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A NEW FISH OF THE GENUS *APOCOPE* FROM A WYOMING WARM SPRING

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WHILE in the service of the United States Bureau of Fisheries in 1934, supervising some trout stream improvement work in Wyoming, the junior author was sent into the upper Green River basin on the Wyoming National Forest to survey the trout streams with reference to their improvement. In the course of this work Mr. Harmon Shannon, the ranger at the Kendall Ranger Station, made inquiries regarding the identity of a small green fish which he had occasionally taken from a warm spring several miles upstream from the station. The first examination of the spring was made on May 29, 1934, and a collection of 251 specimens was made on June 20. Later collections were made in the same spring by the Bureau of Fisheries survey party in 1934 and by J. R. Simon in 1936. A detailed examination of these fish, and comparison of them with series of *Apocope* from neighboring waters, have indicated that all the fish from the warm spring represent an apparently undescribed subspecies of *Apocope oscula,* seemingly restricted to this one spring.

THE HABITAT

(Pl. I, and Pl. II, Figs. 1 and 2)

Kendall Warm Spring, in which these dace were collected, is in or near Section 2, Township 38 N., Range 110 W., Sublette County, Wyoming, about 5 miles north of the Kendall Ranger Station. It emerges as 3 separate main springs and numerous small contributing springs, from the north side of a hill along Green River. The springs unite to form a small stream which flows several hundred feet before emptying into Green River. The temperatures of the springs differ somewhat, but do not diverge greatly from the average temperature of about 85° F. A reading of 85° F. was taken on June 20 where a road crosses the stream. When the stream was examined at the same point by the Bureau of Fisheries survey party on July 3, the temperature was 84.5° F. It is probable that the springs emerge at a somewhat higher temperature the year around, and the stream doubtless forms a sharp temperature gradient during the cold winter, varying from the approximate temperature given (85° F. or more) in the springs to nearly freezing as the water flows into Green River. The springs give off a distinct sulphurous odor, which, however, is not nearly so noticeable as about most of the other hot springs of the same general region. The biota associated with the spring dace includes an abundance of *Chara contraria* and other algae, moss (*Drepanocladus aduncus polycarpus*), a few of the higher plants (including *Mimulus glabratus fremontii*), numerous snails (*Physa smithiana*), frogs, toads, and insects.

It is evident that part of the hill from which the springs emerge has been formed of deposits from the spring water, possibly of gypsum and sinter (Pl. I, Fig. 1). Below the hill these deposits have built a sloping terrace, the outer edge of which rises abruptly about 10 feet above the normal level of Green River. The spring water spreads out into numerous rills as it passes over the edge of the terrace along a 50-foot front, falling abruptly over the 10-foot cliff into the river (Pl. II, Fig. 2).

The fish in the spring have long been isolated, for the spring has been separated from the river, perhaps for several thousand years, by the natural barrier of its own making, so high that even during floods in the Green River, no fish can ascend from it into the spring. Although there is nothing to prevent the fish from going over the falls, two factors presumably militate against the survival of any spring fish in the river. The first is the physiological effect of the temperature change, which may kill them in a short time. The second factor is a biological barrier, consisting of a large number of adult trout which lie in the deep hole that margins the ledge. These fish, normally hungry, regularly and readily take spring minnows used as bait. Furthermore, some of the spring minnows, frightened into the swift current of the creek above, were seen to be eaten as soon as they were washed into the river. Whether some of the creek fish do survive in the stream below was not determined, for opportunity did not permit making collections in the river near the spring. Collections made elsewhere in the upper Green River and tributaries, however, indicate that such stragglers as may have survived in the river probably have not spread far nor established any populations in the river or its tributary creeks.

Cultural operations on the forest have changed the aspect of the warm springs and the spring creek in two ways. A road built across the stream has dammed it to some extent (Pl. II, Fig. 1), forming a pond less than an acre in area (Pl. I, Fig. 2). The water flows under the road in 2 or 3 large culverts, so that the stream probably spreads more widely than it originally did, as it falls over the cliff. One of the springs has been dug out and walled in to form a bathing place for the CCC boys, who often lie in the warm water after the day's work. The cattle that are grazed on the area probably further modify the natural conditions to some degree, by wading in the stream.

There is a possibility that the Forest Service may in the future find it advisable to dam the stream still further in order more effectively to raise minnows as food for trout in the stream below. The total present population of the spring dace was estimated to be between 200,000 and 500,000.

NATURAL HISTORY OBSERVATIONS

It is possible that the dace breed throughout the year in these waters of relatively uniform temperature, but there is no evidence to prove this point. It can be said definitely, however, that they breed at least from the latter part of June to the early part of September. At the first seining, on June 20, individuals were found having ova in all advanced stages; only a few had already spawned, and no young were found. The fish taken on July 3, 1934, include 1 young of the year and a large number of spent females; a few of the females had very large, well-developed eggs, apparently ready to be deposited. Some of the adult females collected by Mr. Simon on September 5, 1936, were still gravid, and on that date 10 young only 7 to 11 mm. in standard length were collected, with 150 half-grown to adult fish, 15 to 44 mm., mostly 18 to 35 mm. long. Mr. Simon contributes the interesting observation, that the very young lived toward the upper part of the spring flow in the warmer water, while the adults were commoner in the cooler water downstream.

The sex ratio of the 251 specimens in our June 20 collection, 50 males to 201 females, probably represents the true sex ratio of the population as a whole. Since the fish were collected with a small-meshed seine hauled generally over the whole habitat, there is little possibility that enough fish of either sex escaped so as to make the seining selective. Probably the adverse environmental conditions lead to a differential mortality, destroying the males more frequently than the females, as in other species of fish.

ACKNOWLEDGMENTS

We are indebted to the United States Bureau of Fisheries for granting the junior author the privilege of collecting these and other fish during his spare time, while he was in the employ of the Bureau, and for permission to study this problem and to publish this paper. The Wyoming State Fish and Game Commission granted a permit to collect fish for scientific purposes. The United States Forest Service aided with advice in the field, and provided photographs of the springs. Professor R. V. Chamberlin of the University of Utah loaned us some of the paratypes of the new subspecies, and comparative

material from other localities. Mr. James R. Simon provided information concerning the collections made by the Bureau under his direction in 1934, made supplementary collections of the warm spring biota in 1936, and took additional photographs. Colleagues at the University of Michigan have kindly identified important elements in the biota of Kendall Warm Spring: W. R. Taylor, the *Chara;* W. C. Steere, the *Drepanocladus;* G. M. Ehlers, the *Mimulus;* Calvin Goodrich, the *Physa.* Dr. W. D. Baten suggested the formulas used in the statistical treatment of our data.

METHODS

Scales were counted only along the lateral line, from the last one in contact with the shoulder girdle to the last one lying entirely or mostly in advance of the base of the caudal rays.

The fin ray counts were made by means of transmitted light. The anteriormost dorsal and anal fin ray counted was the first well-developed one (i.e., the last unbranched ray); the last ray of these fins was always considered as divided to the base. All stages of atrophy, from well-developed to absent, were noticed in the second half of the last ray. When this half of the last fin ray was found to be completely atrophied, what had been the first half of the ray was counted with the ray preceding as the last ray. In most of the vertical fins of *thermalis* having the normal number of rays for *Apocope* (8 dorsal and 7 anal), the second half of the last ray is very weak, often represented only by a stub which extends more nearly parallel to the body than to the other fin rays. The pectoral and pelvic fins of the left side only were used in the ray counts, and every ray in these fins was counted that showed independent origin from the base of the fin and that exhibited the characteristic cellular structure. Owing to the small size of the fish and to the difficulty of distinguishing the last ray in this form, the ray counts for *thermalis* were made under a magnification of 64 ×.

All measurements were recorded to the nearest tenth millimeter, were taken with a Keuffel and Esser ''Minusa'' brand precision caliper, and were read on a Browne and Sharpe standard steel scale graduated in half millimeters. The measurements were taken and read under a binocular microscope, using sufficient magnification to insure accuracy. The standard length as stated is the distance between the tip of the snout and the base of the caudal rays. The length to dorsal is the distance between the tip of the snout and the origin of the dorsal fin. The depth of the body is the greatest depth. The length of the head is the distance between the tip of the snout and the posterior end of the right opercle, including the opercular membrane. The depth of the head is the distance between the occiput and a point on the ventral surface of the head vertically below. The width of the head is the greatest width. The length of the snout is the distance between the tip of the snout and the anterior rim of the socket of the eye. The length of the eye is the greatest distance across the cornea. The length of the depressed dorsal fin is the distance between the origin of the dorsal fin and the tip of the longest ray, measured when the dorsal fin is folded down on the back. The length of the pectoral fin is the distance between the insertion of the fin and the tip of the longest ray.

All measurements were converted into thousandths of the standard length with the use of a calculating machine.

The percentage classes into which the measured variates were grouped, for the computations summarized in Table V, were of the smallest class size which would not obscure a smooth curve of frequency distribution.

The formulas used in the statistical analysis of the measurements and counts are given below. In these formulas, M_v = true mean; M_o = provisional mean; v' = deviation from the provisional mean; f = frequency; w = width of the class; N = number of variates; Σ = the sum.

$$(1)\ \text{Mean (M)}:\ M_v = M_o + \left(\frac{\Sigma v'}{N}\right) w$$

(2) Standard deviation of the set of variates:

$$\sigma_V = \left(\sqrt{\frac{\Sigma V'^2}{N} - \left(\frac{\Sigma V'}{N}\right)^2 - \frac{1}{12}}\right) w, \text{ for continuous variates,}$$

$$\text{or, } \sigma_V = \sqrt{\frac{\Sigma V'^2}{N} - \left(\frac{\Sigma V'}{N}\right)^2}, \text{ for non-continuous variates.}$$

(3) Standard error of the mean: $\sigma_M = \frac{\sigma_V}{\sqrt{N}}$

(4) Significance of difference between means:

$$\text{Sign.} = \frac{M_1 - M_2}{\sqrt{(\sigma_{M_1})^2 + (\sigma_{M_2})^2}}$$

If this index of the significance of the difference between two means is greater than 2.5 (plus or minus), the difference may be regarded as of virtually certain significance.

All of the computations as well as the counts and measurements were made by the junior author.

Apocope oscula thermalis, n. subsp.

(Pl. II, Figs. 3 and 4, and Pl. III)

TYPE SPECIMENS.—The holotype, Cat. No. 110098, Mus. Zool., Univ. Mich., is a mature male 34.0 mm. long to base of caudal, and 45.5 mm. in total length. It was collected on June 20, 1934, by Eugene R. Kuhne, in Kendall Warm Spring, Wyoming (more specifically located and described above). The paratypes, all from the same spring, comprise 250 specimens taken with the holotype, and 79 taken by a Bureau of Fisheries party led by James R. Simon on July 3, 1934, and 160 taken by Mr. Simon on September 5, 1936. The largest paratype measures 44.5 mm. in standard length and 56.2 mm. in total length. The paratypes are deposited in the collections of the Museum of Zoology, the United States National Museum, the University of Utah, and the University of Wyoming.

CHARACTERS OF THE HOLOTYPE.—Scales in lateral line 63; dorsal rays 8; anal rays 7; pectoral rays 12; pelvic rays 8. Measurements in hundredths of total length: length to dorsal

60.9; greatest depth of body 25.6; least depth of caudal peduncle 12.6; length of head 30.9; depth of head 20.0; width of head 17.9; length of snout 10.6; length of eye 6.8; length of depressed dorsal fin 27.1; length of pectoral fin 28.5.

DISCUSSION.—The description of these specimens as representing a new subspecies is a part of a revisionary study of the species and subspecies of the Western dace referable to *Apocope.* Anticipating the publication of a more general treatment of this group, we merely state here that we accept the distinction of *Apocope* from *Agosia* as a genus, and refer most of the seemingly numerous local forms of *Apocope* to a widely ranging species, *Apocope oscula.*

The dace of Kendall Warm Spring are odd little fish unlike those which we have seen from any other body of water. In this paper we do not attempt to compare them with many of the other forms of *Apocope oscula,* for these races are at present very incompletely separated and very inadequately described. We compare *A. o. thermalis* only with the Green River form which we identify as *A. o. yarrowi.* Except for *thermalis,* that subspecies is the only one known in the Green River system, where it is generally common in suitable habitats. Since the isolated spring inhabited by *thermalis* is thus surrounded by the range of *yarrowi,* it seems reasonable to suppose that it is a local derivative of *yarrowi.* This supposition is confirmed by the not infrequent development in each of these subspecies, but in no other form so far as known, of a narrow frenum connecting the premaxillaries with the forehead (in which respect these forms approach *Rhinichthys*). In certain other characters *thermalis* and *yarrowi* show a definite agreement; for instance, the barbel is developed in nearly all of the specimens of each form.

To allow a statistical comparison of their characters, we have counted and measured 121 specimens of *thermalis,* the holotype and the 120 paratypes taken with it, and 152 specimens of *yarrowi* representing 8 collections taken in the Green River and its tributaries both above and below Kendall Warm Spring. The data for the series of *yarrowi* studied, all from

Wyoming, and in parenthesis the number of specimens counted and measured in each lot, are given below:

Green River at Green River; Carl L. and Laura C. Hubbs; September 16, 1934 (16).

Pine Creek, just below Fremont Lake; Eugene R. Kuhne; June 17, 1934 (10).

Fremont Lake, near Pinedale; James R. Simon; August 10, 1934 (2).

Duck Creek, at Highway 187 crossing near Pinedale; Eugene R. Kuhne; August 29, 1934 (68).

New Fork River, at Highway 187 crossing near Pinedale; Eugene R. Kuhne; August 29, 1934 (10).

Halfmoon Lake, Wyoming National Forest; James R. Simon; August 21, 1934 (15).

Wagon Creek, at mouth in Green River, Wyoming National Forest; James R. Simon; June 27, 1934 (17).

Boulder Creek, Wyoming National Forest; James R. Simon; September 4, 1934 (14).

Although the specimens from these localities show some differences, they are essentially consistent and all seem referable to a single subspecies. In comparing *thermalis* and *yarrowi*, it seems legitimate to treat as a unit all of the series of *yarrowi* studied. Only for the number of scales in the lateral line, and for the sum of the scale counts and of all the fin ray counts, have we tabulated separately the counts for the 8 different lots of *yarrowi*.

NUMBER OF SCALES IN LATERAL LINE (Table I).—The sharpest single difference between *Apocope oscula thermalis* and *A. o. yarrowi* lies in the number of scales. Those in the lateral line number 45 to 66 in *thermalis*, as contrasted with 62 to 79 in *yarrowi* from the Green River basin.[1] The data are relatively consistent, for there is little overlap between the scale counts of *thermalis* and those of any of the series counted of *yarrowi*. The index of significance of the difference between the number of scales in the two forms is very high, 34.1.

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[1] Typical *yarrowi* from Tomichi Creek, Gunnison, Colorado, was described as having 74 to 83 scales in the lateral line (Jordan, 1891: 28). That the Green River race has fewer scales than typical *yarrowi* was noted by Evermann and Rutter (1895: 484); they counted 70 to 76 scales in specimens from the Green River at Green River, and 74 to 80 in types of *Agosia yarrowi* from Gunnison, Colorado.

Although there can be no question as to the statistical significance of the difference in the mean number of scales in *thermalis* and *yarrowi,* some doubt may be raised as to the systematic significance of the difference. It has been proved that great differences in the number of scales in the lateral line in minnows may be induced directly by the conditions modifying the development of the individual (Hubbs, 1927: 82), and that the number of meristic parts, including the scales, tends to vary inversely with the temperature of the water during the development of the structure involved (Hubbs, 1926, 1934, and other papers cited therein). It is therefore conceivable that the large difference between *thermalis* and Green River *yarrowi* in the number of scales, amounting on the average to 14 scales in the lateral line count, may be due directly to the temperature of the water and may therefore have no genetic significance.

Within the Green River population of *yarrowi,* we find differences as great as 2 to 5 in the average number of lateral line scales. These differences also seem to be correlated with differences in water temperatures. In the accompanying table of scale counts, we have arranged the Green River basin collections as nearly as possible in a temperature sequence, as follows:

(1) The Kendall Warm Spring is certainly by far the warmest water.

(2) Green River (at Green River) is almost as surely warmer than any of the other much more nearly headwater stations, except of course the warm spring.

(3) Pine Creek (with Fremont Lake) is presumably the next cooler water; we found that this stream warmed up considerably during summer days as it arose from the surface of the somewhat dammed Fremont Lake. the largest lake of the region.

(4 and 5) Duck Creek and New Fork River, though at a somewhat lower elevation (about 7300 instead of 7600 feet) are probably a little cooler than Pine Creek, because they do not arise in lakes.

(6) Halfmoon Lake may be cooler than Duck Creek and New Fork River because it is at a higher elevation (about 8650 feet), but may be warmer because it is a lake.

(7) Wagon Creek, at about 7850 feet elevation, is probably next coldest to:

(8) Boulder Creek, at about 8500 feet elevation.

TABLE I
NUMBER OF SCALES IN LATERAL LINE

Scales	*thermalis*	*yarrowi*							
	All data	Green R.	Pine Cr.*	Duck Cr.	New Fork R.	Half-moon L.	Wagon Cr.	Boulder Cr.	All data
45	1	......	......	......	......	......	......	......	......
46	......	......	......	......	......	......	......	......	......
47	......	......	......	......	......	......	......	......	......
48	1	......	......	......	......	......	......	......	......
49	1	......	......	......	......	......	......	......	......
50	1	......	......	......	......	......	......	......	......
51	2	......	......	......	......	......	......	......	......
52	2	......	......	......	......	......	......	......	......
53	10	......	......	......	......	......	......	......	......
54	9	......	......	......	......	......	......	......	......
55	14	......	......	......	......	......	......	......	......
56	12	......	......	......	......	......	......	......	......
57	16	......	......	......	......	......	......	......	......
58	10	......	......	......	......	......	......	......	......
59	15	......	......	......	......	......	......	......	......
60	12	......	......	......	......	......	......	......	......
61	6	......	......	......	......	......	......	......	......
62	3	......	......	1	......	......	......	......	1
63	......	......	......	......	......	1	......	......	1
64	3	......	......	2	......	......	1	......	3
65	1	......	......	2	......	......	......	......	2
66	1	2	1	3	......	......	......	......	6
67	......	2	......	3	......	1	......	1	7
68	......	5	2	3	1	2	1	......	14
69	......	1	1	6	2	3	2	......	15
70	......	3	5	9	1	2	2	1	23
71	......	2	3	9	1	......	1	1	17
72	......	1	......	9	3	1	1	2	17
73	......	......	......	5	......	1	1	3	10
74	......	......	......	7	......	......	4	2	13
75	......	......	......	2	......	1	2	2	7
76	......	......	......	5	2	2	2	1	12
77	......	......	......	......	......	......	......	1	1
78	......	......	......	......	......	1	......	......	1
79	......	......	......	2	......	......	......	......	2
N	120	16	12	68	10	15	17	14	152
Mean	56.90	68.7	69.5	71.0	71.5	70.9	72.0	73.0	70.93
σ_V	3.43	......	......	......	......	......	......	......	3.30
σ_M	0.31	......	......	......	......	......	......	......	0.27
Order†	1	2	3	4	5	6	7	8	2–8

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* Including 2 specimens, with 68 and 71 scales, from Fremont Lake, of which Pine Creek is the outlet.

† The probable order of temperature.

Unfortunately, we have little actual temperature data for most of the series, since the few available readings were taken on single examinations at varying hours of day and on different dates. The most significant temperatures would be those prevailing on the average in each water when the postlarval dace are forming their scales. We feel confident that the order in which the collections are listed in Table I is approximately correct though it may not represent exactly the gradient of water temperatures at that time. If this be true, the correlation between the average number of scales and the water temperatures (see the bottom rows of Table I) is very striking. Whether this correlation is due to a direct (individual) or an indirect (racial) response needs to be determined by experiment. For the present, we can only proceed under the assumption that the reduction in scale number in *thermalis* has, at least in part, a genetic basis.

A close parallel to *Apocope oscula thermalis* is *Rhinichthys cataractae smithi* Nichols (1916: 69), a local form of a related genus described from a hot spring and likewise characterized by a markedly reduced number of scales.

That the differences between *Apocope oscula thermalis* and *A. o. yarrowi* in scale number are paralleled by local variations in other parts of the wide range of the species *oscula* (more commonly called *nubila*), is shown by the counts published by various authors, particularly Gilbert and Evermann (1894: 43), Rutter (1908: 140), and Snyder (1908a: 99; 1908b: 180).

NUMBER OF FIN RAYS (Tables II and III).—Compared with the samples of *Apocope oscula yarrowi* from the Green River drainage, *thermalis* shows an average reduction in the number of rays in each fin, with the probable exception of the caudal fin which was not studied. The reduction in dorsal and anal rays is greater than indicated by the figures in Table II, for the second half of the last ray is usually more or less rudimentary in those specimens of *thermalis* having the usual number of rays for an *Apocope* (8 dorsal rays, 7 anal rays), as already pointed out (p. 5).

TABLE II

NUMBER OF RAYS IN EACH FIN

	Number of fin rays										
	6	7	8	9	10	11	12	13	14	15	Mean
Dorsal fin rays											
thermalis	......	52	68	......	......	......	......	......	......	......	7.57
yarrowi	1	5	146	......	......	......	......	......	......	......	7.95
Anal fin rays											
thermalis	......	28	92	......	......	......	......	......	......	......	6.77
yarrowi	1	4	147	......	......	......	......	......	......	......	6.96
Pectoral fin rays											
thermalis	......	......	......	......	4	59	54	3	......	......	11.47
yarrowi	......	......	......	......	......	6	89	51	5	1	12.38
Pelvic fin rays											
thermalis	1	40	78	1	......	......	......	......	......	......	7.66
yarrowi	......	3	137	12	......	......	......	......	......	......	8.06

Since the reduction in number of rays involves each of the fins, all of the ray counts for each individual fish were added, in the expectation that the sum would be more distinctive than the counts for any one fin. Table III shows that this expectation is confirmed. The difference between *thermalis* and *yarrowi* in the sum of the fin ray counts is of certain statistical significance, for the index of significance is 13.5. Whether the difference has a genetic and systematic significance, however, has not been proved.

SUM OF SCALE AND FIN RAY COUNTS (Table IV).—By adding the scale count to the sum of the fin ray counts for each

TABLE III

SUM OF THE FIN RAY COUNTS

The figures represent the sum of the counts of the rays in the dorsal, the anal, and the left pectoral and left pelvic fin of each individual.

	Sum of the fin ray counts										
	31	32	33	34	35	36	37	38	Mean	σ_V	σ_M
A. o. thermalis	8	20	28	32	28	4	......	......	33.53	1.28	0.12
A. o. yarrowi	......	......	1	17	74	48	11	1	35.55	0.82	0.07

individual we have obtained a character index, which on comparing *thermalis* with Green River *yarrowi* shows a minimum amount of overlap; this sum varies in *thermalis* from 76 to 99, and in *yarrowi* from 98 to 115. If we place the division between the values for the two forms between 98 and 99, we find only 3 specimens of each, out of 120 and 152 respectively, for which the index is beyond this limit, by only 0.5 point. The means for this summary index are 90.43 for *thermalis* and 106.29 for *yarrowi*. The index of significance of the difference between these figures, 34.5, is very high, slightly higher than for the scale counts, and much higher than for any of the other characters studied. The difference therefore is of great statistical significance, but will be of certain systematic value only when the differences in number of scales and of fin rays are proved to have a genetic basis, at least in part. The average value of this summary character index, as of the scale counts (Table I and p. 10), seems to be correlated negatively with the water temperature.

The summation of different characters to produce a character index is a legitimate and useful procedure (Hubbs and Whitlock, 1929: 470). The sum of the scale and fin ray counts in this study gives an index more distinctive and with less overlap in frequency distribution than is shown by any of the separate counts. This result follows because the scales and the rays of each fin all show a correlated tendency to become reduced in number in the warm spring form *thermalis*.

PROPORTIONATE MEASUREMENTS.—*Apocope oscula thermalis* differs further from the populations of *A. o. yarrowi* which surround it, and from which it was presumably derived, in every character which was measured, with the probable exception of the depth of the body (which measurement we have considered too variable and unreliable to warrant statistical analysis). In *thermalis* as compared with *yarrowi* an enlargement is evident in all of the anterior parts measured, namely length to dorsal; length, depth, and width of head; and length of snout and of eye. The fins are also larger in *thermalis* than in *yarrowi*, as illustrated by our measurements of the length

TABLE IV

SUM OF THE SCALE AND FIN RAY COUNTS

The figures represent the sum of the counts for the scales in the lateral line, and for the rays in the dorsal, the anal, and the left pectoral and left pelvic fin of each individual.

Sum of counts	*thermalis*	*yarrowi*							
	All data	Green R.	Pine Cr.*	Duck Cr.	New Fork R.	Half-moon L.	Wagon Cr.	Boulder Cr.	All data
76......	1	......	......	......	......	......	......	......	......
77......	......	......	......	......	......	......	......	......	......
78......	......	......	......	......	......	......	......	......	......
79......	......	......	......	......	......	......	......	......	......
80......	2	......	......	......	......	......	......	......	......
81......	......	......	......	......	......	......	......	......	......
82......	1	......	......	......	......	......	......	......	......
83......	......	......	......	......	......	......	......	......	......
84......	2	......	......	......	......	......	......	......	......
85......	5	......	......	......	......	......	......	......	......
86......	6	......	......	......	......	......	......	......	......
87......	7	......	......	......	......	......	......	......	......
88......	10	......	......	......	......	......	......	......	......
89......	15	......	......	......	......	......	......	......	......
90......	15	......	......	......	......	......	......	......	......
91......	8	......	......	......	......	......	......	......	......
92......	12	......	......	......	......	......	......	......	......
93......	8	......	......	......	......	......	......	......	......
94......	8	......	......	......	......	......	......	......	......
95......	10	......	......	......	......	......	......	......	......
96......	5	......	......	......	......	......	......	......	......
97......	......	......	......	......	......	......	......	......	......
98......	2	......	......	2	......	1	......	......	3
99......	3	1	......	1	......	......	......	......	2
100......	......	......	......	1	......	......	......	......	1
101......	......	......	......	4	......	......	1	1	6
102......	......	3	1	3	......	......	......	......	7
103......	......	4	2	4	......	2	......	......	12
104......	......	3	2	5	3	3	3	......	19
105......	......	......	2	6	1	2	1	......	12
106......	......	2	4	7	2	1	1	1	18
107......	......	2	......	12	1	......	2	2	19
108......	......	1	1	6	1	1	......	4	14
109......	......	......	......	5	......	1	3	1	10
110......	......	......	......	6	......	1	3	......	10
111......	......	......	......	3	......	1	2	2	8
112......	......	......	......	......	1	2	1	1	5
113......	......	......	......	1	1	......	......	2	4
114......	......	......	......	1	......	......	......	......	1
115......	......	......	......	1	......	......	......	......	1
N	120	16	12	68	10	15	17	14	152
Mean	90.43	103.94	104.83	106.19	106.90	106.27	107.59	108.71	106.29
σ_V	3.98	......	......	......	......	......	......	......	3.46
σ_M	0.36	......	......	......	......	......	......	......	0.28

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* Including 2 specimens, with summary counts of 103 and 106, from Fremont Lake, of which Pine Creek is the outlet.

of the dorsal and pectoral fins. All of these differences are of average significance only, for the measurements of the 2 forms widely overlap in frequency distribution. But the average differences are all of apparent statistical significance, as shown by the index of significance in the last column of Table V. Least certain significance is indicated for the differences in length of snout and of dorsal fin; greatest significance for the differences in the 3 head measurements and in the length of the eye. These various significant differences in proportions are not independent, for they are all correlated with a tendency of the anterior regions to grow relatively faster in *thermalis* than in *yarrowi*, or, conversely, for the posterior parts of the body to be more stunted; or, to express the differences in yet another way, for the adult to retain and to some degree even to emphasize the juvenile proportions. It is characteristic of dwarfed forms, and of warm-water forms of fishes, to show such proportions (Hubbs, 1926: 62), but whether as a result of direct or of genetic adaptation is usually not certain.

The proportionate measurements of the pectoral fin are given for each sex, because this fin shows a very considerable sexual dimorphism in *Apocope* as in many other cyprinids. Sex was determined by dissection for all fish except a few mature adults of obvious sex, and for a few immature specimens of *yarrowi* that were treated statistically as females. The pectoral fin of the male averages 3.28 per cent of the standard length longer than that of the female in *thermalis*, and 3.15 per cent longer in *yarrowi*; this fin in *thermalis* averages 2.26 per cent of the standard length longer than in *yarrowi* for the males, and 1.53 per cent longer for the females. The index of the significance of the differences between the sexes in pectoral fin length, 12.5 for *thermalis* and 14.9 for *yarrowi*, is greater than that between the species, 7.8 for males and 7.6 for females.

The fins are somewhat more produced and falcate in the adult male than in the adult female or the young. The tips of all the vertical fins are rounded. The dorsal has a subvertical and usually somewhat concave edge when the fin is in

TABLE V

MEASUREMENTS IN HUNDREDTHS OF STANDARD LENGTH

The statistical methods used are explained on p. 6; 120 specimens of *thermalis* and 152 of *yarrowi* were measured

Character (see p. 6) Subspecies	Minimum	Maximum	Mean	σ_V	σ_M	Index of significance
Length to dorsal						
thermalis ...	55.0	61.2	58.59	1.29	0.12	15.4
yarrowi	52.8	59.6	56.28	1.15	0.09	
Depth of body						
thermalis ...	17.5	26.8	....	....	....	....
yarrowi	18.9	27.5	....	....	....	
Length of head						
thermalis ...	26.1	34.2	30.17	1.20	0.11	20.2
yarrowi	25.5	29.7	27.44	0.96	0.08	
Depth of head						
thermalis ...	17.1	20.3	18.55	0.68	0.06	24.4
yarrowi	14.2	19.5	16.33	0.82	0.07	
Width of head						
thermalis ...	13.8	19.5	16.75	0.80	0.07	17.7
yarrowi	12.4	17.4	14.76	1.06	0.09	
Length of snout						
thermalis ...	7.9	11.7	9.51	0.68	0.06	2.9
yarrowi	7.9	10.9	9.30	0.53	0.04	
Length of eye						
thermalis ...	5.2	7.5	6.46	0.40	0.04	17.3
yarrowi	4.0	7.0	5.42	0.60	0.05	
Length of depressed D.						
thermalis ...	18.9	27.0	22.83	1.28	0.12	4.0
yarrowi	19.4	27.0	22.18	1.38	0.11	
Length of pectoral, male						
thermalis ...	21.3	29.3	26.09	1.75	0.25	7.8
yarrowi	19.8	27.1	23.83	1.23	0.14	
Length of pectoral, female						
thermalis ...	17.1	28.7	22.21	1.52	0.12	7.6
yarrowi	17.9	25.0	20.68	1.34	0.16	
Standard length of specimens measured, mm.						
thermalis ...	25.4	44.5	....	....	....	....
yarrowi	30.8	95.0*	....	....	....	

---

* Only one rather aberrant specimen of *yarrowi* measured was more than 78.3 mm. in standard length. It had only 62 scales in the lateral line and an unusually wide frenum for an *Apocope*.

normal position. The anal lobe is produced so that the usually somewhat concave edge is oblique. The paired fins are broadly rounded. The inner pelvic ray is not connected with the body by stays.

FRENUM.—Of special interest is the not infrequent occurrence in *Apocope oscula thermalis* of a narrow frenum or dermal bridge connecting the upper lip with the snout, so as to render the premaxillaries technically nonprotractile. Since the protractibility of the premaxillaries is the one trenchant character by which *Apocope* is distinguished from *Rhinichthys,* the presence of a frenum in 49 of the 326 specimens of *thermalis* examined for this character suggests that these genera are more closely related than often supposed, and casts some doubt on the validity of the generic separation. The frenum when developed in *thermalis,* however, is narrow rather than broad as in *Rhinichthys.* Furthermore, other characters of *thermalis,* especially the mottled coloration, are typical of *Apocope,* and its locality indicates relationship with *Apocope* rather than *Rhinichthys,* which is apparently absent in the Colorado River system.

The not infrequent development of a narrow frenum in *A. o. thermalis* points toward relationship with *A. o. yarrowi,* the only other form of *Apocope* described as sometimes developing a frenum. Jordan and Evermann (1891: 28) described the condition of the frenum in the types of *Agosia yarrowi* as follows:

> Upper lip, in about half the specimens, separated from the skin of the snout by a fold, as usual in *Agosia* and most other *Cyprinidae.* In the rest of the typical examples the upper lip is joined mesially to the snout by a distinct frenum. These specimens, although to all appearance specifically identical with the others, would belong to the genus *Rhinichthys,* as now defined. The frenum is, however, considerably narrower than in *Rhinichthys,* and this fact may for the present serve to separate the species from that genus.

Curiously, we find a frenum developed in only 4 of the 152 specimens examined of what we call *A. o. yarrowi* from the Green River drainage.

MAXILLARY BARBEL.—Unlike some local forms of *Apocope oscula* (Snyder, 1908a: 99), *A. o. thermalis* seldom lacks the maxillary barbel. Of the 121 specimens examined for this character only 1 has no barbel on either side. The others have on both sides a single barbel, usually of medium size but varying from short to relatively long.

The maxillary barbel is also usually developed in *A. o. yarrowi* from the Green River basin. Of the 152 specimens examined, 5 have no trace of a barbel, 142 have a simple barbel, usually of medium length but varying in size as in *thermalis*, and 5 show a double or compound barbel.

COLOR.—The general color, less bicolored, less brownish, and more greenish than in *yarrowi* from near-by waters, is usually a dull olive green in the females. The greener color may be a genetic character, or may be due to the abundance of *Chara* and other green plants in the warm spring water. The body of the breeding males becomes rather bright purple—a peculiar color not seen in *yarrowi* or other forms. The dorsal and pectoral fins of the males also become deeply pigmented with purple. Some females also show purple color, but not to so general or intense a degree as the brighter males. The body is variably covered with fine to coarse mottlings, as usual in *Apocope*. The lateral band is weak forward, but is rather strong though irregular posteriorly.

NUPTIAL TUBERCLES.—In addition to minute tubercles which cover all surfaces of the head including the branchiostegal membranes, rather weak low conical tubercles are scattered over the top of the head from nostrils to occiput, on the upper part of the opercle, and, in an irregular file, near the suture between opercle and subopercle. Other low conical tubercles, one to several per scale, chiefly small and weak, occur over the entire body, most prominently between occiput and dorsal fin. The rather large tubercles on the top of the flattened and expanded pectoral fin are arranged on each ray in 1 row basally, branching into 2 rows distally, with 1 tubercle on each ray segment; each of these tubercles is a low though rather sharp cone, directed obliquely forward and inward in dorsal view. Similar though weaker and less regularly developed tubercles, in a single file, follow the pelvic, dorsal, anal, and even the caudal rays, in high males; these tubercles are progressively weaker and more likely to be obsolescent on the fins, in the order in which the fins are named.

SUMMARY

Apocope oscula thermalis is described as a new subspecies, supposedly confined to Kendall Warm Spring along the Green River in Wyoming. Compared with *A. o. yarrowi* of other waters in the Green River basin, the new form differs in having fewer scales, and on the average in having fewer rays in dorsal, anal, pectoral, and pelvic fins. The difference in fin ray numbers is best indicated by comparing the forms on the basis of the sum of all the fin ray counts in each individual. When this sum is added to the number of scales on the lateral line, values are obtained which show a minimum of overlap in frequency distribution. The head, and all its parts, and the fins are larger than in *yarrowi*. The size is smaller. The females are greener; the males are purple. Virtually all of the characters of *thermalis* may be correlated with the warm water habitat, but whether they represent a racial or only an individual response is not certain. Like *yarrowi*, the new form approaches *Rhinichthys* in the not infrequent development of a narrow frenum.

The origin of this new subspecies seems to have been related to the isolation of the population behind a wall formed by deposits from the warm spring water.

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PLATE I

Kendall Warm Spring, Wyoming, the Habitat of *Apocope oscula thermalis.*

FIG. 1. Sources of the springs, from side of hills at south, looking across the terrace to Green River and its valley. Photograph by United States Forest Service.

FIG. 2. The main body of water, looking toward the falls into Green River, showing stream terraces on the far side of the river. Photograph by United States Forest Service.

FIG. 1

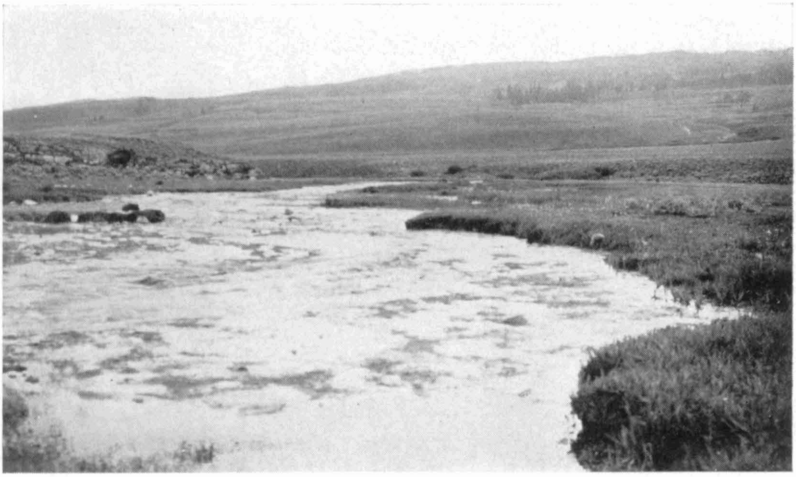

FIG. 2

PLATE II

Kendall Warm Spring, Wyoming, and two subspecies of *Apocope oscula.*

FIG. 1. Kendall Warm Spring, from below the road which partially dams the springs, showing the small flow of water through the culverts. Photograph by J. R. Simon.

FIG. 2. The falls of the spring creek, plunging over the bank of spring deposit into Green River. Photograph by United States Forest Service.

FIG. 3. *Apocope oscula thermalis:* a dorsal view of a nuptial male, the holotype, 34 mm. in standard length, from Kendall Warm Spring, Wyoming. Photograph by F. W. Ouradnik.

FIG. 4. *Apocope oscula yarrowi:* a comparable view of a nuptial male 67 mm. in standard length, from Duck Creek, Wyoming. Photograph by F. W. Ouradnik.

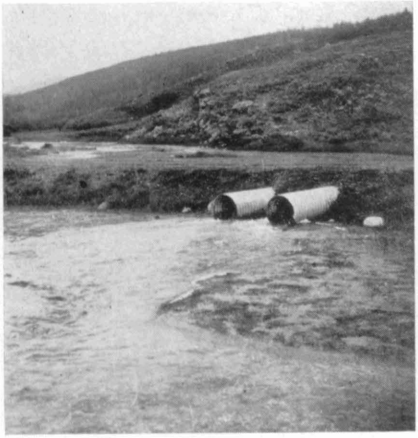

FIG. 1

FIG. 2

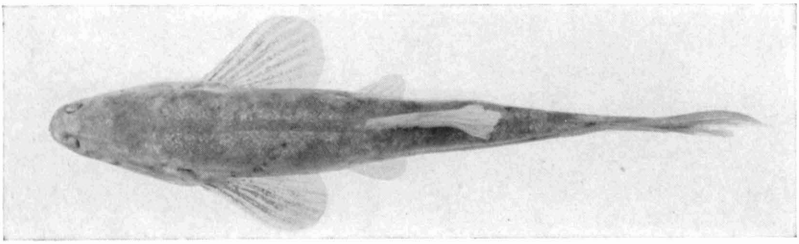

FIG. 3

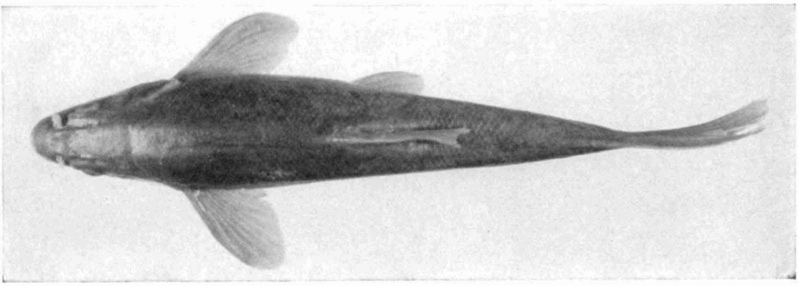

FIG. 4

PLATE III

Two subspecies of *Apocope oscula.*

FIG. 1. Mature male (upper figure) and female of *Apocope oscula thermalis,* respectively 33 and 37 mm. in standard length; collected with the holotype in Kendall Warm Spring, Wyoming. Photograph by F. W. Ouradnik.

FIG. 2. Mature male (upper figure) and female of *Apocope oscula yarrowi,* respectively 63 and 64 mm. in standard length; from Duck Creek, Wyoming. Photograph by F. W. Ouradnik.

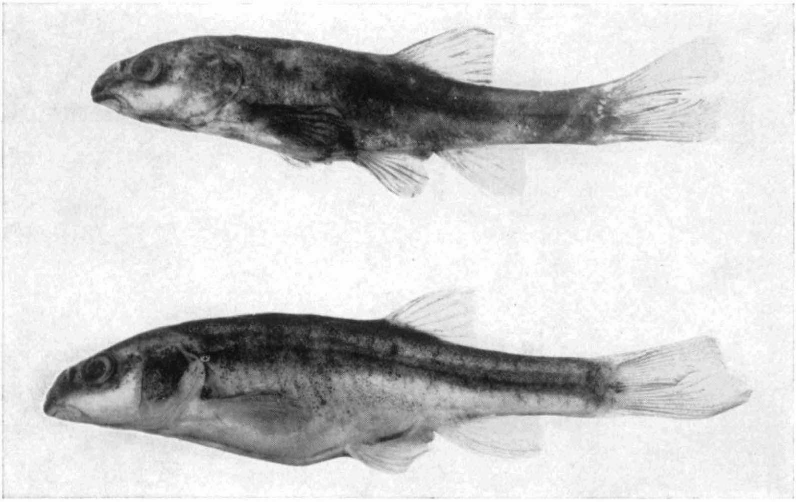

FIG. 1

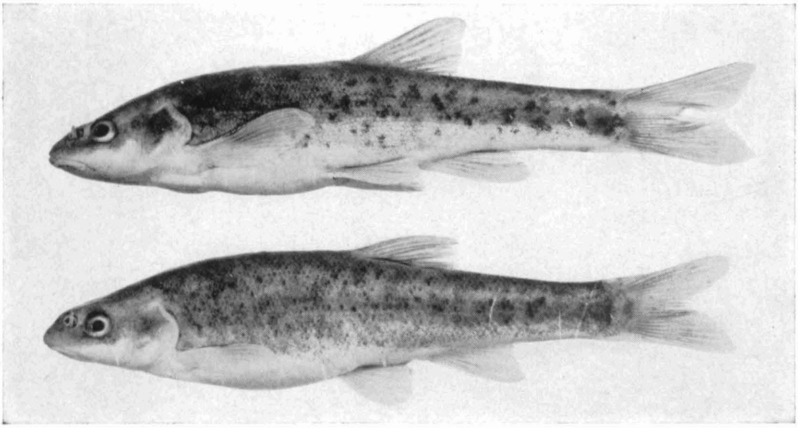

FIG. 2