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DIPLOSTOMOSIS IN NORTH PARK, COLORADO¹

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Abstract: The life cycle of *Diplostomum spathaceum* (Rudolfi 1819), as it exists in North Park, Colorado, is elucidated. California gulls (*Larus californicus*), common mergansers (*Mergus merganser*) and Forster's terns (*Sterna forsteri*) act as definitive hosts. Two species of water snails, *Physa gyrina* and *Lymnaea elodes*, act as first intermediate hosts with seven species of fish as second intermediate hosts: brassy minnows (*Hybognathus hankinsoni*), brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), mackinaw (*Salvelinus namaycush*), rainbow trout (*Salmo gairdneri*), western long nose suckers (*Catostomus catostomus*) and western white suckers (*C. commersoni*). Infection of fish by larvae of *D. spathaceum* results in cataracts of the lens and impaired vision.

INTRODUCTION

While trapping fish with a gill net at East Delaney Butte Lake in North Park, Colorado, personnel of the Colorado Division of Wildlife observed that most of the rainbow trout (*Salmo gairdneri*) had bilateral cataracts (Fig. 1). Several of these fish were taken to our laboratories where it was determined that the cataracts were caused by metacercaria of the genus *Diplostomum*.

The adult fluke recovered from fish eating birds in North Park was identified as *Diplostomum spathaceum* (Rudolfi, 1819). The life cycle of this fluke was elucidated by van Haitsma⁷ who called the fluke *Diplostomum flexicaudum* (Cort & Brooks, 1928). In later papers, Dubois^{8,4} and Hoffman⁵ considered *D. flexicaudum* as a synonym of *D. spathaceum* and this classification will be followed in this paper. *Diplostomum spathaceum* is a digenetic fluke which requires a snail as the first intermediate host, fish as the second intermediate host and a piscivorous bird as the definitive host.

In 1970, we initiated a 2 year study of the life cycle of *Diplostomum spathaceum* in North Park to determine the species of birds, snails and fish that are involved and the level of infection in each species.

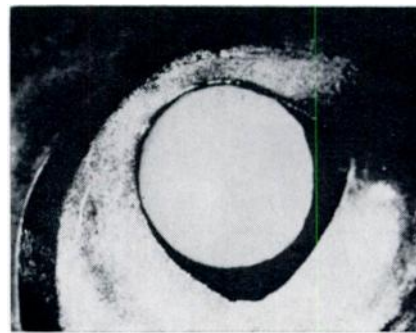


FIGURE 1. Rainbow trout eye showing a dense cataract and small herniations along the periphery caused by *D. spathaceum*. Both eyes were similarly involved. 7X photo by Dr. G. A. Severin.

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THE STUDY AREAS

North Park is a large mountain park in North-central (Jackson County) Colorado, just south of the Wyoming border. Data were collected from six lakes in North Park. Big Creek Lake is the largest with a surface area of 140 ha (350 acres) and a depth of 17 m. This lake is also highest in altitude at 2,740 m. Coniferous forests surround the lake. The lake has a rock bottom and therefore supports very few small aquatic invertebrates. Cowdrey Lake is the lowest in elevation at 2,140 m, has a surface area of 32 ha (80 acres) and is surrounded by sagebrush (*Artemisia tridentata*) and greasewood (*Sarcobatus vermiculatus*). The bottom is mud and has an abundance of aquatic vegetation and invertebrates. Both lakes are stocked with catchable (15-25 cm) rainbow trout.

The other four lakes, North, East, and South Delaney Butte Lakes, and Lake John, lie within 7 km (4.5 miles) of each other at an altitude of 2,470 m (± 15 m). Vegetation surrounding the lakes consists of sagebrush and greasewood with a grass understory. These lakes are highly alkaline (pH ~ 8) and have a mud bottom with a great deal of aquatic vegetation which in turn supports a large population of snails. Snails comprise 90% of the diet of the trout from July through May. These four lakes are stocked each year in early spring with fingerling rainbow trout which grow at a rate in excess of 2.5 cm per month. Catches of 28-50 cm trout are common.¹

METHODS AND MATERIALS

Feeding habits of all birds were observed and individual birds were collected by shooting. All local species of birds that contained fish as part of their diet were collected. The birds were either examined within 6 hours or frozen for later examination. During necropsy the entire gastrointestinal tract was removed, opened and washed, and its contents examined with the aid of a dissecting microscope. Parasites recovered were preserved in 10% formalin.

Snails were recovered from shallow waters of all three Delaney Butte lakes,

and deep water bottom samples were taken with a 15 cm x 15 cm Ekman Dredge. Line transects were established on North, East and South Delaney Butte lakes at 152 m intervals on East-West and North-South directions. Five samples, equidistant from each other, were taken on each transect. Snails were either preserved in 10% formalin for later study or placed in jars and observed for emergence of cercariae.

Fish were obtained from fishermen, or collected with gill nets and by electrofishing. Fish eyes were examined within 48 hours or preserved in 10% formalin for later examination. Each eye was separately dissected and tissues were teased apart while being observed with a dissecting microscope in order to ensure the recovery of all metacercariae. Metacercariae were preserved in 10% formalin.

RESULTS

Representatives of 7 of the 35 species of birds observed at the study areas were examined. Three species of birds, California gulls (*Larus californicus*), common mergansers (*Mergus merganser*) and Forster's terns (*Sterna forsteri*), were found infected with adult *Diplostomum spathaceum*.

California gulls probably were the most important definitive hosts as these birds arrived in North Park about the first of April each year and remained until the lakes were completely frozen in October or November. They were also the most numerous of the gulls present.

Thirteen California gulls collected during August and September of 1970 were infected with an average of 224 flukes, the range being 3-495. California gulls collected during the spring of 1971 carried a lighter parasite load than did those collected late in the summer. There was a large migration of gulls into the study area from nesting areas about the first of August, resulting in lower levels of infection of birds collected in August as well as an increase in the percentage of immature flukes recovered at that time. Thirty-two of 36 gulls examined in 1971 were infected with an average of 132

flukes (range 1-1055). A California gull nestling collected during July, 1970 from Antero Reservoir in South Park, Colorado was found infected with 46 *D. spathaceum*. Adult *Diplostomum* were recovered primarily from the small intestine. Specimens were also recovered from the large intestine and ventriculus of birds carrying heavy parasite loads.

Nine of ten Forster's terns were found to be infected, the infections ranging from 3-61, with an average of 12 per infected bird. Two common mergansers were infected with *D. spathaceum*, one with 37, the other with 1,752.

California gulls are scavenger birds and fed along the leeward shores of the lakes where dead fish washed ashore. Gulls also fed near the boat ramps of the lakes where fishermen cleaned their catch. The gulls would often ingest only the eyes of a fish, leaving the remainder.

Forster's terns and common mergansers are both active fish predators. Forster's terns fed almost exclusively on brassy minnows (*Hybognathus hankinsoni*), but the fish species fed upon by the mergansers were not determined.

Snails were found primarily in water

less than 4.5 m deep, and in close association with the plant species *Elodea canadensis*, *Chara* spp. and *Ceratophyllum demersum*. Four species of snails, *Lymnaea aricularia*, *L. elodes*, *Physa gyrina* and *Gyraulus* spp. (Fig. 2), were recovered from the study areas. Of the 1,463 snails examined, one *P. gyrina* and one *L. elodes*, were shedding cercariae of *D. spathaceum* (Fig. 3).

Seven species of fish, brassy minnows, brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), mackinaw (*Salvelinus namaycush*), rainbow trout, western longnose suckers (*Catostomus catostomus*) and western white suckers (*C. commersoni*), were examined and found to be infected with metacercariae of *D. spathaceum*.

Suckers were the most heavily infected species. Nine of 11 western longnose suckers (17 of 22 eyes) were infected with an average of 108 metacercariae per infected eye (range 1-266). All but three of the metacercariae were recovered from the lens. All of four western white suckers were infected. They averaged 105 metacercariae per eye, all in the lens. The range of infection was 2-233.

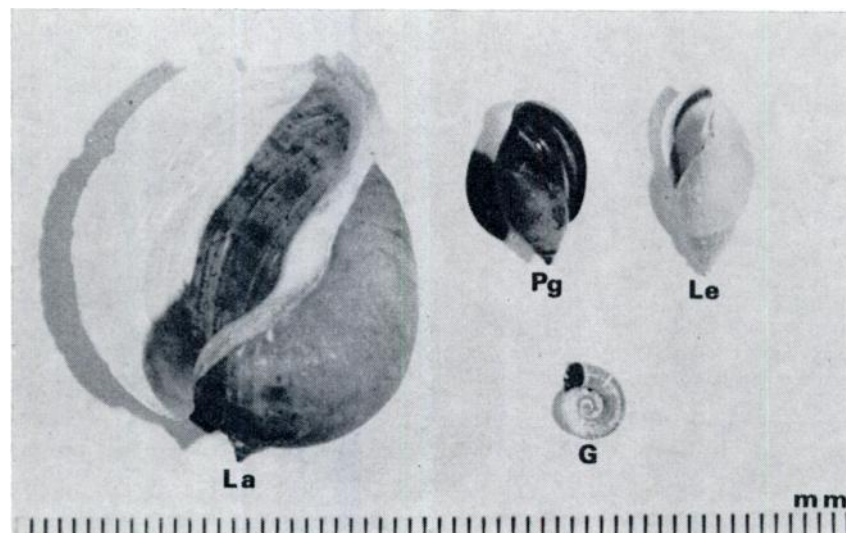


FIGURE 2. Specimens of the four species of snails recovered from North Park; *Lymnaea aricularia* (La), *Physa gyrina* (Pg), *Lymnaea elodes* (Le) and *Gyraulus* spp. (G).

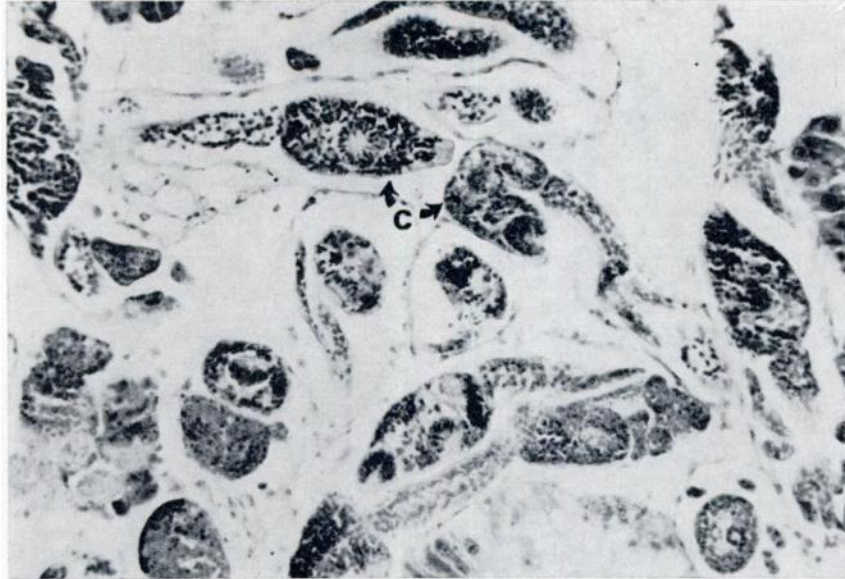


FIGURE 3. Cross section of an infected *Lymnaea elodes* showing many cercariae (C) in the digestive gland. 400X.

Rainbow trout were the most numerous fish examined, and 98 of 126 of these fish (176 of 239 eyes) were infected. Infections ranged from 1-479, with an average of 47 metacercariae per infected eye. Eighty percent of the metacercariae were recovered from the retina, 18% from the lens, 1% from iris and 1% from vitreous humor. Two eyes recovered from rainbow trout had large herniations (Fig. 4).

The eyes from one brook trout were examined during 1971. The left eye contained six metacercariae in the retina and the right eye contained 11 in the retina.

Nine of 13 brown trout (16 of 26 eyes) were infected with an average of 43 metacercariae (range 1-193). Very few changes were observed in brown trout, even in those with heavy infections. Most of the metacercariae (62%) were recovered from the retina. Metacercariae were also recovered from the lens (28%), iris (7%) and vitreous humor (3%).

Five of five mackinaw (nine of ten eyes) were infected with an average of three metacercariae per eye (range 1-10).

Eighty percent of the metacercariae were recovered from the retina, 13% from the lens and 7% from the iris.

Each eye of two brassy minnows was infected with an average of 24 metacercariae (range 4-40). Metacercariae were recovered primarily from the lens (76%); the remainder (24%) were recovered from the retina.

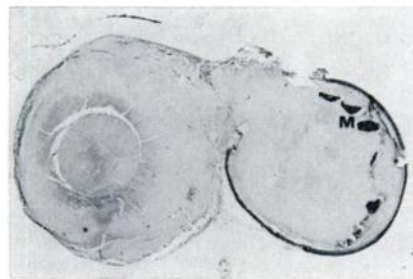


FIGURE 4. One of two rainbow trout eyes which demonstrated a large lens herniation. Note that all of the metacercariae (M) are in the herniated portion of the lens. 7X.

DISCUSSION

California gulls were the most important definitive hosts for *D. spathaceum* as they were in the area for approximately 7 months of the year; moreover, they were the most numerous birds and their feeding habits enabled them to acquire large numbers of the flukes. Forster's terns were present for 3-4 months during the summer and common mergansers were observed only during early spring and late fall. It is believed that the finding of metacercariae in the iris and vitreous humor, which occurred at the beginning of the study, are incorrect. Careful examination of the technique used to dissect the eye revealed that metacercariae were being disturbed from the retinal tissues and subsequently being observed in the vitreous humor and iris. Thus, those metacercariae which were found in the vitreous and iris should be included with those from the retina. The lakes were stocked once a year with fingerling rainbow trout, marked with a fluorescent pigment, as soon as ice had disappeared (April), and these fish were first found infected in mid-July. By mid-August, all of the fingerlings were infected, with most fish showing considerable lens opacity.

Although a very low number of snails were found shedding cercariae, quite possibly many snails examined supported immature infections. The fact that one snail may shed up to 48,000 cercariae every 24 hours² for a 2 month period suggests that only a few snails need be infected to produce enough cercariae to infect the fish in a body of water.

Birds collected in the spring (and the gulls collected just after leaving the nesting grounds) carried a lighter parasite load than those collected late in the summer. Recently captured ring-billed gulls (*Larus delawarensis*) from Denver, Colorado were examined in December 1971 and found infected with *D. spathaceum*. In August, 1972, birds from the original group, with access only to cooked foods, were found uninfected. It therefore appears that the parasite will not survive over winter and the gulls arrive in North Park with either a very

light infection of parasites (most of which were immature) or with none at all. Common mergansers are present at the lakes for a short time in the spring, yet they return in the fall with larger parasite burdens than those possessed by California gulls which had been at the lakes all summer. It is believed the common mergansers acquire infection in nesting areas and re-infect the lakes of North Park on their southern migration.

Diplostomum mergi (Dubois, 1932) has been reported from common mergansers.⁶ This parasite is 0.8-1.62 mm long. Supposedly, the ovary is located at the beginning of the hind body and two testes are present. Since the specimens of *Diplostomum* recovered from common mergansers at North Park, Colorado were smaller than those found in gulls and terns, the possibility that they could be *D. mergi* was considered. Examination revealed that these flukes were in that size range (1-2 mm, average 1.4 mm), but the ovary was midway in the hind body and three or four testes were present, which is characteristic of *D. spathaceum*.⁶ Flukes recovered from experimentally infected chickens also resembled those removed from the mergansers. Therefore, it is believed that the size difference is the result of physiological differences of the host's intestine and only one species of *Diplostomum* was recovered from the different bird species.

Fish in a small pond southeast of the study areas were examined periodically during the summer of 1971 and found uninfected. Several common mergansers were observed on this pond in the fall of 1971. Blind fish with metacercariae of *D. spathaceum* in the lenses were recovered from the pond the following spring. This seems to demonstrate the ability of the mergansers to distribute the parasite.

Fish in the lakes appear to survive quite well even though many are heavily infected. Opacity of the lens was observed with infections of four or five metacercariae and in many cases the entire lens was opaque. Fish infected at a level sufficient to cause obvious cataracts (25% or more of the lens tissue affected) were

observed to swim into objects in holding tanks (such as boards 5 cm x 10 cm) and into the sides of the tank.

The great number of snails in the lakes provides an excellent food source for trout, and even fish with complete cataracts of both eyes contained snails in their stomachs. Bait fishermen tended to catch the more heavily infected fish, while lure and fly fishermen caught lightly infected fish. The quality of fly and lure fishing has decreased in the area as a result of this parasite.

The Colorado Division of Wildlife has initiated a program of stocking different fish species in North Park. North De-

laney Butte has been stocked with brown trout and East Delaney Butte with brook trout. These stockings serve a dual purpose: (1) to provide a variety of fish for sportsmen and (2) planting fish which are possibly more resistant to infection by *D. spathaceum*. There is sufficient evidence that brown and brook trout are resistant, and since plans to offer a variety of fish was the primary purpose of the stocking program, biologists felt that resistance in these species could thereby be further assessed. A monitoring program is currently underway to determine if this approach will alleviate the problem.

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