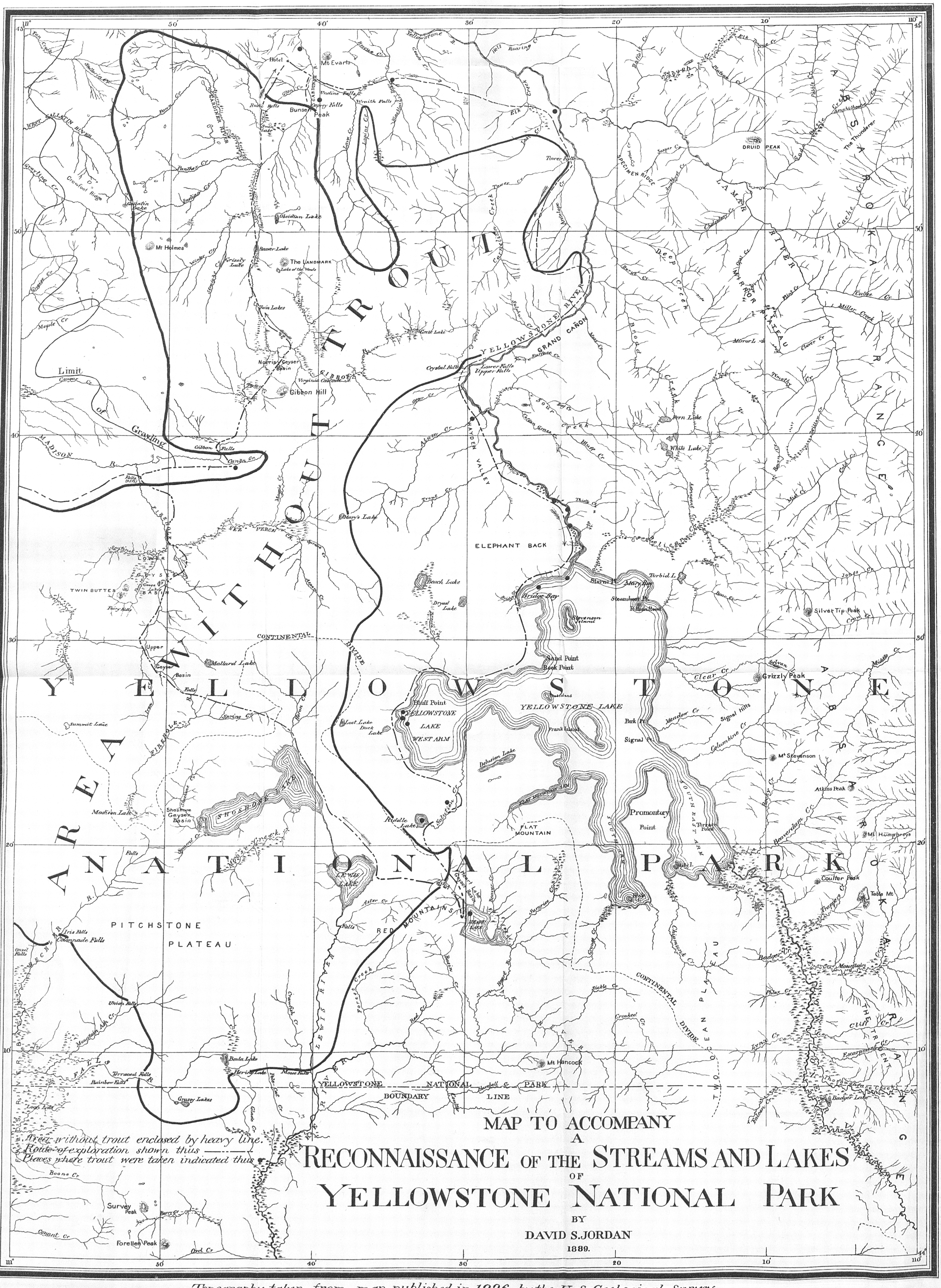


Topography taken from map published in 1886, by the U. S. Geological Survey.

2.—A RECONNOISSANCE OF THE STREAMS AND LAKES OF THE YELLOWSTONE NATIONAL PARK, WYOMING, IN THE INTEREST OF THE UNITED STATES FISH COMMISSION.

BY DAVID STARR JORDAN.

[Plates VI to XXII.]

In the summer of 1889, at the instance of Capt. F. A. Boutelle, U. S. Army, acting superintendent of the Yellowstone National Park, a brief visit was made to the Park by Hon. Marshall McDonald, U. S. Commissioner of Fish and Fisheries. It was made very evident from the observations of the Commissioner that much could be done towards enhancing the attractions of the great national "pleasuring ground" by the stocking of those of its various streams and lakes which are now destitute of fishes.

In September, 1889, the writer was requested by the Commissioner to make a visit to the Park for the purpose of procuring exact data preliminary to the work of introducing trout and other fishes. Dr. Charles H. Gilbert was asked to assist in this work.

The memorandum of instruction ran as follows:

"A considerable portion of Yellowstone Park is a volcanic plateau, in which have been excavated the lakes Yellowstone, Shoshone and Lewis, and a number of smaller lakes. The drainage from this region reaches the headwaters of the Snake and Missouri Rivers by falls impassable to fish, most of which are within the limits of the Park, and some beyond the limits. The waters above these falls (the aggregate basins embracing an area of some 1,500 square miles), so far as my observation extends, are entirely barren of fish except Yellowstone Lake and its tributaries, in which the black-spotted trout, *Salmo purpuratus* [*Salmo mykiss*], is very abundant. I have proposed to undertake to stock these waters with different species of *Salmonidæ*, reserving a distinct river basin for each.

"It is important to settle in advance what I believe to be the fact, that there is now an entire absence of fish fauna in the region above the falls, except Yellowstone Lake, and to determine precisely and fully the species to be found in the waters draining from the Park and below the impassable obstruction. It is also desirable to get information in regard to the parasitic flesh-worm which is so common in the Yellowstone trout, and to receive suggestions as to the study of this parasitic worm.

"The waters proposed to be stocked should also be examined with reference to the abundance of other forms of aquatic life which might serve as food for the fishes, both the fry and the adult. Special study in this regard should be made of the waters of

Lakes Shoshone and Lewis, which it is proposed to stock with the land-locked salmon and Loch Leven trout.

"Capt. F. A. Boutelle, U. S. Army, acting superintendent of the Park, will be notified by telegraph of your proposed exploration, and requested to give you every facility for it."

Other engagements rendered it impossible for us to start before September 24, 1889, a late date for such work, as the climate of the Park is subarctic, and serious snow-storms may be expected at any time after the middle of September. We were very fortunate, however, as we arrived in the Park just after a storm, and throughout our stay Indian-summer weather prevailed and no time was lost on account of snow.

The following is the itinerary of the trip:

September 24.—Left Bloomington, Ind., in company with Dr. Charles H. Gilbert and Mr. William W. Spangler, librarian of the Indiana University, volunteer assistant.

September 27.—Arrived at the Mammoth Hot Springs.

September 28.—Examined Gardiner River, above and below the Osprey Falls; also visited Obsidian and Glen Creeks.

September 30.—Seined Gardiner River about the mouth of Hot River.

October 1.—Started with tents, pack-horses, etc., on a tour of the Park, accompanied by Elwood Hofer, guide; David Rhodes and John Innes, packers; and Richard Randall, cook. Visited Lava Creek and its falls, and Black-tail Deer Creek. Encamped at night at Yancey's on Elk Creek.

October 2.—Visited Tower Creek and Autelope Creek, crossed Mount Washburn and encamped at its base on the south side.

October 3.—Ascended the Yellowstone River and encamped on its banks about 1½ miles south of the Giant's Cauldron.

October 4.—Encamped on Yellowstone Lake, on the north shore of the western arm or "Thumb."

October 5.—Passed around the "Thumb" of the Lake; ascended Solution Creek, and encamped on Riddle Lake.

October 6.—Crossed the Divide to Heart Lake; examined Witch Creek.

October 7.—Went from Heart Lake across the base of Red Mountain; passed Lewis Lake to Shoshone Lake; encamped at the mouth of Heron Creek.

October 8.—Went from Shoshone Lake across the Divide to Firehole River; encamped at the Upper Geyser Basin.

October 9.—Went down the Firehole River to its falls; encamped on Cañon Creek.

October 10.—Examined Gibbon River, Twin Lakes, Obsidian Creek, etc. Reached Mammoth Hot Springs in the evening.

October 11.—Received fishes from Horsethief Spring, obtained by Mr. E. R. Lucas. Left Mammoth Hot Springs.

October 15.—Reached Bloomington, Ind.

Our trip was necessarily considerably hurried, though long enough to enable us to make out the leading points of the problems in question. A more complete survey of the Park and the surrounding region would enable us to work out in detail the distribution of the fishes found lower down the streams. The distribution of the Miller's Thumb or Blob (*Cottus bairdi punctulatus*) needs special study. The distribution and conditions of life of the parasitic worm (*Dibothrium cordiceps* Leidy), found in the trout of Yellowstone Lake, as well as those of the larger worm found in the sucker of Witch Creek, will demand a whole summer's attention from some one familiar with the subject.

In all our work we had the cordial and intelligent co-operation of Capt. F. A. Boutelle, acting superintendent of the Park, of Lieut. W. E. Craighill, of the U. S. Engineer Corps, and of Lieutenant Edwards, U. S. Army. We were fortunate in securing

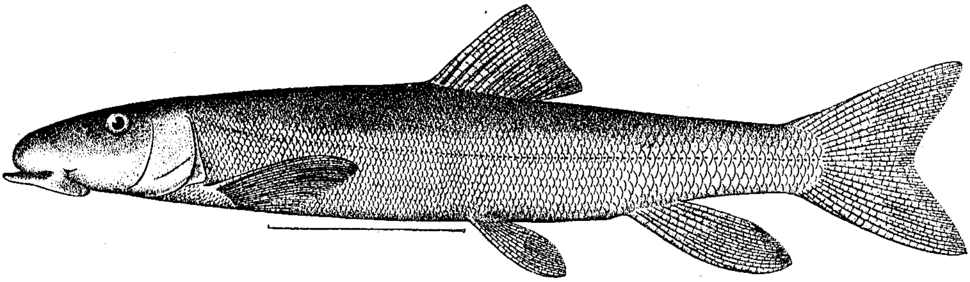


FIG. 1. GRAY SUCKER (*Catostomus griseus*). (See page 46.)

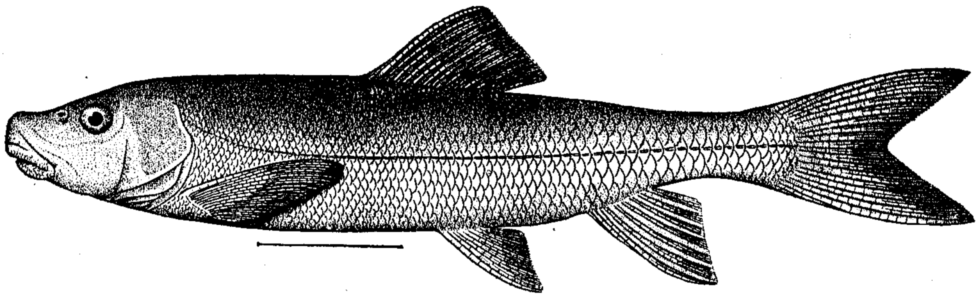


FIG. 2. RED HORSE SUCKER (*Catostomus ardens*). (See page 47.)

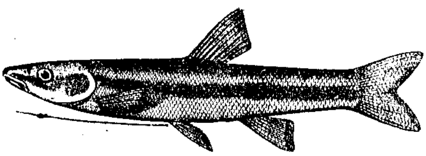


FIG. 3. THE DACE (*Rhinichthys dulcis*). (See page 48.)

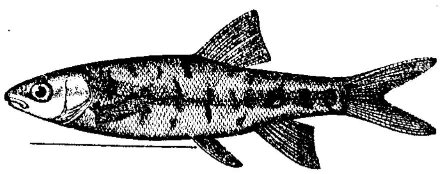


FIG. 4. (*Agosia nubila*). (See page 48.

the services, as guide, of Mr. Elwood Hofer, to whom we are indebted for much valuable help. Mr. E. R. Lucas, of the distributing division of the U. S. Fish Commission, also aided us materially by collecting specimens from tributaries of Madison River and Henry River. Mr. Arnold Hague, of the U. S. Geological Survey, also gave us considerable valuable information.

The following is a classified list of the waters examined, those lakes and streams containing trout being printed in italics:

Yellowstone Basin:

Yellowstone River.
Yellowstone Lake (altitude, 7,741 feet).
Riddle Lake (altitude, 7,900 feet).
Solution Creek.
Bridge Bay Creek.
Arnica Creek.
Trout Creek.
Alum Creek.
Cascade Creek.
Sulphur Creek.
Antelope Creek.
Tower Creek.
Lost Creek.
Elk Creek.
Oxbow Creek.
Geode Creek.
Black-tail Deer Creek.
Lava Creek.
Lupine Creek.
Gardiner River.
Twin Lakes.
Obsidian Creek.
Beaver Lake.

Yellowstone Basin—Continued:

Winter Creek.
Indian Creek.
Glen Creek.

Madison Basin:

Madison River.
Firehole River.
Iron Spring Creek.
Little Firehole Creek.
Goose Lake.
Nez Percé River.
Gibbon River.
Cañon Creek.
Horsethief Spring.

Snake River Basin:

Shoshone Lake (altitude, 7,740 feet).
Heron Creek.
Lewis Fork.
Lewis Lake (altitude, 7,720 feet).
Heart Lake (altitude, 7,469 feet).
Witch Creek.
Howard's Creek.
Henry's Lake.

The Yellowstone Park is a high plateau, having a general elevation of 7,000 to 8,000 feet above the sea. Its entire surface, with the exception of the Gallatin range of mountains in the northwest, and some granitic summits in the northeast, is covered with lava, with its varieties of obsidian, rhyolite, etc. This mass of lava covers to a great depth what was previously a basin in the mountains. According to Mr. Hague, the date of the lava flow is probably Pliocene. Its existence was of course fatal to all fish life in this region. Since its surface has become cold, the streams flowing over it, most of them now wholly unaffected by the heat within, have become well stocked with vegetable, insect, and crustacean life, but are for the most part destitute of fishes. The cause of this absence of fishes is to be found in the fact that nearly all the streams of the Park on leaving the lava beds do so by means of vertical water-falls situated in deep cañons. Except in the Yellowstone and its tributaries, in Gibbon River and in Lava Creek, no fishes have been found above these falls, and the presence of fishes in the Upper Yellowstone and Lava Creek is doubtless due to the imperfect character of the water-sheds separating these streams from others.

The following is a list of the water-falls in the Park, supposed to be unsurmount able by trout. No account is here taken of the numerous falls in small brooks or in mountain torrents unsuited to fish life:

Great Falls of the Yellowstone, 308 feet high.
Upper Falls of the Yellowstone, 109 feet high.
Crystal Falls in Cascade Creek, 129 feet high.
Tower Falls in Tower Creek, 132 feet high.
Undine Falls in Lava Creek, 60 feet high.
Lower Falls in Lava Creek, 50 feet high.
Wraith Falls in Lupine Creek, 100 feet high.
Falls in Slough Creek.
Osprey Falls in Gardiner River, 150 feet high.
Rustic Falls in Glen Creek, 70 feet high.
Virginia Cascades in Gibbon River, 60 feet high.
Gibbon Falls in Gibbon River, 80 feet high.
Keppler's Cascade in Firehole River, 80 feet high.
Firehole Falls in Firehole River, 60 feet high.
Falls in Lewis River, 80 and 50 feet high.
Moose Falls on Crawfish Creek.
Union Falls on Mountain Ash Creek.
Terraced Falls and Rainbow Falls on Falls River.
Iris Falls and Colonnade Falls on Bechler River.

Outside the Park the falls in Clarke's Fork of the Yellowstone exclude fish from that river, and perhaps the great Shoshone and American Falls in Snake River exclude from the upper part of the stream the fauna of the Lower Columbia. Another supposed obstacle to the spread of fish life in the Yellowstone Park is the presence of the innumerable hot springs, solfataras, and geysers, for which the region is famous. Although these springs exist in almost every lake basin, cañon, or other depression in the Park, we do not think that in their present condition, at least, they would stand in the way of the stocking of the streams and lakes with fishes.

The water of the geysers and other calcareous and silicious springs does not appear to be objectionable to fishes. In Yellowstone Lake trout are especially abundant about the hot overflow from the Lake Geyser Basin. The hot water flows for a time on the surface, and trout may be taken immediately under these currents. Trout have also been known to rise to a fly through a scalding hot surface current. They also linger in the neighborhood of hot springs in the bottom of the lake. This is probably owing to the abundance of food in these warm waters, but the fact is evident that geyser water does not kill trout.

In Heart Lake trout were found most plentiful about the mouth of the Warm Witch Creek. Suckers and chubs (*Leuciscus atrarius*) ascend this creek for some distance, although half its water comes from geysers and hot springs. The chubs are found in water in which the temperature is about 85° Fahr.

The Hot River, which drains the Mammoth Hot Springs, flows into Gardiner River. Trout abound about the mouth of this stream, and here, as in numerous other places in the Park, the conventional trick of catching a trout in cold and scalding it in hot water is possible. Below the mouth of this Hot River young suckers (*Catostomus griseus*) were found in a temperature of about 88°, and young trout in a temperature of about 75°.

Miller's Thumbs abound in the Gibbon River, about the hot springs. Three were found boiled in the edge of the river below Elk Park, at the mouth of a hot tributary. The volume of hot water poured into any river is greatest in the Firehole, below the upper Geyser Basin. The stream, however, is hardly warm, and the water has little mineral taste, though the abundant vegetation gives it something of the flavor of stewed plants. Even this stream, it would seem, is probably not so hot nor so heavily charged with mineral substance as to be unfit for trout. Its waters constitute a very dilute alkaline silicious solution. The following analysis of the waters of Firehole River is given by Gooch and Whitfield:*

* Bull. U. S. Geol. Survey, No. 47, page 57.

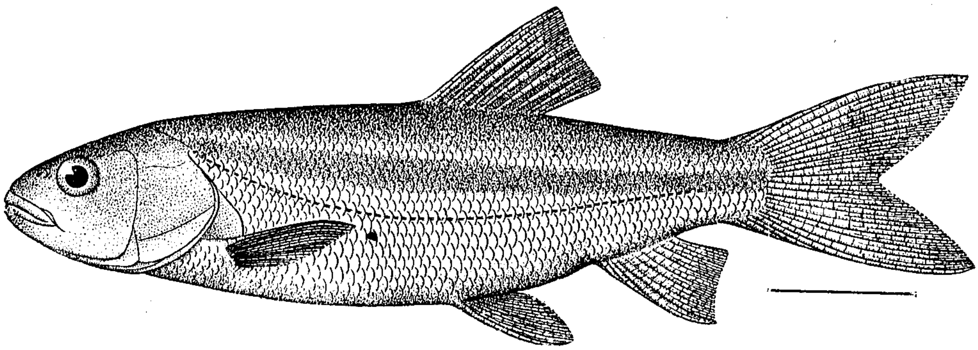


FIG. 5. THE UTAH CHUB (*Leuciscus atrarius*). (See page 48.)

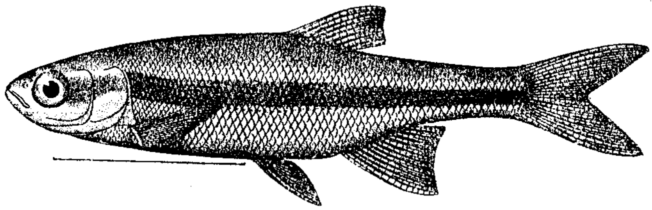


FIG. 6. (*Leuciscus hydrophlox*). (See page 48.)

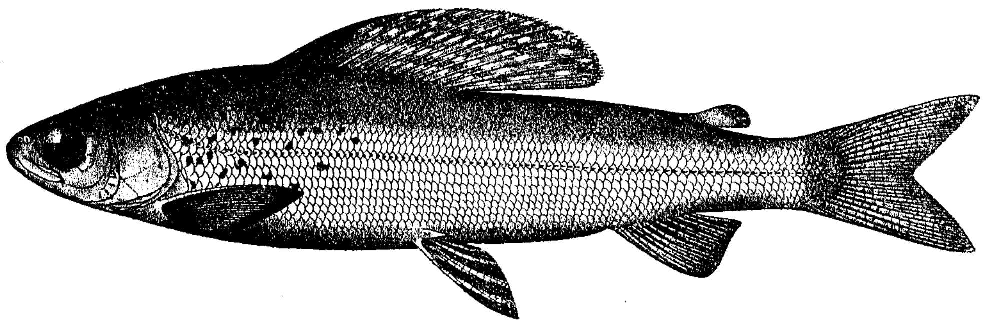


FIG. 7. THE GRAYLING (*Thymallus signifer*, var. *ontariensis*). (See page 49.)

[The sample was taken from above the mouth of Nez Percé River August 24, 1884; temperature 8° C; reaction, alkaline; specific gravity, 1.00031.]

[Hypothetical combination.]

Constituents.	Grams per kilogram of water.	Per cent. of total material in solution.	Constituents.	Grams per kilogram of water.	Per cent. of total material in solution.
Na_2CO_3	0.1201	27.51	$Na_2B_4O_7$	0.0087	1.99
SiO_2	0.0965	22.10	$LiCl$	0.0067	1.53
$NaCl$	0.0867	19.86	Al_2O_3	0.0059	1.35
CO_2	0.0457	10.47	$MgCO_3$	0.0024	0.55
KCl	0.0325	7.44			
$CaCO_3$	0.0165	3.78		0.4366	100.00
Na_2SO_4	0.0149	3.42			

This analysis may be compared with that given by the same authors for the Gardiner River above and below the mouth of Hot River, in both of which localities trout are abundant.

[Gardiner River above Hot River, October 12, 1883; temperature 8° C.]

[Hypothetical combination.]

Constituents.	Grams per kilogram H_2O.	Per cent. of material in solution.	Constituents.	Grams per kilogram H_2O.	Per cent. of material in solution.
$CaCO_3$	0.0625	29.25	Al_2O_3	0.0079	3.70
SiO_2	0.0469	21.95	K_2SO_4	0.0056	2.62
Na_2CO_3	0.0340	15.91	$MgCO_3$	0.0018	0.84
CO_2	0.0286	13.38	$LiCl$	trace	....
Na_2SO_4	0.0161	7.53			
KCl	0.0103	4.82		0.2137	100.00

[Gardiner River below Hot River, September 26, 1884; temperature, 13° C.]

Constituents.	Grams per kilogram H_2O.	Per cent. of material in solution.	Constituents.	Grams per kilogram H_2O.	Per cent. of material in solution.
$CaCO_3$	0.1873	37.94	KCl	0.0200	4.00
CO_2	0.0852	17.26	$MgCO_3$	0.0094	1.95
$MgSO_4$	0.0739	14.97	Al_2O_3	0.0019	0.38
Na_2SO_4	0.0549	11.12	$LiCl$	trace	....
$NaCl$	0.0339	6.87			
SiO_2	0.0272	5.51		0.4937	100.00

There are, however, numerous springs in the park which discharge sulphurous liquids (some of them the black ammonic sulphide $(NH_4)_2S$, very offensive in odor and doubtless fatal to fishes. Most of these springs have but a very slight discharge, and so exert no appreciable influence on the streams. The upper part of Obsidian Creek between Twin Lakes and Beaver Lake is the only running stream noticed by us as likely to prove uninhabitable by fishes. An obstacle of equal importance in the lower course of the same creek is the series of three beaver-dams, to which the existence of Beaver Lake is due; these, with their covering of brush, must be wholly impassable.

The following is a list of the species of fishes found by us in the park, with a list of the localities from which specimens of each were actually obtained:

Catostomidæ (Suckers).

1. *Catostomus griseus* (Girard). Gardiner River (below Mammoth Hot Springs).
2. *Catostomus ardens* Jordan & Gilbert. Witch Creek; Heart Lake.

Cyprinidæ (Minnows, Chubs, etc).

3. *Rhinichthys dulcis* (Girard). Gardiner River (below Mammoth Hot Springs).
4. *Agosia nubila* (Girard). Witch Creek; Heart Lake.
5. *Leuciscus atrarius* (Girard). Witch Creek.
6. *Leuciscus hydrophlox* (Cope). Heart Lake; Witch Creek.

Thymallidæ (Grayling).

7. *Thymallus signifer* Richardson. Horse-thief Spring; Madison River; Gallatin River.*

Salmonidæ (Trout, etc.).

8. *Coregonus williamsoni* Girard, var. *cismontanus* Jordan. Horse thief Spring; Madison River, Gardiner River (below falls); Yellowstone River (below the falls).
9. *Salmo mykiss* Walbaum. The "Red-throated," *Cut-throat*, or "Rocky Mountain Trout." Heart Lake; Henry Lake; Howard Creek; Yellowstone Lake; Yellowstone River (above falls); Yellowstone River (at Livingston); Gardiner River (below falls); Black-tail Deer Creek; Alum Creek; Solution Creek; Riddle Lake; Cañon Creek; Madison River.
10. *Cottus bairdi* Girard, (var. *punctulatus* Gill); Gibbon River (above falls); Cañon Creek; Horse-thief Spring.

In August and September, 1889, plants of fishes were made by the U. S. Fish Commission as follows:

Eastern Brook Trout (*Salvelinus fontinalis*), in Glen Creek and in Gardiner River above the falls (5,000 fishes).

Rainbow Trout (*Salmo irideus*), in Gibbon River, above Virginia Cascades, (1,000 fishes).

Loch Leven Trout (*Salmo trutta levenensis*) in Firehole River above Keppler's Cascades (1,000 fishes).

Mountain Whitefish (*Coregonus williamsoni*). One thousand fishes in each of the Twin Lakes and in Yellowstone River below the lake.

Red-throat Trout (*Salmo mykiss*), in Lava Creek above the falls.

THE FISHES OF THE PARK.

The following notes are those made by us on the species of fishes collected in the Park:

1. **Catostomus griseus** Girard. (*Acomus lactarius* Girard; *Catostomus retropinnis* Jordan.) (Plate VII, Fig. 1.)

This sucker is abundant in the Yellowstone and Gardiner Rivers below the falls, and numerous young specimens were taken by us in Gardiner River near the bridge below the mouth of the Hot River. No large examples were seen, but the species is said to reach a length of 18 inches.

These specimens apparently belong to the form described by Girard from the Milk River, Montana, under the name of *Acomus lactarius*. This is probably a slight variety, or perhaps it is identical with the species found in the Platte Valley, and described by Girard under the name of *Acomus griseus*. It is probable that *Catostomus retropinnis* Jordan (from the Milk River and the Platte) was based on adult specimens of *Catostomus griseus*, a species very close to *Catostomus catostomus*.

* Specimens not seen by us.

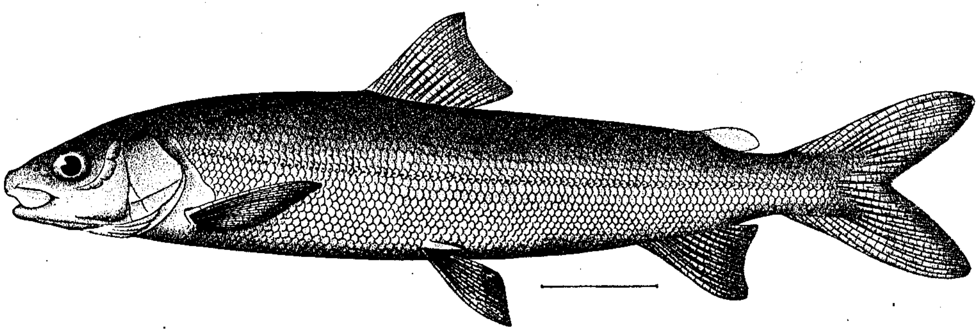


FIG. 8. MOUNTAIN WHITEFISH (*Coregonus williamsoni*, var. *cismontanus*). (See page 49.)

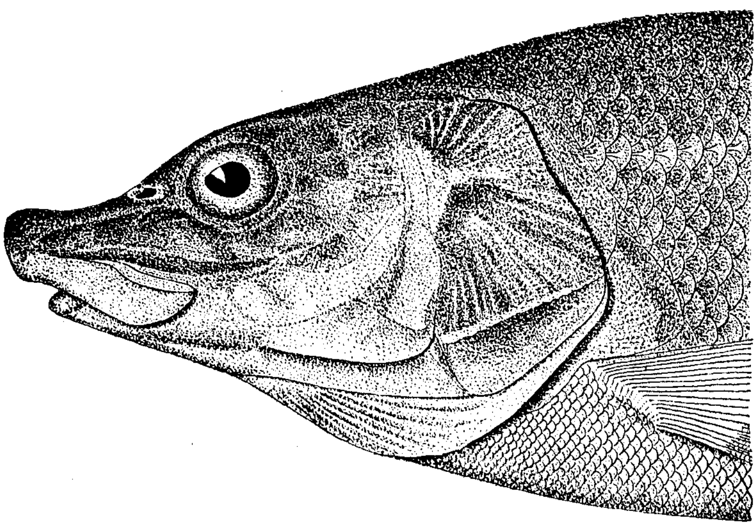


FIG. 9. MOUNTAIN WHITEFISH (*Coregonus williamsoni*, var. *cismontanus*).
(Head of breeding male.) (See page 49.)

Compared with the young of *C. catostomus* (from Keweenaw Bay), *C. griseus* has the upper lip much thicker, with 5 or 6 instead of about 3 rows of tubercles. The lower lip is much larger in *C. griseus*, and the lower jaw has a rather distinct cutting edge. The head is larger, and the eye larger in *griseus*, and the scales on the posterior part of the body are less reduced in size. I am not sure, however, of the permanent value of any of these characters. The specimens from Gardiner River have the scales 88 to 90, while in more typical examples of *C. griseus* (from the South Platte River at Hartsell's Hot Springs and at Denver) the scales are 105 to 110. Should the difference prove constant, the specimens from the Upper Missouri region should stand as a separate variety of *Catostomus griseus lactarius*. It is not at all likely that these characters can be depended upon.

Dorsal rays 10 or 12; fontanelle well developed; color, dark gray, irregularly mottled and barred with black.

2. Catostomus ardens Jordan & Gilbert. (Plate VII, Fig. 2.)

Head $3\frac{5}{6}$ to 4 in length; depth, $4\frac{1}{4}$ to $4\frac{1}{2}$; D. 2.11 to 2.13; A 7. Scales 12–70 to 72–12. Length of types, 6 to 8 inches.*

Body moderately elongate, not strongly compressed; head broad, acutely conical, the snout short and sharp, $2\frac{1}{3}$ to $2\frac{1}{2}$ in head. A depression behind tip of snout, so that it forms a distinct projecting nose. Eye small, $5\frac{1}{2}$ in head. Lower jaw rather strong, obliquely placed, $2\frac{4}{5}$ in head. Mouth small, the lips full, the upper thick, with about 6 rows of rather coarse papillæ; lower with many rows of papillæ which are coarser in front, the lip deeply bifid: lower jaw without evident cartilaginous sheath. Interorbital space broad, $2\frac{3}{4}$ in head. Fontanelle well developed. Scales small, crowded anteriorly, about 32 before dorsal. Fins moderate; dorsal with its free margin nearly straight, its longest rays reaching when depressed somewhat beyond the middle of the last rays, their length $1\frac{2}{3}$ in head. Caudal moderate, well forked, the upper lobe the longer, the peduncle moderate. Pectorals long, $1\frac{1}{8}$ in head. Ventrals and anal moderate.

Color grayish-olive above, paler below; no distinct markings; the young vaguely barred with dark olive. Very abundant in the warm waters of Witch Creek, the young also abundant in Heart Lake. The largest taken are about 8 inches in length.

This species seems to be indistinguishable from the common sucker of Utah, *Catostomus ardens*, and is quite unlike the *Catostomus macrocheilus* of the Lower Columbia. This fact, together with the general affinity of the fishes of Heart Lake with those of the Great Basin, suggests that the fauna of the Upper Snake River, above the great Shoshone Falls, may have been derived from the Great Basin rather than from the Lower Columbia. The effect of the Shoshone Falls as a barrier to the distribution of fishes is worthy of a careful investigation.

About one specimen in every three or four of *Catostomus ardens* was found to contain a long, flat, intestinal worm of unusual size, so large as much to distend the walls of the abdomen. Some of these worms were more than a foot in length, and greater than the whole abdominal viscera of the fish. The worm is apparently loose in the abdominal cavity, and can be found in every case by making an incision along the median line of the belly. The infected individuals did not appear poor or dis-

* A much larger example, some 16 inches long, has since been sent us by Dr. S. A. Forbes. It was taken with a trammel net in Heart Lake in July, 1890. The lips seem a little fuller in the Heart Lake fishes as compared with those from Utah.

eased. These and other worms taken by us in fishes of the Park are the subject of a special report by Prof. Edwin Linton.

3. Rhinichthys dulcis (Girard.) (Plate VII, Fig. 3.)

This species is common in nearly all cold clear streams in the Rocky Mountains. It is rather abundant in the Gardiner River below the falls, and it might probably be introduced to advantage in the rivers above the falls as food for trout. Our specimens agree with all others examined by us from both slopes of the Rocky Mountains in having the barbel very small and the insertion of the dorsal a little farther back than in the Eastern species, *Rhinichthys cataractæ*, midway between nostril and base of caudal. In *R. cataractæ* the insertion of the dorsal is about midway between tip of snout and base of caudal. The western form may stand as *Rhinichthys dulcis* (=*Argyreus dulcis* Girard=*Rhinichthys maxillosus* Cope=*Rhinichthys transmontanus* Cope=*Rhinichthys luteus* Garman=*Rhinichthys ocella* Garman.)

Rhinichthys dulcis is an active little minnow, abounding about cascades and in swift brooks. It reaches a length of about 5 inches.

4. Agosia nubila (Girard). (Plate VII, Fig. 4.)

A little fish inhabiting brooks and swift waters, agreeing very closely in appearance and habits with *Rhinichthys dulcis.* It is as abundant in the Columbia basin as the other is on the eastern side. It extends its range southward to Utah, and perhaps beyond. We found this species rather common in the warm waters of Witch Creek. Scales 63 to 65; lateral line complete.

5. Leuciscus atrarius Girard, (Plate VIII, Fig. 5.)

I identify with Girard's *Siboma atraria* a chub which is abundant in Heart Lake and which ascends its warm tributary—Witch Creek—in great numbers, going up farther than any other fish (temperature 88°). It reaches a length of about 7 inches.* *Cheonda cœrulea*, known from a single specimen from Lost River, Oregon, may be the same also. The Witch Creek fish is less slender than Girard's type, but the probabilities are that the two are identical.

The Witch Creek fish seems to belong to the same species as the common chub of Utah (*Leuciscus atrarius*). It is a rather slenderer fish than the latter, with heavier head, lower back, and more slender tail; scales a little smaller, 11–56–6; 28 to 30 before dorsal (23 to 28 in *atrarius*). In form of mouth, eye, fins, and coloration there is no evident difference. Color dusky olive; the scales everywhere with dark points. Head 4 in length; depth $3\frac{4}{5}$; teeth 2, 5, 4, 2, with rather broad grinding surface. Mouth oblique, the maxillary just reaching eye; lateral line much decurved; dorsal inserted behind ventrals; pectorals short, not nearly reaching ventrals.

The females of this species were full of eggs at the time of our visit. No worms were found in this species.

6. Leuciscus hydrophlox (Cope). (Plate VIII, Fig. 6.)

A few specimens, the largest about 4 inches long, were taken in Heart Lake and in Witch Creek. This species was previously known from Blackfoot Creek, Idaho,

* A specimen over a foot long and entirely similar to the large chubs of Utah Lake has been lately sent us by Dr. S. A. Forbes. It was taken with a trammel net in Heart Lake in July, 1890.

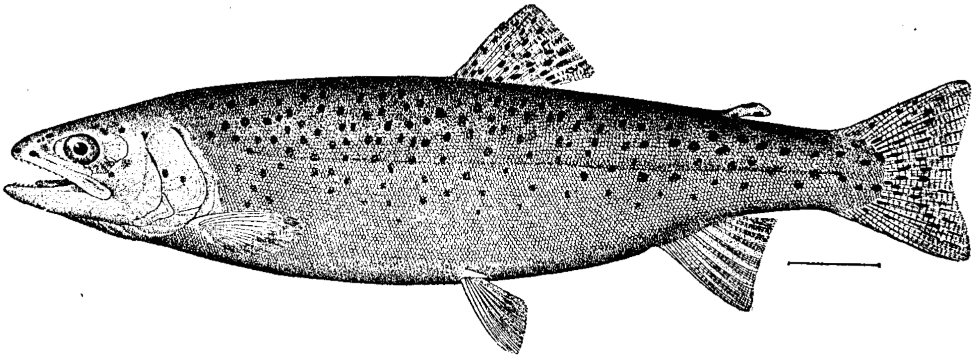


FIG. 10. RED-THROATED TROUT (*Salmo mykiss*). (See page 50.)

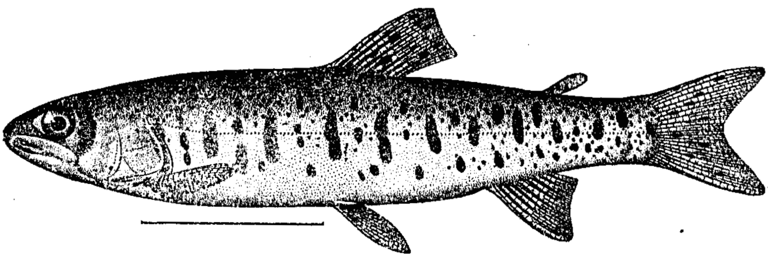


FIG. 11. RED-THROATED TROUT (*Salmo mykiss*). Young. (See page 50.)

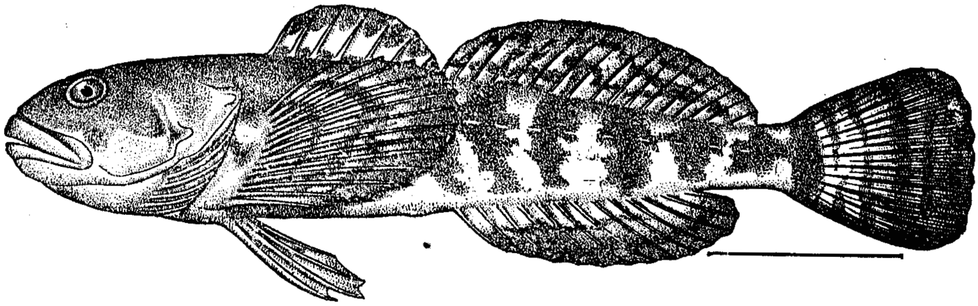


FIG. 12. MILLER'S THUMB (*Cottus bairdi*, var. *punctulatus*). (See page 53.)

which flows into the Snake River lower down. This species is allied to *Leuciscus montanus* (= *Clinostomus tænia*) Cope, differing chiefly in the longer anal, sharper snout, and smaller eye. In technical characters it has much in common with *Richardsonius lateralis*, which suggests that *Richardsonius* may be a near ally of the *Clinostomus* group of the genus called *Leuciscus*.

Head, $4\frac{1}{4}$ in length; depth, $3\frac{1}{4}$ to 4. Anal 2, 13; lat. l. 55. Color silvery, a plumbeous lateral band, dusted with dark points; traces of red coloration on belly in largest specimen. Lateral line much decurved. Pectoral and ventral fins long and falcate. Base of anal $6\frac{1}{2}$ in body; lower jaw slightly projecting; upper jaw less blunt and decurved than in *L. montanus*. Eye as long as snout; $3\frac{1}{2}$ in head (young).

7. **Coregonus williamsoni** Girard (var. *cismontanus.*) (Plate IX, Figs. 8 and 9.)

The mountain whitefish is abundant in the Madison River below the falls. It is said to be equally common in the Yellowstone River, but none were obtained by us. It is a slender and graceful fish, readily taking the fly like a grayling or trout. It is most abundant, so far as we have noticed, in the eddies or deeper places in swift streams. It seems to be essentially a river fish, rather than an inhabitant of lakes.

Comparing our specimens from Horsethief Creek, a tributary of Madison River, with others collected at Walla Walla (Washington, Captain Bendire), these specimens from the Missouri seem notably different, the body being much more slender and the fins shorter. In coloration, and in the form of the head, mouth, and eye, there is substantial agreement.

In the Madison River specimens, the depth is 5 to $5\frac{1}{4}$ in the length, the head 5, the pectoral, $1\frac{1}{2}$ in head, the ventral $1\frac{4}{5}$, the longest dorsal ray, $1\frac{1}{2}$, the scales, 90. In the Walla Walla fishes, the depth is $4\frac{1}{2}$ to $4\frac{3}{4}$, the head $4\frac{3}{5}$, the pectoral $1\frac{1}{5}$, the ventral $1\frac{2}{5}$, the dorsal $1\frac{1}{3}$, the scales 83. Specimens from the Willamette River at Salem, Oregon, and others from Jordan River and Provo River in Utah, agree in these respects with the specimens from Walla Walla.

If these differences should prove at all constant, the Missouri River whitefish should stand as a distinct variety, *Coregonus williamsoni cismontanus*. The type of *Coregonus couesi* Milner, is from Chief Mountain Lake, Montana, a tributary to the Saskatchawan on the east side of the Divide. This specimen, lately examined by me, shows the prolonged snout characteristic of the males in the breeding season. In all respects, so far as I can see, it agrees with the typical form of *Coregonus williamsoni* and not with the variety found in the Park. Its scales are 84; the pectoral is $1\frac{1}{5}$ in the head, $5\frac{1}{2}$ in the body; the ventrals are $1\frac{1}{3}$ in head. The depth $4\frac{1}{2}$ in length; the dorsal is broken. *C. williamsoni* much resembles *C. quadrilateralis*, but the latter has a smaller mouth and the gill-rakers notably shorter and thicker.

8. **Thymallus signifer** Richardson. (Var. *ontariensis.*) (Plate VIII, Fig. 7.)

The Grayling is very abundant in the Madison River below the junction of the Firehole and the Gibbon. Numerous specimens were collected for us in Horse Thief Spring, a small stream just outside the limits of the Park, by Mr. Lucas. The grayling is said to ascend the river in summer as far as the Firehole Falls and Gibbon Falls. It is said also to be found in the Gallatin River, in the northwestern part of the Park.

We have carefully compared our specimens with others collected by Judge D. D. Banta, in Otter Creek, in the Keweenaw Peninsula, and with a specimen from Au Sable

River, in the southern peninsula of Michigan. The first-named locality, by the way, is one not generally known and not previously recorded. The occurrence of Grayling in the northern peninsula of Michigan is even disputed by anglers.

The differences noted by Mr. Milner as distinguishing the Montana fish (as *Thymallus montanus* Milner) do not seem to be constant. The Montana specimens are not deeper than the others (depth 5¼), and in the number of the scales (98) they agree with the Otter Creek specimens. The Au Sable specimen has 93 scales. The dorsal rays are 21 or 22 in Michigan specimens, 19 in those from Montana. The only differences evident are in the color of the dorsal fin. This is alike in all the Montana specimens, but its peculiarities may be due to difference of season. In the Montana examples (in alcohol) the fin is largely dusky green. Its posterior part has three or four rows of bright orange-brown spots, faintly ocellated, irregular in position, some of the spots oblong and obliquely placed. Above this is one regular row of similar spots, extending obliquely across the fin from the end of the second third of the anterior rays to the tip of the last ray. Fin edged above with the same bright orange-brown.

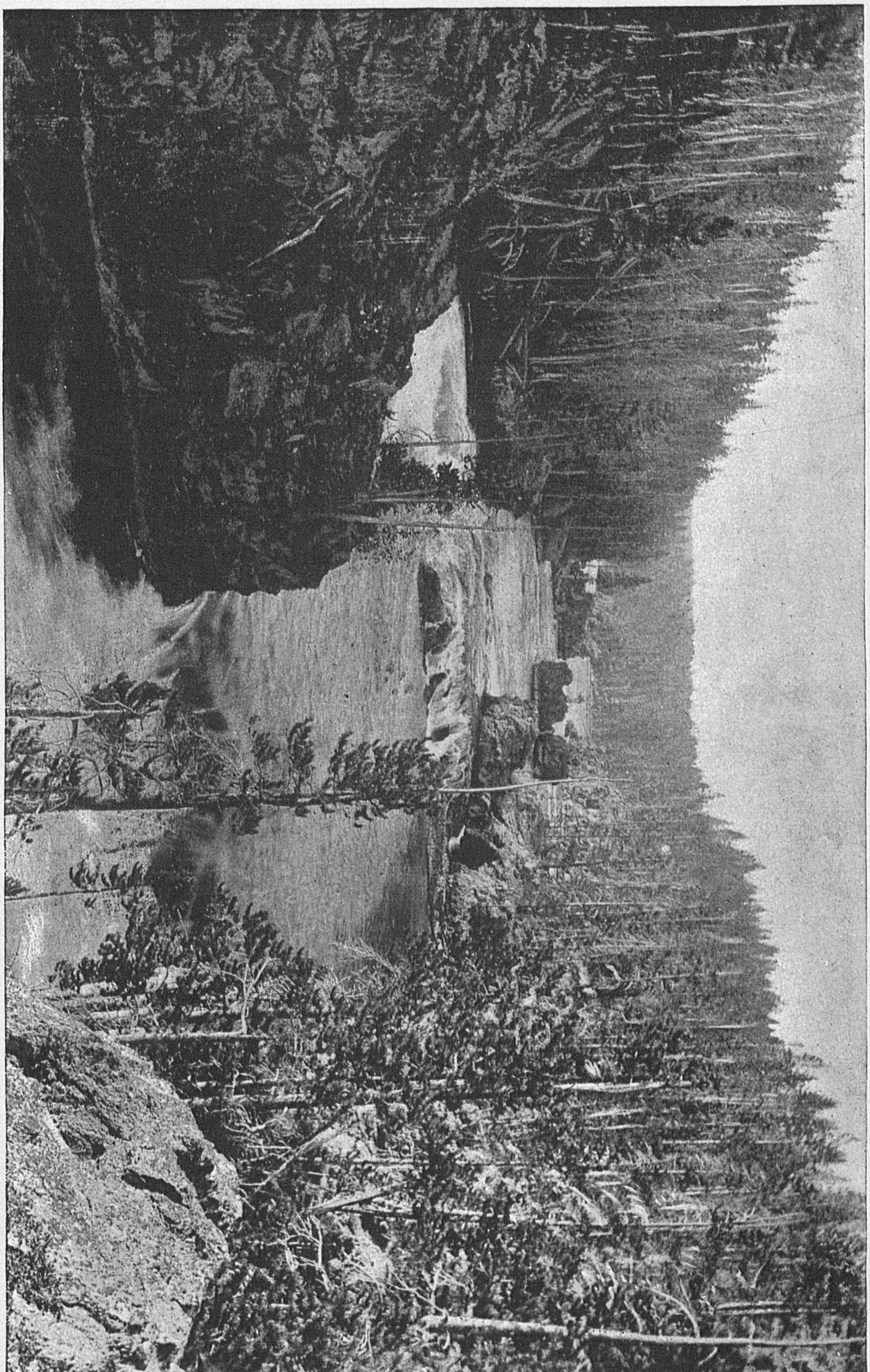
I have no specimens of the true northern *signifer*, but taking the figure published in the Natural History of Aquatic Animals, plate 195, as a basis of comparison, the grayling of Montana and Michigan may differ in the lower and less spotted dorsal and the slightly smaller scales (98 instead of about 92). Should these differences hold, it will stand as *Thymallus signifer ontariensis* (=*T. tricolor* Cope=*T. montanus* Milner).

9. **Salmo mykiss** Walbaum. The Red-Throated or Rocky Mountain Trout. (*Salmo purpuratus* Pallas: *Salmo stellatus, clarkei, virginalis, lewisi*, etc., of authors). (Plate X, Figs. 10 and 11.)

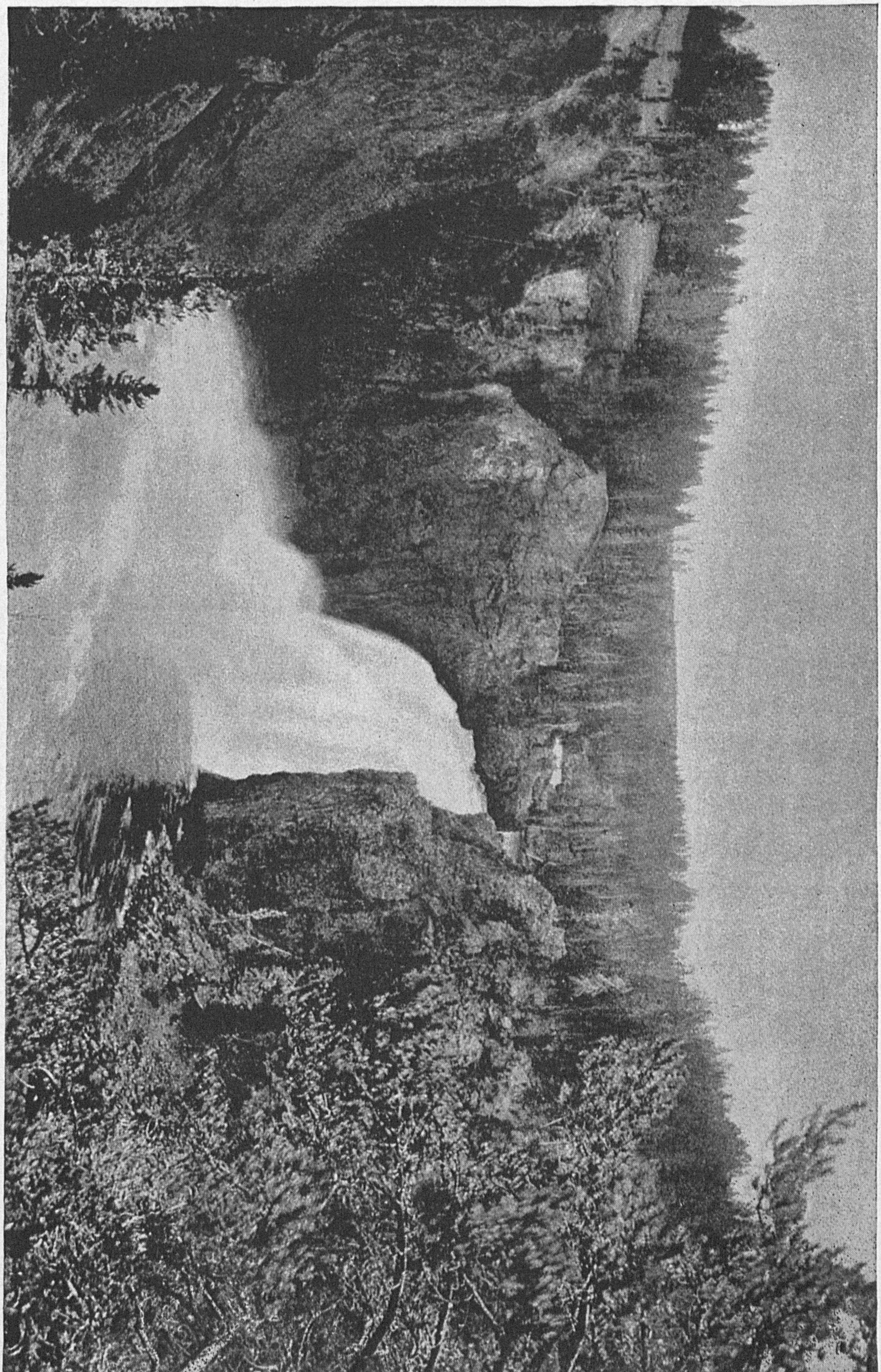
I have compared a large series of trout from the Park with trout from various other streams in the Rocky Mountain region. There seems to be no doubt that all the trout in the Park belong to a single species, and that this species is indentical with the common red-throated or black-spotted trout of the Lower Columbia, and of the coast rivers from Oregon to Kamtschatka. This species was first mentioned by Steller under its Russian name of *mykiss*. Later it received the binomial names—*Salmo mykiss* Walbaum, 1792, *Salmo muikisi* Bloch & Schneider, 1801, and *Salmo purpuratus* Pallas, 1811. Probably all the trout of the Rocky Mountain region belong to this single species, but certain marked varieties of it occur in waters of Colorado, of which a detailed discussion is given in another paper.

The trout of Yellowstone Lake seem to differ from those of Heart Lake and Henry's Lake in having the black spots larger and more distinct and rather less numerous. In these respects very much individual variation is shown. The trout from Heart Lake and from Henry's Lake are essentially like others from Walla Walla in this regard, and those from the Yellowstone below the falls have the spots generally smaller than in those from the lake. The trout of the Upper Missouri region have received the name of *Salmo lewisi* Girard, but I can not recognize *S. lewisi* as even varietally distinct from *S. mykiss*. In fact, as elsewhere stated in this paper, there is good reason to believe that the Yellowstone Lake was stocked originally from Snake River, through Pacific Creek, Two-Ocean Pass, and Atlantic Creek. It is, moreover, not unlikely that an interchange of individuals still occasionally takes place across the Continental Divide.

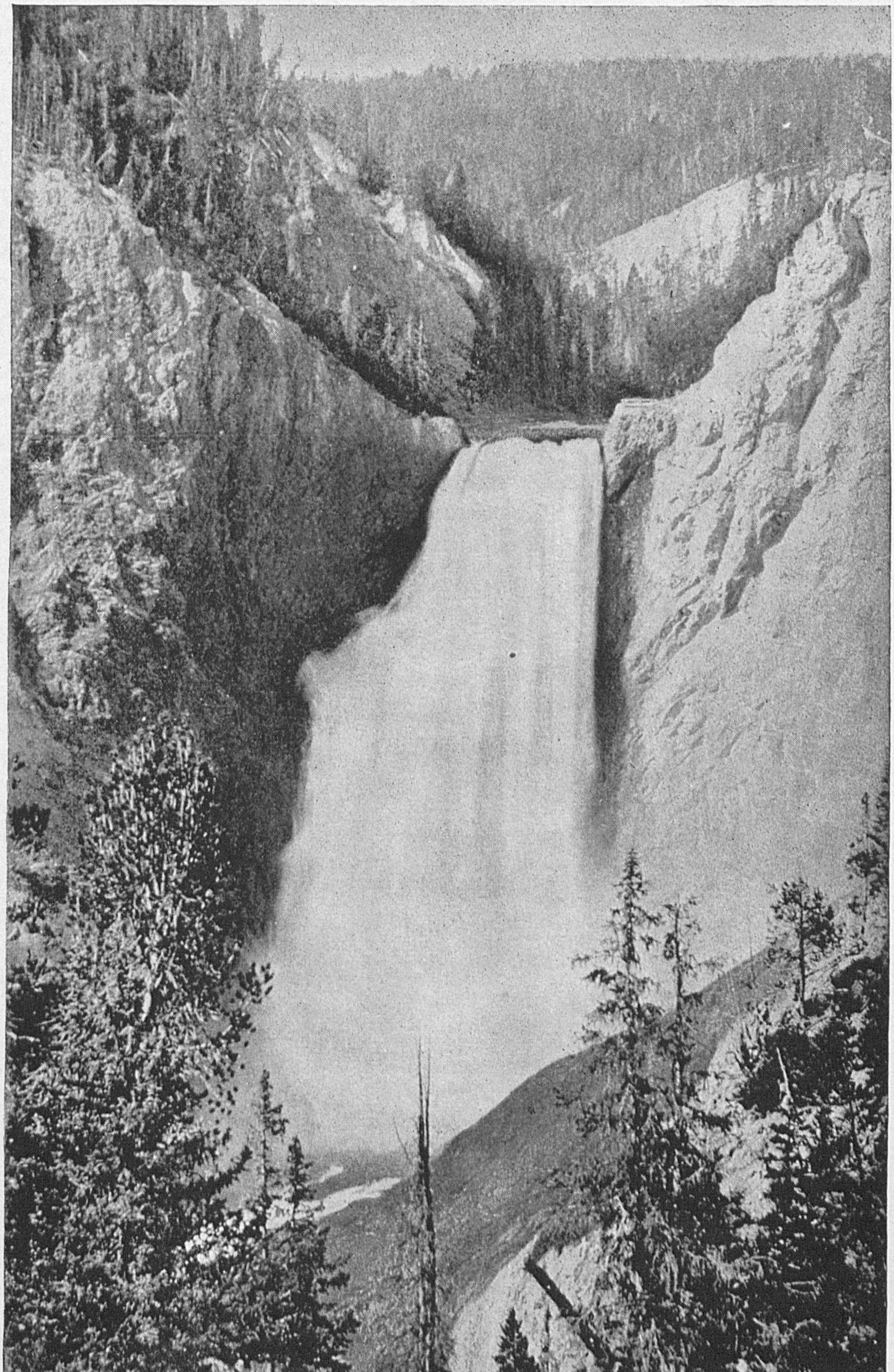
The trout of the Yellowstone Lake and of many of its tributaries above the falls are infested by a parasitic worm (*Dibothrium cordiceps* Leidy). Of the specimens ex-



YELLOWSTONE RIVER; RAPIDS ABOVE THE UPPER FALLS. (See page 54.)



UPPER FALLS OF THE YELLOWSTONE RIVER. (See page 54.)



LOWER OR GREAT FALLS OF THE YELLOWSTONE RIVER. (See page 54.)

amined by us from the Yellowstone, between the falls and the Lake, all showed some traces of the presence of the worm. These were first noticed by us as small whitish cysts, about as large as a grain of wheat, around the pyloric cœca, sometimes in the ovary. These cysts contain small worms, apparently similar to the larger ones. These larger worms, from 1 to 5 inches in length, are found in the liver, in the abdominal cavity, or in the muscular substance of the belly or sides. When worms exist in the flesh they can usually be found by skinning, as the flesh about them is more or less diseased. These facts may perhaps be better appreciated by the following notes on specimens examined:

Female (dissected) from Yellowstone River (taken like the next four in the eddy at the bend of the river, about 1¼ miles above the Giant's Cauldron and Mud Geyser). A worm 10 inches in length, in a sac along the intestine; another worm about 4 inches long, in a sack, in the muscle of the abdominal wall, the flesh pale and diseased for an inch about the worm. Ovaries full of little worm cysts, and imperfectly developed. Numerous cysts among the pyloric cœca in this and all other diseased specimens.

A large male (No. 137): Liver, pyloric cœca, and spleen with worms; the worm in liver large. Testes wholly empty and shrunken. Had external appearance of a female trout.

Male (421): No worms evident, except a few cysts about the stomach; testes full and normal.

Female; No worms evident; ovaries large and full of normal eggs; cysts present among the pyloric cœca in this and all other specimens from Yellowstone River.

Male (285); Pyloric cœca full of cysts.

Males (323, 244); Worms present; sexual organs little developed.

Nos. 3 and 4, Riddle Lake. Viscera normal; no trace of worms or cysts.

Female (494); from Heart Lake, at mouth of Witch Creek; intestines and cœca with cysts and with some small worms. Other worm-like parasites of other genera in cavity of mouth and on dorsal fin.

Young male (365); Heart Lake: a single small encysted worm among the pyloric cœca; no others evident.

A basket of dressed trout, taken in the Yellowstone River at Livingston was examined. Among these was one worm 3 inches long, apparently of the same species as the others. Numerous other specimens were examined without developing any facts other than those included below.

I offer the following generalizations with much hesitation, as I know practically nothing of the life-history of intestinal worms of the group to which *Dibothrium* belongs.

Worms are found more or less abundant in nine-tenths or more of the grown trout in the Yellowstone Lake, and its larger tributaries, and in the Yellowstone River as far as the Lower or Great Falls. The trout in the upper Yellowstone are likewise affected, those in Bridger's Lake being (according to Mr. Arnold Hague) largely wormy, as also those in Atlantic Creek (Elwood Hofer). The small trout (under 6 inches) have not been found to contain worms.

Worms are popularly believed not to exist in the Lower Yellowstone (below the falls). The discovery of a worm at Livingston would contradict this. Perhaps worms exist, but are small or scarce. Those in the encysted condition would hardly attract popular notice, for ordinary observers do not even distinguish the worms from the pyloric cœca.

Worms certainly exist in the trout of Heart Lake, to all appearance identical specifically with those in Yellowstone Lake. This lake is on the west side of the Divide and is drained by Snake River. It has at present no connection with Yellowstone Lake.

Yellowstone Lake and Heart Lake have one feature in common, and one shared by no other lakes containing trout with which I am acquainted (Shoshone and Lewis Lakes being destitute of fishes). Both have a large influx of hot water from geysers and from hot springs, some of them outside the lake, but many of them opening under the water. This suggests the theory that the existence of the worm itself, or perhaps its malignity as a parasite, is dependent on the presence of hot water, instead of the cold waters ordinarily frequented by trout.

As bearing on this suggestion I may notice: In both lakes the trout actually frequent the warm waters, attracted apparently by the great abundance of fish food to be found there. It is perhaps not impossible that with the great variety of insect, crustacean, and worm life, the germ of the worm may occur also. The streams in which wormy trout occur, so far as known, are all in easy access from Yellowstone Lake. Riddle Lake, although tributary to the Yellowstone, has an outlet long, narrow and tortuous, being dry at both ends in the summer. It is so difficult of access that probably trout do not often ascend it. Only young trout were seen in the creek, and the trout found in the cold waters of Riddle Lake showed no sign of worms. The trout in Pelican Lake and other waters to the east of Yellowstone Lake and tributary to it are said to be infested with worms. These lakes receive much water from Hot Springs.

Connected with this fact of the development of worms in warm waters is the fact that the suckers in the warm (largely geyser) waters of Witch Creek (*Catostomus ardens*) are afflicted with another parasitic worm. I know nothing of the history or relationships of this worm, but it is hard to avoid the supposition that the warm water favors its development. Although the sucker is a small fish, the worm infesting it is larger than any other parasitic worm I have ever noticed among fishes, and, as elsewhere stated, it often occupies more space in the abdomen of the fishes than do the fish's own viscera.

The lakes of Washington, Colorado and Utah, abounding in trout of the same species, show, as far as we know, neither geyser water nor *Dibothrium*.

It will be interesting to know whether the trout introduced into Lakes Shoshone and Lewis, both of them with similar hot tributaries, will be afflicted with worms. It will also be interesting to know whether any other species of trout will show immunity from them. Possibly an abundance of other fishes as food for trout would draw them away from the hot waters, and free them from worms.

The "wormy" trout are leaner and more compressed than others, and the sides of the belly are likely to show ridges and lumps. The flesh is said to be redder in the diseased fish, and the external color is more likely to be dusky or brassy.

In the trout examined the presence of many worms was accompanied by a shrunken or irregular condition of the ovaries or testes. Perhaps spent fish are more likely to be wormy. According to Mr. Arnold Hague, the best trout are in swift or deep waters; the wormy ones about eddies or among logs or masses of floating vegetation. The wormy trout takes the fly freely but is in general little gamey. In fact, all the Yellowstone trout seem less active than is usual for the species.

The value of these attempts at generalization can only be determined by the thorough study of some competent helminthologist in the field. The life-history of the worms is yet to be made known. When this is done possible remedies may be suggested. The probabilities are that the trout and the worm will never be divorced in Yellowstone Lake.

CRYSTAL FALLS OF CASCADE CREEK. (See page 55.)

It is said the bears are often seen going about the shores of the lake picking up the dead fish.

10. **Cottus bairdi** Girard. (Var. *punctulatus.*) (Plate X, Fig. 12.)

The "Miller's thumb" or "blob" is found in great abundance in the grassy bottoms of Madison River, Gibbon River, and Cañon Creek. In Gibbon River it is found above the falls as well as below it, an anomaly of distribution as yet unexplained, unless we call in the aid of the Osprey or some similar agency. It is said that the species is found also in the Yellowstone below the Park.

The specimens taken by us in the Gibbon and Cañon Creeks, as well as those procured by Mr. Lucas in Horsethief Spring are identical with specimens taken by us from Eagle River, Colorado, and in other tributaries of the Colorado. All of them belong to the variety or species named *Potamocottus punctulatus* Gill, although the dark spots are generally coarser and more diffuse than is shown in Professor Gill's figure.*

In the specimens from the Park the band of palatine teeth is broad; there are no prickles on the skin. The head is 3½ in length and the rays are D. VII–17; A. 13; V. I, 4.

Comparing these with specimens (*Cottus bairdi carolinæ*), from Mammoth Spring, Missouri, the differences seem well marked. Var. *punctulatus* has the head blunter, lower and more rounded, the cheeks more tumid and the top of the head without median longitudinal depression. Var. *carolinæ* has the axil prickly, the outline of the head angular, the top of head with a median longitudinal depression from snout to nape, and the body has broad distinct black cross-bars.

These two forms seem like distinct species, but other specimens are intermediate; specimens from Torch Lake, Michigan, agree with *punctulatus* in color, and are intermediate in form; specimens from White River, Indiana, are colored like var. *carolinæ*, but are intermediate in form. Apparently *punctulatus* should be recognized as a subspecies but its range and distinctive characters are yet to be made out in detail.

THE STREAMS AND LAKES OF THE PARK.

The following is the substance of our field-notes on the physical characteristics of the streams and lakes of the Park:

YELLOWSTONE BASIN.

THE YELLOWSTONE RIVER.—The Yellowstone River drains an area of 1,900 square miles, or about half the surface of the Park. It has its rise in the Continental Divide, to the southeastern limit of the Park. One of its tributaries, Atlantic Creek, flows to the eastward by the side of a low part of the Divide, known as Two-Ocean Pass. On the opposite side of this pass, at a distance of about one-eighth mile, flows Pacific Creek, in the opposite direction, though parallel with Atlantic Creek. Pacific Creek is a tributary of Snake river. The Divide between the Yellowstone and Snake River is a marshy meadow, more or less overflowed in spring, its whole width scarcely more than an eighth of a mile. It is supposed that the stock of trout in the Yellowstone, above the falls, must have originally come from Pacific Creek. Whether the lower Yellowstone and the upper waters of the tributaries of the Missouri were stocked in this way is less certain. If the trout of the Missouri came across Two-Ocean Pass

* Ichthyology Captain Simpson's Rept. Expl. Basin of Utah.

the whitefish might have done so also; but this is unlikely, as no whitefish are now in Yellowstone Lake nor in Yellowstone River above the falls. The Yellowstone is a very clear, cold stream (temperature 50° to 60°), and, taking its whole extent, it is one of the most picturesque in America. It flows through a large glacial depression in which it expands to form the Yellowstone Lake (7,741 feet elevation). This is a large body of water, of very irregular form, which is often compared to that of an uncouth hand with a very large thumb and three shrunken fingers. Its greatest length, north and south, is about 22 miles, and its greatest width across the thumb is about 15. West and south of the lake are high mountains, and the lake banks are, in many places, bold and rocky, the hills being covered with pine and fir trees. Toward the north end of the lake the banks are lower, and here terraces show previous greater extension, covering the marshy pastures and woodlands of its outlet, the territory known as Hayden Valley.

Above the lake the Yellowstone River winds through marshy meadows, between wooded hills, behind which are the rugged peaks of high volcanic mountains. The current is sluggish above the lake, and between the lake and the upper falls there is also no great descent. The river below the lake is bordered by low hills, some of them wooded, others forming open grassy pastures. Below the lake the large river flows for about 15 miles with a quiet current, then plunges into a deep cañon over two vertical falls 109 feet and 308 feet in height (see plates XI, XII, XIII). This famous cañon, which needs no description here, is more than 20 miles long, with nearly perpendicular walls, 800 to 1,100 feet in height. The current of the stream below the falls is swift until it leaves the Park. The Yellowstone retains its general character as a clear, cold, and swift river for almost its whole course through Montana until it joins the Missouri. Trout abound throughout from the source of the river in the mountains as far as Livingston, and doubtless for many miles beyond. Above the falls the river contains no other kind of fish. The abundance of trout above the falls is remarkable. In one eddy in the river, eleven, averaging 1½ pounds each, were seen together, and in parts of the lake they are as numerous as in the river. They are everywhere eager to take the fly, but they are regarded as indifferent fighters in comparison with the trout of other streams.

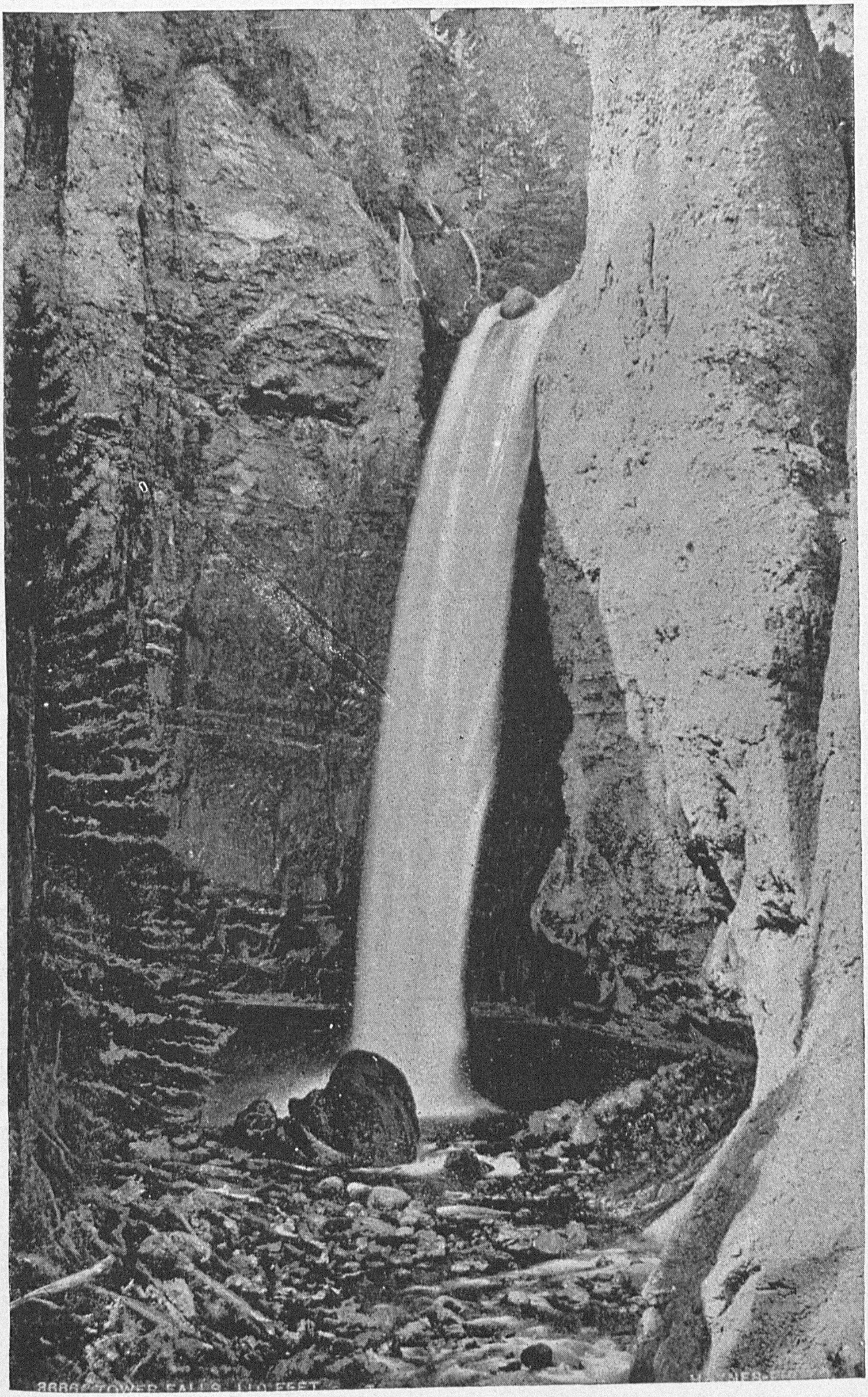
In Yellowstone River, and in most parts of the lake, fish-food, such as insects, crustacea, larvæ, etc., are very abundant. The stomach of one trout taken in the river contained helgramites (larvæ of *Corydalus*), grasshoppers, and caddis-worms.

Of the tributaries of the Upper Yellowstone, none were visited by us. Common report says that all are well stocked with trout, and that the trout in all or most of them are wormy.

The following tributaries of the lake were examined:

Solution Creek is a small, narrow stream, with lava bottom and grassy banks lined with willows. At the time of our visit it was dry for 2 or 3 miles above its mouth, and for about the same distance below its source in Riddle Lake. In the standing pools of its middle course were numerous young trout.

Riddle Lake (so called because of the mystery of its outlet, "solved" by the discovery of the little creek) is a clear pond of roundish outline about 1½ miles in diameter. About its outlet are numerous lily-pads and other plants. Its shores are shallow, and its bottom chiefly lava gravel. Trout seem to be numerous in the pond. Two were taken, one a female with full ovaries, the other a male with shrunken testes.



TOWER FALLS OF TOWER CREEK. (See page 56.)

Both seemed to be free from worms. There is no evidence of hot-water action in Riddle Lake. The temperature of the lake is about 50°.

Bridge Bay Creek is a small brook of no importance.

Arnica Creek is a similar stream, the water of which is warmed by hot springs. No trout were seen there.

Trout Creek is a clear stream with grassy banks and gravel bottom. Water clear and clean, about 58°. Its course lying chiefly in Hayden Valley it has no falls. No fish were seen, although it is said to be a fair trout stream but inferior to the next.

Both of these enter the Yellowstone River from the west some 12 miles below the lake.

Alum Creek is a clear stream about 8 feet wide and 1 or 2 feet deep, rising in the Continental Divide opposite the head of Nez Percé Creek and flowing eastward through the grassy fields of Hayden Valley. Its bed contains much white alkali from the hot springs above and there is a perceptible alkaline taste to the water. Its temperature is about 60°. In its upper course it has some hot tributaries, one of these, Violet Creek, with a number of hot springs and mud-holes. Still another fork is charged with alum. A third branch is said to be one of the best trout streams in the park. One small trout was noticed while fording this stream, a fact which tends to show that alkaline and warm waters are not specially avoided by trout.

Sour Creek, a large stream, entering the river opposite Alum Creek, was not examined nor was the cause or degree of its sourness made out.

Cascade Creek, a clear brook about 3 feet wide, enters the Yellowstone between the falls. The high, nearly vertical "Crystal Falls" (129 feet) is near the mouth of the stream and, of course, prevents the ascent of fishes (see plate XIV). It is said that fifty trout from the Yellowstone were placed in Crystal Lake, a pond toward the head of this stream, last spring by Mr. Cummings. The planting of Yellowstone trout in streams without trout has been since forbidden on account of the danger of the spread of the parasitic worm.

Sulphur Creek, a small clear stream having in its course numerous sulphur springs and boiling sulphur holes, flows into the grand cañon. It has, of course, no fish. Another small stream, Surface Creek, with a very high cascade, "Silver Cord," flows into the cañon from the opposite side.

Lamar River, or east fork of the Yellowstone, is a large stream, flowing into the Yellowstone from the east at a point below its cañon.

This is well stocked with fish, as are its tributaries, the chief of which are Slough Creek and Soda Butte Creek. These streams were seen by us only from a distance. At Baronette's Bridge, at the mouth of Lamar River, a trout was taken which weighed 4 pounds 4 ounces, when dressed. It was 16 inches long.

Slough Creek is said to be well stocked with fishes up to the lakes at its head which is near the mining camp of Cooke City, Mont. One of these lakes is said to be without trout on account of the presence of much iron in its outlet, so much that the bottom is red. Another has no trout but multitudes of "blob" (*Cottus bairdi punctulatus*). This stream has a small water-fall in its outlet. Still another, "Lake Abundance," is said to be full of trout.

Soda Butte Creek is well stocked with fish except in its upper part where a water-fall keeps them back.

Hellroaring Creek flows into the Yellowstone from the north below the mouth of

Lamar River. Its lower part is well stocked with fish. The upper part is almost unknown. Its rise is seen to be in high granite mountains, and in its course there are probably numerous cascades. According to Gannett "it comes from the granite portion of the range north of the Park, cutting a tremendous gorge through it." At the foot of the gorge is a sharp conical peak of granite known as Hellroaring Mountain.

Crevice Gulch, the next stream on the right bank, is beyond the limits of the Park. It is said to contain both trout and whitefish.

Antelope Creek, on the left bank, is a small stream flowing down a grassy slope on the south side of Mount Washburn. This stream has no cañon and no distinct cascade and is fairly stocked with fish.

Tower Creek is a larger stream, draining the semi-circle of mountains of which Mount Washburn is the highest, a group, according to Gannett, comprising twenty-five summits ranging in height from 9,000 to 10,400 feet. The current of Tower Creek is swift and for almost its whole length the stream is hidden in dense forests. It is, perhaps, the coldest stream in the Park (about 45°). About one-fourth mile from its mouth (at which point this stream is separated by a narrow lava ridge from Antelope Creek) Tower Creek forms a singularly picturesque fall of 132 feet (see plate XV). This fall is quite vertical and it is surrounded by lofty pillars or towers of volcanic conglomerate. Below the fall is a deep and narrow cañon. The stream is here some 10 feet wide by 1 deep. There are no fish above the falls but for those species of trout which are especially fond of cold and shade no better stream exists in the Park.

Lost, Elk, Geode and *Oxbow Creeks* are small steams—too small to be of consequence for fish. Although having a large bed Oxbow Creek was entirely dry in October and the other streams had little water.

Black-tail Deer Creek is a clear, rather cold stream (55°) running largely through open pastures, with willows along its course. It has no cañon or falls. Its bottom is of lava gravel and rocks with some weeds. It is 5 or 6 feet wide by 1 or 2 deep, and is well stocked with trout. Young trout were seen in the little pool at the bridge, but no minnows.

Lava Creek or East Fork of the Gardiner River, is a clear mountain stream resembling Tower Creek, and like the latter flowing chiefly through evergreen forests on the north side of the mountain range. The stream is about 10 feet wide by 1 or 2 deep. Towards its mouth it cuts its way into a broad, flat shelf of lava, forming two successive cataracts about one-tenth of a mile apart. The upper falls, called Undine Falls, is vertical for about 30 feet, then with two additional leaps of about 20 and 10 feet (see plate XVI). The lower fall is vertical and about 50 feet high. Below this fall the stream flows through a highly picturesque cañon joining the Gardiner River, above Mammoth Hot Springs. In this cañon trout are abundant.

Lupine Creek is a small tributary of Lava Creek entering it above the falls. This stream has a high cascade (Wraith Fall), about 100 feet high.

Notwithstanding the barrier offered by Undine Falls, it is said, on good authority, that small trout have been seen in Lupine Creek below Wraith Fall (Elwood Hofer) and trout have been taken in Lava Creek above the falls. This raises the question as to how they came there. Our attention was called by Mr. Hofer, to the way in which trout may have crossed the Divide from Black-tail Deer Creek to Lava Creek.

UNDINE FALLS OF LAVA CREEK. (See page 56.)

The easternmost tributary of Lava Creek is a grassy slough with very little current. The narrow stream in its midst is nearly dry in summer. The same conditions extend to the summit of the Divide, which rises to the height of about 3 feet above a small pond with which the slough begins. The Divide is a rod or two across at its lowest part near the pond. On the east side of it, but lower down, is a similar pond with grassy surroundings, which flows into Black-tail Deer Creek. Into both these depressions considerable springs flow, especially into the one on the west.

The grassy slough first named, tributary to the Lupine Creek, has very little slope for a mile or more. Should its waters rise in spring so that the almost dry pond would be 3 feet in depth, this pond would overflow on both sides, and a continuous water-way would be made from Lupine Creek down into Black-tail Deer Creek. This water-course would be shallow, and is doubtless seldom traversed by fishes. It is, however, a possible one, and serves to account for the presence of trout in Lava and Lupine Creeks.

By order of the U. S. Fish Commissioner other trout from Howard Creek have this year been placed above the falls in Lava Creek.

Gardiner River (or *Middle Gardiner*) rises in the east slope of the Gallatin Mountains in the northwestern part of the Park. It flows eastward, southeastward, then abruptly northward, bending around Bunsen's Peak, and forming a deep cañon, toward the head of which is the large Osprey Falls (see plate XVII). Gardiner Cañon is some 800 to 1,000 feet deep, with vertical walls of lava, basalt, etc., and in grandeur is surpassed only by the Cañon of the Yellowstone. The Osprey Falls is about 150 feet high, and nearly vertical.

Trout are abundant in the river from the foot of the fall to its junction with the Yellowstone, some 4 or 5 miles below. No fishes have been seen in the Gardiner or any of its tributaries above the Osprey Falls except the brook trout (*Salvelinus fontinalis*), lately planted at the bridge below the mouth of Indian Creek.

Above the falls Gardiner River is a clear, cold stream (about 50°), with numerous stones, boulders, and deep holes. It is well provided with fish food.

Its principal tributaries above the falls are Obsidian Creek and Indian Creek, the latter coming in from the southwest, the former from the south. The largest of these, Obsidian Creek, heads in or near the Twin Lakes. There are two small ponds about one-half mile and 1 mile long, with no visible inlet, the small stream connecting them being dry in summer. The lower and smaller pond is said (by Mr. Lucas) to have large alum springs near its outlet, the water being so charged with alum that horses will not drink it. The outlet, Obsidian Creek, is at first very small, and its course for 2 or 3 miles is full of hot springs, solfataras, boiling mud-holes, and various similar heated areas offensive to fish. It is not likely that a fish could pass through this stream, except in very high water.

Lower down cold springs enter the stream, and at Beaver Lake the water is clear and cold. Beaver Lake is a shallow grassy pond, about a mile long, formed by the beavers. Three large beaver dams cross it, and each of these dams in ordinary seasons would be likely to block the ascent of fishes (see plate XVIII). The lower one especially is covered with brush, over which fishes could not leap. Below this lake Obsidian Creek receives the clear, cold waters of Winter Creek, a large stream which heads in Christmas Tree Park, at the foot of Mt. Holmes. The stream now flows through Willow Park, a large mountain meadow, in which it joins the Gardiner River.

Obsidian Creek with Winter Creek will, apparently, be one of the best of trout streams. Its temperature is about 50°. Its bottom of lava gravel is lined with grass, algæ, and water plants in which small crustacea swarm.

Indian Creek is a clear, cold stream, similar to the Gardiner, and like it, heading in the east slope of the Gallatin Mountains.

Glen Creek, or West Fork of the Gardiner, rises in Sepulchre Mountain and flows southeast, then northeast, joining the Gardiner at the foot of its cañon.

This is a small stream, which runs mostly through open meadows. It is 5 or 6 feet wide and 1 to 2 feet deep, with gravelly and grassy bottom. Its waters are very cold (about 48°) and full of crustacean life. The red-bellied frog, *Rana septentrionalis*, is abundant. Glen Creek has a high waterfall, some 70 feet high (Rustic Falls), at the "Golden Gate," near the base of Bunsen's Peak (see plate VIII).

Below the fall the deep cañon is so choked up with boulders and talus that fish can not ascend it. Above the fall Glen Creek receives a considerable tributary, which drains Swan Lake. Swan Lake is a small roundish pond, about half a mile long, with a bottom of crumbled lava. While its shores are very shallow, the depth in the center seems considerable. The waters are clear and cold, abounding in insects and crustacea. In Glen Creek and the Gardiner River 5,000 Brook trout, *Salvelinus fontinalis*, were placed in August of this year.

The lower course of the Gardiner, below the three falls (Osprey, Undine, and Rustic), is well stocked with trout and contains whitefish (*Coregonus williamsoni*), suckers (*Catostomus griseus*), and minnows (*Rhinichthys dulcis*). Below Mammoth Hot Springs it receives the scalding Hot River, the drainage of the springs. That these hot calcareous and sulphuretted waters are not destructive to fish life, even to that of trout, has been already shown. It is said that in winter the trout are especially abundant about the mouth of this stream.

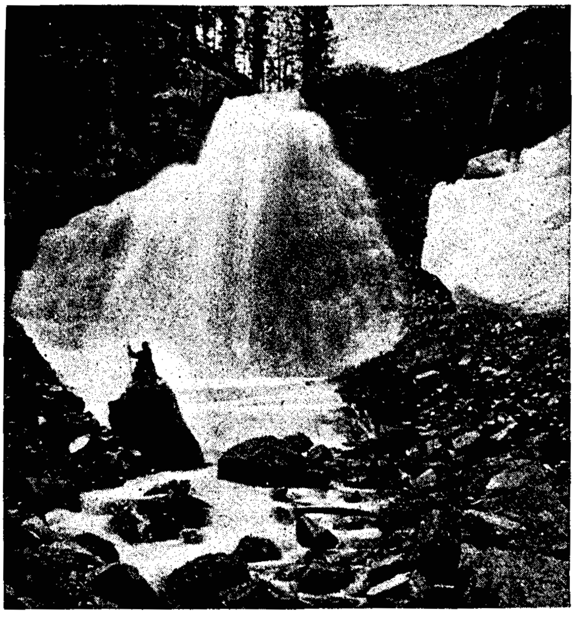
MISSOURI DRAINAGE (730 square miles).

The three streams which unite near Gallatin City, Mont., to form the Missouri are the Jefferson, the Madison, and the Gallatin Rivers. Of these, the Jefferson lies outside the Park. The Gallatin and two little-known tributaries (Fan Creek and Grayling Creek) rise in the wild region west of the Gallatin Mountains in the northwest corner of the Park. These cold, clear streams, rarely visited by sportsmen, are said to be well-stocked with trout and grayling.

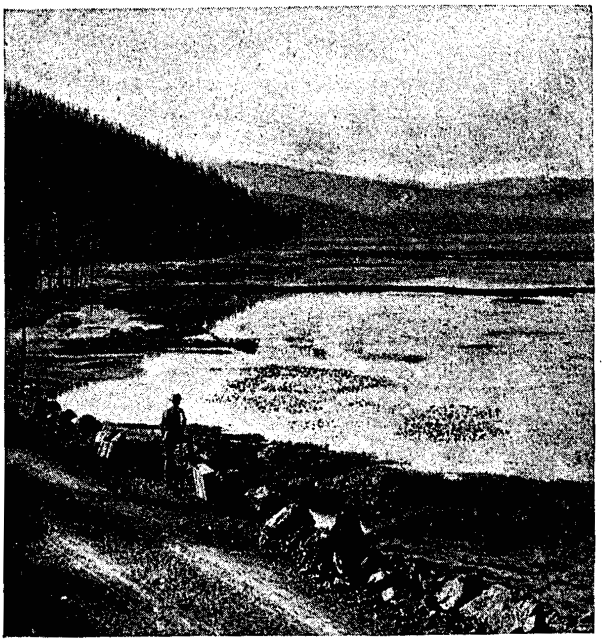
Madison River drains an area of 730 square miles in the Park; this includes the country to the west of the Yellowstone and to the north of the Continental Divide. The name Madison is only used for the river below the junction of its chief tributaries, the Firehole River and the Gibbon River.

Gibbon River, the smaller of the two streams, rises north of the center of the Park in the hills and marshes around Grebe Lake, a body of water not far from Crystal Lake, on Cascade Creek. Grebe Lake, about a mile long, surrounded by mountain meadows, is said (by Mr. Hague) to be one of the finest lakes in the Park. In the outlet of the lake above the falls known as Virginia Cascades, 1,000 rainbow trout (*Salmo irideus*) have been lately planted. The region about the upper course of the Gibbon is heavily timbered and its basin is separated by low divides from that of Obsidian Creek. Notwithstanding the influx of many hot springs, solfataras, soda springs, and even iron springs, the Gibbon remains a clear, cold river (55°) throughout its course. The Vir-

OSPREY FALLS OF GARDINER RIVER. (See page 57.)



RUSTIC FALLS OF GLEN CREEK. (See page 58.)



BEAVER LAKE; SHOWING BEAVER DAMS. (See page 57.)

ginia Cascade (some 60 feet high) will probably prevent the ascent of fish (see plate XIX). Below these cascades is the open valley of the Norris Geyser Basin, and still lower a broad meadow known as Elk Park. Several miles below Elk Park in a narrow cañon is the Gibbon Falls (80 feet high), a picturesque cataract, which trout certainly can not ascend (see plate XX). Above this fall are no trout, but an abundance of blob, or miller's thumb (*Cottus bairdi punctulatus*), and it is not easy to explain how they come to be there. Below the falls trout are abundant and, as in the Madison, grayling are said to be found.

Cañon Creek, a small clear stream, very cold and with grassy bottom, joins the Gibbon River below the falls. This stream flows through steep pastures, without falls except near its source. It is 6 to 8 feet wide and 1 to 3 deep, and is well stocked with trout. In this stream the blob is very abundant, absolutely swarming in the grass.

Firehole River, about twice the size of Gibbon River, joins it from the south. "This stream heads just west of Shoshone Lake, separated from it and from the head of Bechler River by relatively low divides" (Gannett). It flows through a small lake nearly dry in summer (Madison Lake), below which it receives a fine clear tributary from the east (Spring Creek). Along Firehole River are the most noteworthy of the geyser basins, and a great volume of hot water is poured into it without, however, rendering its waters at any point really warm, the average being probably 55° to 60°.

In its upper course, the Firehole, like the Spring Creek, is a clear and very cold stream flowing through dense woods, with narrow marshy valleys, alternating with small cañons. In this part of the stream 1,000 Loch Leven trout (*Salmo trutta levenensis*) were planted in September, 1889. Keppler's Cascades, above the upper geyser basin is a series of three or four very picturesque falls, some of them probably impassable to trout (see plate XXI). In the upper geyser basin the Firehole River receives the drainage of a multitude of hot springs, besides two considerable streams, also of mixed cold and hot water, the Iron Spring Creek and the Little Firehole River. The stream is here very clear. It is full of plants and other organisms, and its waters have a taste of decayed vegetation. Even at the midway geyser basin the stream is probably not too warm for trout. At the lower basin the Firehole receives the waters of Sentinel Creek, Fairy Creek, and the larger Nez Percé Creek. The latter, which comes in from the east, is nearly half as large as the Firehole and similar as to character and temperature of the water. It is fed by numerous short streams, some of them hot, and most of them confined to a narrow cañon. Some five miles below the mouth of the Nez Percé the Firehole, now a large river 2 to 3 rods wide and 2 to 5 feet deep, enters a wild cañon with banks of rough lava. In this cañon are the imposing falls of the Firehole, about 60 feet in height (see plate XXII), and forming an effective barrier to the ascent of fishes. Below this falls the common fishes of the Madison River, trout, whitefish, grayling, and blob, are said to be abundant. Lower down on the Madison River collections were made by Mr. E. R. Lucas, and a series of specimens given to us with the following notes:

"On October 2, I collected from Horsethief Spring 2,000 whitefish, which I planted next day in the Twin Lakes. Horsethief Spring heads in the Divide in Montana and flows $1\frac{1}{2}$ miles, emptying into the North Fork of the Madison River. The first half mile of this stream is of a rocky bottom, with no growth of moss or grass. The second half mile is of white sandy bottom, completely filled with a growth of moss and some grass. This moss is alive with fish food (specimens of which were sent). On October 15, I collected 1,000 more whitefish and planted them in Yellowstone River, above the falls. There are unlimited numbers of these whitefish in Horsethief Spring, running in size from 2 to 5 inches. There are also quite a large number of grayling in the stream."

Besides the grayling and whitefish, numerous specimens of the blob were taken in Horsethief Spring.

COLUMBIA RIVER DRAINAGE (682 square miles).

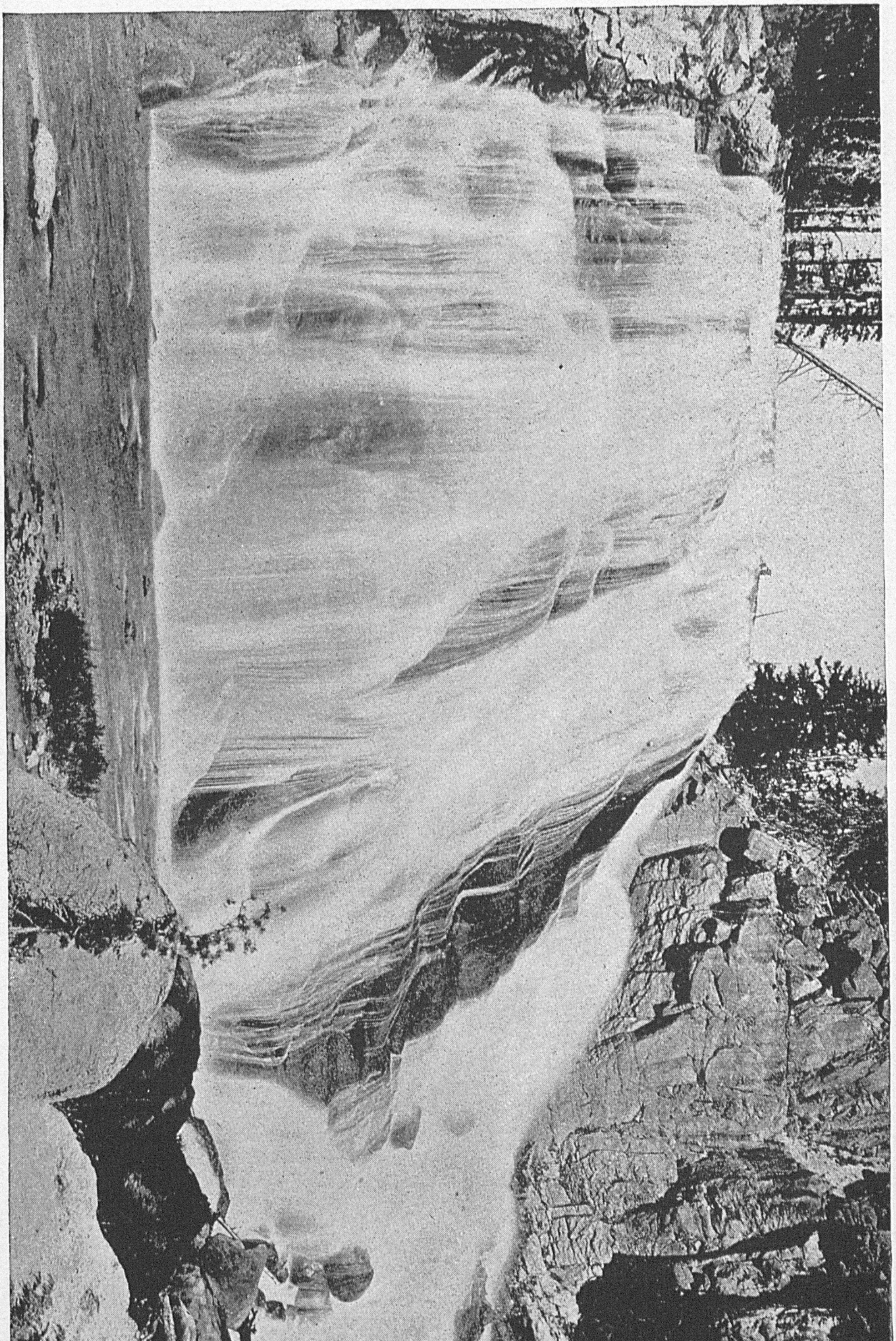
The Snake River, the largest tributary of the Columbia, drains that part of the Park (nearly one-fourth of the whole area) which lies to the southwest of the Continental Divide. This large territory is chiefly a densely wooded plateau and contains three large lakes, Shoshone, Lewis, and Heart, the largest lakes in the Park, next to the Yellowstone. Two of these lakes, with their tributary streams, are without fish, but the other rivers, Snake, Heart, Falls, and Bechler, are said to abound in trout except in certain of the headwaters where their ascent is prevented by water-falls (see plate XXI). As only a small part of this region was visited by us, I shall speak of the waters actually examined.

Heart Lake (elevation 7,469 feet).—This beautiful little lake lies in a deep depression at the eastern foot of Mount Sheridan and Red Mountain. It is about 3½ miles long from northwest to southeast and not quite 2 miles broad. Its bottom is of lava gravel, rather shallow near shore but becoming deep in the middle. It is drained by Heart River, a considerable tributary of Snake River, without falls, and said to be well stocked with fish. Near the head of the lake and in the lake are numerous geysers and hot springs. In the lake were found trout (*Salmo mykiss*), slightly afflicted with the same worm that is found in the Yellowstone. These trout were most numerous about the mouth of Witch Creek, and several were taken without the fly after chubs had been thrown into the lake to lure them. These chubs are eagerly swallowed by the trout. Besides these trout, a sucker (*Catostomus ardens*), chub (*Leuciscus atrarius*), shiner (*Leuciscus hydrophlox*), and minnow (*Agosia nubila*), are found in the lake. All of these except the trout ascend Witch Creek. A blob (*Cottus*) is also in the lake, but we were unable to catch specimens of it. There is plenty of fish-food in the lake and the water is not very cold, its temperature varying according to the nearness to the hot springs and geysers.

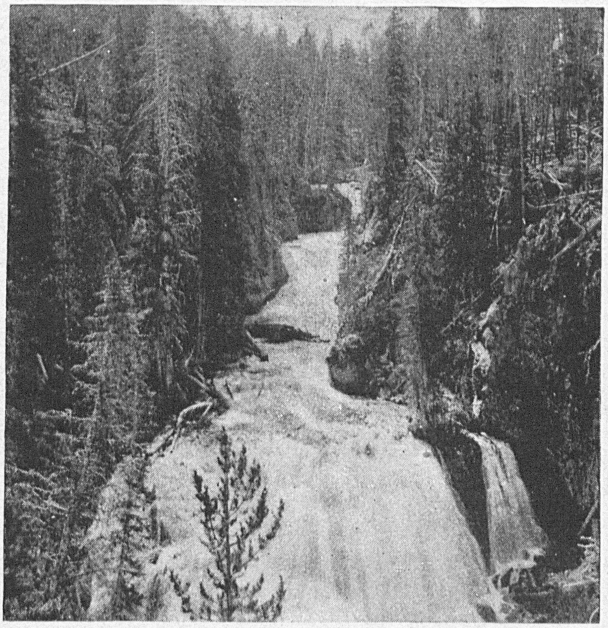
Witch Creek has its rise 2 or 3 miles above the lake, in the singular collection of geysers, hot springs, and steam holes known as "Factory Hill." Its water is at first scalding hot, but it gradually cools, receiving the waters of one cold tributary as large as itself. The chubs ascend until they reach water fairly to be called hot, and the sucker is not far behind. The lower course of Witch Creek winds through grassy meadows with a bottom of fine lava gravel and sand. In this part of the stream fishes are excessively abundant, chiefly suckers and chubs. As already noticed, the suckers are here infested by a very large parasitic worm, but no worms were seen in the chubs. Witch Creek has at its mouth a temperature of about 75° F.

Shoshone Lake (elevation 7,740 feet) has a length of about 6½ miles and a width of one-half to 4½ miles, it being dumbbell-shaped or constricted in the middle. Its area is about 12 square miles. At the head of the upper and smaller lobe of the lake is Shoshone Creek, fed by numerous hot springs and geysers. No hot springs exist on the

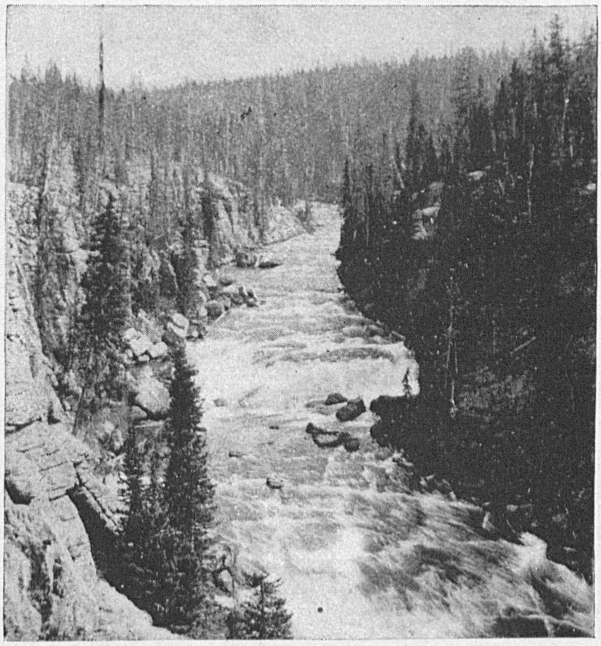
VIRGINIA CASCADE OF GIBBON RIVER. (See page 59.)



GIBBON FALLS OF GIBBON RIVER. (See page 59.)



KEPPLER'S CASCADE OF FIREHOLE RIVER. (See page 59.)



RAPIDS ON LEWIS FORK OF SNAKE RIVER. (See page 60.)

lower part of the lake. Its shores are mostly bold, rocky, and densely wooded, the eastern shore being especially abrupt, and the bottom is there made by large boulders of lava. There are no fishes in the lake. Along the eastern shore there is little fish-food, the lava rocks being barren, but the amount of water plants, lily-pads, etc., drifted on shore by the wind shows that a different condition must exist at the other end of the lake. Some crustacea and insects were noticed even on the east side. The lake is clearer and colder than either Yellowstone Lake or Heart Lake, and its mountainous shores render it extremely picturesque.

Heron Creek is a small grassy stream suitable for trout, flowing into the northeast angle of Shoshone Lake. It has now no fish life.

The outlet of Shoshone Lake is called *Lewis River*, a broad, swift, very clear stream, well provided with fish-food. This beautiful stream flows with a sluggish current for about 3 miles, where it expands suddenly forming the following lake:

Lewis Lake (elevation 7,720 feet).—This lake occupies a rounded basin with rather low banks. It is pear-shaped, about 3 miles long by 2 broad, very clear and cold and apparently in every way suited for trout. Its bold shores are heavily wooded and without tributary streams. A few hot springs, not seen by us, enter it on the western side. Below Lewis Lake, Lewis River enters a deep and narrow cañon, very rarely visited, and which lack of time prevented us from examining. According to Mr. Arnold Hague, there is at the head of this cañon a cascade of about 80 feet, of which 20 feet at the top is perpendicular. Toward the end of the cañon, above its junction with Snake River, is another cascade of some 50 feet in height, concerning which we were unable to secure information. Fishes are unable to ascend the upper fall, and perhaps the lower one also.* Near the lower fall is the mouth of Crawfish Creek, which has a considerable cascade called Moose Fall. In this creek crawfishes (*Astacus*) are said to abound.

None of the streams in the valley of Falls River in the southwestern part of the Park were examined. This region is said to be rather level, full of ponds, marshes, and springs. Here trout are reported to be very abundant.

Trout were also procured by Mr. E. R. Lucas, of the Fish Commission, in Howard's Creek, Idaho. Mr. Lucas gives us the following notes:

"On October 14, I collected 1,000 black-spotted trout from Howard's Creek, and on October 16 I planted them in the East Fork of the Gardiner River (Lava Creek) above the falls. Howard's Creek is the headwater of Henry's Lake. It rises in the mount-

* Prof. Frank H. Bradley (Report U. S. Geol. Survey, 1872, p. 256, *fide* Gannett), thus speaks of Lewis River:

"In descending from Lake Lewis, the party found the river-banks low and rocky for a short distance before the stream enters a cañon with walls 150 to 200 feet high, in which were encountered sharp rapids and a vertical fall of about 30 feet. Then for a mile or two the slopes are gradual with narrow, swampy bottoms along the river. About 3 miles below the lake high, rocky banks indicate the approach to a deep cañon which really commences at about 3½ miles, with perpendicular walls on both sides inclosing a narrow channel with a rapidly-sloping rocky floor, in some places partially obstructed by huge tumbling masses of rock, but apparently without any accumulation of gravel. Considerable rapids occur through nearly the whole cañon, and one fall of nearly 50 feet was noticed. The cañon deepens rapidly to from 700 to 800 feet, with width of less than half the depth at the deepest precipitous portions. * * * About 3 miles down it reaches its culmination and is truly grand. It has none of the brilliancy of coloring so characteristic of the Yellowstone Cañon, but the sombre tints of its gray, brown and dark-red lichen-covered rocks, variegated with smaller patches of green and yellow, constitute a peculiar style of beauty and add greatly to the effect of its narrow dark depths."

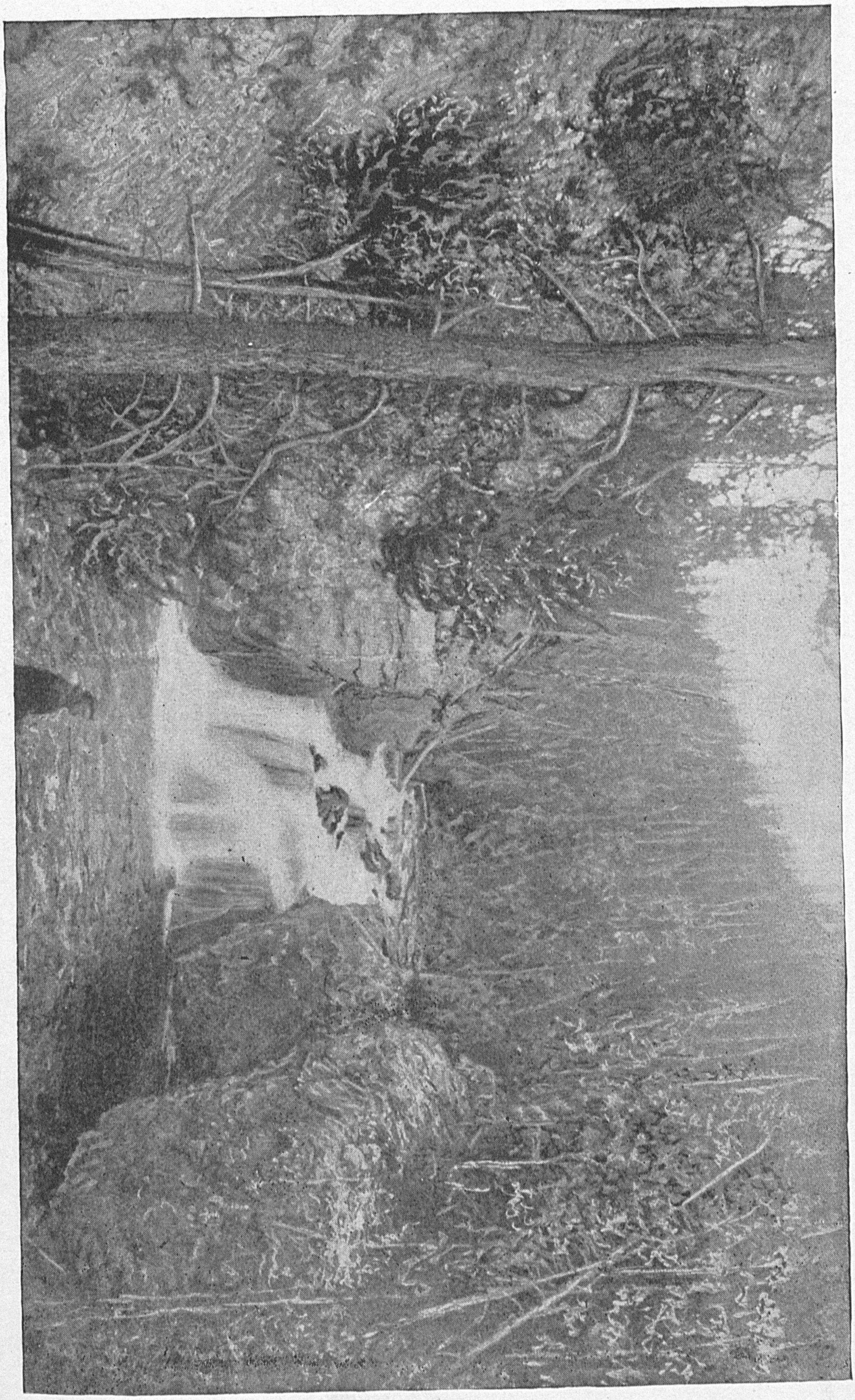
ain (Continental Divide) and flows about 2 miles, emptying into Henry's Lake. Howard's Creek is very small, averaging not more than 6 feet in width, and 6 to 12 inches deep. The bottom of this stream is mostly covered with small stones, in places a mud bottom. It contains no vegetable growth, except grass along its banks. There are no fish in this stream except trout, ranging from 1 inch to 4 inches in length. I caught 1,000 of these fish in about one hour and a half. It is impossible to estimate the number of trout that could be caught in this stream."

The following is a classified list of the lakes and streams in the Park (including a few outside its southern boundary) suitable for trout. Those in which trout are supposed not to exist are indicated by a star.

Upper Yellowstone River:
- Atlantic Creek.
- Jay Creek.
- Bridger Lake and Creek.
- Falcon Creek.
- Thoroughfare Creek.
- Escarpment Creek.
- Cliff Creek.
- Lynx Creek.
- Phlox Creek.
- Mountain Creek.
- Badger Creek.
- Trapper's Creek.

Yellowstone Lake:
- Beaverdam Creek.
- Rocky Creek.
- Elk Trail Creek.
    - Chipmunk Creek.
    - Riddle Lake and Solution Creek.
    - Arnica Creek with Beech Lake.
    - Columbine Creek.
    - Clear Creek.
    - Turbid Lake* and Bear Creek.
    - Pelican Creek.

Lower Yellowstone River:
- Sour Creek.
- Trout Creek.
- Alum Creek.
- Crystal Lake and Cascade Creek.*
- Broad Creek.*
- Deep Creek.*
- Antelope Creek.
- Tower Creek.*
- Lamar River.
    - Cold Creek.
    - Willow Creek.
    - Timothy Creek.
    - Miller Creek.
    - Calfee Creek.
    - Cache Creek.
    - Soda Butte Creek, Pebble Creek, Amphitheatre Creek.
    - Slough Creek with Buffalo Creek, Lake Abundance, etc.
- Hellroaring Creek.



LOWER FALLS OF FIREHOLE RIVER. (See page 59.)

Lower Yellowstone River—Continued.
- Black-Tail Deer Creek.
- Gardiner River.
  - Lava Creek, Lupine Creek.
  - Obsidian Creek* (with Twin Lakes,* Obsidian Lake,* Beaver Lake,* Lake of the Woods*), Winter Creek,* Straight Creek,* with Grizzly Lake.*
  - Indian Creek.*
  - Panther Creek.*
  - Fawn Creek.*
  - Glen Creek,* with Swan Lake.*

Gallatin River:
- Gallatin Lake.
- Fan Creek.
- Grayling Creek.

Madison River:
- Gibbon River:* with Grebe Lake.*
  - Solfatara Creek.*
  - Cañon Creek.
- Firehole River.*
  - Madison Lake.*
  - Spring Creek.*
  - Iron Spring Creek.*
  - Little Firehole River.*
  - Fairy Creek.*
  - Goose Lake.*
  - Sentinel Creek.*
  - Nez Percé Creek* (with Aspen,* Spruce* and Magpie* Creeks).
- Cougar Creek.
- Maple Creek.
- Gneiss Creek.

Snake River:
- Fox Creek.
- Crooked Creek.
- Sickle Creek.
- Pacific Creek.
- Heart Lake and Heart River.
  - Witch Creek.
  - Beaver Creek.
  - Surprise Creek.
- Basin Creek.
- Coulter's Creek, with Harebell and Wolverine Creeks.
- Red Creek.
- Forest Creek.
- Lewis River.*
  - Shoshone Lake,* with Shoshone Creek,* Moose Creek,* and Heron Creek.*
  - Lewis Lake.*
- Crawfish Creek.*
- Falls River with Beula,* Hering* and Grassy* Lakes.
  - Mountain Ash Creek.
  - Bechler River.