE II