COLORADO PARKS & WILDLIFE

Observations of Parasites of the Fishes of Colorado

A Summary of Case Findings and Unique Observations

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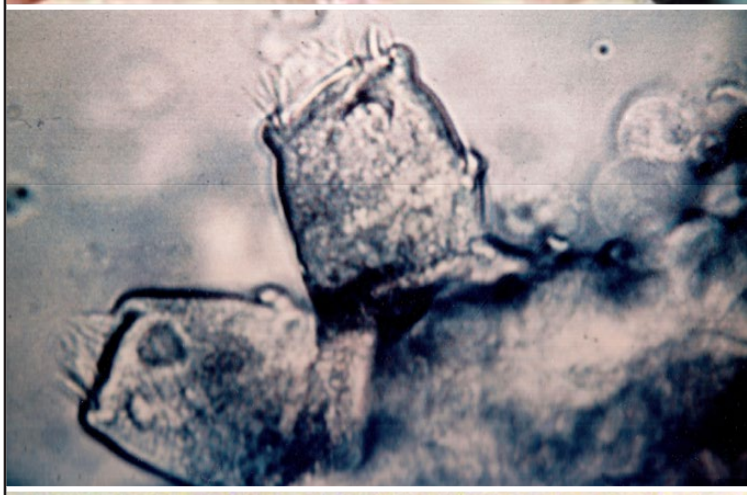

COVER PHOTOS

Top left: The author with a *Myxobolus cerebralis*-infected Rainbow Trout fingerling (left) and a normal fingerling (right).

Top right: *Trichodina* sp. found on a Rainbow Trout in the upper Colorado River (photo by the author).

Middle left: *Ambiphrya* sp. found on Brown Trout in the upper Colorado River (photo by the author).

Middle right: *Salmincola californiensis* found on a Sockeye Salmon (kokanee) in Elevenmile Reservoir, Colorado (photo by Estevan Vigil).

Bottom left: *Chilodonella* sp. found on a Tiger Muskie in Wray State Fish Hatchery (photo by John Drennan).

Bottom right: *Gyrodactylus* sp. found on a Greenback Cutthroat Trout in Glenwood Springs State Fish Hatchery (photo by John Drennan).

Back cover: *Gyrodactylus* sp. found on an Arkansas Darter (photo by John Drennan).

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A Summary of Case Findings and Unique Observations

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OBSERVATIONS OF PARASITES OF THE FISHES OF COLORADO

Peter G. Walker, Senior Fish Pathologist

ABSTRACT

Previous investigations involving parasites of fish in Colorado have been focused on specific drainages or fish hosts. Beginning in 1984, detailed documentation of fish health diagnostic cases and research projects in Colorado over a 29-year period identified twenty-one genera of protozoans, two genera of myxosporeans, nine genera of monogenean flatworms, six species of larval digeneans and one species of adult digenean fish parasites. Five genera of cestode plerocercoids and juvenile forms and eleven species of adult tapeworms were encountered as well as six genera of nematodes. A single parasitic crustacean was observed, as were four species of parasitic copepods. Case details and diagnostic observations are provided for parasites such as *Tetrahymena corlissi*, *Thecamoeba hoffmani*, *Glugea pimephales*, *Diplostomum spathaceum* and others. This report also includes a new range extension for the invasive copepod *Neoergasilus japonicus*.

INTRODUCTION

The State of Colorado encompasses 104,100 square miles straddling the Continental Divide, and contains the headwaters of four major watersheds. Relatively few fish species are native to these high elevation headwaters. However, early settlers of northern European descent made numerous non-native fish introductions (Ellis 1914, Wiltzius 1985). As a result, native Cutthroat Trout, *Oncorhynchus clarki*, populations were replaced by introduced salmonids in all but a small number of streams. Similarly, non-salmonid species have been introduced into Colorado at an alarming rate, approaching 95 if various tropical and subtropical aquarium species released into geothermal springs and ditches are included. Deliberate and accidental introductions continue to this day in Colorado, including the relatively recent discoveries of New Zealand mudsnails in Boulder Creek (South Platte River drainage) in 2005 and zebra and quagga mussels in Pueblo Reservoir (Arkansas River drainage) in 2008. The range and number of fish parasites has presumably expanded as well.

While very early information on the distribution of freshwater fish parasites in Colorado is lacking, many studies have been useful in establishing a more recent record. During a thorough examination of 353 warm water fish from four northeastern reservoirs, Cook (1954) found just two species of nematodes and two species of cestodes. Studies conducted by Tonn (1955) and McCrea (1960) expanded our knowledge of caryophyllid tapeworms in Colorado suckers. Siddiqi (1981) conducted the most thorough systematic study of helminth parasites in Colorado warm water fishes, examining 23 species of fishes on the northeastern plains. Of those, 11 non-salmonid fish species were found to host 22 species of helminthes.

Davies et al. (1973) studied the digenetic eye fluke *Diplostomum spathaceum* in the North Platte River drainage in north central Colorado and identified two snail species as the first intermediate hosts and three fish-eating birds as the definitive hosts. The metacercariae of *D. spathaceum* were observed in Brassy Minnows, *Hybognathus hankinsoni*, Longnose Suckers, *Catostomus catostomus*, White Suckers, *C. commersoni*, Rainbow Trout, *Oncorhynchus mykiss*, Brook Trout, *Salvelinus fontinalis*, and Lake Trout, *S. namaycush*.

In a study of the pathology of the copepod parasite *Lernaea cyprinacea*, Khalifa and Post (1976) obtained parasite specimens from Goldfish, *Carassius auratus* and Golden Shiners, *N. chrysoleucas*, and experimentally infected Fathead Minnows, *Pimephales promelas*, Golden Shiners, Green Sunfish, *Lepomis cyanellus*, and White Suckers. A high incidence of the fish leech *Helobdella stagnalis* was observed on Flannelmouth Suckers, *Catostomus latipinnis*, and, to a lesser extent, on Silvery Minnows, *Hybognathus nuchalis*, in the Colorado River (Malek and McCallister 1984).

Walker and Nehring (1995) in ascertaining the cause of a Rainbow Trout reproductive crash in the Colorado River that subsequently proved to be whirling disease, which now occurs in most drainages of Colorado, observed seven genera of protozoan parasites and commensals plus the monogenetic trematode *Gyrodactylus* sp. on free-ranging Rainbow Trout and Brown Trout. A more intensive survey by Schisler et al. (1999), studied young-of-the-year Rainbow Trout and Brown Trout in the Upper Colorado River over a two year period and found nine genera of protozoan gill parasites and commensal protozoans.

Seven species of bivalve mussels (Unionidae), which have parasitic glochidia stages, were historically present in Colorado. However, only the giant floater, *Pyganodon grandis grandis*, and pond horn, *Uniomerus tetralasmus*, currently have verifiable surviving populations (Cordeiro 1999).

While these previous studies provide useful information to the occurrence of fish parasites in Colorado, they are limited individually by their scope and duration. This investigation, while not intended to be a completely comprehensive accounting, is the compendium of data from formal fish health diagnostic cases and research projects over a 29-year period.

METHODS

The Colorado Parks and Wildlife Aquatic Animal Health Laboratory (AAHL) fish health program began in 1984. Typical case loads currently exceed 300 per year and include regulated inspections for all fish species that are to be stocked or transferred from wild populations and fish culture facilities, analysis of research cases, fish culture diagnostics, and fishery management cases. Detailed records from 1984 to 2013 facilitated compilation of a list of fish protozoan and metazoan parasites observed throughout the state, which are presented here.

Fish for examination were collected by netting from holding tanks at aquaculture facilities, or obtained via electrofishing, seining, or gill netting from free-ranging populations. Fish were humanely euthanized and specimens were examined as soon after collection as possible for external and internal parasites using standard methods for parasitology (Hoffman

1967, 1999, and examined grossly for obvious abnormalities. Next skin scrapings were made by scraping a streak from the posterior apex of the left pectoral fin to the tail with the side of a scalpel blade and placing the scraped material in a droplet of water on a glass microscope slide. This was examined under a coverslip with a compound microscope for the presence of ectoparasites, fungi, or long bacterial rods. Gill examinations of very small specimens were accomplished by excising whole arches and placing them in a droplet or two of water under a coverslip. In larger fish, the soft filaments from the same arches were excised and flared in water under a coverslip then examined with a compound microscope.

After the ectoparasite examination, the abdomens of specimens were opened by scalpel and the organs teased out for gross examination for lesions and parasites. The gastroinstestinal tract from esophagus to vent was flayed open by sharp scissors and examined grossly for parasites before wet tissue squashes of gut scrapings and various organs (liver, kidney, spleen, mesenteries, gall bladder and urinary bladder) were examined microscopically. After examining the internal organs, the cranium was split carefully to expose the brain and portions were squashed and examined. Unidentified parasites and lesions of undetermined cause were preserved for later examination. Tissue samples were fixed and preserved in neutral buffered 10% formalin for histological examination. Worm parasites were dipped in hot tap water to obtain full extension of the head parts, then fixed in 5% or 10% formalin for later examination. Parasite specimens were identified using reference texts and published accounts. Unique observations occurring during these inspections were recorded throughout the time period. Some of the more common parasites could be identified in vivo. Others were later identified at least to genus. For many parasites, only a presumptive identification of species was made if any.

RESULTS AND DISCUSSION

Parasites Identified

Twenty-one genera of protozoans were observed in or on fish in Colorado during the study period. These results are listed in Table I. In some instances, the species was identified and in others the genus was identified but no attempt was made to determine the species. The list contains three genera of flagellates. Twelve genera of ciliates were observed, with five genera of peritrichs, three genera of holotrichs, and three genera of trichodinids. The list includes a single observation of *Eimeria* sp. and several observations of the cochliopodid amoeba *Thecamoeba hoffmani*. The opisthokontid protist *Ichthyophonus hoferi* is listed here since the taxonomy of this organism is still uncertain. Three microsporidian genera were also found, including *Loma*, *Glugea,* and *Nucleospora.*

Two genera of myxosporean parasites (Myxozoa, Myxosporea, Bivalvulida), *Myxobolus* and *Henneguya,* were observed in Colorado fishes. Multiple species in each genus were identified, including one unidentified *Myxobolus* species in the striated muscles of a Sand Shiner *Notropis stramineus,* collected in the South Platte River in August 2012. (Figure 1). The list of myxosporean observations is provided in Table II.

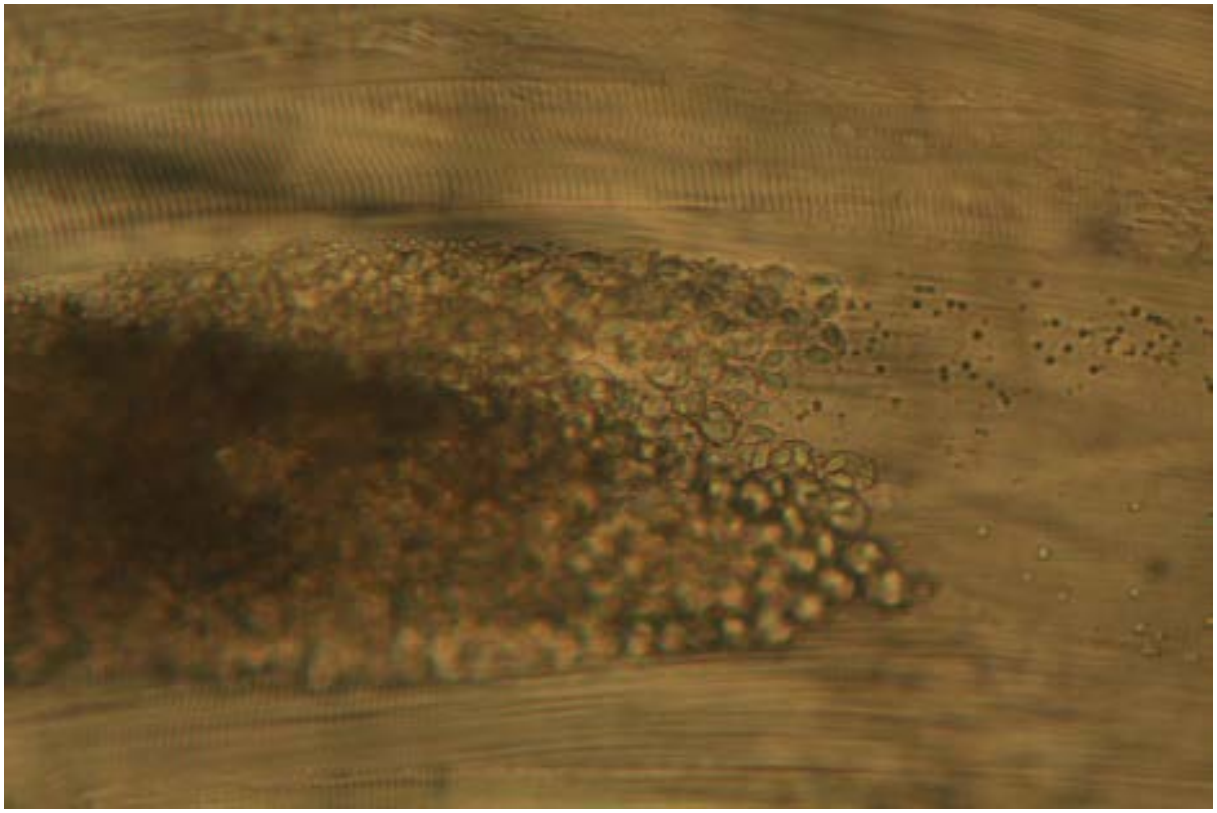

Figure 1. Spores of a yet unidentified species of *Myxobolus* species in the striated muscles of a Sand Shiner *Notropis stramineus.* (Photo by author.)

Nine genera of monogenean flatworm gill and skin parasites found during the inspections are listed in Table III. Digenean metacercariae of nine species were identified in Colorado fishes during the study period and are listed in Table IV, including *Ornithodiplostomum ptychocheilus* found in the mesenteries of a Sand Shiner (Figure 2). Several adult Digenea were observed in Colorado fishes, but only *Crepidostomum farionus* from the intestinal lumens of Cutthroat Trout and Brown Trout *Salmo trutta* was identified.

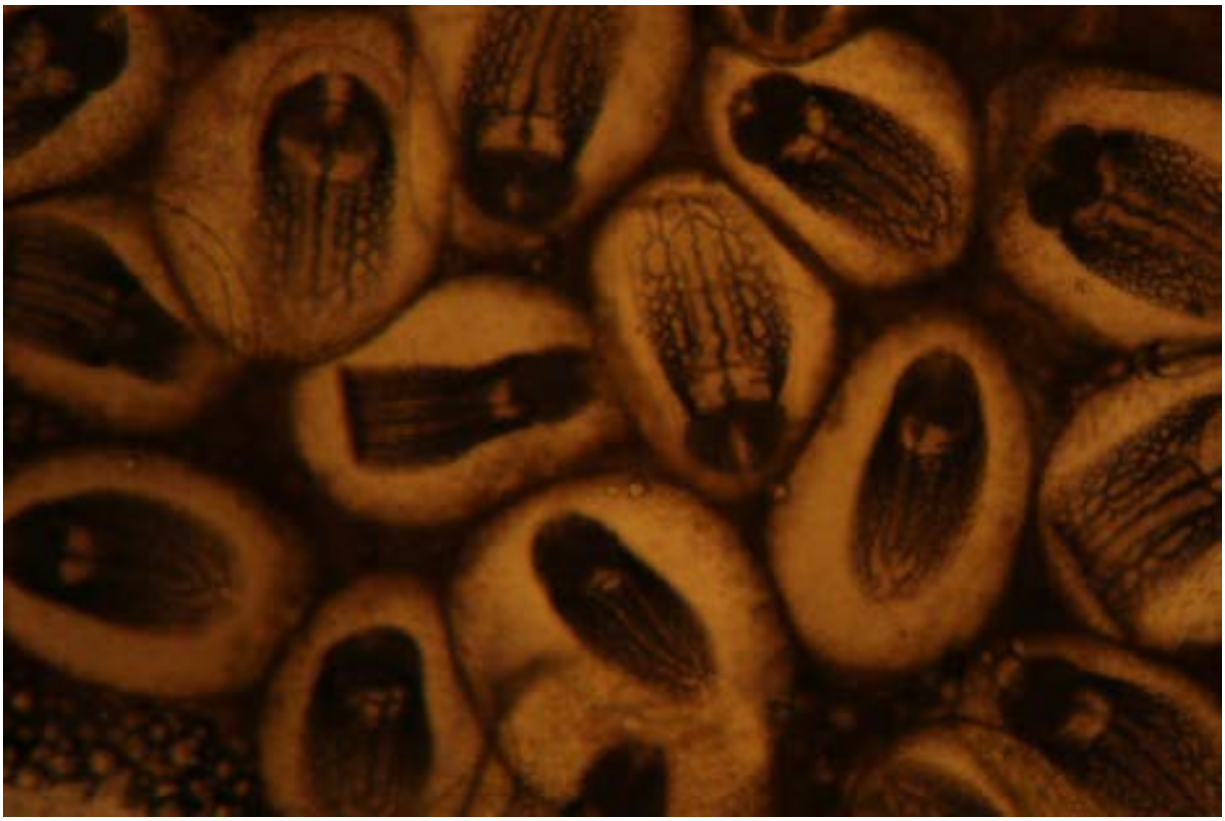

Figure 2. Metacercariae of *Ornithodiplostomum ptychocheilus* (Digenea) in mesenteries of a Sand Shiner collected in Sedgwick County in August, 2012. (Photo by author.)

Five genera of tapeworm plerocercoids or other immature stages were observed in the visceral cavities of fishes. This included species such as *Hunterella nodulosa*, a very small caryophyllid tapeworm with indistinct scolex and no discernable segments, collected from a White Sucker *Catostomus commersonii* (Figure 3). Eleven species of adult cestodes were observed. A list of these parasites and the host fish that harbored them is presented in Table V.

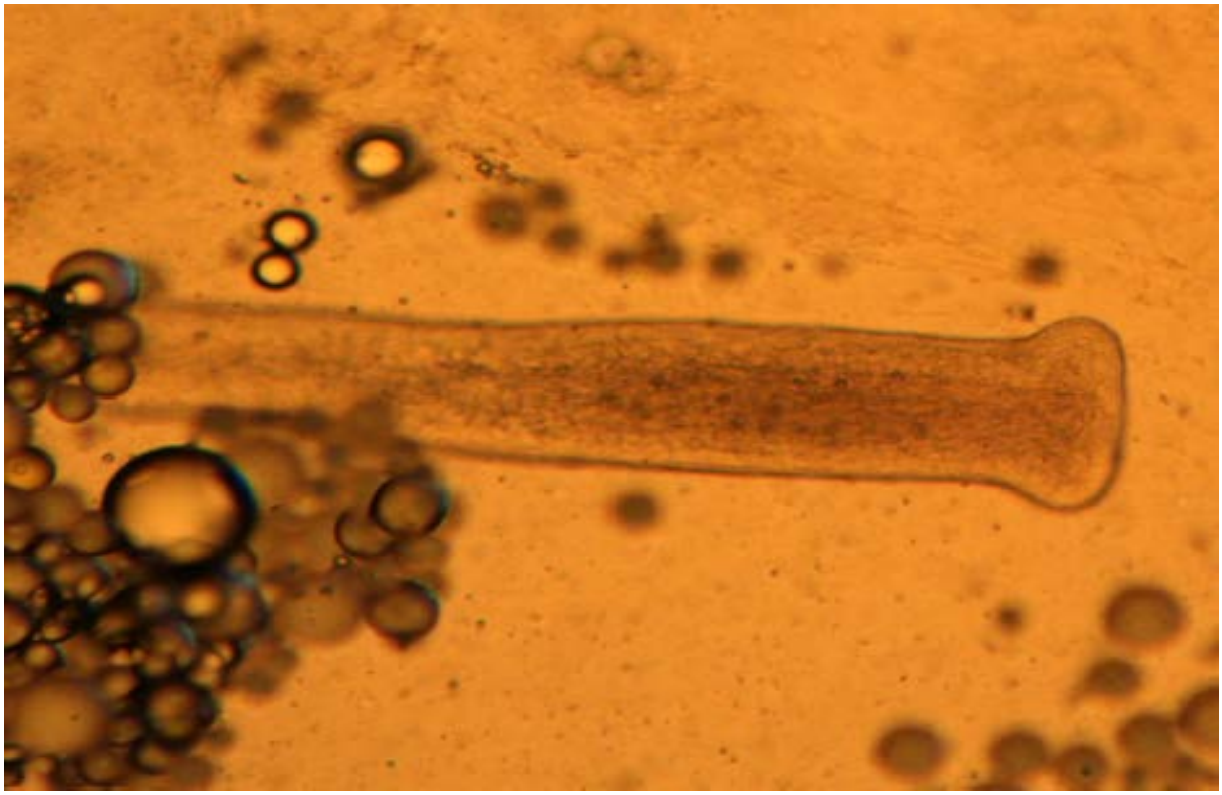

Figure 3. *Hunterella nodulosa* (Cestoda) from a White Sucker *Catostomus commersonii* collected in Sedgwick County in August, 2012. (Photo by author.)

Eight species from six genera of Nematoda were found during the study period, including *Capillaria commersoni* liberated from the gut lining of a Fathead Minnow *Pimephales promelas* (Figure 4). Nemodata observations are listed in Table VI. Parasitic leeches (Annelida, Hirudinea) of the families Glossiphonidae and Piscicolidae were observed on fish species in every major drainage.

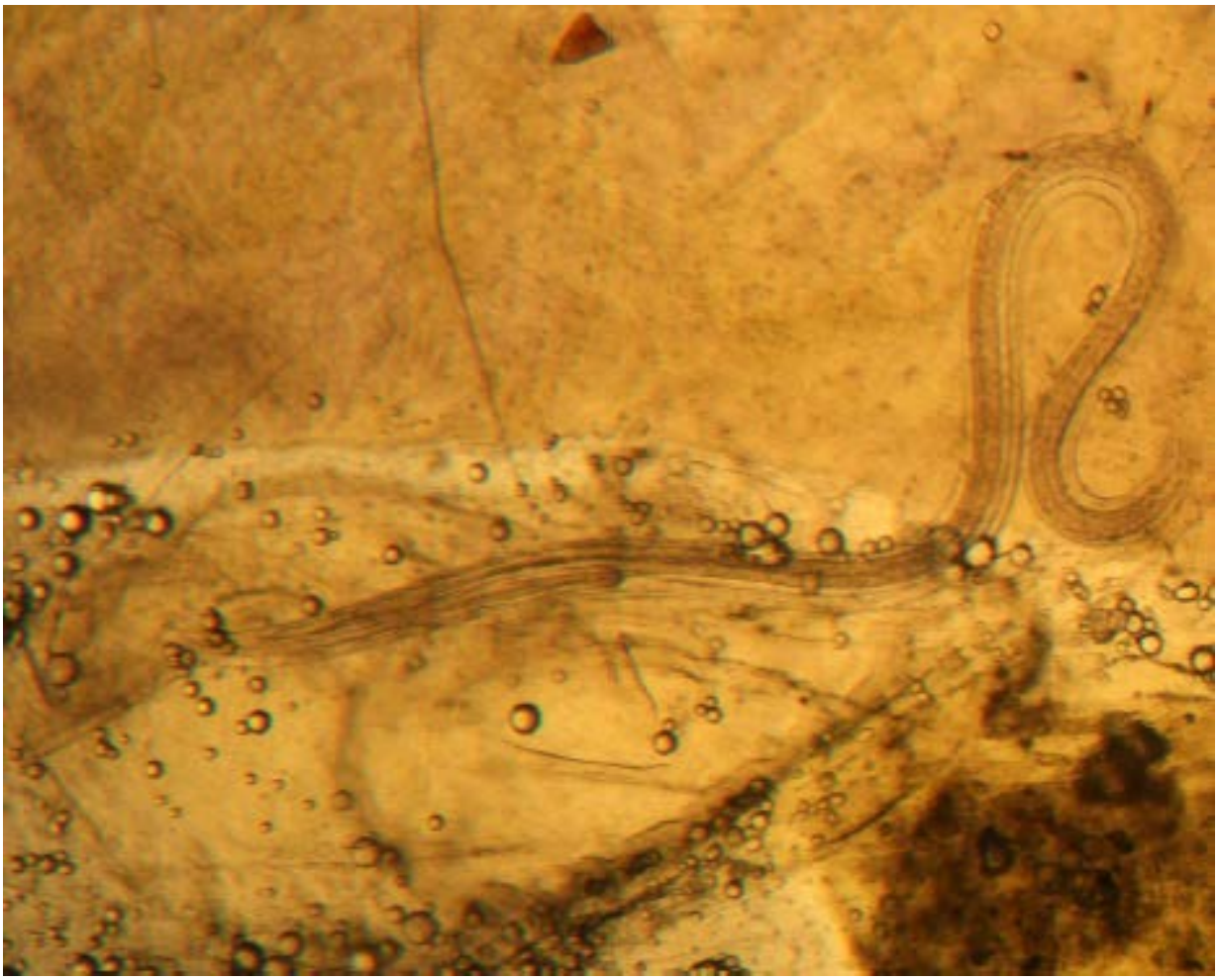

Figure 4. *Capillaria commersoni* (Nematoda) found in the gut lining of a Fathead Minnow *Pimephales promelas.* (Photo by author.)

A single specimen of *Argulus* sp. (Branchiura, Arguloidea) on a Brook Stickleback, *Apeltes quadracus*, was the sole record of this genus of crustacean parasite in Colorado over the 29-year period. The copepods *Lernaea cyprinacea* and *Salmincola californiensis* were frequently encountered. A possible second species of *Salmincola* as well as *Ergasilus* sp. and *Neoergasilus japonicus* were observed. A list of these parasites and their hosts is presented in Table VII.

Two of three unionid mussels (Bivalvia, Unionioda) once native to Colorado remain extant. Both species, the pond horn, *Uniomerus tetralasmus*, and the giant floater, *Pyganodon grandis*, have brief larval stages parasitic to fishes' gills. Unionid glochidia were observed on free ranging fishes regularly.

Unique Observations and Diagnostic Details

Ichthyobodo necatrix, a highly deleterious flagellate of freshwater fishes, was observed frequently on the gills of both cultured and free-ranging fishes in Colorado. Most notable was an epizootic in wild Brown Trout in Rifle Creek, Garfield County during a period of low flow and resultant environmental stress. A *Cryptobia* sp. was observed three times, once on gills of cultured Black Crappie, *Pomoxis nigromaculatus*, and again on gills of free-ranging Gizzard Shad, *Dorosoma cepedianum*, in winter. The organisms were easily differentiated morphologically from *Ichthyobodo*. Mitchum (1995) reported a single observation of *C. branchialis* in Wyoming in Goldfish, *C. auratus*. The organism in both Colorado cases may have actually been *C. branchialis*. Members of this genus are bacterivores and are reported as weakly pathogenic to fishes (Noga 2010). No pathology was evident in either diagnostic case in Colorado despite the density of the infestation. Mortalities in both cases were explained by environmental factors and other parasites present.

The third observation of a Cryptobia sp. was unusual. Free-ranging gravid female Mosquitofish, *Gambusia affinis*, were found to harbor very large populations of Cryptobia in the ovarian fluid surrounding developing embryos. No pathology was observed in this event. It is postulated that the parasite may be vectored on the copulatory organs of male Mosquitofish.

Four genera of peritrichous ciliates consisting of *Ambiphrya*, *Apiosoma*, *Epistylis* and *Heteropolaria* were found over the course of the study period. *Heteropolaria* was observed in Colorado only once in catfish in poor health in a farm pond on the eastern edge of Colorado. *Heteropolaria colisarum* is parasitic (Foissner et al. 1985), especially to cultured Channel Catfish, *Ictalurus punctatus*. The suctorean ciliate *Capriniana piscium*, a sessile protozoan possessing stinging organelles, was infrequently observed in cultured centrarchids and Channel Catfish as well as in a free-ranging population of Rainbow Trout and Cutthroat Trout. Although commensal, *C. piscium* causes necrotic damage and resultant irritation and impairment to host gills, as was the case with the infestations observed in this study.

The ciliate, *Tetrahymena corlissi*, was observed in two different circumstances. At Wray State Fish Hatchery (tributary to the North Republican River in Yuma County), *T. corlissi* was observed scattered among trichodinid parasites in skin scrapings of asymptomatic Bluegills in summer. In contrast, pathology was observed in *Tetrahymena*-infected cultured Rainbow Trout, more or less concurrently in two surface water supplied fish hatcheries and in free-ranging Longnose Suckers in very cold water in the winter of 2001 in the Cache la Poudre River system in Larimer County. The pathology resembled that described by Hoffman et al. (1975). In each case, infected fish displayed raised, hard blebs on the dorsal and lateral surfaces that were pigmented much like the rest of the surrounding epidermis. The blebs and the underlying material consisted of tissue debris. Each lesion penetrated the dermis into the underlying musculature. Concentrations of protozoans lay at the bottom of cone-shaped craters and none were to be found in the debris itself.

Another protozoan parasite of note is the tiny cochliopodid amoeba *Thecamoeba hoffmani* first described by Sawyer et al. (1974). During the study period, epizootics of this opportunistic parasite were observed in several state trout hatcheries as well as asymptomatic infections in wild trout. Often the pathology of these infections was observed before the

parasites themselves. The organisms, about the same size as host epithelial cells, were easy to see histologically in gill sections stained with hematoxylin and eosin. Focal aggregations of amoebae cause gross proliferation of the gill epithelium binding two to six individual filaments into swollen, off-white nodules. In vivo, tiny, barely motile to non-motile organisms with metallic appearing cytoplasmic granules could be found lying flat on the surfaces of the nodules. If shaken free of their substrate, the amoebae were observed extending and retracting fine, needle-like cochliopods. Because trout affected by amoebic nodular gill disease endure water quality stress poorly, the infections often responded only temporarily to formalin treatments and would soon return unless the water quality improved.

Trichodina fultoni is the most noteworthy of the multiple species of trichodinid parasites of three genera, *Trichodina*, *Trichodinella* and *Tripartiella,* observed in Colorado fishes. Most of the parasites of this group are of low to moderate pathogenicity. However, *T. fultoni*, identified by the distinctive shape of its denticles (Wellborn 1967), has been shown to be highly pathogenic to centrarchid fishes (Hoffman and Lom 1967, Walker and McNeish 1981). *T. fultoni* caused moderate mortalities in cultured Bluegill *Lepomis macrochirus* at Wray State Fish Hatchery before being successfully treated with formalin. However, it caused a severe die-off of Largemouth Bass, *Micropterus salmoides*, and Bluegill in a farm pond in Morgan County in the early 1990s.

The microsporidian *Glugea pimephales* has long been present in Fathead Minnows at Wray State Fish Hatchery and has served as a specimen source for researchers (Morrison et al. 1985). The organism is virtually undetectable for most of the year in the minnow population. For a 4-6 week period from mid-August to mid-September each year most fish become distorted with huge, white xenomas randomly located throughout the body and head and often interfering with the host's swimming ability. Then the xenomas rupture and the organism once again became hard to locate. There have never been mortalities associated with these episodes with the possible exception of increased vulnerability to avian predation.

Xenomas of the microsporidian *Loma salmonae* were observed in the gills of Rainbow Trout at several state fish hatcheries in Colorado during the late 1990s. These were optically dense and irregular in shape. Mitchum (1995) reported an established and recurring infection of *L. salmonae* at the Clark's Fork State Fish Hatchery in northern Wyoming which he described as a low-level pathogen and stressor. In the years since, Wyoming fish health workers have found the parasite at Clark's Fork at times to be a serious pathogen (Dee Dee Hawke, Wyoming Game and Fish Department, personal communication). The parasite incidence was low in Colorado state hatcheries and, despite annual testing with molecular polymerase chain reaction, the organism has not been found in the years since.

Observations of the erythrocyte infecting microsporidian *Nucleospora salmonis* (formerly *Enterocytozoon salmonis*) were similarly brief and inconsequential from a clinical standpoint. A few individual meronts were found in the cytoplasm of erythrocytes in stained blood smears of trout but there was no evidence of negative effects on the hosts.

A single observation of a myxosporean parasite, *Henneguya* sp., was made in free-ranging Rainbow Trout in Leroux Creek, a tributary of the North Fork of the Gunnison River in Delta County. A similar *Henneguya* sp. observed in Utah and Wyoming (Wilson 1999; David

Money, Wyoming Game and Fish Department, personal communication). The organism has been found in cartilage in the nose of brook trout, cutthroat trout and rainbow trout, where a granulomatous host response to erosion of the cartilage occurs (Chris Wilson, Utah Division of Wildlife Resources, personal communication).

Another myxosporean worth noting was a very large *Myxobolus* sp. observed in very low numbers in the milt of an adult Razorback Sucker, *Xyrauchen texanus*, from the Colorado River. The myxospores were slightly ovoid with polar capsules shaped and proportioned similarly to those of *M. cerebralis*. There was no sutural ridge. The myxospores were approximately 30 µm x 28 µm, making them about 2.5X larger than *M. cerebralis*. The host specimen was too rare and valuable to sacrifice, so exact site of infection is unknown. This appears to be an undescribed parasite species in an extremely rare fish host.

Species from eight genera of monogenean flatworm parasites of gills and external surfaces have been observed in Colorado. *Gyrodactylus* spp. and at least one *Dactylogyrus* sp. have at times caused health problems in cultured fishes in the state hatchery system. Monogeneans of the genus *Salsuginus* were recently found in Plains Killifish, *Fundulus zebrinus*, in the South Platte River in Sedgwick County and Plains Topminnows, *F. sciadicus*, in a tributary of the South Platte River in Weld County. Janovy et al. (1989), described *S. thalkeni* in Plains Killifish in the South Platte River in Nebraska, and Ferdig et al. (1991), described *S. yutanensis* in plains topminnows in eastern Nebraska. More study is needed to determine the identity of *Salsuginus* spp. in Colorado's two native cyprinodonts.

Yellow grubs, *Clinostomum marginatum* and *C. complanatum*, and black grub, *Uvulifer ambloplitis* have been observed, often abundantly, on fishes imported into the state on numerous occasions, but natural infections in free ranging fish have only occasionally been recorded. Metacercariae of both genera encyst in the musculature of fish. *U. ambloplitis* is principally a parasite of centrarchids while *Clinostomum* spp. are found in a very broad range of fish hosts. The primary host for *U. ambloplitis* in North America is the belted kingfisher, *Ceryle alcyon*, and the primary hosts for *Clinostomum* spp. worldwide are herons (Ardeidae). The first intermediate hosts for both parasites are aquatic snails of the genus *Helisoma*. All of these hosts are nearly ubiquitous in eastern Colorado, suggesting the parasites are probably present but not formally diagnosed.

The eye fluke, *Diplostomum spathaceum*, remains prevalent in fish in lakes on the North Park Plateau in north central Colorado. Yet, despite the ubiquity of its three host species across Colorado, the parasite has not been observed in any other waters of the state. Palmieri et al. (1976) reported finding *D. spathaceum* in fishes in 17 lakes in eleven counties from north to south through Utah. The snail species *Lymnaea stagnalis* and *Lymnaea palustris* were found to be the first intermediate hosts of the parasite in Utah waters. The authors of that paper attribute differences in parasite abundance and distribution to the relative abundance of shoreline and bottom vegetation necessary for the success of the snails. However, Utah hosts many gull rookeries while the only two gull rookeries, one each of ring-billed gulls, *Larus delewarensis* and Franklin's gull, *Leucophaeus pipixcan*, are found in Colorado, both in the immediate vicinity of the one lake where *D. spathaceum* has been observed. It is therefore concluded that conditions

for all three hosts for this parasite must be ideal to support a robust infection of this parasite in fish.

Observations of the Asian tapeworm, *Bothriocephalus acheilognathi*, were made on numerous individuals of at least five fish species throughout the study period. The invasive cestode is currently established in the Colorado River Basin, the Upper Rio Grande Basin on the San Luis Valley Plateau in south central Colorado. The parasite was first observed in North America in 1975 (Hoffman 1980) and is believed to have been vectored and disseminated by imported grass carp, *Ctenopharyngodon idella.* By 1985, the tapeworm was well established in the Lower Colorado River (Heckmann et al. 1986). The first observation in Colorado was made in Fathead Minnows imported from Dexter National Fish Hatchery in New Mexico and stocked as forage for endangered Colorado River Pikeminnows, *Ptychocheilus lucius*, in gravel pit ponds along the Colorado River floodplain in Mesa County in 1985 (Paul Janeke, United States Fish and Wildlife Service, personal communication).

The larval nematode, *Capillaria commersoni*, is long established in Fathead Minnows at Wray State Fish Hatchery. No deleterious health effects due to the pathogen have been observed or suspected at this location, although it has elsewhere been reported to be a serious pathogen of certain minnows (Hoffman 1999). In Fathead Minnows, Golden Shiners, and White Suckers, the worms can be found imbedded in the walls of the esophagus and sometimes upper intestines. The author observed a comparatively robust *Capillaria* sp. loose in the visceral cavities of wild-caught Red Shiners, *Cyprinella lutrensis*, being used in a laboratory experiment at Colorado State University. All mortalities examined possessed one to three worms while none of the live shiners sacrificed for comparison were parasitized. These worms appeared to be the sole cause of mortalities in those fish.

The parasite commonly known as the gill louse, *Salmincola californiensis,* is likely not native to Colorado. Its spread was documented from west to east across the United States during the latter half of the 20th Century (Hoffman, 1984 and 1999). However, *S. californiensis* was already present in Green Mountain Reservoir in the Colorado River drainage in Summit County and in a private trout hatchery on the Arkansas River in Chaffee County when this study began. In the years since, it has been spread by unregulated fish culture to many other sites. Heavy infestation by *S. californiensis* was judged to be a major contributing factor in a massive asphyxiation die-off of adult kokanee *Orcorhynchus nerka* during a late summer period of environmental stress in Elevenmile Reservoir in the South Platte River drainage in Park County in 2007.

The nearly microscopic parasitic copepod *N. japonicus* was first found in Colorado in 2009 at the bases of and on the fins on Black Bullheads, *Ameiurus melas*, Bluegills, and Green Sunfish, in two private farm ponds contiguous with West Salt Creek, tributary to the Colorado River, in Mesa County. The source of this introduction was not determined but indiscriminate fish stocking including goldfish, *C. auratus*, is suspected. The genus *Ergasilus* (Copepoda, Ergasilidae) is nearly worldwide in distribution with many species native to North America. *N. japonicus* was first found in North America in 1993 at Auburn, Alabama (Hayden and Rogers 1998). Hudson and Bowen (2002) found *N. japonicus* in the Great Lakes the following year. This finding represents a range extension of more than 1,000 miles.

SUMMARY

The occurrences of fish parasites in fish diagnostic cases in Colorado over the past 29 years have included a wide range of species and target hosts. Many of these observations are related to importation of non-native species of fish, and occurrence of several species of fish parasites in Colorado appear at much later dates than occurrences in other parts of North America. Rare or single encounters occurred with a number of these parasites, and in many cases were associated with other disease outbreaks or stressful environmental conditions. The effects and distribution of some of these parasites in Colorado are relatively unknown, and impacts, especially from future invasions are a concern for fisheries culture and management. Research in freshwater fish parasitology has declined over the last two decades in Canada and the United States (Scholz and Choudhury 2014). A greater understanding of the distribution, life history, ecology, and population effects of freshwater fish parasites both in Colorado and throughout North America is needed. The information presented here will hopefully contribute to that increasing body of knowledge.

Table I. Protozoan fish parasites encountered in Colorado.

Protozoan parasite	Host species
Ambiphrya ameiuri	*Oncorhynchus mykiss* *Oncorhynchus clarki* *Salmo trutta* *Micropterus salmoides* *Micropterus dolomieu* *Lepomis macrochirus* *Ictalurus punctatus* *Pimephales promelas* *Notropis stramineus* *Cottus bairdi* *Catostomus commersoni*
Apiosoma sp.	*Oncorhynchus mykiss* *Salmo trutta* *Micropterus dolomieu* *Lepomis macrochirus* *Ictalurus punctatus* *Cottus bairdi*
Capriniana piscium	*Oncorhynchus mykiss* *Oncorhynchus clarki* *Micropterus dolomieu* *Lepomis macrochirus* *Ictalurus punctatus*
Chilodonella cyprini	*Ctenopharyngodon idella* *Lepomis macrochirus*
Chilodonella hexasticha	*Oncorhynchus mykiss* *Salmo trutta* *Micropterus dolomieu* *Lepomis macrochirus* *Ictalurus punctatus*
Cryptobia agitans	*Pomoxis nigromaculatus* *Gambusia affinis*
Cryptobia sp.	*Dorosoma cepedianum*
Eimeria sp.	*Pimephales promelas*
Epistylis sp.	Widespread with little or no host specificity
Glugea pimephales	*Pimephales promelas*
Glugea sp.	*Fundulus sciadicus*
Glugea sp.	*Cottus bairdi*
Heteropolaria colisarum	*Ictalurus punctatus*
Hexamita salmonis	*Oncorhynchus mykiss* *Oncorhynchus clarki* *Cyprinella lutrensis*
Ichthyobodo necatrix	Widespread with little or no host specificity.
Ichthyophonus hoferi	*Oncorhynchus mykiss* *Pomoxis nigromaculatus*
Ichthyophthirius multifiliis	Widespread with little or no host specificity
Loma salmonae	*Oncorhynchus mykiss*
Nucleospora salmonis	*Oncorhynchus mykiss*
Tetrahymena corlissi	*Oncorhynchus mykiss* *Catostomus catostomus* *Lepomis macrochirus*
Thecamoeba hoffmani	*Oncorhynchus mykiss* *Oncorhynchus clarki* *Salmo trutta*
Trichodina fultoni	*Micropterus salmoides* *Lepomis macrochirus*
Trichodina spp.	The genus is ubiquitous with many species with various host specificities.
Trichodinella spp.	*Oncorhynchus mykiss* *Oncorhynchus clarki* *Micropterus dolomieu* *Notropis stramineus* *Hybognathus hankinsoni* *Catostomas commersoni* *Fundulus zebrinus* *Semotilus atromaculatus*
Tripartiella spp.	*Oncorhynchus mykiss* *Salmo trutta* *Semotilus atromaculatus*

Table II. Myxosporidian parasites observed in Colorado fishes. PL = Platte River (both South and North); AR = Arkansas River; NR = North Republican River; RG = Rio Grande; CO = Colorado River and tributaries.

Parasite	**Fish host**	**Infection site**	**Major River Drainage**				
			PL	AR	NR	RG	CO
Henneguya exilis	*Ictalurus punctatus*	*gill*	X	X	X		
Henneguya postexilis	*Ictalurus punctatus*	*gill*		X	X		
Henneguya sp.	*Oncorhynchus mykiss*	*nose*					X
Myxobolus cerebralis	*Oncorhynchus mykiss*	*skeleton*	X	X		X	X
	Oncorhynchus clarki		X	X		X	X
	Oncorhynchus nerka						X
	Salmo trutta		X	X		X	X
	Salvelinus fontinalis		X	X		X	X
	Salvelinus fontinalis X *S. namaycush*			X			
	Prosopium williamsoni		X				X
Myxobolus neurobius	*Oncorhynchus nerka*	*brain*					X
Myxobolus sp.	*Xyrauchen texanus*	*testis*					X
Myxobolus sp.	*Catostomus commersoni*	*gill*	X				
Myxobolus sp.	*Notropis stramineus*	*gill*	X				
Myxobolus sp.	*Notropis stramineus*	*striated muscle*	X				
Myxobolus sp.	*Fundulus sciadicus*	*brain*	X				
Myxobolus sp.	*Cottus bairdi*	*unknown*					X

Table III. Monogenean parasite genera (Platyhelminthes; Monogenea) of Colorado fishes

Parasite	**Fish host**
Actinocleidus sp.	*Lepomis macrochirus*
Cleidodiscus sp.	*Pomoxis nigromaculatus* *Lepomis macrochirus*
Dactylogyrus spp.	*Lepomis macrochirus* *Ictalurus punctatus* *Cyprinus carpio* *Ctenopharyngodon idella*
Gyrodactylus spp.	*Salmonids* *Micropterus salmoides* *Micropterus dolomieu* *Ictalurus punctatus* *Pimephales promelas*
Haplocleidus sp.	*Micropterus salmoides* *Micropterus dolomieu*
Lissorchis sp.	*Notropis stramineus*
Onchocleidus sp.	*Micropterus salmoides* *Lepomis macrochirus*
Salsuginus sp.	*Fundulus zebrinus*
Salsuginus sp.	*Fundulus sciadicus*

Table IV. Digenean (Trematoda, Digenea) metacercariae of Colorado fishes.

Parasite	**Fish host**
Apophallus brevis	*Salvelinus fontinalis* *Salmo trutta* *Apeltes quadracus*
Cotylurus communis (Tetracotyle larvae)	*Notropis stramineus*
Diplostomum spathaceum	*Oncorhynchus mykiss*
Crassiphiala bulboglossa	*Pimephales promelas* *Notemigonus chrysoleucas* *Phenacobius mirabilis* *Perca flavescens*
Hysteromorpha triloba	*Ictalurus punctatus*
Ornithodiplostomum ptychocheilus	*Pimephales promelas* *Notropis dorsalis* *Notropis stramineus* *Hybognathus hankinsoni* *Semotilis atromaculatus* *Lepomis macrochirus*
Plagioporus sinitsi	*Semotilus atromaculatus*
Posthodiplostomum minimum	*Micropterus dolomieu* *Micropterus salmoides* *Lepomis macrochirus* *Ictalurus punctatus* *Amieurus melas* *Pimephales promelas* *Ctenopharyngodon idella* *Hybognathus hankinsoni* *Phenacobius mirabilis* *Campostoma anomalum* *Semotilus atromaculatus* *Notropis stramineus* *Notropis dorsalis* *Fundulus zebrinus*
Neascus, unidentified	*Catostomus commersoni*

Table V. Cestode parasites of Colorado fishes.

Parasite	Parasite life stage	Fish host
Biacetabulum sp.	Adult	*Catostomus commersoni*
Biacetabulum sp.	Unknown	*Notropis stramineus* *Pimephales promelas*
Bothriocephalus cuspidatus	Adult	*Lepomis macrochirus* *Micropterus salmoides* *Perca flavescens*
Bothriocephalus acheilognathi	Adult	*Ctenopharyngodon idella* *Cyprinus carpio* *Gila elegans* *Ptychocheilus lucius* *Pimephales promelas* *Gambusia affinis*
Corallobothrium fimbriatum	Adult	*Ictalurus punctatus* *Amieurus melas*
Corallotaenia parva	Adult	*Ictalurus punctatus*
Eubothrium salvelini	Adult	*Oncorhynchus mykiss* *Oncorhynchus clarki* *O. mykiss X O. clarki* *Oncorhynchus nerka*
Glaridacris sp.	Plerocercoid	*Lepomis macrochirus*
Hunterella nodulosa	Adult	*Catostomus commersoni*
Ligula intestinalis	Plerocercoid	*Catostomus catostomus* *Catostomus commersoni* *Pimephales promelas*
Proteocephalus ambloplitis	Adult	*Micropterus salmoides* *Micropterus dolomieu*
Proteocephalus tumidicollis	Adult	*Oncorhynchus mykiss* *Oncorhynchus clarki* *O. mykiss X O. clarki*
Proteocephalus pinguis	Adult	*Esox lucius*
Proteocephalus sp.	Plerocercoid	*Pimephales promelas*
Triaenophorus nodulosus	Plerocercoid Adult	*Lepomis macrochirus* *Micropterus salmoides* *Catostomus commersoni* *Esox lucius*

Table VI. Nematode parasites of Colorado fishes.

Nematode species	Observed host spp. In Colorado
Eustrongylides sp.	*Ictalurus punctatus* *Pimephales promelas* *Gambusia affinis*
Camallanus oxycephalus	*Notropis dorsalis*
Capillaria commersoni	*Pimephales promelas* *Notemigonis chrysoleucas* *Notropis stramineus* *Catostomus commersoni*
Capillaria sp.	*Cyprinella lutrensis*
Contracaecum spiculigerum	*Micropterus dolomieu* *Micropterus salmoides* *Ictalurus punctatus* *Perca flavescens* *Fundulus zebrinus*
Philometroides nodulosa	*Catostomus commersoni*
Rhabdochona cotti	*Cottus bairdi*
Rhabdochona sp.	*Cottus bairdi*

Table VII. Crustacean parasites of Colorado fishes.

Parasite species	Fish host species
Argulus sp.	*Apeltes quadracus*
Lernaea cyprinacea	*Oncorhynchus mykiss* *Pomoxis nigromaculatus* *Ictalurus punctatus* *Ctenopharyngodon idella* *Cyprinus carpio* *Catostomus commersoni* *Catostomus discobolus* *Catostomus latipinnus* *Xyrauchen texanus*
Salmincola californiensis	*Oncorhynchus mykiss* *Oncorhynchus nerka*
Salmincola sp.	*Salvelinus fontinalis*
Ergasilus sp.	*Micropterus salmoides* *Perca flavescens*
Neoergasilus japonicus	*Ameiurus melas* *Lepomis cyanellus*

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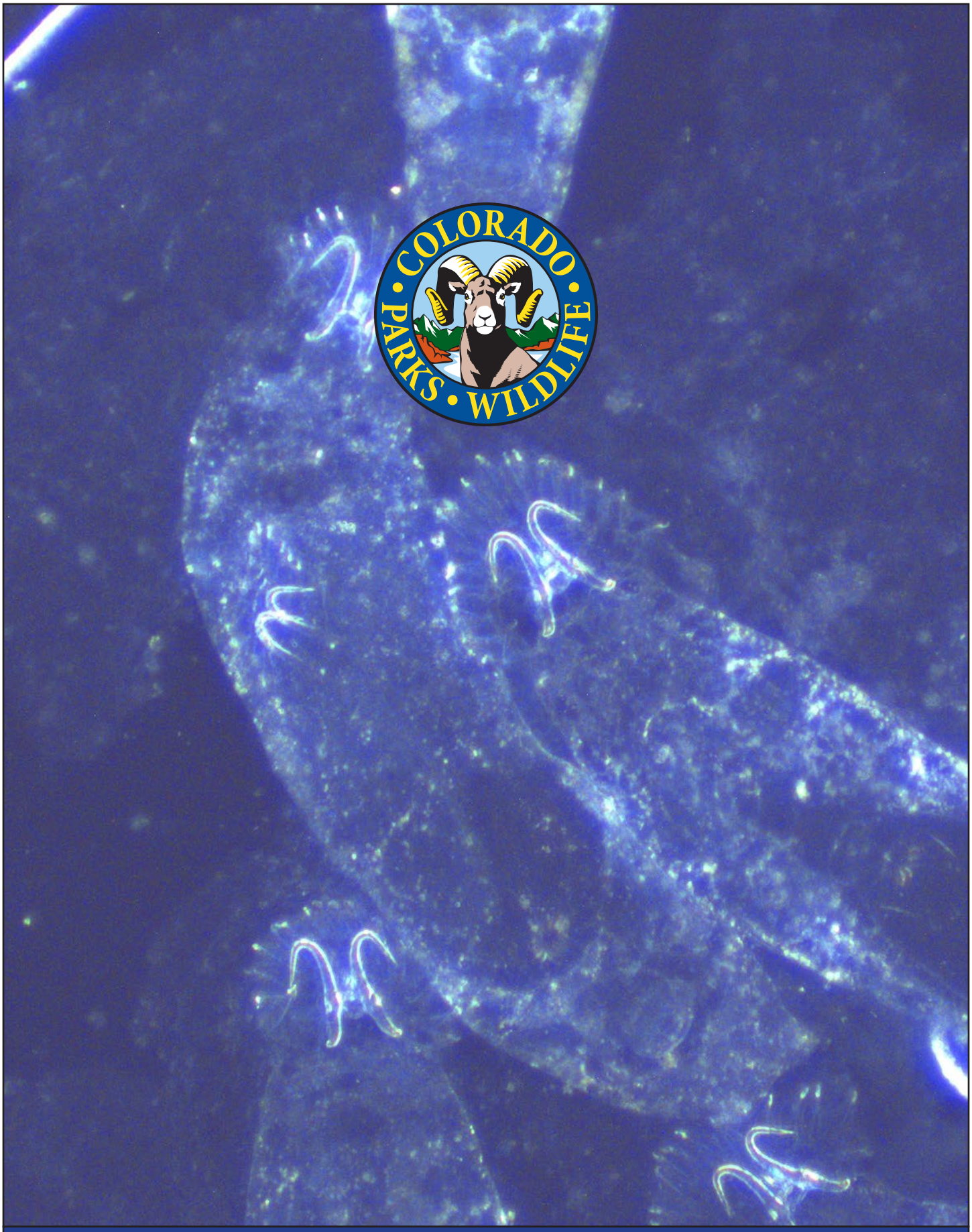

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