C. Dale Becker

Fisheries Research Institute, College of Fisheries
University of Washington
Seattle, Washington

The Parasitic Fauna of Teleosts in Six Washington Lakes[1]

The parasitic fauna associated with freshwater teleosts in lakes, reservoirs, and streams of the Pacific Northwest is imperfectly known, and much of the meager information now available concerns brief studies of individual species of parasites in restricted areas and habitats. Yet the management of freshwater fisheries in the region, particularly for salmonids, continues to grow in complexity with their increasing utilization by an expanding population. The Washington State Department of Game now estimates that 90 per cent of the trout caught in the state originates from hatchery plants. Soon, undoubtedly, the parasites of these stocks will receive as much attention as is now given to related infections of domestic animals. Such emphasis already has been devoted to parasites of fishes in the USSR (Dogiel, Petrushevski, and Polyanski, 1958; Bauer, 1959; Ergens and Ryšavý, 1964).

This paper lists and discusses the parasites of resident teleosts found in a survey of six Washington lakes from June, 1963, to June, 1966: Goodwin, Shoecraft, and Silver in western Washington (Snohomish County), and Canal, Crater, and Upper Goose in eastern Washington (Grant County). Brief considerations are given to the problems imposed by helminths affecting directly and indirectly the survival of salmonids originating from hatchery stock. The knowledge derived from this survey is of value to the effective management of rainbow trout and other fishes linked to salmonids by environmental association in waters of the Northwest states.

Some helminth parasites of freshwater fishes in limited areas of the Northwest region are reported in four previous surveys: Griffith (1953), from the Palouse region, Washington; Haderlie (1953), from northern California; Fritts (1959), from northern Idaho; and Alexander (1960), from central Oregon. In addition, Bangham and Adams (1954) identified 47 species of parasites from fishes in British Columbia, and Pratt and McCauley (1961) compiled an annotated catalog of the Trematoda recorded from vertebrate and invertebrate hosts in Washington, Oregon, Idaho, and British Columbia.

Study Lakes and Methodology

The study lakes represent the two diverse geographical areas of Washington, western and eastern. Observations were made in all three years in the western Washington lakes (Goodwin, Shoecraft, and Silver), in the latter two years in Canal and Crater (eastern Washington), and only in 1964-65 in Upper Goose (eastern Washington), which was rehabilitated with rotenone in the fall of 1965.

Samples were taken in all lakes from discrete populations of rainbow trout (*Salmo gairdneri*) that had been planted as fingerlings in the spring, and also from stocks of legal-sized fish (larger than 8 in.) planted in the fall in the western Washington lakes. From Goodwin Lake, samples of young coho salmon (*Oncorhynchus kisutch*) were taken as well in all years, and of cutthroat (*Salmo clarki*) and brook trout (*Salvelinus fontinalis*) in 1964-65.

Over the study period, 1053 salmonids from western Washington and 352 salmonids from eastern Washington were examined, and about 200 fishes of other species, primarily centrarchids and cottids. Samples were taken by gill net from each lake at irregular intervals of one to two months, and were comprised of five (fall-planted) to 10 (spring-planted) salmonids of each species, together with other fishes incidentally caught.

Most postmortems were conducted on fish which had been kept temporarily (a maximum of 48 hrs.) under refrigeration. Specimens were examined externally and internally under a dissecting microscope. The visceral remains were artificially digested in a pepsin-HCL solution (Meyer and Penner, 1962) to liberate encysted or overlooked helminths. Identifications of living parasites were verified from mounted whole specimens, prepared by standard techniques and retained in the author's collection.

The Parasitic Fauna

The parasites of salmonids and other fishes examined from all lakes are listed in Table 1. These parasites include three protozoans, two monogenetic trematodes, four digenetic trematodes, six cestodes, one nematode, one acanthocephalan, and a water mite. No parasitic fungi, myxosporidians, microsporidians, copepods, or leeches were observed.

Table 1. The parasitic fauna of freshwater teleosts collected in six Washington lakes, 1963-66 (X, parasite found; O, parasite not found; —, host not present or not collected; *, immature parasite).

Parasite species and teleost host	Western Washington			Eastern Washington		
	Goodwin	Shoecraft	Silver	Upper Goose	Canal	Crater
PROTOZOA						
Trichodina sp.						
Salmo gairdneri Richardson	O	O	X	O	O	O
Oncorhynchus kisutch (Walbaum)	X	—	—	—	—	—
Micropterus salmoides (Lacépède)	X	X	—	O	—	O
Trichophyra sp.						
S. gairdneri	X	X	X	O	O	O
Salmo clarki Richardson	X	—	—	—	—	—
Salvelinus fontinalis (Mitchill)	X	—	—	—	—	—
O. kisutch	X	—	—	—	—	—
Scyphidia sp.						
S. gairdneri	O	O	O	O	X	O
MONOGENEA						
Gyrodactylus sp.						
S. gairdneri	O	O	X	O	O	O
Cottus asper Richardson	O	O	—	—	—	X
Urocleideus sp.						
Lepomis gibbosus (Linnaeus)	—	—	—	X	—	X
M. salmoides	X	O	—	O	—	O

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Table 1. The parasitic fauna of freshwater teleosts collected in six Washington lakes, 1963-66 Continued

Parasite species and teleost host	*Western Washington* Goodwin	Shoecraft	Silver	*Eastern Washington* Upper Goose	Canal	Crater
DIGENEA						
* Neascus group						
S. gairdneri	X	X	X	O	O	O
* *Posthodiplostomum minimum* (MacCallum, 1921)						
L. gibbosus	—	—	—	X	—	X
Lepomis macrochirus Rafinesque	—	—	—	—	—	X
* *Diplostomum flexicaudum* (Cort & Brooks, 1928) Van Haitsma, 1931						
S. gairdneri	X	X	X	O	X	X
O. kisutch	X	—	—	—	—	—
Pomoxis annularis Rafinesque	—	—	—	—	X	—
Plagioporus augusticolle (Hausmann, 1896) Dobrovolny, 1939						
S. gairdneri	O	O	O	X	X	O
NEMATODA						
* *Philonema* sp.						
S. gairdneri	X	O	O	O	O	O
CESTODA						
Proteocephalus salmonidicola Alexander, 1951						
S. gairdneri	X	X	X	X	X	X
S. clarki	X	—	—	—	—	—
S. fontinalis	X	—	—	—	—	—
O. kisutch	X	—	—	—	—	—
* *Proteocephalus ambloplitis* (Leidy, 1887)						
S. gairdneri	X	X	O	X	O	O
S. clarki	X	—	—	—	—	—
S. fontinalis	X	—	—	—	—	—
O. kisutch	X	—	—	—	—	—
M. salmoides	X	X	—	X	—	O
C. asper	X	—	—	—	—	O
* *Diphyllobothrium* sp.						
S. gairdneri	X	X	X	O	O	O
S. clarki	X	—	—	—	—	—
S. fontinalis	X	—	—	—	—	—
O. kisutch	X	—	—	—	—	—
* *Schistocephalus solidus* (Müller, 1776)						
C. asper	X	—	—	—	—	O
Bothriocephalus claviceps (Goeze, 1782)						
L. gibbosus	—	—	—	X	—	X
L. macrochirus	—	—	—	X	—	X
Eubothrium salvelini (Schrank, 1790)						
S. gairdneri	X	O	O	O	O	O
ACANTHOCEPHALA						
Neoechinorhynchus rutili (Müller, 1780)						
S. gairdneri	O	O	X	O	O	O
ACARINA						
*Species inquirenda						
S. gairdneri	O	O	O	O	X	O

Three species were considered to contribute to environmental stress and/or intra-population mortalities of salmonids on the basis of incidence, intensity, site or sites of infection, and gross pathological conditions. These were plerocercoids of the cestodes *Diphyllobothrium* sp. and *Proteocephalus ambloplitis,* the bass tapeworm; and metacercariae of the digenetic trematode, *Diplostomum flexicaudum,* the eye fluke. Adults of the cestode *Proteocephalus salmonidicola,* the trout tapeworm, were adjudged to be of major importance also since they are readily detected by sportsmen and reduce the value of their catch.

Protozoa. Infections appeared only on the gills of salmonid fishes. *Trichodina* (Peritricha: Urecolaridae) and *Scyphidia* (Peritricha: Scyphidiidae) occurred sporadically; only a few fish were infected and neither species appeared in numbers sufficient to cause observable damage (extensive hyperplasia of the gill epithelia).

Trichophyra sp. (Suctoria: Dendrosomatidae), however, was frequently encountered but only on salmonids resident in the western Washington lakes. Fingerlings stocked in the spring and legal-sized fish planted in the fall both acquired moderate to heavy infections in about three months, but they did not appear to be injured. Although this suctorean morphologically resembles *T. micropteri* Davis, 1942, a parasite primarily of largemouth (*Micropterus salmoides*) and smallmouth bass (*M. dolomieui*), it did not appear on the gills of largemouths in Goodwin and Shoecraft lakes. It may prove a different species or subspecies restricted physiologically to salmonids.

Monogenea. Only one rainbow, collected in April, 1965, from Silver Lake, was infected with *Gyrodactylus.* A similar but not identical species was occasionally encountered on the gills of prickly sculpins (*Cottus asper*) from Crater Lake. *Urocleideus* were occasionally recorded from the gills of pumpkinseed (*Lepomis gibbosus*) taken in Upper Goose Lake and largemouth bass from Goodwin Lake.

The species of Monogenea are generally host-specific (Hargis, 1957), and are variously associated with but one or a few closely related species of fish. The monogenetic trematodes of sculpins and centrarchids would not normally appear on salmonids. Epizootics of gyrodactylosis commonly develop in hatcheries where conditions for transmission are favorable, causing heavy mortalities among small trout and salmon (Davis, 1953).

Digenea. Light infections of encysted metacercariae belonging to the *Neascus* group (Diplostomatidae) were occasionally noted beneath the epidermis of a few rainbows from western Washington. These parasites cause "black-spot" disease in fishes in certain waters where the necessary molluscan intermediate hosts abound. Heavy metacercarial infections of *Posthodiplostomum minimum* (Diplostomatidae) were encountered on and within the liver and other viscera of most bluegills (*Lepomis macrochirus*) and pumpkinseed in Upper Goose and Crater lakes, but no infections were observed in rainbow trout.

Metacercariae of the eye fluke, *D. flexicaudum,* appeared in the lenses of nearly all rainbows collected from Canal Lake. Relatively heavy (20-30/eye) or prolonged infections were characterized by opaqueness of the lenses, and corresponding loss of vision from parasitic-induced cataracts. Most rainbows overwintering in Canal Lake were severely affected by the following spring. Light infections were encountered in white crappie (*Pomoxis annularis*) from Canal Lake, and in rainbows and coho salmon from other waters (Table 1). Adults were found in one ring-billed gull (*Larus delawarensis*) at Canal Lake, and intermediate stages occurred in the snails *Physa propinqua* Tryon and *Lymnaea palustris nuttalliana* (Lea); other gulls and piscivorous birds can serve as definitive hosts of this trematode.

The only adult Digenea encountered were of the species *Plagioporus augusticolle* (Opecoelidae); five were found in the intestines of three rainbows from Upper Goose and Canal lakes, November and February, 1965. Haderlie (1953) reported the one previous record of this species in North America.

Nematoda. One immature roundworm, *Philonema* sp. (Dracunculoidea), each was found in the abdominal cavities of two rainbows from Goodwin Lake in the fall of 1965. This nematode was apparently not *P. oncorhynchi* Kuitunen-Ekbaum, 1933, a common parasite of lentic rainbows of Pierce County and lower King County (writer's observations). It did not become abundant in the study lakes over the period of investigation.

Cestoda. Two plerocercoids (50-70 mm in length) of *Schistocephalus solidus* (Pseudophyllidea) were found in the abdominal cavity of one prickly sculpin from Goodwin Lake. Immature and gravid adults of *Bothriocephalus claviceps* (Bothriocephalidae) were common in the intestines of pumpkinseed and bluegills from Upper Goose and Crater lakes. Neither of these cestodes appeared in salmonids. Plerocercoids of *S. solidus*, however, exhibit little host specificity and occur in many species of freshwater fish including salmonids in the western hemisphere.

One tapeworm, apparently *Eubothrium salvelini* (Amphicotylidae), appeared in the intestine of a rainbow from Goodwin Lake. This cestode, common in many salmonids in other western Washington lakes (writer's observations), did not become established in any of the study environments.

P. salmonidicola (Proteocephalidae) was the cestode most commonly encountered. It was present in nearly all salmonids examined but never appeared in other species of fish. Infections were generally heavier in the eastern Washington lakes, particularly in Crater Lake, where the number of immature and gravid adult parasites sometimes exceeded 200 per fish. Mature trout tapeworms were concentrated in the anterior intestine, their scolexes inserted in the pyloric caeca and their strobilae tangled in the gut lumen. Nearly all spring-planted fingerlings had acquired infections by the end of the first summer, apparently as a result of the abundance of infected zooplankton, the parasite's first intermediate host during this season. Legal-sized fish stocked in the fall in the western Washington lakes acquired relatively low infections during the winter.

Evidently, under normal conditions infections of *P. salmonidicola* do not harm their salmonid hosts severely. Rainbows burdened with heavy infections in Crater Lake exhibited an enlarged digestive tract and a pronounced thinning of the intestinal wall and pyloric caeca. The intestines of trout, however, are capable of considerable expansion, and none were ruptured. Although heavy infections appeared to block the anterior intestine, they seemed to have little adverse effect on the absorption of nutrients, for rainbows carrying the greatest number of cestodes were also the largest. Since the trout tapeworm is readily observable and is prevalent, it has frequently caused undue concern among sport fishermen over the quality of infected fish for consumption.

My observations on morphological variations of *P. salmonidicola* indicate that *P. primaverus* Neiland, 1952, collected from cutthroat trout near Stevenson (Skamania

County), Washington, is synonymous. Support for this contention is provided by the fact that *P. primaverus* was not identified from salmonids in British Columbia b) Bangham and Adams (1954). Furthermore, *P. salmonidicola* is probably the cestod identified only as *Proteocephalus* sp. by Fritts (1959) from cutthroat trout anc rainbow trout in northern Idaho, and by Griffith (1953) from rainbow trout in th Palouse area, Washington.

Plerocercoids of *Diphyllobothrium* sp. (Diphyllobothridae) appeared only in sal monids from the western Washington lakes. They are known to occur, however, i salmonids from high lakes of the Cascade Range in Washington, Oregon and norther Idaho (Alexander, 1960; Fasten, 1922; Fritts, 1959; Simms and Shaw, 1931). Thei apparent absence in the eastern part of the state poses a biological ambiguity since gull (*Larus* spp.), their probable definitive hosts, are common on most Washington lakes a some season of the year and migrate extensively along the Pacific Coast.

Invasion of *Diphyllobothrium,* in common with other cestodes infecting fish, occur through the ingestion of copepods containing procercoids. Small plerocercoids in sal monids characteristically encyst lightly in the visceral serosa. The larger and presumabl more active plerocercoids frequently penetrate the spleen, liver, kidney, and heart, bu not the body musculature. A major epizootic developed in Goodwin Lake rainbow during the fall and winter of 1963-64, when the average intensities of plerocercoid reached 77.5 per fish in the spring plants and 125 per fish in the fall plants. Heav infections appeared in young salmonids soon after release in the spring. Except fo the epizootic, infections in the fall plants were generally lighter than in the sprin plants, and coho salmon harbored relatively lighter infections than rainbows.

The *Diphyllobothrium* plerocercoids encountered in Washington salmonids grossl resemble but are probably not identical with the notorious "broadfish tapeworm, *D. latum,* which commonly enters the musculature of fish. Since the taxonomy c this genus is poorly known and many species described from plerocercoids are questior able (Stunkard, 1965; Meyer, 1966), specific identification was not possible. (Ther is no evidence that the Northwest *Diphyllobothrium* can be transmitted to man; remov of viscera from fish and thorough cooking preclude any possibility of human infection.

Plerocercoids of *P. ambloplitis* (Proteocephalidae) occurred in salmonids only i lakes where largemouth bass, the definitive host of this cestode, were also resident. Ther are no prior records of the bass tapeworm in the Pacific Northwest, but the *Protec cephalus* reported by Fritts (1959) in largemouth bass of northern Idaho may be thi species. Rainbow and cutthroat trout and prickly sculpins are new host records. It wa reported only twice in salmonids elsewhere: in lake trout, *Salvelinus namaycush,* fror New York State (Hunter and Hunter, 1932), and in lake trout and brook trout, *S. fon tinalis,* in Quebec (MacLulich, 1943).

The plerocercoids of *P. ambloplitis,* like those of *Diphyllobothrium,* encyst in th viscera of salmonids, tending to concentrate in the liver. Infections appeared in rair bow spring plants during the summer and were correlated with warm water temper tures and the reproduction of adult cestodes in bass. Peak infections were recorde in Shoecraft rainbows during the fall and winter of 1963-64 when average intensiti of plerocercoids reached 15-20 per fish, but infections in succeeding years were lowe Fall-planted rainbows acquired no infections during the winter. Young coho salmo were relatively resistant to infection by *P. ambloplitis.* Of 233 cohos from Goodwi

Lake, only nine contained small plerocercoids, and larger stages were not subsequently found; the cestode failed to establish itself in this species.

Acanthocephala. The only acanthocephalan encountered, and only in Silver Lake, was *Neoechinorhynchus rutili* (Neoechinorhynchidae). This parasite was relatively abundant in 1963-64 and common in 1964-65, but did not appear in the 1965-66 samples. Heavy infections occur in salmonids in other western Washington lakes (writer's observations).

Acarina. Larval water mites appeared in the air bladder of several rainbows from Canal Lake during the winter of 1965-66. Infections were probably accidental (the average was 6.1/fish), the spurious parasites entering through the pneumatic duct when the hosts fed on planktonic organisms.

Discussion

The parasitic fauna of teleosts must be considered as distinct entities in each of the six study lakes, and probably as well in most other Washington waters, because of different parasite, host, and environmental associations. Many of the parasites encountered in this survey occurred only sporadically in each population of fish species examined. Others were relatively common, presumably because of more favorable conditions for the completion of their life cycles. Only one parasite, the trout tapeworm, occurred in all six lakes, and it attained highest levels of infection in eastern Washington. The protozoan *Trichophyra* appeared only in the western Washington lakes. The cestode *Diphyllobothrium* also appeared only in western Washington, although earlier records by others indicate that it is widely distributed in the Pacific Northwest. The bass tapeworm existed only in lakes shared with largemouth bass, which is the parasite's definitive host. The trematode *P. minimum*, which did not infect salmonids, occurred only in lakes populated with centrarchids. The eye fluke, although recorded in five lakes, attained its greatest levels of infection in salmonids in Canal Lake where a large concentration of molluscs, the parasite's necessary first intermediate host, existed.

Many helminths and other parasites recorded from teleosts in surveys from surrounding regions (Alexander, 1960; Bangham and Adams, 1954; Fritts, 1959; Griffith, 1953) did not appear in the study lakes. It seems that the existing parasite fauna was of restricted nature; the faunal composition, however, may vary over a period of several years as a result of changed fish (host) composition and altered environmental characteristics, thereby making conditions less or more favorable for the establishment and maintenance of one or more species of parasite.

Some of the parasites identified probably originated from earlier introductions of their teleost hosts. For example, members of the family Centrarchidae were brought into the Pacific Northwest by man at the turn of the present century (Lampman, 1946). The cestodes *B. claviceps* and *P. ambloplitis*, parasites widely distributed in the original range of their normal hosts, were undoubtedly transferred along with these fish. However, the number of helminth species associated with centrarchids in the Northwest, in comparison with the East, is very limited. The absence of certain intermediate hosts or microecological factors necessary for completion of the parasite's biocycle tends to preclude establishment in a new environment.

The parasite fauna of Salmonidae and Centrarchidae clearly differ, and the parasites maturing in or on centrarchids (*e.g., P. minimum, B. claviceps*) do not normally infect trout and lacustrine salmon. This is the result of a parasite's host-specificity, briefly defined as the natural adaptability of the organism to living in or on a certain species of host. As a general rule, however, the intermediate stages of helminths (*e.g., Diphyllobothrium* sp., *P. ambloplitis, D. flexicaudum*) are less specific for teleost hosts than the definitive stage. Furthermore, parasites with an indirect life cycle (Digenea, Cestoda) are less specific for fish than those with a direct life cycle (Monogenea); and there is less host-specificity when there are two essential intermediate hosts than when there is but one.

Of the 18 parasites encountered, four warrant concern in the management of freshwater salmonids in the Pacific Northwest: *P. salmonidicola, P. ambloplitis, Diphyllobothrium* sp., and *D. flexicaudum.* Considerations of biological methods for their control which are practical for application at the management level have been evaluated in an unpublished paper of limited circulation (Becker, 1966). The effectiveness of these methods awaits further experimental studies and refinement.

Future investigations may reveal other parasitic species which influence adversely the survival of salmonid plants in Washington waters. In this survey the helminths which caused the greatest mechanical damage to host tissues, from gross observations were those that utilized fish as intermediate hosts. As a general rule, the normal definitive host in which a helminth achieves sexual maturity and reproduces does not suffer serious damage since the parasite also dies if the host is killed. The host must survive for the parasite to gain the maximum benefit from the association. If a fish serves as an intermediate host, however, the succeeding stage in the development of a helminth is usually reached only when the fish perishes. Death occurs when the fish succumbs to infection, either directly from tissue destruction or indirectly from the lowering of host resistance to environmental stresses, or is killed and eaten by the animal in which the parasite matures.

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James R. Habeck

Department of Botany
University of Montana
Missoula, Montana

Mountain Hemlock Communities in Western Montana[1]

The principal objective of this report is to provide a basic description of the mountain hemlock (*Tsuga mertensiana* (Bong.) Carr.) communities in western Montana. Such a description has importance because this species reaches its easternmost range limits in western Montana, and is one of the rarest coniferous species in Montana. Throughout its botanical range, mountain hemlock is regarded as a highly shade-tolerant, climax species, and the nature of the communities such a climax species forms at its range limits is of additional interest. Its occurrence in western Montana is generally confined to the moist, upper slopes of the Bitterroot Mountains separating Idaho and Montana. Subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*) are nearly constant associates of mountain hemlock in this region, with the three species occurring in various proportions.

Both subalpine fir and Engelmann spruce have rather wide distributional ranges in western North America, and both are commonly encountered at elevations above 5000 feet in the western Montana and northern Idaho area. Mountain hemlock, in contrast has its main center of distribution in the Pacific Coastal mountains, ranging from central California to Alaska, but exhibits a peninsular extension into the Inland Empire region. The eastern range extension is well correlated with a similar eastward penetration of moist, Pacific Coast air masses that have been described in greater detail elsewhere (Kirkwood, 1922, 1928; Daubenmire, 1943; Benson, 1957; and Habeck, 1963).

With the exception of a few brief references by Kirkwood (1922), which report the occurrence of mountain hemlock in Montana, there have been no detailed treatments made of this community type in Montana. Forest communities composed of mountain hemlock, subalpine fir, and Engelmann spruce which occur in contiguous portions of northern Idaho have been treated by Daubenmire (1952, 1966) as a portion of more extensive analyses of the vegetation in that area.

Daubenmire's 1952 description and classification of the spruce-fir zone in northern Idaho includes information on the sociologic position of *Tsuga mertensiana* in this forest zone. At that time (1952), Daubenmire indicated that mountain hemlock could function as a minor climax species in the spruce-fir forests, as a climax co-dominant with subalpine fir and Engelmann spruce, or as a climax species capable of replacing all

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