Studies on Relict Populations of
Snake Valley, Utah Cutthroat Trout:
Preliminary Report to BLM,
Utah State Office

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23 May 1977

Introduction

The ancestral form of cutthroat trout ("large-spotted" type) invaded the upper Snake River from the Columbia River system prior to the formation of Shoshone Falls. From here it radiated into the Bear, Yellowstone, Colorado and other interior river drainages (Roscoe 1974). During the Pleistocene, lava inflows blocked the Snake River canyon and created Shoshone Falls on the Snake River. Shoshone Falls served to isolate the fish fauna of the upper Snake River drainage from the rest of the Columbia River basin.

During the late Pleistocene, lava intrusion in a canyon of the Bear River diverted the Bear River into the Bonneville basin. This may have been the origin of the native cutthroat trout of the Bonneville basin. Sometime between 12,000 and 30,000 years ago, as a result of the greatly augmented inflow from the Bear River, the level of Lake Bonneville rose until it overflowed into the Snake River via Red Rocks Pass (Bright 1963; Broecker and Kaufman 1965; Malde 1968). Thus, the origin of cutthroat trout in the Bonneville basin and its separation from the ancestral large-spotted trout of the upper Snake River (Yellowstone variety) may be no more than 30,000 years and perhaps less. This may explain the small degree of differentiation apparent between S. c. utah and the large-spotted cutthroat of the upper Snake River.

The final desication of Lake Bonneville occurred about 8,000 years ago (Broecker and Kaufman 1965), at which time the Sevier, Jordan, Snake Valley, Provo and Bear River drainages became isolated from contact with each other.

The native cutthroat, which once abounded in the Bonneville basin, suffered a catastrophic decline from introductions of non-native trouts, habitat loss and degradation to a point where several authors have expressed their belief that the native trout of Lake Bonneville was likely extinct (Miller 1950; Cope 1955; Sigler and Miller 1963). Recent work by Behnke (1970, 1973a, 1973b, 1975, 1976a, 1976b, 1976c) has shed new light on the existence of a few relict populations of Lake Bonneville cutthroat trout. These cutthroat trout are not abundant in any part of the Bonneville basin. Most are restricted to isolated headwater reaches.

When Mr. Ted Frantz of the Nevada Fish and Game Department discovered a cutthroat trout population in Pine Creek on Mt. Wheeler, Nevada, in 1953 (Frantz and King 1958), new hope was generated that the native cutthroat trout was not extinct. It was assumed that this trout represented an introduced population of Salmo clarki utah from nearby Trout Creek drainage of the Bonneville basin. Behnke (1976a) indicated that the logical origin of the Pine Creek cutthroat trout was from Lehman Creek (tributary in the southern portion of the Snake Valley region of the Bonneville basin), via Osceola Ditch.

In 1953 the Nevada Fish and Game Department introduced 44 fish from Pine Creek into Hampton Creek, Nevada. A second transplant of 54 cutthroat from Pine Creek was made into Goshute Creek, Nevada, in 1960.

In 1972 Mr. Frank Dodge of the Nevada Fish and Game Department found another population of cutthroat trout in the headwaters of Hendrys Creek (on the Bonneville side of Mt. Wheeler).

Several attempts were made by the Nevada Fish and Game Department to locate populations of cutthroat trout in Snake Valley area but they were unsuccessful. It was believed that the native cutthroat trout of the Snake Valley area of Utah was extinct until personnel of the BLM and Utah Division of Wildlife Resources in 1974 and 1975, discovered two virtually pure populations of cutthroat trout in the extreme headwaters of Trout and Birch Creek, Juab County, Utah (Behnke 1976a).

In 1976, while under contract by the BLM, I conducted an extensive survey of the waters in the Snake Valley region. The remainder of this report deals with the results of the stream surveys, taxonomic analysis of the trout found in these streams, statistical comparisons of these trout with others in the Bonneville basin and management recommendations for the preservation of the Snake Valley cutthroat trout.

Description of the Study Area

The Deep Creek Mountain Range is located 50 miles south of Wendover, Utah-Nevada, in the western portion of the Bonneville basin. It is bordered by the Snake Valley on the east and Antelope Valley on the west. The Deep Creek Range and the valley area primarily consist of Natural Resource Land. As a result of the relict fauna and flora which this area supports the United States government has withdrawn 26,927 acres of federal land within the mountain-valley complex of the Deep Creek Mountain Range (made under the Federal Land Policy and Management Act of 1976). This will aid in the protection of the native cutthroat trout and other unique plant and animal species, especially from proposed mining activities.

The best watershed providing permanent trout habitat is located on the southeast side of the mountain range, which is composed primarily of precambrian metasedimentary rocks, mainly quartzite and agrillite.

The mountain range contains a highly varied ecosystem, ranging from salt-desert shrub at 4,700 ft, to pinyon-juniper near 6,000 ft and a mixed conifer-montane zone above 8,000 ft. The highest elevation is 12,200 ft at Ibapah Peak, near the southern end of the range. Along the stream banks birch, aspen, wildrose, willow and red ozier dogwood are common.

The west side of the Deep Creek Mountain Range drains into the Deep Creek drainage. The streams on this side characteristically have steep gradients and very few pools and are not suited for maintaining permanent trout populations in the upper reaches. The possible exception is Johnson Creek, located at the southwest portion of the mountain range.

Survey of Streams

The following is a list of the streams that were surveyed and the information that was obtained. Stream habitat surveys were conducted following BLM guidelines (Duff and Cooper 1976). Fish were collected by hook and line.

Streams located on the west side of the Deep Creek Mountain Range.

Eightmile Canyon, Kelly Canyon, Durse Canyon and Arts Canyon: All of these streams were dry on 27 July 1976. All of the streams to the north of Eightmile Canyon were also dry, except for periods of heavy rainfall and during the spring run-off.

Rocky Canyon: North Fork--was dry on 28 July 1976.

South Fork--originates at a spring approximately .75 miles upstream from the junction of the north and south forks. Water chemistry samples were analyzed. The discharge was less than .4 CFS and the water temperature was 8°C on 28 July 1976. No fish were observed or caught. This stream receives heavy livestock use and is not suitable for a trout fisheries.

Delle Creek: North Fork--water chemistry samples were analyzed. The discharge was less than .3 CFS and the water temperature was 13°C on 28 July 1976. No fish were observed.

Middle Fork--water chemistry samples were analyzed. The discharge was approximately .3 CFS and the water temperature was 10°C on 28 July 1976. No fish were observed or caught.

South Fork--The discharge was approximately .2 CFS and gradient is very steep. No fish were observed.

Delle Creek can not support a trout fishery due to steep gradient, low discharge and livestock impact.

Birch Creek (not to be confused with Birch Crk. on the east side): Discharge was less than .2 CFS on 28 July 1976. No fish were observed, gradient is very steep. Not conducive to supporting a trout fishery.

Sams Creek: Discharge was approximately .4 CFS on 29 July 1976. No fish were observed or caught. The upper section would not likely support a trout fishery due to steep gradient.

Steves Creek: Discharge was approximately .5 CFS on 29 July 1976. No fish were caught or observed. As a result of the steep gradient a trout fishery would probably not establish.

Dads Creek: Discharge was approximately 1.5 CFS and the water temperature was 12°C on 29 July 1976. No fish were caught or observed in the headwaters. In the lower sections rainbow trout are present. There is a slight possibility that cutthroat could establish in the headwater reaches, but the stream is on the Goshute Indian Reservation.

Fifteen Mile Creek: Discharge was 2 CFS and the water temperature was 10°C on 29 July 1976. No fish were observed in the headwater reaches. Rainbow trout are present in the lower sections. This stream is one of the better areas on the west side for establishing a cutthroat population, but the stream is located on the Goshute Indian Reservation.

Erickson Canyon: Discharge was approximately .5 CFS and the water temperature was 14°C on 31 July 1976. No fish were observed. This stream receives heavy impact from sheep and cattle and lacks suitable habitat.

Johnson Creek: North Fork--dry on 1 August 1976.

Middle Fork--Discharge at the headwaters was 1 CFS and the water temperature was 11°C. No fish were observed or caught in the headwater reaches. Stream habitat surveys were conducted in the headwater area (S-1). This area is not very conducive to cutthroat introduction because of the steep gradient, resulting in few shallow pools, and because of heavy livestock impact.

Cutthroat hybrids were found about .12 miles downstream from the Goshute Indian Reservation boundary, at a small waterfall. All of the trout collected in this area are rainbow x cutthroat hybrids (based on identification made by Dr. Behnke in 1974 and myself in 1976). The trout population is very depleted and the trout appear to be much more wary than those in Trout and Birch Creek. The origin of the cutthroat in Johnson Creek is unknown. They may have gotten there via a headwater transfer from Birch Creek (they are about .5 miles apart), or they may have come upstream from Deep Creek, which connects with Johnson Creek at the mouth of the canyon. In 1884 H. C. Yarrow collected one specimen from Deep Creek (Table 1), which appears to be typical of the Snake Valley cutthroat (high gillraker and basibranchial teeth counts).

Introduction of pure cutthroat into this stream would require eradication of existing hybrids. There is a heavy impact from livestock along the entire length of the stream and most of the suitable habitat is on the Goshute Indian Reservation, therefore a successful establishment of cutthroat trout is questionable.

Streams on the east side of the Deep Creek Mountain Range.

Middle Canyon: This stream was dry on 5 August 1976. All of the streams to the north of Middle Canyon were dry on 5 August 1976. They appear to have water only during periods of heavy rainfall and during spring run-off.

North Canyon: This tributary which drains into Basin Creek was dry on 5 August 1976.

Table 1. Character analysis.

Locality	Gillrakers	Pyloric Caeca	Scales Above Lateral Line	Scales in Lateral Line Series	Basibranchial Teeth
Trout Creek 1974, 1976 n=29	18-22 (19.7)	28-40 (34.3)	33-41 (37.3)	146-170 (153.5)	9-41 (23.3)
Birch Creek 1976 n=11	19-20 (19.1)	34-43 (38.1)	36-41 (38.1)	150-170 (158.3)	1 of 11 w/o teeth [10] 1 - 22 (14.5)
Pine Creek 1959, 1970, 1972 n=61	19-25 (21.8)	25-47 (33.9)	33-46 (38.8)	133-176 (146.9)	8-50 (27.3)
Goshute Creek (Pine Creek stock) 1972 n=20	17-22 (20.0)	31-45 (35.7)	35-45 (39.0)	128-162 (143.9)	8-46 (24.7)
Hendrys Creek very headwaters 1972 n=20	18-23 (20.9)	29-46 (36.1)	35-45 (39.1)	129-163 (149.9)	1 of 20 w/o teeth [19] 14 - 19 (24.5)
Johnson Creek 1976 n=1	20	35	40	160	5
Trout Creek 1933 n=2 (ummz 191644)	19,22	37,41	38,40	147,149	10,18

Table 1 continued.

Locality	Gillrakers	Pyloric Caeca	Scales Above Lateral Line	Scales in Lateral Line Series	Basibranchial Teeth
Leman Creek 1938 n=2 (ummz 141701)	20,21	-	40,42	148	17,20
Deep Creek 1884 n=1 (FMNH 260)	21-22 ?	-	-	-	At least 32
S. c. utah Raymond Creek Thomas Fork drainage Wyo. 1974, 1976 n=30	16-21 (17.7)	39-54 (45.3)	36-44 (39.0)	148-183 (167.9)	1 of 30 w/o teeth [29] 1 - 22 5.4
Reservoir Canyon and Water Canyon Virgin R. drainage 1959, 1973 n=30	17-21 (19.2)	29-40 (35.3)	38.45 (40.3)	139-169 (157.2)	6-19 (11.2)
Willow Creek Jordan R. drainage 1973, 1976 n=22	17-21 (18.7)	25-39 (34.0)	35-42 (37.5)	141-180 (162.9)	13-36 (20.1)
Birch Creek, trib. Beaver River 1973 n=12	18-20 (19.1)	24-43 (36.3)	36-42 (38.4)	151-161 (156.3)	1-19 (11.2)

Table 1 continued.

Locality	Gillrakers	Pyloric Caeca	Scales Above Lateral Line	Scales in Lateral Line Series	Basibranchial Teeth
S. c. utah museum collections 1872-1915 Salt L. Utah L. drainages n=19	17-22 (19.7)	-	32-43 (37.8)	150-186 (163.0)	3-20 (9.9)
Bettridge Creek Pilot Peak 1976 n=2	19,19	47,44	28,27	139,131	2,0
Typical Colo. River cutthroat *S. c. pleuriticus*	18-20	35-40	43-47	180-195	5-15
Typical Rainbow trout *S. gairdneri*	19-20	50-60	26-28	125-130	absent

have not established in the headwaters, the gradient is very steep and the pools are few and shallow.

Rainbow trout appear below a large waterfall barrier (Fig. 4). From this point the rainbow extend down to the valley floor, into an old campground constructed by the CCC. This campground receives some recreational use. In 1976 BLM personnel constructed habitat improvement devices along this stretch of the stream, to enhance the fisheries in the area.

This stream should be managed for rainbow trout with the same idea in mind as Toms Creek, to provide fishing opportunities while the cutthroat are being established on the mountain range.

Red Cedar Canyon: Stream habitat surveys were conducted on 2 August 1976 (S-3, S-4).

Rainbow trout extend to a series of large waterfalls barriers (Fig. 5). Russ Haufman, (former manager of Fish Springs National Refuge), indicated that he carried rainbow trout upstream above some of the waterfalls, after the Red Cedar Canyon fire. This would explain why some rainbow trout are found above the first few waterfalls and not the others upstream.

The headwater reaches are barren of trout and the habitat appears to be in good condition. The gradient is low and there are many deep pools (ie. 92-153cm in depth). The discharge was approximately 2 CFS and the temperature was 8^{o}C in August 1976. There is no current livestock impact, at one time sheep grazed in the headwater meadows area but this stopped in the late 1940s or early 1950s. The upper section of Red Cedar Creek appears to be the best suitable habitat for Snake Valley cutthroat introduction. The banks are stable and the deep pools will provide protection during the winter and growth in the summer months. There will be little fishing pressure

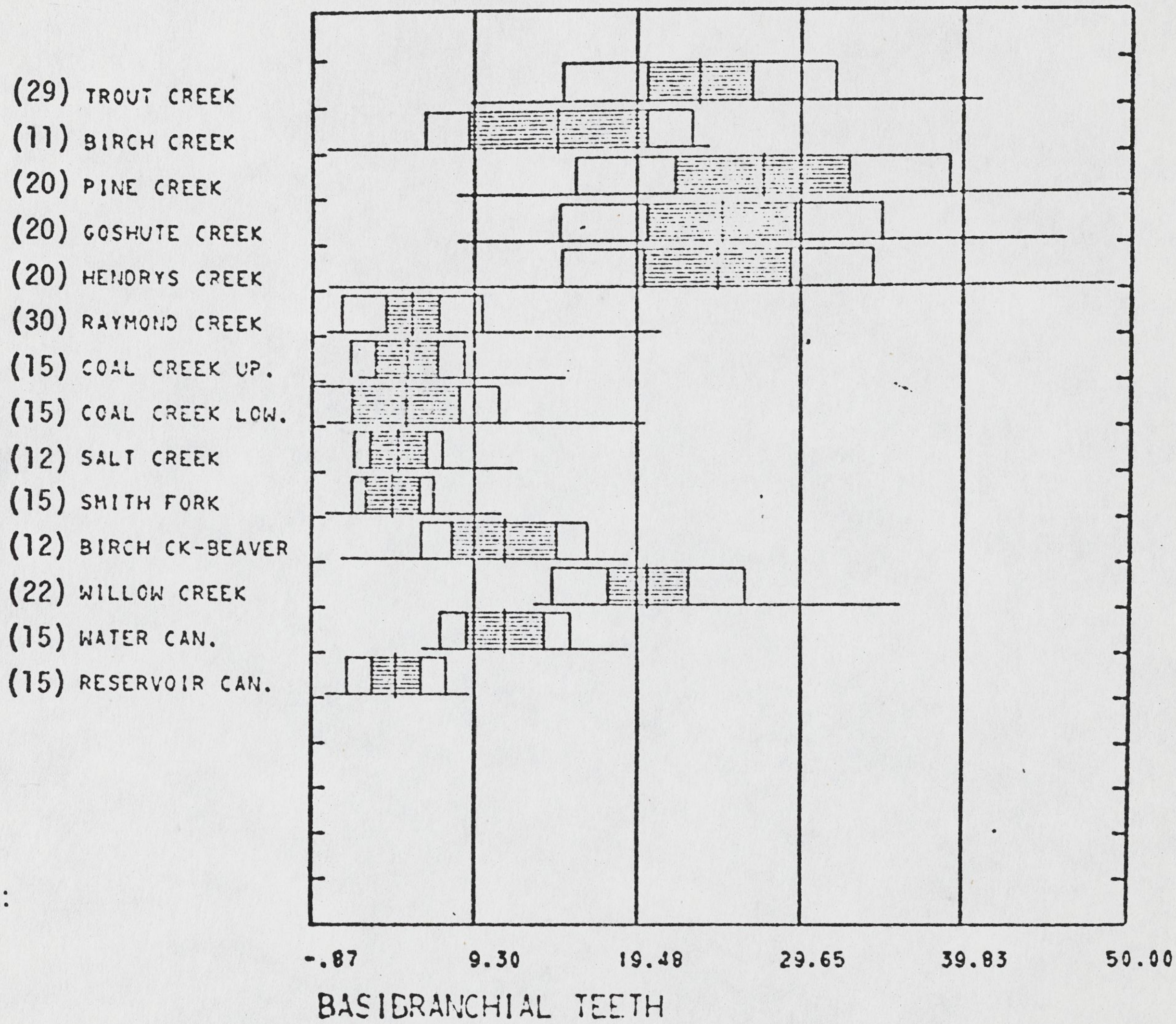


Figure 1a. Hubbs Diagram

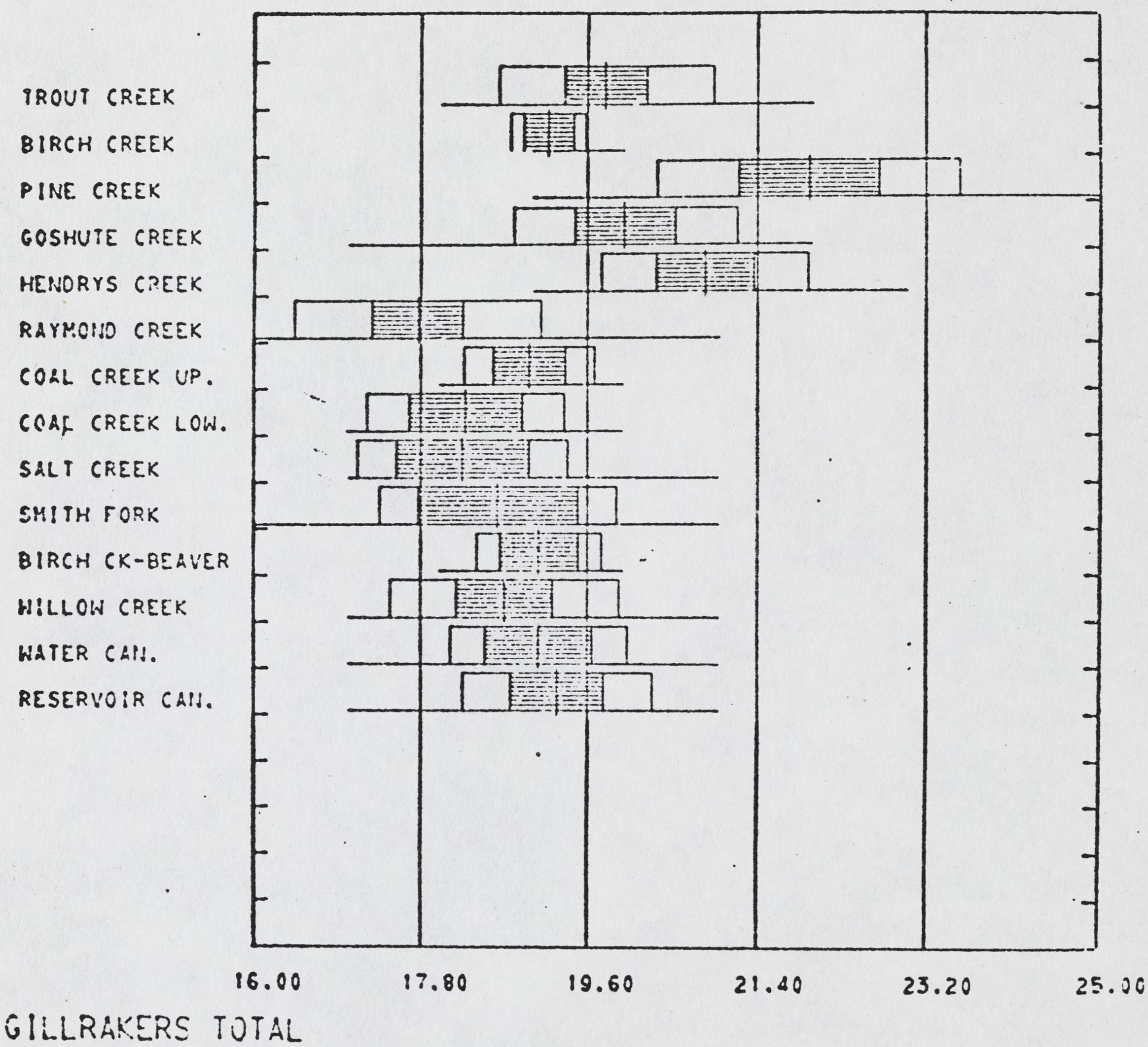


Figure 1b. Hubbs Diagram

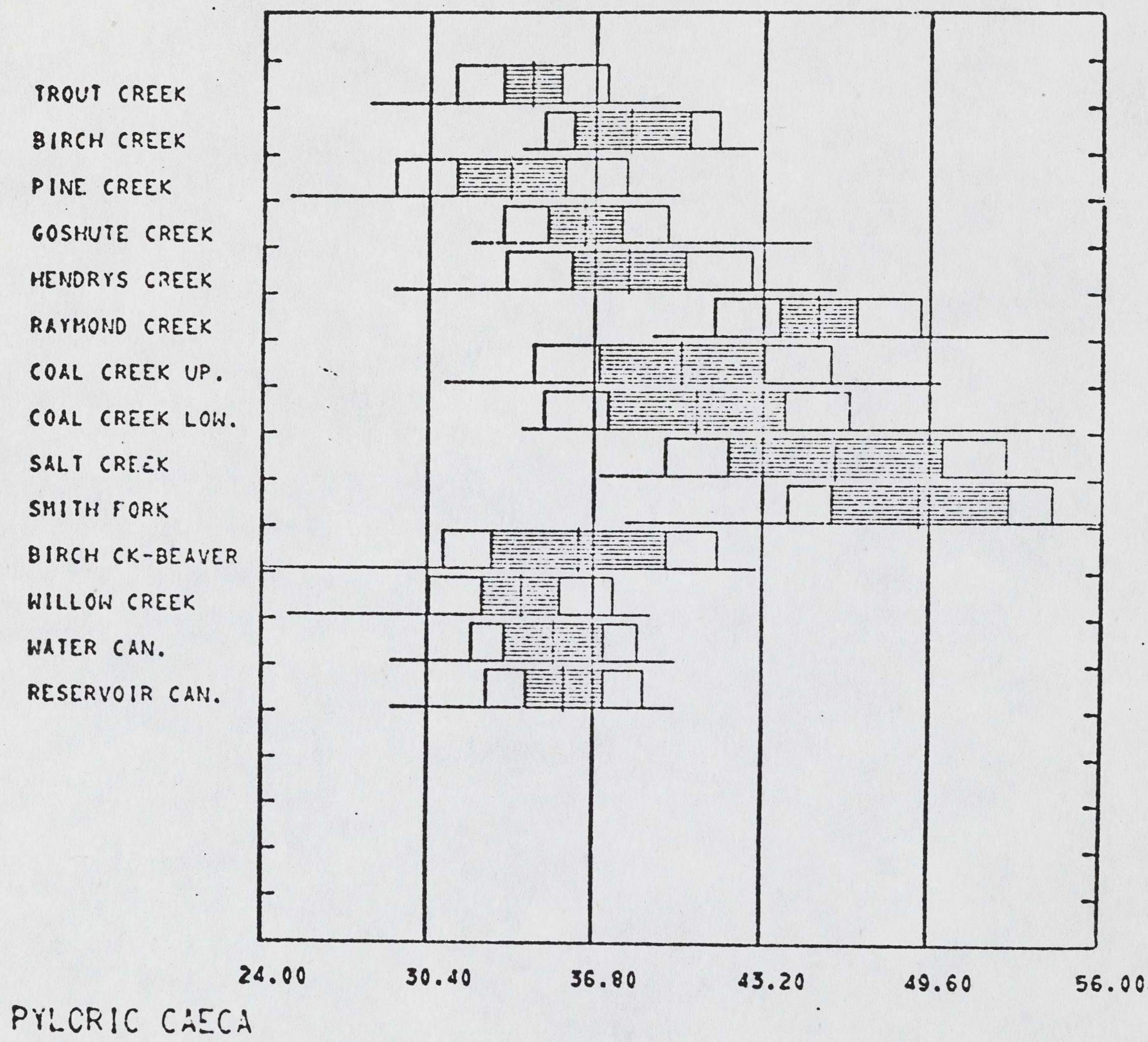


Figure 1c. Hubbs Diagram

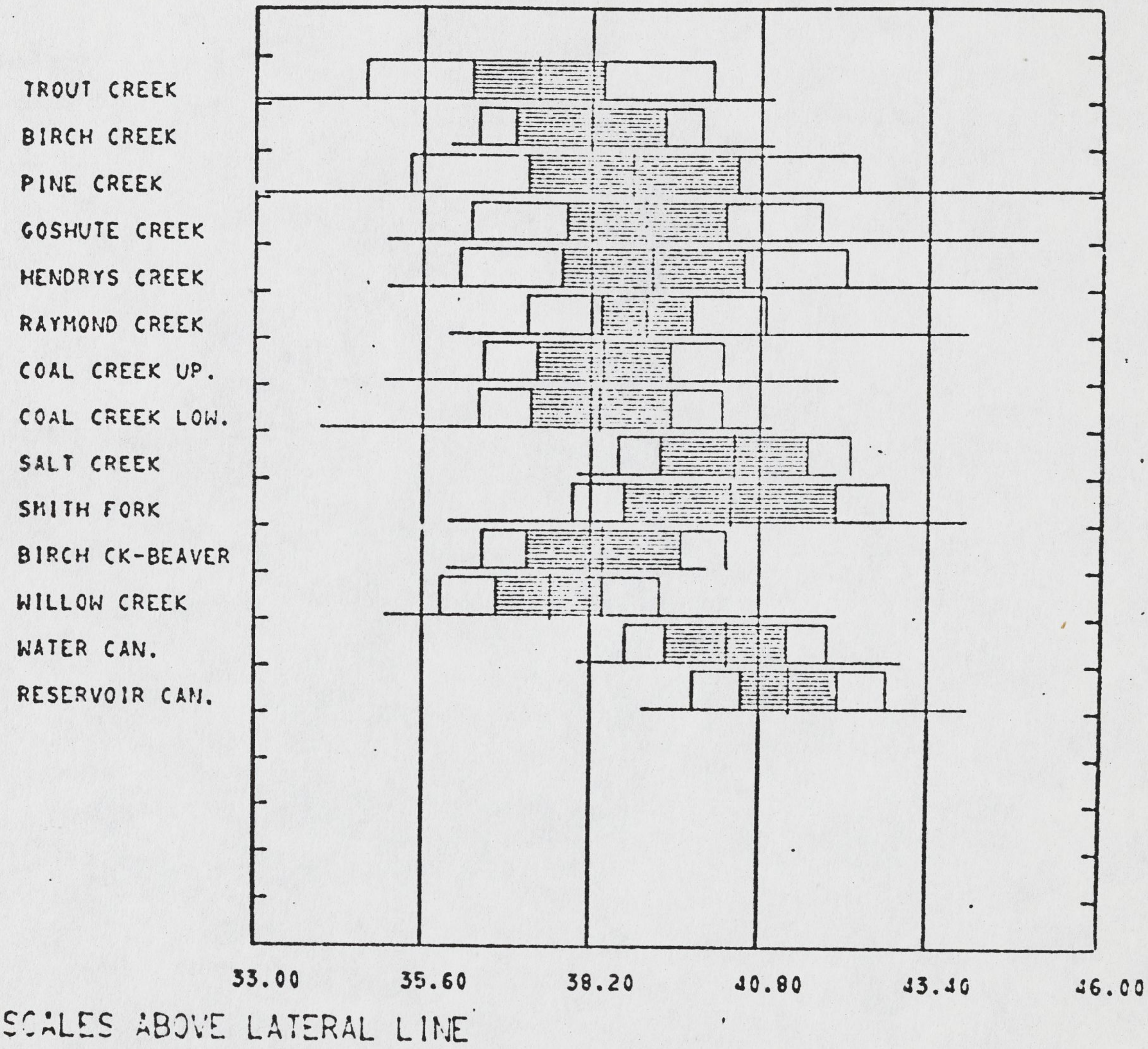


Figure 1d. Hubbs Diagram

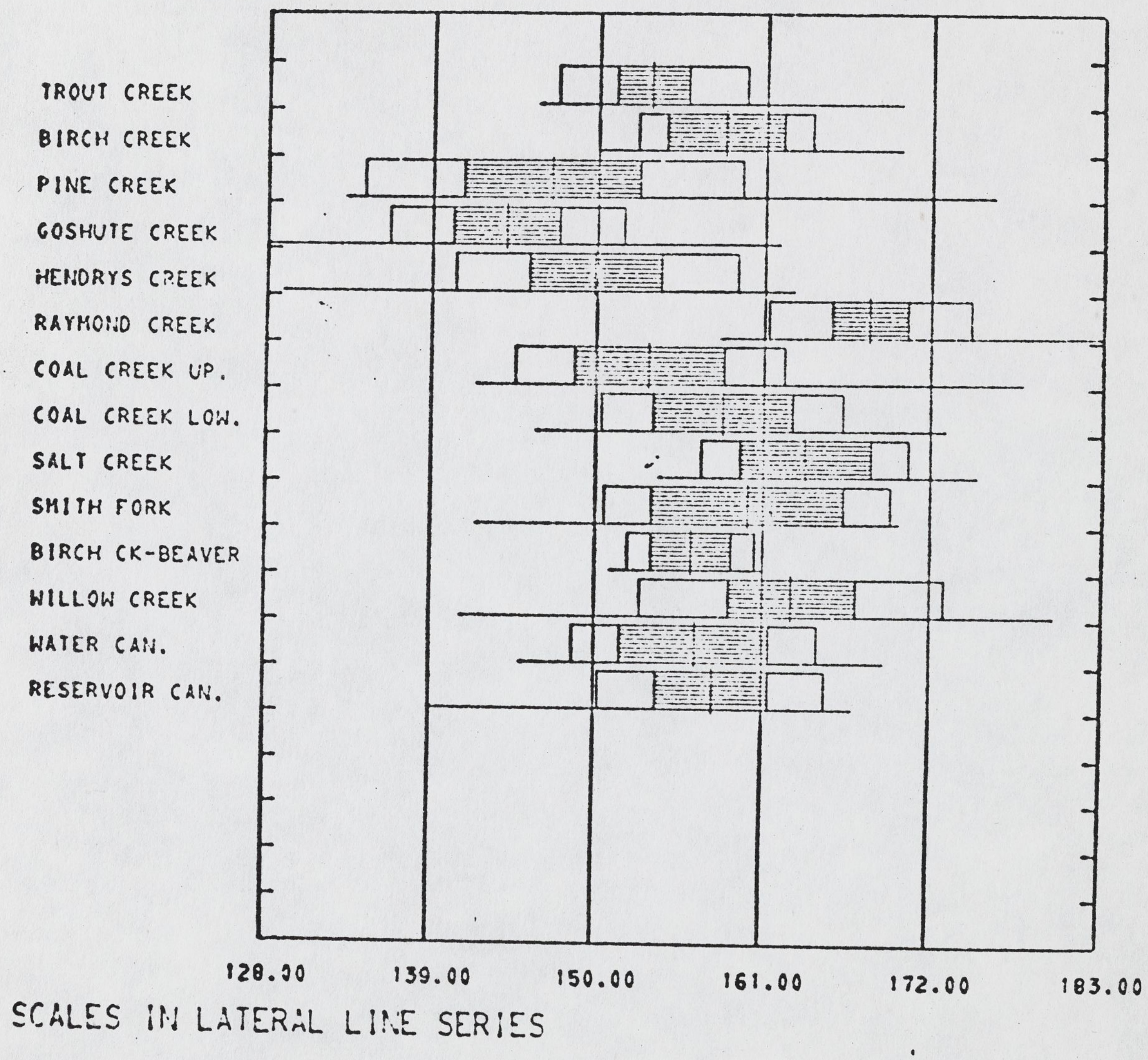
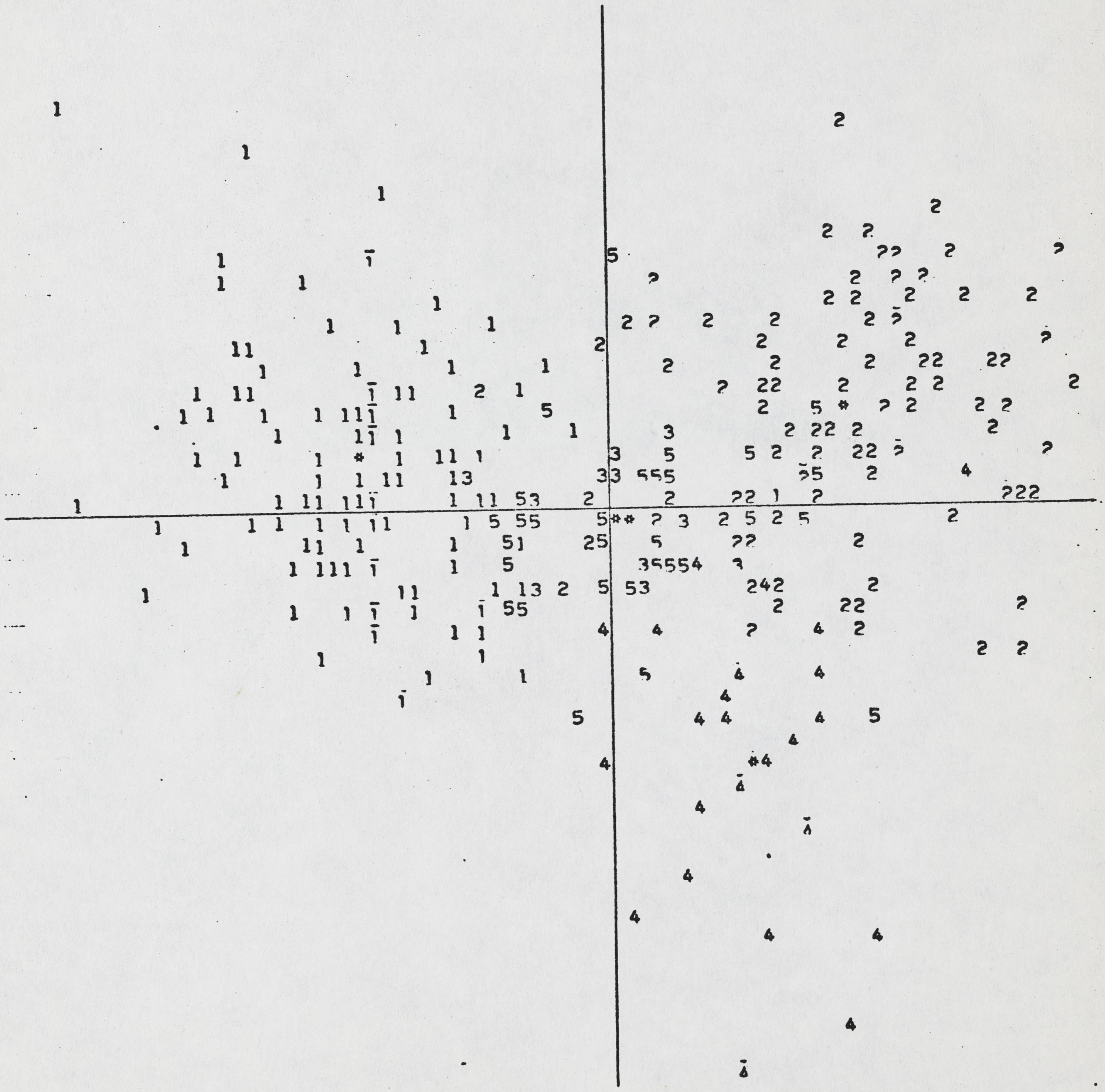


Figure 1e. Hubbs Diagram

Figure 2. Five drainage systems within the Bonneville basin plot of discriminant score 1 (horizontal) vs. discriminant score 2 (vertical). * indicates a group centroid.



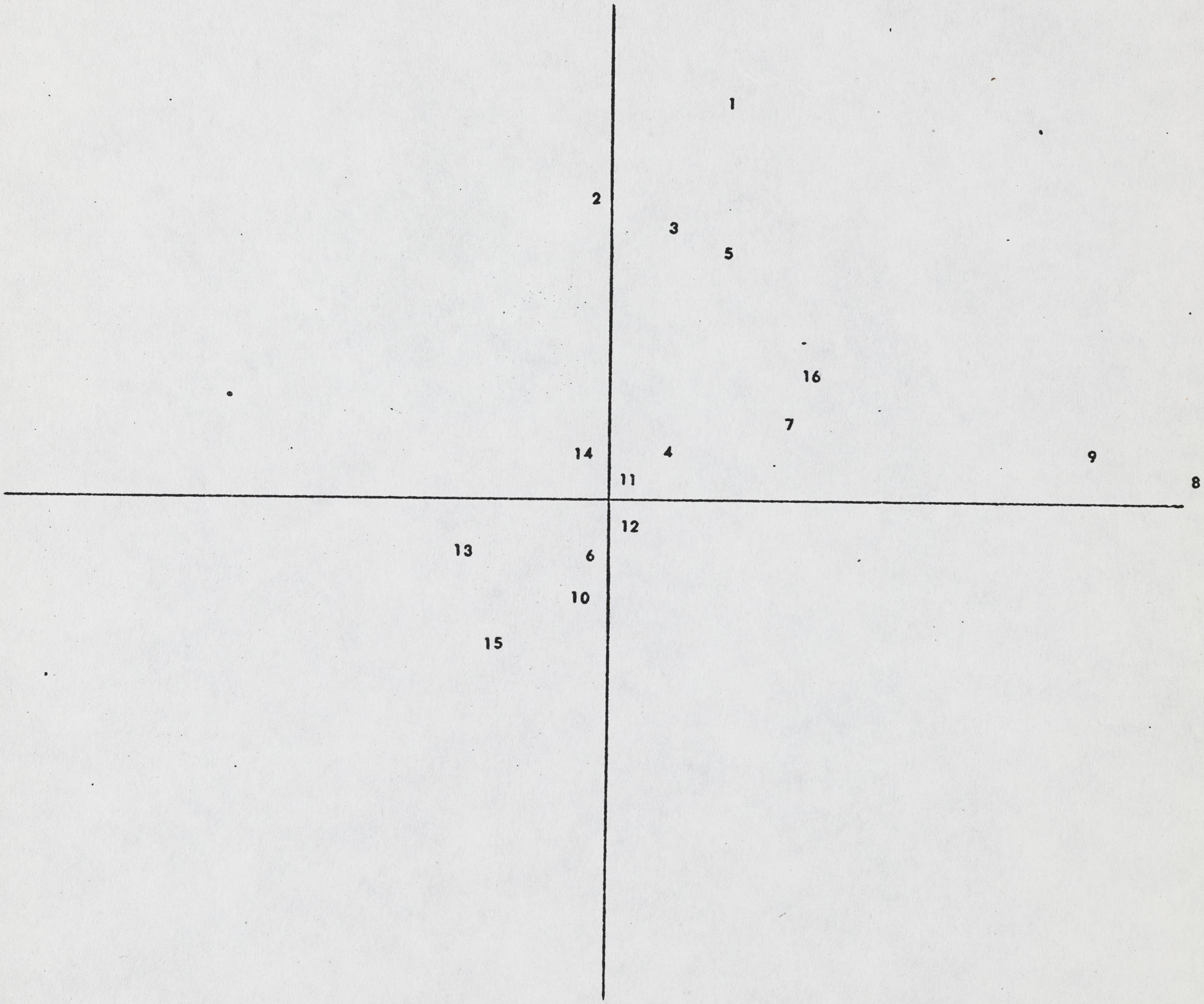


Figure 3. Results of the Principal Component Analysis.

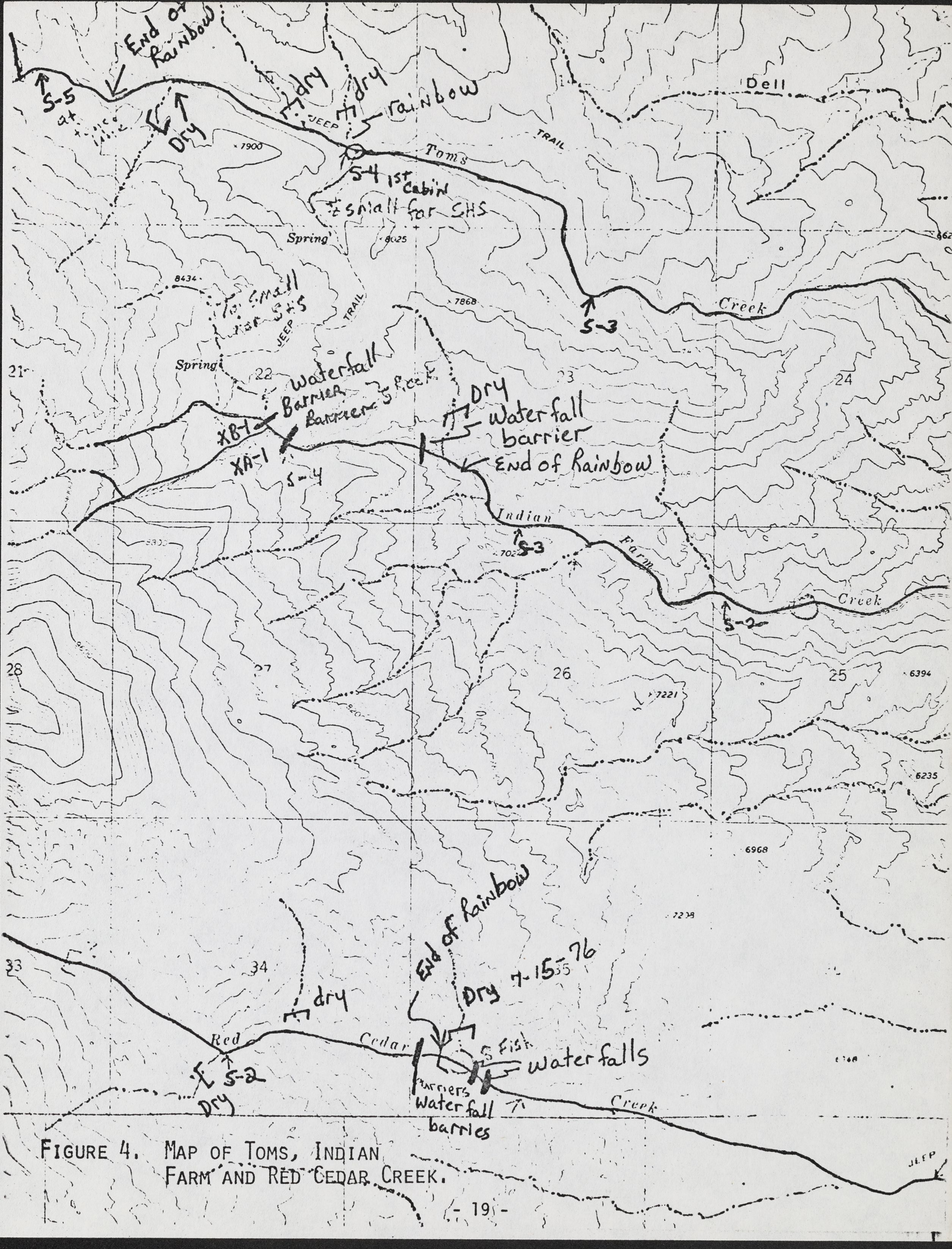


FIGURE 4. MAP OF TOMS, INDIAN FARM AND RED CEDAR CREEK.

Basin Creek: Stream habitat surveys were conducted on 5 August 1976 (S-1, S-2). The discharge was 1 CFS and the water temperature was 22^{o}C. No fish were observed or caught. The majority of the basin is privately owned and receives heavy livestock impact. The conditions are not conducive for a trout fishery.

Toms Creek: Stream habitat surveys were conducted in June, 1976 (S-6, S-7). The headwaters meadow area is privately owned and receives heavy livestock use. The discharge in the headwater region was 1 CFS and the temperature was 13^{o}C on 3 June 1976. No fish were caught or observed. The cattle have destroyed virtually all of the stream habitat for fish.

Rainbow trout were caught at the first upstream cabin (Fig. 4). At this point the flow was 4 CFS in June, 1976. This appears to be the upper limit of the fish, the gradient becomes very steep before leveling off into the meadow area.

Rainbow are found the entire length of the stream below the gradient barrier. A jeep trail goes from the mouth of the canyon to the first upstream cabin. Portions of the canyon is privately owned. Impact from livestock and recreation may hinder successful establishment of cutthroat trout. It might be beneficial to leave the rainbow trout in the stream to take some of the fishing pressure off of the cutthroat trout, especially if a few years is needed to successfully establish the native cutthroat in other streams.

Indian Farm: Stream habitat surveys were conducted on 14 June 1976 (S-4, XA-1, XB-1). The discharge was 3 CFS and the temperature was 5^{o}C in the headwater reaches. No fish were observed or caught. Previous trout introductions

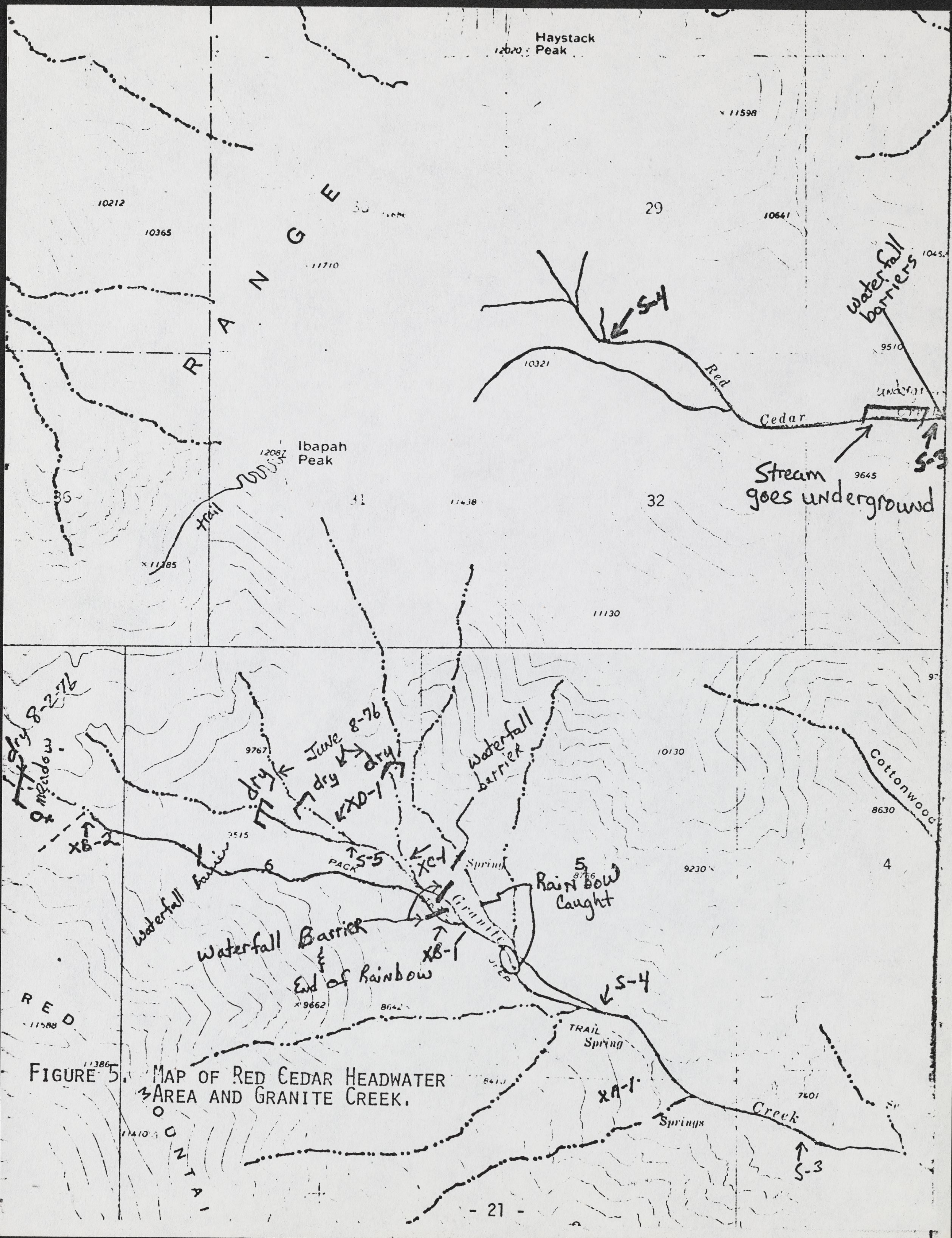


FIGURE 5. MAP OF RED CEDAR HEADWATER AREA AND GRANITE CREEK.

in this upper section, the steep canyon makes access difficult. Once the rainbow trout are eradicated the numerous waterfalls should provide protection against accidental stockings. With time the cutthroat should spread naturally downstream.

Cottonwood Canyon: A stream habitat survey was conducted on 12 August 1976 (S-1). The discharge was approximately .3 CFS and the water temperature was 16°C. No fish were observed or caught. The water is diverted at the mouth of the canyon into an aquaduct which supplies the Falkenburg Ranch area. This creek would not be conducive to cutthroat introduction because of the low discharge and lack of deep pools.

Granite Canyon: Stream habitat surveys were conducted during June and July, 1976 (XA-1, XB-1, XC-1, XD-1, XB-2, S-5).

This canyon drains a large watershed, primarily from Ibapah Peak (elevation 12,202 ft), and Red Mountain (elevation 11,588 ft).

Rainbow trout extend upstream to a large waterfall barrier (Fig. 5). Above this barrier, and the other smaller waterfalls on the tributaries, no trout were caught or observed. The headwaters area (Pack Trail Tributary), originates in a meadow-spring area. The discharge was 1.5 CFS and the water temperature was 6°C on 6 July 1976. This area would be the second "best" area for Snake Valley cutthroat introductions. The area is isolated, barren of trout, supports a few deep pools and maintains a good discharge throughout the year. There is no apparent impact from livestock. There is a jeep trail that goes to the barrier waterfalls and throughout the length of this trail are campgrounds. The canyon receives some recreational use as a result of the trail.

Complete eradication of rainbow trout throughout the entire length of the stream is recommended to discourage unauthorized reintroductions above the barrier. The cutthroat could then be stocked the entire length of the stream. This would require some work though, since there are many tributaries and small springs. Stocking of the lower section could be made a few years after introductions in the headwaters, if necessary. This would enable a thorough check on the effectiveness of the treatment.

The possibility of closing the jeep trail, near the mouth of the canyon, should be considered in order to protect the introduced cutthroat.

Trout Creek: In 1976 a new barrier was built by BLM personnel (Fig. 6), to replace the one that had been washed out in the spring of that year. It was built to be more effective, and hopefully to last longer than the old one. Yearly monitoring of the barrier should be made to ensure protection of the cutthroat trout from hybridization with the rainbows. This may not be necessary if the rainbow trout could be eradicated in 1977.

The upper range of the cutthroat trout extends to approximately 200 yards below the mine shaft (Fig. 6). The total length of stream inhabited by the pure population of Snake Valley cutthroat is about 1.25 miles. Virtually the entire section of the stream above the barrier is shaded. The discharge in July 1976 was 1.5 CFS and the temperature was $9^{o}C$. A thermograph was placed at the barrier from 4 June 1976 to 17 July 1976. The lowest reading (on 4 June), was $6.5^{o}C$ and the highest reading was $10.9^{o}C$ (on 17 July).

There appears to be very little recreational use on the stream, livestock grazing occurs only at the mouth of the canyon. The most serious threat may be from mining. There are a few "inactive" mining claims above the barrier.

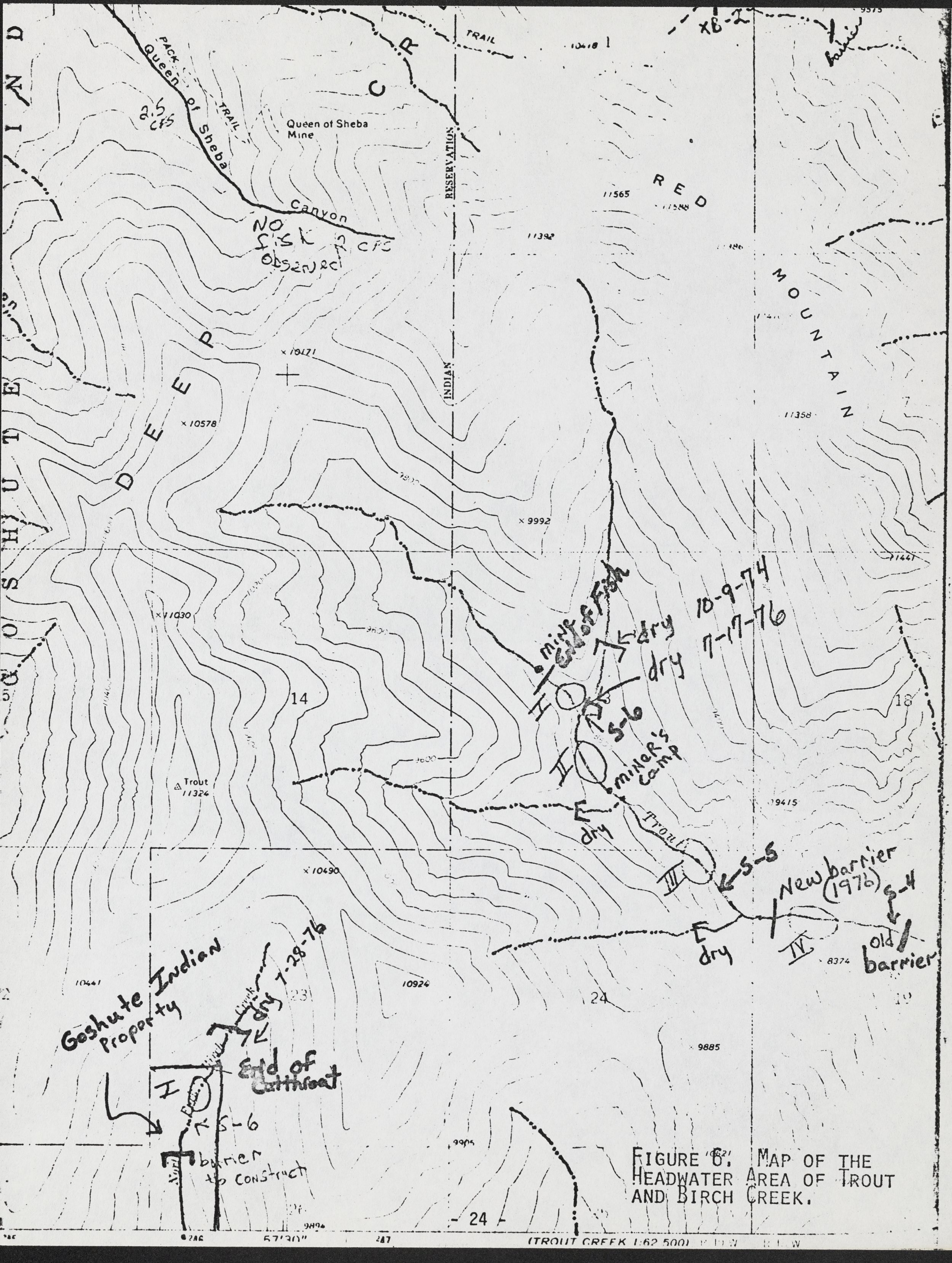


FIGURE 6. MAP OF THE HEADWATER AREA OF TROUT AND BIRCH CREEK.

There is a need for habitat improvement above the barrier, to enhance the bank stability and create deeper pools. Six miles of the stream is on National Resource Land, the remainder is on the Goshute Indian Reservation (this section is void of trout, the gradient is very steep). Behnke (1976a), indicated that the trout above the barrier represent a pure population of Snake Valley cutthroat. Examination of more specimens, collected in 1976, supports Dr. Behnke's findings. The total number of cutthroat trout above the barrier is probably between 300-500. As a result of the recent survey and analysis of specimens from Birch Creek, Trout Creek may be the only known stream in Utah supporting a pure population of Snake Valley cutthroat. Immediate action should be taken to preserve this highly restricted population of cutthroat trout. In addition to complete eradication of the rainbow trout, other means to protect and improve the habitat above the barrier should be initiated. Introductions from Trout Creek to the streams previously mentioned, should also be undertaken.

Birch Creek: Stream habitat surveys were conducted in July 1976 (S-6, XC-1), in the headwater area. The discharge during this period was .5 CFS and the water temperature was 15^{o}C.

Rainbow trout were collected in the area that Utah Division of Wildlife personnel collected virtually pure specimens of cutthroat trout in 1975 (Behnke 1976a). No specimens identified as rainbow trout or hybrids were found within .5 mile of the very headwaters, but no physical barriers were present to prevent free movement of rainbows or hybrids into the upper limits of trout habitat. A barrier was constructed by BLM personnel in 1976 to prevent invasion into the uppermost .25 mile of Birch Creek. One of the 11 specimens of cutthroat collected here in 1976 lacked basibranchial teeth and significant differences can be noted in gillrakers and basibranchial teeth between Birch Creek and Trout Creek samples, suggesting some rainbow trout genes have infiltrated this population. Future sampling and examination of specimens should be conducted to study this situation. At present, the Birch Creek population, although phenotypically showing no sign of hybridization, should be considered as probably "less pure" than Trout Creek cutthroat, especially for the purpose of new introduction. There was no sign of livestock grazing in the meadow headwater area during 1976, but indications of past livestock use were evident. The rainbow trout should be eradicated immediately, even if the upper headwaters population is found to be hybridized, Birch Creek would be an excellent stream for introductions from Trout Creek. Livestock grazing along the lower sections should also be controlled.

Pilot Peak - north of Wendover, in Utah.

Bettridge Creek: Stream habitat surveys were conducted on 14 August 1976 (S-1, S-2, S-3). The discharge was approximately 1 CFS and the water temperature was 12^{o}C, in the upper section, during this period. Many large trout were observed in this section. Further work on this stream, and the others in the Pilot Peak Range, need to be conducted before conclusions can be made relating to cutthroat existence and possible introductions (discussed below).

Taxonomy

A total of 112 trout, collected in 1976 from eight sites, were examined for recording taxonomic characters. Seven of these sites are located in the

Deep Creek Mountain Range and one from the Pilot Peak Range.

Only Trout, Birch and Johnson Creeks contain populations of pure or hybridized Snake Valley cutthroat (the one hybrid from Pilots Peak is of uncertain classification at the present). Granite, Red Cedar, Indian Farm and Toms Creeks contain typical rainbow trout with no detectable influence of hybridization with cutthroat trout. The Johnson Creek specimen has rainbow influence (detected primarily by the low number of basibranchial teeth).

For taxonomic evaluation and comparison I have used samples from Pine Creek and its derivative population in Goshute Creek, plus Hendrys, Birch, Trout and Johnson Creeks, to represent the Snake Valley region. These samples were compared with S. c. utah from the Thomas Fork drainage (Wyoming), Jordan River drainage, Sevier River drainage, Virgin River drainage and Pilot Peak Range, all of which are located in the Bonneville basin (Virgin River population is derived from the Bonneville basin, Behnke 1976b).

Table 1 presents data from selected meristic characters of the Bonneville basin cutthroat trout as well as typical S. c. pleuriticus and S. gairdneri. Hubbs and Hubbs diagrams (1953), (Figs. 1a, 1b, 1c, 1d, 1e), were used to display the data in Table 1 in a more graphic comparison. The diagrams indicate the mean (center point), 95 percent confidence limits of the mean (black lined rectangle), one standard deviation on either side of the mean (outer limits of open rectangle), and sample range (basal line). Raymond, Coal, Salt and Smith Creeks are in the Bear River drainage, Wyoming, and have been determined to be virtually pure representatives of S. c. utah (Behnke 1976c).

To further compare the evolutionary affinities between the different populations of cutthroat trout in the Bonneville basin, statistical analysis of character measurements was completed. SPSS computer programs and a CDC 6400 computer were used to compute discriminant analysis (Fig. 2), principal component analysis (Fig. 3), and a Wilks Lambda analysis (Table 3), (Nie 1975). The discriminant analysis gives individual fish a weighted score, and prints out plots for evaluation of similarities and differences between samples. The results correctly classified 84.6 percent of the fish (Table 2).

The principal component analysis was primarily undertaken to justify the use of the five groups of cutthroat trout in a discriminant format on the basis of character analysis alone. Examination of the results of the principal component analysis and the Wilks Lambda analysis indicates that basibranchial teeth, pyloric caeca, scales in the lateral line series, caudal peduncle depth and gillrakers are the five characters with the best discriminating power.

The discriminant function analysis did complement the systematic results, in that the Snake Valley cutthroat differ from the Thomas Fork drainage populations, while there appears to be more overlap between the other drainages, yet they maintain "loosely" defined groups.

The Snake Valley group (2) is concentrated on the right hand side of the graph and the Thomas Fork group (1) is concentrated to the left hand side of the graph. The Jordan River drainage population (4) is concentrated mainly in the fourth quadrant overlapping with Thomas Fork and the Virgin River drainage (5), to some degree. There is a large degree of overlap between the Birch Creek (*S. c. utah* from Beaver River drainage) (3) and the Virgin River group, in the center of the graph. It would seem that there should be overlap in these two groups if the Virgin River population were introduced

Table 2. Discriminant analysis prediction results.

	Actual group	N of cases	Predicted group membership				
			Thomas Fork R.	Snake Valley	Seveir River	Jordan River	Santa Clara R.
1	Thomas Fork R.	112	99	0	8	4	5
2	Snake Valley	101	2	77	5	8	9
3	Seveir River	12	0	0	12	0	0
4	Jordan River	24	0	1	1	20	2
5	Santa Clara R.	31	0	1	1	0	28

Table 3. Wilks lambda and univariate F-ratio with 4 and 275 degrees of freedom. The lower the Wilks lambda the higher the discriminating power.

Character	Wilks Lambda	F
Head length	.722	26.413
Upper jaw length	.877	9.689
Snout tip to dorsal fin origin	.860	11.220
Dorsal fin depressed length	.890	8.517
Caudal peduncle depth	.611	43.804
Caudal peduncle length	.876	9.722
Gillrakers upper	.834	13.728
Gillrakers lower	.709	28.223
Gillrakers total	.698	29.800
Branchiostegal rays right	.810	16.086
Branchiostegal rays left	.910	6.799
Scales above the lateral line	.891	8.425
Scales along the lateral line	.683	31.865
Pelvic fin rays	.933	4.894
Pyloric caeca	.546	57.081
Basibranchial teeth	.418	95.541

from the southern part of the Bonneville basin.

The Snake Valley cutthroat are differentiated from the cutthroat in the rest of the Bonneville basin by usually having more basibranchial teeth, longer head, deeper, more compressed body and a long dorsal fin positioned more than half of the distance from the snout tip to the end of the vertebral column (Behnke 1976a, b). The high degree of differentiation, formerly found between Snake Valley and S. c. utah, in basibranchial teeth, has decreased with the addition of the 1976 specimens. The Birch Creek sample shows a low mean basibranchial teeth count (14.5) while the Willow Creek population (Jordan River drainage) has a mean count of 20.1. Dr. Behnke indicated that the Willow Creek population has likely undergone microdivergence, probably from genetic drift, from the original ancestor typical of other S. c. utah (letter from R. J. Behnke to Don Andriano, 30 March 1977). The original parent probably had lower numbers of basibranchial teeth typical of Thomas Fork, Birch Creek (Beaver River drainage) and Water and Reservoir Canyon cutthroat. The low basibranchial teeth count in Birch Creek may be a result of slight rainbow influence and/or lack of specimens. In 1975 six cutthroat from upper Trout Creek had a mean tooth count of 11.2 (Behnke 1976a), but with the analysis of more specimens collected from that area in 1976, the mean tooth count was 23.3.

Wydoski et al (1976) conducted a study of the electrophoretic patterns of proteins in cutthroat located in the Bonneville basin and several other groups of cutthroat and rainbow trout. No protein was unique or distinctive for S. c. utah specimens, but they found an unusual variation for muscle lactate dehydrogenase (LDH) in the Snake Valley cutthroat (in specimens from Birch, Trout and Goshute Creek). This unusually complex variation seems to indicate the presence of a variant allele. A unique evolutionary event, or series of events, occurred in the Snake Valley cutthroat trout LDH, which would indicate long-term isolation from the rest of the Bonneville cutthroat trout. This unusual variation has not been found in any other cutthroat or rainbow trout.

The considerable variability among the various disjunct populations of cutthroat trout, native to the Bonneville basin, is a result of isolation from one another for thousands of years. The Snake Valley cutthroat may represent a differentiated group of S. c. utah, possibly derived from a parental ancestor which was restricted to the western half of the Bonneville basin (possibly by some type of salinity barrier or geographical barrier resulting from fluctuation in the level of Lake Bonneville). Divergence among the original large spotted cutthroat may have occurred before the dessication of Lake Bonneville resulting in two differentiated forms (representing the western and eastern portions of the Bonneville basin), inhabiting Lake Bonneville. Future collections from the Pilot Peak Range may substantiate or disprove this theory. BLM stream habitat surveys and taxonomic evaluation of the trout in this area is planned for early June, 1977. Hopes have been raised that a population of native cutthroat still exists there. Utah Division of Wildlife Resources personnel found a possible population of cutthroat trout on a sampling trip in early April, 1977 (letter to Don Duff from Dexter Pitman, 15 April 1977).

Previous Stocking Records in the Deep Creek Mountain Range

The first known stocking of rainbow trout in the Deep Creek area, that I'm aware of, occurred in 1928 when Mr. C. Stewart and Mr. W. Sabey obtained rainbow trout (amount unknown) from the Utah Fish and Game Department.

The rainbow were carried up to the upper sections of Toms and Indian Farm Creeks, which were barren of fish, in milkcans packed on cows (personal communication with Mr. C. Timm and Mr. D. Sabey, residents of Callao, Utah). Mr. D. Sabey indicates that he continued to catch these rainbow until about 1940 when the only remaining rainbow population was in Toms Creek. This seems to correlate with the statements of Mr. D. Bagley and Mr. C. Timm (pers. comm., residents of Callao), who indicated that they caught rainbow in the upper section of Indian Farm Creek until the early 1940s. It is possible that the rainbow were wiped out during a torrential rainfall, as often is the case in headwater areas having steep gradients.

On 12 July 1942, Carl Hubbs obtained testimony from Julian Neilson at the old Trout Creek Ranch, Utah, concerning fish life in the region. Neilson reported that in 1930, Dave Madsen, of the Utah Fish and Game Department, sent him 2,000 rainbow trout which were stocked in Birch, Trout, Granite and Red Cedar Creeks. That same year (1942) Neilson indicated that a large trout stocking was being planned (letter from R. R. Miller to R. J. Behnke, 30 July 1970). It is not known if these rainbow trout were distributed in the headwater areas of Birch and Trout Creeks. Behnke (1976a) discusses the possibility of a slight rainbow influence in Trout and Birch Creeks. It would have been difficult to stock rainbow above the rock slide area in Trout Creek. Access to the headwater area of Birch Creek would have been less difficult.

Mr. G. Douglas indicated that Mr. W. Falkenburg (Ely, Nevada) packed trout from nearby streams into the upper section of Granite Creek, in the 1930s, when the lower reaches of Granite Creek went dry (pers. comm. with Mr. G. Douglas, Falkenburg Ranch, Juab Co., Utah). How far Mr. Falkenburg went up to stock, and what type of trout he stocked in unknown.

Beginning in the early 1950s rainbow trout were stocked in the Deep Creek Mountain area on a regular basis by the Utah Fish and Game Department. At the present, virtually every stream in the Deep Creek Mountains, with a yearly discharge of 1 CFS, contains rainbow trout.

In 1914 Mr. G. Timm and his son Charles brought 13 cutthroat trout from Red Cedar Canyon to Toms Creek in a 15-gallon wooden barrel with a gunny sack placed over the top. The barrel was hauled in a wagon. In the early 1920s they caught 18 cutthroat trout at the mouth of Granite Canyon in a small diversion dam, the total weight of these trout was 26 lbs. These cutthroat and other like them were stocked into other streams on the east side of the Deep Creek Mountains during the early 1920s by the father and son (pers. comm. with Mr. C. Timm, resident of Callao, Utah). Other testimonies confirm that cutthroat trout were transported from one stream to the other before 1930. Many of the sheep herders who ran sheep in the Deep Creek Mountains transported trout from one headwater area to another prior to 1940 (pers. comm. with Cecil Bates, Gandy, Utah). The sheep herders restricted themselves primarily to the streams south of Indian Farm Canyon. With this amount of stocking going on, one would expect to find more populations of cutthroat trout or some sign of hybridization in the streams other than Trout, Birch and Johnson Creeks. It is possible that the drought which caused Granite Creek to go partially dry in the 1930s also had an effect on the other streams. As a result of the large annual discharge in Trout and Birch Creeks, these streams may not have been effected as much. Mr. S. Bagley indicated that he was informed that all of the streams in the Deep Creek Range went dry, during the drought of the 1890s, except Trout and Birch Creeks (pers. comm. with Mr. S. Bagley, former resident of Callao, presently residing in

Salt Lake City, Utah).

Fires, such as that in Red Cedar Canyon, and periods of heavy rainfall may also have depleted cutthroat populations. It is possible that some of the areas received heavy fishing pressure prior to the 1950s. The following statement by Mr. R. Dewsnup seems to indicate that the Deep Creek Mountains were a popular area to fish:

"The annual outing that I looked forward to most, as a boy, was the fishing trip that the family would take in June after the hay was cut, hauled and stacked. We always went to Trout Creek, which is in the Deep Creek Mountains of western Utah near the Nevada border. The trip always seemed long across the desert, but is was a rewarding experience, because the stream, though small, was clear and and pure, and was loaded with native trout." (Dewsnup 1976). One of the main limiting factors of the cutthroat trout as a sport fishery is their vulnerability to angling. McPhee (1966) found that 32 hrs of angling removed 50% of the cutthroat trout six inches or more in size from a 2.4 mile section of Rochat Creek, Idaho. My own angling observations on Trout Creek and Birch Creek found the cutthroat trout are readily caught.

It is evident from many testimonies that cutthroat trout existed in more streams than Trout and Birch Creeks, prior to the 1930s, after which time the cutthroat populations began to decline rapidly until they were eliminated from many streams. This decline seems to be correlated with the introduction of rainbow trout. In most instances where the rainbow trout has been established beyond its native range and stocked with interior subspecies of cutthroat trout, hybridization and eventual displacement has resulted (Behnke 1976a).

Life History and Ecology

Until now no detailed knowledge existed on the life history and ecology of the Snake Valley cutthroat (Behnke 1973, 1976a).

Food and Feeding:

Analysis of 30 stomachs taken from cutthroat trout, in Birch and Trout Creeks during May and June, 1976, showed that terrestrial insects comprised 50% (by volume) of the diet, with ants (Hymenoptera) being the main terrestrial insects. The most abundant aquatic food was caddisfly larvae (Trichoptera). In addition to Hymenoptera and Trichoptera, other taxa of food found in the diet were, in order of abundance, Ephemeroptera, Diptera, Plecoptera, Coleoptera, Hemiptera, Araneida and Lepidoptera.

Since feeding is generally limited during the winter months, the terrestrial invertebrates make a significant contribution to the diet of the Snake Valley cutthroat in Trout and Birch Creeks. Management recommendations of these cutthroat should also take into consideration land use practices that affect the terrestrial community (Hunt 1975). Winget et al (1976) indicated that streamside vegetation is possibly the most important factor in controlling quality stream habitat in the Deep Creek Mountain area. This has more significance when the terrestrial community is considered. Birch Creek has had impact from cattle grazing, and if grazing resumes it could severely reduce the riparian vegetation which would affect the abundance of the terrestrial invertebrate food supply of the trout.

Reproduction:

On 28 May 1976 five ripe males were collected from Trout Creek, on 29 May 1976 three more ripe males and six females were collected from Birch Creek. On 3 June 1976 Don Duff (Utah BLM state biologist) and myself observed spawning activities of cutthroat trout approximately 30 yards above the barrier in Trout Creek. On 4 June 1976 three ripe females and 2 ripe males were collected in the headwater area of Trout Creek. Four females (169mm-194mm, $\bar{X}$170mm), contained an average of 180 eggs. All of the cutthroat collected after 20 June 1976 were spawned-out or immature. On 30 July 1976 Dr. Behnke and myself observed 15 cutthroat fry (approximately 35mm) in a small pool near the barrier in Trout Creek.

Sex ratios of the 27 cutthroat collected from Trout Creek and the 11 from Birch Creek are almost identical (five females and six males in Birch Creek and 13 males and 14 females in Trout Creek).

Size:

The largest cutthroat caught was taken in the headwater meadow area of Birch Creek. It was 241mm in length and weighed 125g. It was collected in a pool with a depth of 62cm and a width of 110cm. This ability to reach such a size in extremely small streams and under harsh environmental conditions indicates a fisheries management potential for Snake Valley cutthroat (Behnke 1976a). The rainbow observed on the mountain range appeared severely stunted and the hybrids were not over 170mm standard length.

The average size of the 11 cutthroat collected from Birch Creek is 83g and 201mm, while the 27 cutthroat collected from Trout Creek average 67g and 191mm. This difference may be a result of the few specimens collected from Birch or it may be due to better conditions for growth offered by Birch Creek. The temperature is 5-7^{o}C warmer than Trout Creek during the summer months, the headwaters of Birch Creek is an open meadow while that in Trout Creek is shaded by conifer and birch trees and the terrestrial food supplies appears to be more abundant in Birch Creek.

Status:

Behnke (1976a) suggested that the Snake Valley cutthroat was a threatened fish with a restricted distribution. Based upon the 1976 collections the only known pure population of Snake Valley cutthroat trout in Utah, exists in approximately 1.25 miles of stream in Trout Creek. The cutthroat trout population in Birch Creek appears to have a slight rainbow influence.

The additional specimens from Willow Creek (S. c. utah, Jordan River drainage), obscures some of the differences formerly noted between Snake Valley cutthroat and S. c. utah. Because of a lack of more clear-cut differentiation between all specimens of Snake Valley cutthroat and all S. c. utah, it is premature to make an authoratative statement on subspecific separation of the Snake Valley cutthroat from S. c. utah. The statistical analysis of several characters supports the contention of Behnke (1976a) that the Snake Valley cutthroat represents an evolutionary divergence from S. c. utah. For present, the Snake Valley cutthroat trout should be recognized as a local, divergent group of native Bonneville basin trout which is indeed very rare. The validity of subspecific designations in the highly variable and polytypic Salmo clarki is a problem with no simple solution. S. c. utah itself exhibits no consistent differentiation from the "Yellowstone" cutthroat of the upper Snake River and the Yellowstone drainage as might be expected from the relatively brief geological time period they have been separated from each other.

Management Recommendations

1. Protect the population of cutthroat trout in the headwater area of Trout Creek. Estimates of numbers and biomass should be obtained. Protect the habitat from livestock use, mining and geothermal activities, install stream improvement structures and protect the riparian vegetation to provide an abundant terrestrial invertebrate community and to protect bank stability. Immediate action should be taken to eliminate the rainbow trout from the stream below the barrier.

2. Further analysis of specimens from the headwater area of Birch Creek to better determine the status of cutthroat in that area. Estimation of numbers and biomass should be obtained. Eradication of the rainbow will be necessary if Trout Creek is treated because Trout and Birch Creeks converge on the valley floor and rainbow could get back into Trout Creek.

3. Introduce Snake Valley cutthroat trout from Trout Creek into the headwaters of Red Cedar and Granite Canyon. Eradicate all rainbows from these two streams. Close jeep trail in Granite Canyon.

4. Manage Toms Creek and Indian Farm as a rainbow fishery. Install stream improvement structures to enhance the fisheries. Later when the cutthroat become established in the other streams, they may be introduced into Toms and Indian Farm Creek.

5. Conduct surveys in other suitable habitats in the western region of the Bonneville basin (ie. Pilots Peak Range), in an attempt to find new sources of pure populations of cutthroat trout and to more authoritatively determine the systematic status of Bonneville and Snake Valley cutthroat trout.

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CURRENT STATUS OF CUTTHROAT SUBSPECIES IN THE WESTERN BONNEVILLE BASIN

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Presented to the Desert Fishes Council
Annual Meeting, November 17-18, 1977
Death Valley, California

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Abstract. Recent discoveries of native cutthroat trout populations in desert mountain ranges on the western fringe of the Bonneville Basin have prompted intensified management efforts by state and federal agencies. Analysis of Snake Valley cutthroat specimens in Trout Creek, Deep Creek Mountain range, Utah indicate this is a pure strain of the trout which once inhabited Pleistocene Lake Bonneville and which was though to be extinct in Utah. The Snake Valley cutthroat is similar to *Salmo clarki utah* of the eastern Bonneville Basin, however electrophoretic and morphomeristic analysis show unique genetic differences brought about by long-term isolation (8,000 years) from the rest of the Bonneville Basin cutthroat. This cutthroat is a common ancestor to several other limited cutthroat populations within the Basin in Nevada. In May 1977 the BLM withdrew from mineral entry about 27,000 acres within the Deep Creek Mountains for protection of this cutthroat and other unique resources on the range. Results of 1977 stream surveys on the Pilot Peak Mountain Range Utah indicate the presence of the threatened Lahontan cutthroat, *Salmo clarki henshawi*, in one isolated stream.

INTRODUCTION

Historically, the ancient Pleistocene Lake Bonneville in the Great Basin once supported a cutthroat trout, native to the Snake Valley area of Utah-Nevada. This trout once abounded in the area's several streams upon the Lake's decline (Hickman, 1977). The cutthroat population rapidly declined because of deteriorating habitat in the Twentieth Century to a point where it was believed to be extinct within its native range (Behnke 1976a) (Refer Figure 1).

In 1953 Ted Frantz, Nevada Fish and Game Department, discovered a cutthroat trout population in Pine Creek on Mt. Wheeler, Nevada (Frantz and King 1958). Samples were sent to Dr. Robert Miller who indicated

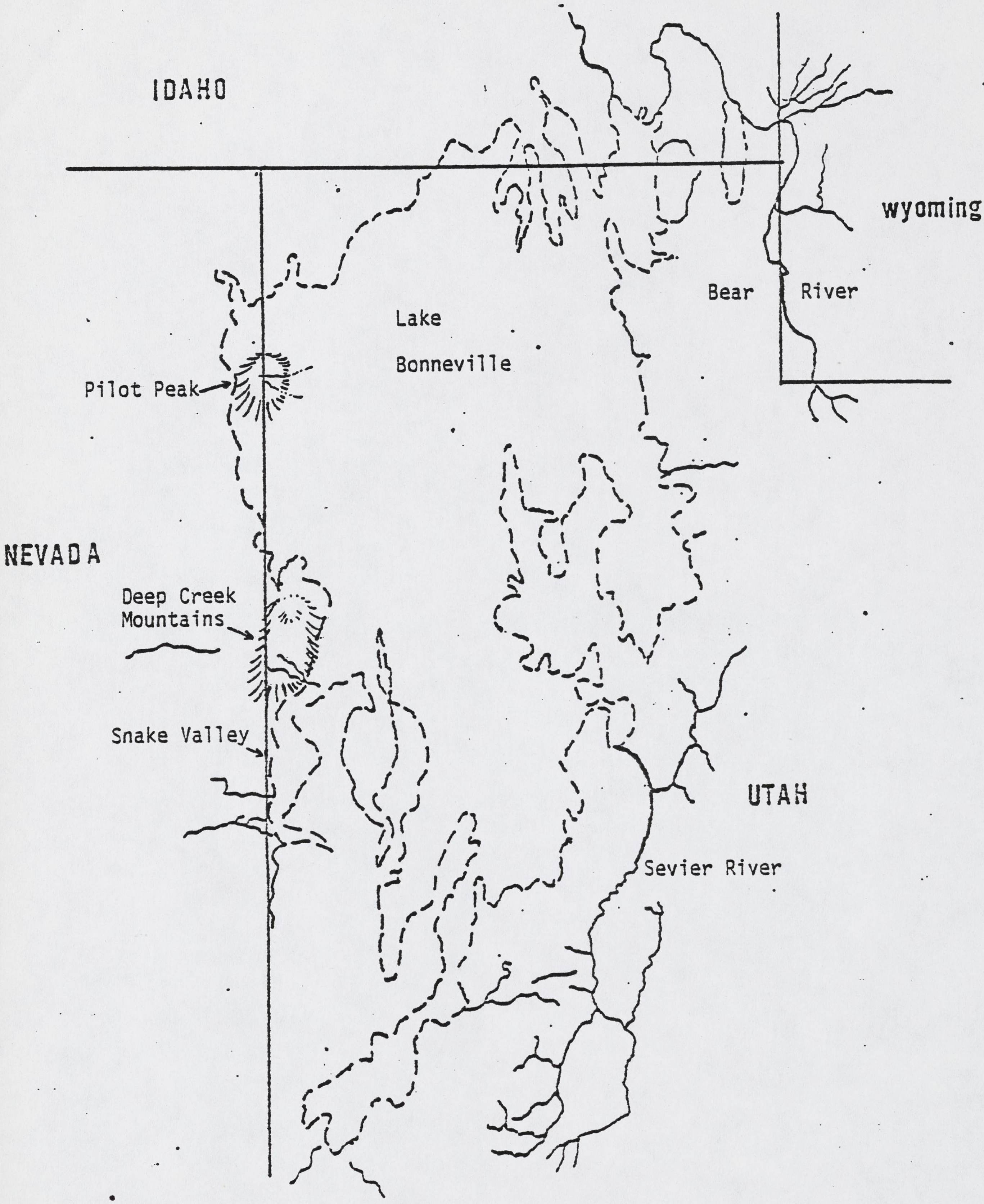

Figure 1. Area Map Location Showing The Western Bonneville Basin Area.

that they represented pure cutthroat trout. But Dr. Miller was unable to assign them to any described subspecies (letter from Dr. Miller to F. Dodge, May 26, 1971). It was assumed that this cutthroat was introduced from Trout Creek drainage of the Snake Valley area (Miller and Alcorn, 1946). This seemed unlikely when one considers that there were streams closer to Pine Creek which probably contained cutthroat trout (Lehman, Baker, Snake and Hendrys Creeks). Behnke (1976a) indicates the most logical origin of the Pine Creek cutthroat was from Lehman Creek (Mt. Wheeler tributary of the Snake Valley region) via the Osceola Ditch, constructed as a pioneer waterway.

During 1953 the Nevada Fish and Game Department introduced 44 fish from Pine Creek into Hampton Creek, Nevada. A second transplant of 54 cutthroat from Pine Creek was made into Goshute Creek, Nevada, in 1960. The Nevada Fish and Game Department, assuming these were Utah cutthroat, Salmo clarki utah, closed these streams to fishing and listed S.c. utah as an endangered species in Nevada. Mr. Frank Dodge, Nevada Fish and Game Department, in 1972, found a population of cutthroat trout in the headwaters of Hendrys Creek (Mt. Moriah tributary of the Snake Valley region) which resembled those found in Pine Creek. Following this, several unsuccessful attempts were made by the Nevada Fish and Game Department to locate additional pure populations of cutthroat trout in the Snake Valley area of Utah and Nevada.

In 1973 the BLM (Utah) began stream habitat surveys in the Deep Creek Mountain Range in an attempt to define critical habitats and possible remnant populations of the cutthroat. In the spring of 1974, BLM biologists Don Duff and Josh Warburton discovered cutthroat in the extreme headwaters of Trout Creek, Utah, above a natural barrier falls. Subsequent sampling and analysis by the BLM, Utah Division of Wildlife Resources and Colorado State University (under contract funded by BLM) determined that Trout Creek specimens were pure strain fish of the Bonneville Basin. Inventories have coninued to date and the only stream found to contain a pure population was Trout Creek. Hybridized populations (with rainbow trout) were found in Birch Creek and Johnson Creek (Hickman, 1977) (Refer to Figure 2).

REASONS FOR DECLINE

When the Snake Valley arm of Lake Bonneville dried up there were relatively few perennial streams in the area. In addition to this, since the mid 1800's, introductions of non-native trouts, climatic conditions, irrigation practices and habitat loss and degradation have been influential in reducing the number of cutthroat populations in the Snake Valley area. Replacement and hybridization from introductions of exotic rainbow trout (Salmo gairdneri) has posed the most

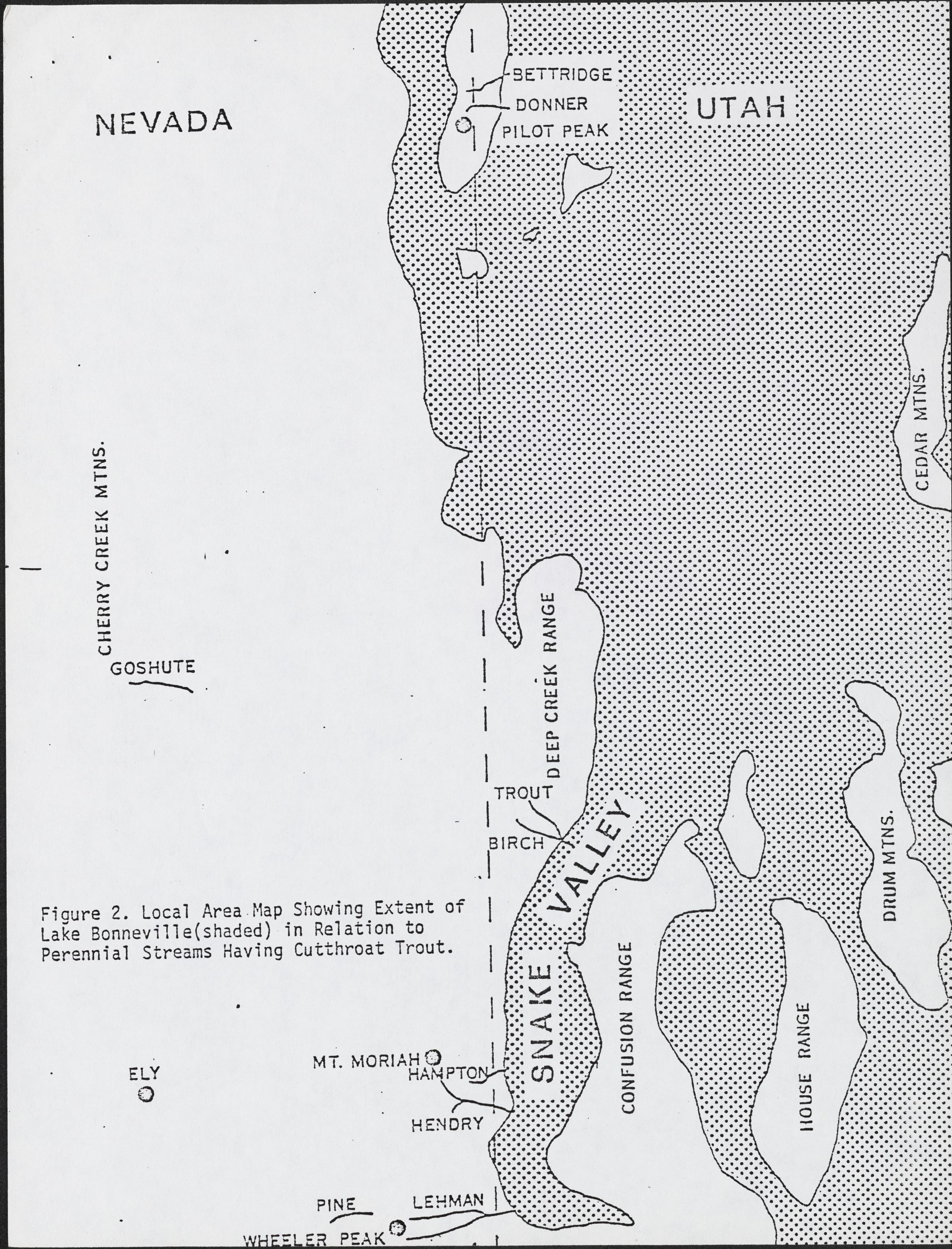

Figure 2. Local Area Map Showing Extent of Lake Bonneville(shaded) in Relation to Perennial Streams Having Cutthroat Trout.

significant impact to the survival of the Snake Valley cutthroat. Virtually every stream in the Snake Valley region, capable of supporting trout, has been stocked with rainbows. Brook trout are also capable of replacing the cutthroat through competition because of earlier spawning periods and it's ability to become better adapted to life in small spring-fed headwater streams.

Exploitation, though not likely a limiting factor by itself, can reduce the number of catchables and may act to favor other exotics such as the brooks, browns, and hybirds. It has been documented that cutthroat trout are highly vulnerable to angling mortality (Behnke and Zarn 1976.)

Livestock grazing imposes a serious and subtle threat to the survival of the cutthroat trout, in the arid Snake Valley region. Grazing becomes significant when discussing sites for reintroductions, since much of the prime grasslands exist in headwater meadow areas. Livestock interests in the Bonneville Basin have been unconcerned about stream protection of rare trout populations. These problems have made the BLM very cautious in planning for additional habitat sites for future reintroductions of the Snake Valley cutthroat. Many studies have shown that livestock grazing destroys and degrades riparian vegetation, and streambanks soil stability resulting in alterations of channel morphology, loss of cover, and a reduction in numbers and biomass of fish particularly older and larger trout (Behnke 1977). Studies and management of livestock impacted areas should be made in order to rehabilitate the grazed areas either through improvement of the existing grazing system, or livestock exclusion (Platts 1977). The BLM in Utah and Nevada has been involved in stream side fencing programs to protect the riparian habitat of streams containing sensitive, or rare trout populations from continued livestock damage (Goshute Creek, Nevada, and Birch Creek, near Beaver, Utah).

Droughts and violent thunder storms may have historically eliminated cutthroat populations from some high gradient streams, since natural recolonization could not be effective after desiccation of the pluvial lake in Snake Valley. This may account for the high number of barren streams found in the Snake Vally region prior to rainbow trout introductions.

Past surface disturbance impacts from mining have been slight and of short duration, the main damage resulting from equipment movement and road construction to and from the mine site. There exists little room for trails or roads in some of the narrow canyons, therefore, the streambed may be utilized for such purposes, in some areas. Recent uranium mining activities in Utah's Deep Creek Mountains have caused concern over the future impacts of mining to the resources of this fragile desert island ecosystem environment.

The effects of all these environmental impacts on the cutthroat trout populations are greatly magnified when considered collectively. Many of the streams in the Snake Valley region have been affected by all of these major impacts at some point in time during the recent past history of the area.

UNIQUENESS OF SNAKE VALLEY CUTTHROAT TROUT

Ancient Lake Bonneville went through several periods of fluctuations in which water levels which were closely associated with climatic conditions (Gilbert 1879). According to Broecker and Kaufman (1965), four low levels occurred between 8,000 and 22,000 years ago, including one period of complete desiccation followed by refilling that took place about 11,000 years ago. The final desiccation occurred approximately 8,000 years. This final desiccation of Lake Bonneville resulted in ten or twelve independent basins being formed, one of which was the Snake Valley basin (Gilbert 1890). The northern portions of Snake Valley shows a lake level elevation of about 5,100 feet. This would have prevented water from flowing out of Snake Valley and into the Great Salt Lake Basin. In addition to such physical isolation, the cutthroat were forced to seek refuge in the streams to overcome the increased saline conditions brought on by the desiccation (Hunt et al 1953). Thus, many populations of cutthroat in the Bonneville Basin have been isolated from contact with each for about 8,000 years.

Wydoski et al (1976) conducted a study of the electrophoretic patterns of proteins in cutthroat located in the Bonneville Basin, as well as with several other groups of cutthroat, and rainbow trout. No protein was unique or distinctive for S. c. utah specimens, but an unusual variation for muscle lactate dehydrogenase (LDH) was found in cutthroat from Trout and Goshute Creeks, indicating a common ancestor. This unusually complex variation seems to indicate the presence of a variant allele. A unique evolutionary event, or series of events, occurred in the Snake Valley cutthroat trout LDH, which would indicate long-term isolation from the rest of the Bonneville Basin cutthroat trout.

Comparison of samples of the least chub, Iotichthys phlegethontis in the western Bonneville Basin add credence to the assumption of incipient speciation in fishes isolated in Snake Valley. Samples from Donner Springs (Pilot Peak Area) have the typical fin ray counts given by Sigler and Miller (1963). These found in Snake Valley have one less ray in the dorsal (7), anal (6) and pelvic (7) fins.

Smith (1966) stated that the mountain suckers, (Pantosteus platyrhynchus) of Deep Creek, in the Deep Creek Mountain area, is differentiated from the typical Northern Bonneville form.

The Snake Valley cutthroat trout differs from other cutthroat trout of the Bonneville Basin by having more basibranchial teeth and gillrakers, and fewer scales in the lateral line series. The spotting pattern is more uniformly distributed over the body, and not so concentrated posteriorly as in other Bonneville Basin cutthroat. The head appears longer and deeper with the body being more compressed and caudal peduncle deeper, all of which gives it a more chunky body appearance (Behnke 1976 a, b).

STATUS OF THE SNAKE VALLEY CUTTHROAT TROUT

Pure populations are found in Pine, Goshute, Hampton, and Hendrys Creeks of Nevada and in Trout Creek, in Utah (refer to Figure 2). Hybridized populations are found in Muncy and Mill Creeks, Nevada, and Birch and Johnson Creeks, in Utah (Behnke 1976a, Hickman 1977).

Goshute Creek probably has the highest number of Snake Valley cutthroat, having about 1,500 in 4 miles of stream (McLelland 1975). The Nevada BLM, and Nevada Fish and Game Department (NFG), have been instrumental in protecting and enhancing the habitat in Goshute Creek. During the 1977 drought Goshute Creek lost about 38% of the cutthroat population per mile. Because of these conditions a concerned NFG took 71 cutthroat from Goshute Creek and transplanted them proportionately into Water Canyon Creek (four stream miles habitat) and Clear Creek (one stream mile habitat).

Pine Creek, a very small stream with little habitat, has about 100 cutthroats (excluding fry), as does Hampton Creek, which is also a small stream (McLelland 1975). Pine Creek suffered some mortality as a result of the 1977 drought. Mile Creek, another creek with transplanted cutthroat, lost its entire population as the creek dried up from the drought.

Hendrys Creek had about 200 cutthroat in the headwater area in 1973. In 1974 eradication of rainbow trout below the barrier was conducted on Hendry's Creek to aid the fish's survival. Hendrys, Goshute, and Pine Creeks have now closed to angling use. Goshute and Hampton Creeks have past histories of losing all of their fish from flash floods, and this is the reason they were barren in 1953 and 1960. Because of its small size Pine Creek is also vulnerable to flash flooding. Therefore, the potential exists that the cutthroat populations in these streams could be lost in the future. During the 1977 drought NFG estimates that 50% of the cutthroat populations in Hendry's and Hampton Creeks were lost because of dry stream sections. In the interest of managing these unique fish, NFG has identified about 25 streams suitable for reintroductions. They plan to rehabilitate about two to four streams per year in this effort.

During 1977, one of the most significant items to take place in the basin for the protection of desert fishes, and the environment occurred in the Deep Creek Mountains when the BLM filed for an emergency withdrawal of a 27,000 acre area of critical environmental concern within the mountain range because of increased uranium mining activity, which threatened to destroy many of the unique resources of the mountain area. A significant item in justifying this action was the presence of the rare Snake Valley cutthroat in only about 1¼ miles of critical habitat on Trout Creek as well as the presence of the rare giant stonefly (Pteronarcys princeps). The area was withdrawn from mineral entry on May 3, 1977 by the Secretary of the Interior under section 204(e) of the Federal Land Policy and Management Act of 1976 (PL 94-579). This withdrawal stays in effect for a 3-year period, and allows time for study of all resources to ascertain their values.

In September, 1977, the BLM (Utah) funded a contract to the Utah Division of Wildlife Resources to provide for an inventory of all fish and wildlife resources on the mountain range. The contract will last until April, 1979, and will provide BLM with inventory data necessary to evaluate the future withdrawal status. Hopefully, the contract will define possible other streams inhabited by the cutthroat on the mountain.

In late October, 1977, the Utah Division of Wildlife Resources(DWR), eradicated the rainbow trout below the natural falls barrier on Trout Creek as a start to implement management plans designed to expand the cutthroat population. Future plans call for the transportation cutthroat from Trout Creek into the headwaters of Red Cedar Creek a remote stream on the mountain, which was given first priority for transplant efforts. The DWR plans to rehabilitate about seven additional east slope streams to enhance cutthroat survival back into their historic range. A habitat management plan (HMP) is being developed for the entire mountain ecosystem by the BLM, in cooperation with the Utah Division of Wildlife Resources, will specify management of all east slope streams for the cutthroat. The complete HMP is scheduled for completion in 1978-79 for all of the mountain resources, of which the cutthroat is an integral part of the fauna. At present the BLM has developed a HMP for Trout Creek and began implementation of this plan in 1977 using Sikes Act (P.L. 93-452) authorities. Using Youth Conservation Corps (YCC) workers, some 75 long-type stream improvement structures were constructed in July in Trout Creek to aid the bank stabilization and pool quality enhancement for the cutthroat. Stream improvement work is scheduled again in 1978 by BLM using the YCC.

Although there are differences in the taxonomic characters between S. c. utah and the cutthroat found in Snake Valley, there also exists much overlap. Basibranchial teeth counts, which seem to be a distinctive characteristic separating the two forms, were found to be similar in number in one S. c. utah sample from Willow Creek, Jordan River drainage, Utah (Hickman 1977). With the analysis of more samples from the Bonneville Basin the degree of overlap between these cutthroat becomes more obvious. This overlap is further substantiated through the use of a computer-aided discriminant function analysis, which evaluates the similarities and differences between samples (Hickman 1977). Sixteen(16) morphomeristic character measurements (refer to Table 1) from samples of various described and undescribed subspecies of cutthroat trout, and one sample of rainbow trout, were compared (refer to Figure 2). The closer the group centroid (represented by dot in Fig. 3) the more similar the samples. The cutthroat trout in Snake Valley and S. c. utah are closely situated, indicating a high degree of similarity. Of interest is the similarity depicted in the discriminate function plot between S. c. pleuriticus (Colorado River Cutthroat) and S. c. stomias (Greenback cutthroat). This supports the taxonomic evaluations of Behnke and Zarn (1976) that S. c. pleuriticus gave rise to S. c. stomias via an ancient headwater transfer, and that there exists little taxonomic difference between the two subspecies.

Table 1. Morphomeristic Characters Used in the Discriminant Function Analysis, 1977.

Head Length	Gillrakers total
Upper Jaw Length	Branchiostegal rays right
Snout tip to dorsal fin origin	Branchiostegal rays left
Dorsal fin length	Scales above latera line
Caudal peduncle depth	Pelvic fin rays
Caudal peduncle length	Pyloric caeca
Gillrakers upper	Basibranchial teeth
Gillrakers lower	

DISCRIMINANT FUNCTION PLOT

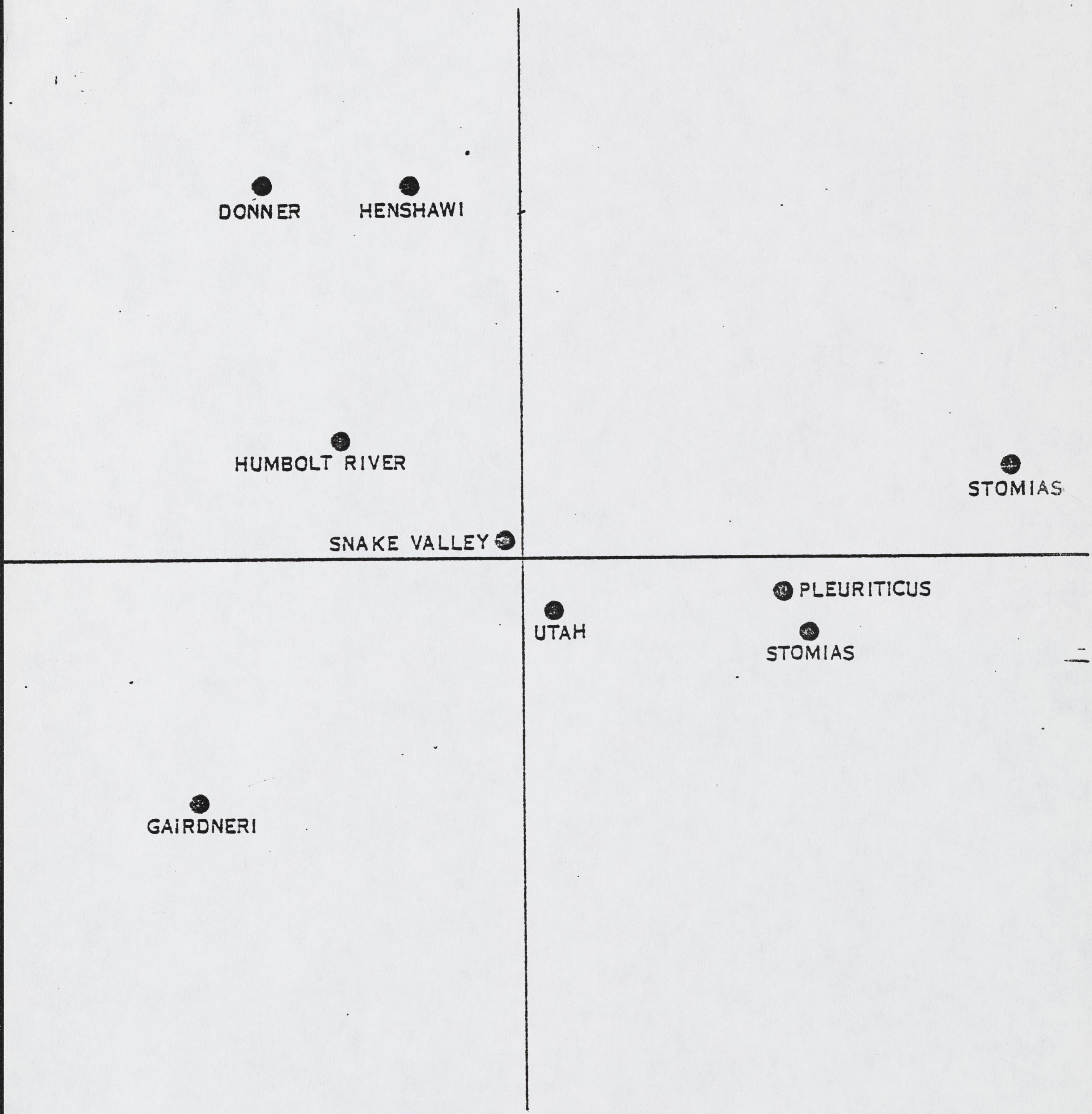

Figure 3. Discriminant Function Plot Analysis Chart Showing Relationship of Cutthroat Subspecies Based on Morphomeristic Characters.

To avoid taxonomic confusion, which has led to subspecies classification delays, the cutthroat trout in Snake Valley should be considered a unique form of S. c. utah. S. c. utah is not abundant in any portion of its native range, and at one point was thought to be extinct as a pure form (Miller 1950, Cope 1955, Platts 1957, and Sigler and Miller 1963). The 1973 version of the U.S. Department of Interior's "Red Book" of endangered and threatened species listed S. c. utah as "status undetermined;" the International Union for the Conservation of Nature (1969) listed it as rare; Holden et al (1974) considered it endangered; the Wyoming Game and Fish Department lists it as rare, the Nevada Fish and Game Department considers it endangered, and Behnke (1973, 1976b) considers it to be rare with a highly restricted distribution.

CUTTHROAT DISCOVERY IN THE PILOT PEAK RANGE

In an effort to locate additional populations of Bonneville Basin cutthroat trout, a survey of the Pilot Peak Range (North of Wendover on the Utah-Nevada border) was conducted in 1977 by the BLM and Colorado State University (under a contract funded by BLM).

As a result of these surveys only two streams were found containing sufficient annual flows to support trout populations. One stream, to the north of Pilot Peak, Bettridge Creek has an abundant population of rainbow trout which were first stocked by the Utah Division of Wildlife Resources in the 1940's, or early 1950's. The other stream, located in the adjacent canyon to the south of Bettridge Creek, is unnamed (for the present we have called it Donner Creek since it historically drained into Donner Springs). The city of Wendover, Utah obtains a portion of its water supply from this creek.

Mr. Kent Sumners, Utah Division of Wildlife Resources, discovered the presence of the cutthroat in Donner Creek in April, 1977 while sampling the stream at the request of the BLM. Subsequent collection of specimens by the authors and their later analysis at Colorado State University confirmed this classification. Taxonomic analysis of the 17 trout sampled from Donner Creek proved most interesting. They are pure strain cutthroat trout (no sign of hybridization) and have a higher gillraker count than any other cutthroat population (24-29, avg. 26.1).

The origin of this cutthroat is uncertain, however Mr. Howard Gibson, retired water master for the city of Wendover, indicated that the cutthroat were in Donner Creek when he commenced work on the stream in 1952 (personal comm. with H. Gibson, Wendover Utah). None of the other local residents contacted could provide any information pertaining to the cutthroat, and most were unaware of its existence in Donner Creek. The Nevada Fish and Game Department has no record of cutthroat stockings in the Pilot Peak Range (letter to Don Duff, BLM, SLC from Pat Coffin, Nevada Fish & Game Dept., Elko, October 1977). The only cutthroat exhibiting such high gillraker numbers is the Lahontan cutthroat trout (S.c. henshawi)

(Behnke and Zarn, 1976). The most probable origin of the Donner Creek cutthroat is Pyramid Lake, since from the late 1890's to 1930 cutthroat trout from Pyramid Lake were stocked extensively in Nevada. In 1910 Elko County received a large shipment of eggs but no records exist on where these fish were stocked. Little stocking of Lahontan cutthroat occurred from 1931-1942, but in 1950 Lahontan trout from Summit Lake, Nevada were used for stocking. After 1930 *S.c. henshawi* was considered rare and it seems unlikely that a creek in the Pilot Range would be stocked with this cutthroat subspecies.

The discriminant function analysis (Table 1 and Figure 3) indicates that the cutthroat from Donner Creek are the most similar to *S.c. henshawi*.

SUMMARY

The Snake Valley cutthroat, a form of *S.c. utah*, is a unique desert fish resource located in the western Bonneville Basin which is worthy of protection and management for the scientific community as well as the American public. *S.c. utah* has promising possibilities for enhancing the basin's states fisheries programs for wild trout management. The 1975 listing of endangered and threatened fishes of the western U.S. by the Desert Fishes Council did not consider this subspecies. We feel adequate habitat and species data now exists on which to base subspecies naming and status recommendations for this cutthroat. It is our recommendation to the Council that this subspecies be listed on the Council's list as threatened throughout its range in Utah, Nevada, and Wyoming. This classification should serve as an aid to organizations and agencies responsible for management of habitat and species in the future. The ultimate management design for this subspecies, and all others so classified is to provide management to a degree whereby survival and protection of the species and its habitat is assured, so critical status classification can be removed. However, should environmental conditions continue to deteriorate and this subspecies eventually be listed by the U.S. Fish and Wildlife Service as threatened, then this classification would provide the necessary protective status while still allowing for recovery programs to function.

The interest in desert fishes management has intensified by agencies and the scientific community by the discovery in 1977 of *S.c. henshawi* in Donner Creek of the Pilot Peak Mountain Range. The major significance of this find of *S.c. henshawi* is that it very likely represents the original Pyramid Lake genotype - the largest trout native to western North America and long believed to be extinct (Trojnar and Behnke, 1975, Behnke and Zarn, 1976). This find is worthy of intense management effort by the Utah Division of Wildlife Resources (DWR) and the BLM, since the existence of this pure strain fish is extremely limited as indicated by its official threatened status by the U.S. Fish & Wildlife Service. Colorado State University is continuing contract studies on this mountain range for the BLM. The BLM plans to implement the Pilot Peak Mountains HMP in 1978 under Sikes Act authorities in cooperation with the DWR. Stream habitat improvements are being planned for Bettridge Creek which at present has a natural reproducing population of rainbow trout. This creek could serve in the future as a possible transplant site for the Lahontan cutthroat in Donner Creek. Both creeks have good stream habitat being in a relatively undisturbed state from man and livestock activities and located in a remote area adjacent to the arid wastes of the Great Salt Lake desert salt flats.

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Thesis

Systematic Study of the Native Trout of the Bonneville Basin

submitted by

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In partial fulfillment of the requirements
for the Degree of Master of Science
Colorado State University
Fort Collins, Colorado
May, 1978

ABSTRACT

A systematic study of the Bonneville cutthroat trout *Salmo clarki utah*, was initiated to determine its taxonomic status and affinities with other cutthroat trout.

Only one trout, *S. c. utah*, is endemic to the Bonneville basin, the largest endorheic basin in the Great Basin of western North America. *S. c. utah*, historically abundant throughout all suitable habitat of a vast area of Utah, Wyoming, Nevada and Idaho, suffered a catastrophic decline from massive introduction of non-native trouts and habitat alteration and degradation to a point of virtual extinction as pure populations. Today only 14 populations from primarily small headwater streams and one lake population of pure *S. c. utah* are known.

Historical and zoogeographic evidence and information pertaining to Lake Bonneville and the decline of *S. c. utah* since its desiccation was compiled and analyzed.

Samples of fish were collected, and traditional mensural and meristic characters were recorded. Modified Hubbs and Hubbs diagrams of pure *S. c. utah* populations and pure populations of other subspecies of *S. clarki* and of *S. gairdneri* were used to display the results of the meristic data in more graphic manner. A computer program, multiple discriminant function analysis, was used to compare the evolutionary affinities of *S. c. utah* with other subspecies of *S. clarki* and with *S. gairdneri*. The results show that *S. c. utah* is differentiated from the other trout used in this study, according to the 16 morphomeristic characters used in the program. The computer

results substantiated and statistically verified the results of other morphomeristic analysis documenting the separation of *S. c. utah* from various subspecies of *S. clarki*.

Management goals needed to save and enhance the remnant populations of Bonneville cutthroat trout are discussed.

Sufficient information is presented in this study to warrant protective recognition for the few remaining populations of *S. c. utah*.

ACKNOWLEDGEMENTS

Appreciation and gratitude is extended to several individuals who made the completion of this study possible.

Dr. Robert Behnke, my advisor, provided continual encouragement and patience throughout the study. His many years of experience in trout systematics and taxonomy provided the guidance necessary in a study of this type.

I am grateful for the technical advice, critical analysis of this paper and assistance of my committee members, Dr. Clare Carlson and Dr. James Ward.

A special note of gratitude is directed to Mr. Don Duff, BLM Utah State Office Fishery Biologist, for his assistance in data collection and long hours of service rendered toward obtaining funding for this study. Financing was provided by the U.S. Bureau of Land Management in Utah.

Numerous persons aided in the field and laboratory work, and to each of these I give my sincere appreciation. Special thanks are due Mr. Steve Culver for his preparation of the computer programs used in this study.

Words cannot express sufficient gratitude for the encouragement and long hours of assistance provided by my wife, Vicky, or for the support provided by my sons, Brian and Eric, and also my parents.

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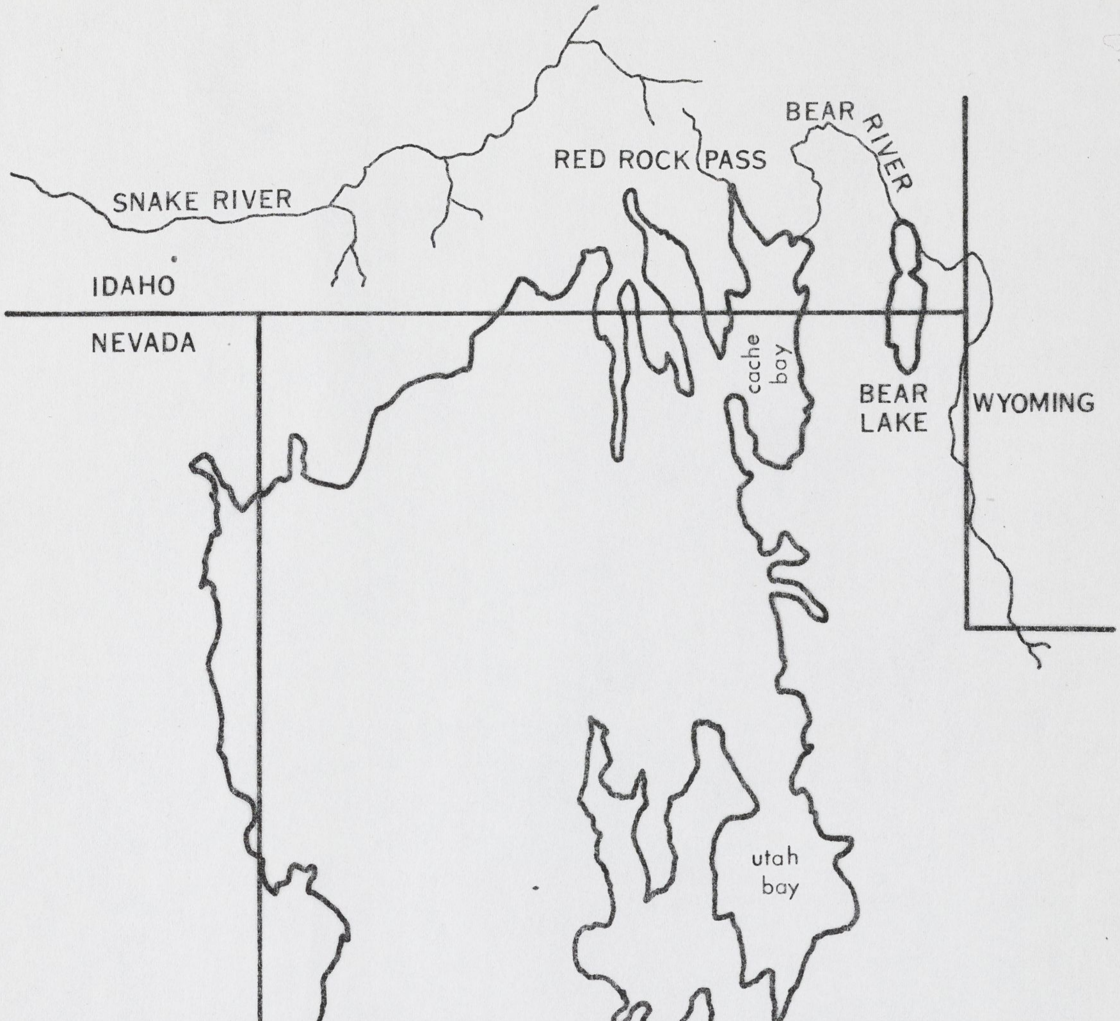
INTRODUCTION

Salmo clarki utah, the cutthroat trout endemic to the Bonneville basin, once abounded throughout its native range, but has suffered a catastrophic decline in the twentieth century. This decline, coupled with the taxonomic confusion surrounding *S. c. utah*, has led many authors to assume this fish to be extinct (Hatton 1939; Miller 1950; Cope 1955; Platts 1957; Sigler and Miller 1963). Recent works by Behnke (1970, 1973, 1975, 1976a,b) and efforts by several individuals and agencies have provided new information on the existence of a few relict populations and added new hope for the future of *S. c. utah*.

Despite recent discoveries of populations of *S. c. utah* and introductions into new habitats, an increase in abundance has not been documented and the remaining pure populations lack the protection needed to insure survival of this unique trout. Sufficient information is presented in this study to warrant protective recognition for the few remaining populations of *S. c. utah*. Lack of efforts to manage and protect the Bonneville cutthroat trout has been due to lack of knowledge concerning the taxonomic and population status. The intentions of this study are to establish the systematic status of *S. c. utah*, identify localities of pure populations and point out the significant potential impacts which may affect these populations.

This report is based on examination of more than 900 specimens from 64 localities.



SNAKE RIVER
RED ROCK PASS
BEAR RIVER
IDAHO
NEVADA
cache bay
BEAR LAKE
WYOMING
utah bay
SEVIER BODY
snake bay
white bay
preuss bay
UTAH
SEVIER RIVER
escalante bay

Figure 5. Multiple discriminant function analysis plot for 568 specimens representing pure populations of *S. c. utah*, *S. c. stomias*, *S. c. pleuriticus*, *S. c. virginalis*, *S. c. henshawi*, *S. c. lewisi*, *S. c. clarki*, an undescribed subspecies from the Humboldt River drainage and *S. gairdneri*, collected from 1872 to 1977.

Kamchatkan trout were distinct from any North American trout. The origin of the cutthroat trout is still uncertain, Behnke (1966) wrote: "If a relict group of trout allied to the cutthroat species occurs in the Far East, they have not yet been discovered and described." Behnke et al (1962) examined a type of Salmo formosanus at Stanford University collected from a stream in Formosa in 1917 (Jordan and Oshima 1919). It possessed four well-developed basibranchial teeth, a primitive salmonid character found in cutthroat trout. This specimen may represent an early ancestor of the cutthroat trout which dispersed in Asia but became extinct except for the river in Formosa. Unfortunately, this trout may be extinct; despite several collections since 1917, no specimens of Salmo formosanus have been found.

Behnke (1978a) indicated the original distribution of cutthroat trout occurred in coastal streams from Prince William Sound, Alaska, to the Eel River in California. In the upper Columbia River basin, the cutthroat trout penetrated up the Spokane, Pend Oreille and Kootenay Rivers and the Snake River prior to the formation of barrier waterfalls. The formation of these falls blocked the interior movement of the rainbow trout and Pacific salmon which are not native above the falls. From the Pend Oreille River, the cutthroat gained access to the headwaters of the Clark Fork and crossed the Continental Divide to the South Saskatchewan and upper Missouri rivers. From other areas of the upper Columbia River drainage, the cutthroat migrated to the Snake River, and the Alvord and Lahontan basins. From the upper Snake River (above Shoshone Falls), the cutthroat trout gained access to the Yellowstone drainage, Bonneville basin and the Colorado

River basin. From the Colorado, the cutthroat trout crossed the Continental Divide (by headwater stream capture) and became established in the South Platte and Arkansas river systems and in the Rio Grande. Cutthroat trout were never native to the North Platte drainage.

The trout of the Bonneville basin was probably derived from the cutthroat trout of the upper Snake River, which became isolated by Shoshone Falls from the cutthroat trout of the lower Snake and upper Columbia Rivers (Jordan 1894; Hubbs and Miller 1948).

LAKE BONNEVILLE

Lake Bonneville (Fig. 1), named by Mr. W. Irving in 1831 in honor of Capt. B. L. E. Bonneville, is the largest endorheic basin in the Great Basin. It was formed during the late Pleistocene epoch, during the Wisconsin Age, by geological and climatical conditions (Hubbs and Miller 1948). The Great Salt Lake of north central Utah is a remnant of this once vast body of freshwater. Lake Bonneville is comparable in size 31,785 km (19,750 sq. mi.), mean depth 244m (800 ft.), regional air temperature 4.4 - 8.3 C, cooler during Pleistocene than today (39.9 - 46.9 F), and fish fauna (with respect to its composition of a large salmonine top carnivore, numerous endemic whitefish planktivores, several minnows, one or two suckers and bottom-dwelling sculpins), to present Lake Michigan (Smith et al 1968). The largest tributary was the Bear River, which supplied more than 50 percent of the total inflow; the remainder came from the Weber, Jordan, Provo and Sevier rivers and small streams and springs.

Lake Bonneville went through several periods of fluctuation associated with wetter and drier climatic periods. Four periods of low water levels occurred between 8,000 and 22,000 years BP (before the present), including one period of complete desication followed by refilling that took place about 11,000 years BP (Bright 1963). The final desiccation occurred approximately 8,000 years BP, at which time the major drainages in the basin became isolated from contact with each other (Broecker and Kaufman 1965).

During late Pleistocene (ca. 25,000 - 35,000 years BP), lava intrusion in a canyon of the Bear River, which was then a tributary to the Snake River, diverted the Bear River into the Bonneville basin. Sometime between 12,000 (Broecker and Kaufman 1965) and 30,000 (Malde 1965) years BP, as a result of the greatly augmented inflow from the Bear River, the level of Lake Bonneville rose to its highest level 1.6 km (5,100 feet above sea level) and overflowed into the Snake River via Red Rocks Pass (Malde 1968), the lowest point on the lake's rim.

The fish fauna of the Bonneville basin, although relatively depauperate, is the most extensive of the interior drainages of the western United States and bears a close relationship to the hydrographic history of the region (Hubbs and Miller 1948). The limited endemism exhibited by Bonneville fishes (Table 1) suggests that mixing of adjacent faunas occurred during Pliocene and Pleistocene times. The most obvious of these faunal connections was with the upper Snake River (above Shoshone Falls). Four species are endemic to the Bonneville basin and upper Snake River (Table 1). Several ichthyologists have discussed the similarities in the fish fauna between the upper Snake River and the Bonneville basin (Jordan 1891; Evermann 1892; Gilbert and Evermann 1894; Jordan 1927; Hubbs and Miller 1948).

Those fish that are found in the Bonneville basin but are not endemic are generally headwater species (Table 1), indicating that the faunal connections with the Bonneville basin were mainly headwater transfers.

The ancestral form of cutthroat trout (large-spotted type) invaded the upper Snake River from the Columbia River system prior to the formation of Shoshone Falls (Murphy 1974). When Bear River

Table 1. Native fishes of the Bonneville basin.

Salmo clarki utah[1]	Bonneville cutthroat trout
Prosopium gemmiferum[1,4]	Bonneville cisco
abyssicola[1,4]	Bear Lake Whitefish
williamsoni[5]	Mountain Whitefish
spilonotus[1,4,7]	Bonneville Whitefish
nannomaculatum[1,4,7]	Spotted Whitefish
Gila atraria[2]	Utah Chub
copei[2]	Leatherside Chub
Rhinichthys osculus[5]	Speckled Dace
cataractae[5]	Longnose Dace
Richardsonius balteatus hydrophlox	Redside shiner
Iotichthys[1] *phlegethontis*	Least Chub
Catostomus ardens[2]	Utah Sucker
platyrhynchus[5]	Mountain Sucker
discobolus[9]	Bluehead Sucker
fecundus[3,6,10]	Webug Sucker
Chasmistes liorus[1,3,6,8]	June Sucker
Cottus extensus[1,4]	Bear Lake Sculpin
echinatus[1,3,6]	Utah Lake Sculpin
bairdi[5]	Mottled Sculpin
beldingi[5]	Piute Sculpin

[1]Endemic to the Bonneville basin.

[2]Endemic to the Bonneville basin and upper Snake River (above Shoshone Falls).

[3]Endemic to Utah Lake.

[4]Endemic to Bear Lake.

[5]Headwater species.

[6]Probably extinct in pure form.

[7]White (1975) found two distinct types of *P. spilonotus* (large and small form), the small form was designated as *P. nannomaculatum* and the large form *P. spilonotus*.

Table 1. (continued)

[8]One specimen of *Chasmistes* was found in Jackson Lake, Wyoming, that was thought to be a separate species from *C. liorus* (Miller 1965; Baxter and Simon 1970).

[9]*Pantosteus delphinus* and *Pantosteus virescens* (green sucker) were united as *C. discobolus* (Smith 1966).

[10]Sigler and Miller (1963) thought *C. fecundus* may represent a hybrid between *C. ardens* and *Chasmistes liorus*. Bailey et al (1970) did not recognize *C. fecundus*.

was diverted into Lake Bonneville the large-spotted cutthroat trout in the upper Snake River had access to the Bonneville basin. This relatively recent separation may explain the small degree of differentiation apparent between S. c. utah and the large-spotted cutthroat of the upper Snake River.

HISTORICAL REVIEW

S. c. utah, particularly those from Utah, Panguitch and Bear Lakes, was of great importance to the Utah Indians as a source of food and to the early settlers both for sustenance and commerce. Yarrow (1874) wrote that the cutthroat trout "provided to the inhabitants of Utah a valuable, healthy and cheap article of diet, as a source of food it could not be surpassed by any other fish." It undoubtedly was one of the most characteristic and abundant fish, in comparison with other fishes, in Utah (Cope and Yarrow 1875, Hatton 1939).

The cutthroat trout, particularly from Utah Lake, played a significant role in supplying food for the hungry pioneers, especially during the times of crop failures and other disasters which left them without food. State Congressman, John Smith, went so far as to say that the trout from Utah Lake were as worthy of historical record as the seagulls (state bird) and the sago lilies (state flower) (Madsen 1910).

The earliest record of which I am aware, specifically referring to trout in Utah, is that made by Father Escalante in 1776, during his journey into Utah (Tanner 1936, Auerbach 1943). Escalante found the trout very abundant in Utah Lake and observed that the Indians living around the lake relied heavily on them and the other fish for food.

In 1833 John K. Townsend, a Philadelphia physician and naturalist commissioned by the American Philosophical Society and the Academy of Natural Sciences of Philadelphia to search for birds, found

Bonneville trout very abundant in the Bear River drainage. In an afternoon of fishing, one of his men caught 13.6 kg (30 pounds) of trout, averaging 381 - 406mm (15-16 inches) and .34 kg (3/4 of a pound) per fish (Thwajts 1907).

John C. Fremont (1845), a government explorer, visited Utah Lake in May of 1844 and recorded that the trout of the lake constituted the main food of the Indians living in the area. He described these trout as being of lesser size than the "salmon trout" in California (Pacific salmon/steelhead).

In December 1847, Parley P. Pratt and associates found Utah Lake "teeming" with trout (Pratt 1970). News of the abundance of trout in Utah Lake had traveled back east to Wilford Woodruff and other Mormon pioneers. Woodruff wrote to Orson Pratt in April of 1849 telling of a Brother Wipple, who had left the Utah Valley in the fall of 1848 with tales of abundant trout in Utah Lake and surrounding streams in the Valley.

Peter Madsen, a Danish fisherman of Utah Lake, mentioned catching trout from the Lake and its tributaries in 1864 (Yarrow 1874). Mr. Madsen and his family began commercially fishing the Utah Lake area in 1856, at which time the trout were very abundant (Hunington 1857), but by the 1870's, as a result of the rapid increase in commercial fishing combined with year-round harvest, a decrease in catch was noticed (Yarrow 1874; Carter 1969).

In 1859, Dr. George Suckley, a U.S. Army surgeon and a student of salmonid fishes, observed the trout of the Bonneville basin during his trip across the western United States. Suckley wrote of catching trout in the Weber and Provo Rivers; the fish in the latter averaging .5 to 1.4 kg (one to three pounds). He indicated that a friend in 1851 caught one trout from the Provo River which weighed about 2.7 kg (six pounds) and was 660mm (26 inches) in length. Suckley believed that the geographical range of S. c. utah extended to the Humbolt River; this conclusion was based upon examination of specimens collected in Deep Creek, 250 km (150 miles) west of the Great Salt Lake (Suckley 1874; this monograph on salmonidae was written and delivered to the Smithsonian Intitution in 1861 but, due to Suckley's death, was not published until 13 years later). In this monograph Suckley gave the name Salmo utah to the trout of Utah Lake.

Suckley (1874) mentioned that the Smithsonian collection contained two fish, obtained by Captain Simpson of the U.S. Army, that seemed to be Salmo utah. Suckley did not indicate the exact date that these specimens were collected, except that it was prior to 1861. Hatton (1939) believed that these trout were collected by Simpson in 1859.

In 1872, Livingston Stone visited the Salt Lake City Trout Hatchery, where he collected two trout fry. He discovered that the brood stock were propagated from Bear Lake, Utah Lake and various streams in the Utah mountains (Stone 1874). Based upon this account, S. c. utah may have been the first cutthroat trout artificially propagated by a public agency (Behnke 1976a).

Dr. H. C. Yarrow, a surgeon and naturalist of the Wheeler Expedition, made his first collections of cutthroat trout in Utah Lake and vicinity in 1872 (Yarrow 1874). He also collected cutthroat trout from other regions of the Bonneville basin, including Beaver River, in the 1870's (Behnke 1960).

A comment made by Yarrow (1874) concerning the knowledge of this trout in Utah is of interest:

> "This fish has existed for years in immense numbers, and for this reason it is rather singular that its occurrence was not noticed until the party under Lieutenant Wheeler, of the Engineers, visited Utah Lake in 1872."

Apparently Yarrow was not familiar with the previous studies or recordings of the trout of the Bonneville basin.

DECLINE OF *S. c. utah*

In the early days of settlement in the Bonneville basin the trout had been so plentiful that few people thought that the supply could ever be exhausted. Soon after the settlers arrived, the cutthroat trout fisheries were overexploited in Bear, Utah and Panguitch Lakes. Yarrow (1874), Siler (1884) and Woodruff (1892) mentioned the former abundance of cutthroat trout and their subsequent decline. The decline in the cutthroat trout of Utah Lake has been vividly documented. In 1864, one haul made by a commercial net secured between 1588 and 1678 kg (3,500 and 3,700 pounds) of trout. By 1872, one haul produced about 227 g (500 pounds) of trout (Yarrow 1874, and by 1889 a 45 kg (100 pound) haul of cutthroat trout was considered good (Sigler and Miller 1963). In 1897, action was taken by the Utah State legislature to protect the cutthroat trout in Utah Lake, but this was probably too late. In 1930 only one cutthroat trout was caught in the lake during the fishing season (Hatton 1939). But, even if trout had ever been caught by man, they would be extinct in Utah Lake today because of habitat degradation and water quality pollution.

The decline of the Bonneville cutthroat trout in and around Utah Lake was accurately foreshadowed by Yarrow (1874) when he made this observation in 1872:

> "In comparison with other fishes of Utah, the Lake trout (Utah cutthroat trout) is undoubtedly the most numerous and the most easily captured; how long, however, this condition of affairs will last it is impossible to say, the supply having greatly diminished during the past few years . . . . In the course of a few years artificial propagation must be resorted to, for although certain

> laws have been passed regulating the size of the meshes of nets, no attention is paid to them by some greedy individuals who think only of filling their own pockets at the expense of future generations."

Hatton (1939) realized that the Bonneville cutthroat trout was fast becoming extinct in the 1930's when he made this statement:

> "To the person interested in sport and the conservation of our native species it is most appalling to become acquainted with the facts concerning _Salmo utah_, and its almost complete disappearance from the waters of the Great Basin. It is also interesting to speculate as to how long the general public will remain unconscious of the need of conservation and allow such valuable species to be ruthlessly exterminated."

Similar words of warning by subsequent writers also went unheeded. Since the late 1930's, there has not been a recorded find of the Bonneville cutthroat trout in Utah Lake; extinction from Panguitch and Bear Lakes soon followed. Today it is only known from a few isolated headwater reaches in streams of the Bonneville basin and in a few streams where it was introduced outside of the basin.

Probably the most detrimental factor causing the rapid decline of _S. c. utah_, since the civilizing impact of man in the Bonneville basin, has been indiscriminate introductions of non-native trouts. Virtually every stream in the Bonneville basin capable of supporting trout has been stocked with non-native trouts. Hybridization of rainbow trout and other interior subspecies of cutthroat trout with _S. c. utah_ has led to almost complete elimination of pure populations. The presence of all degrees of hybridization has greatly confounded the taxonomy of the interior cutthroat trout (Behnke 1976a). Brook trout are capable of replacing the cutthroat trout through competition because of earlier spawning periods and ability to become better adapted to life in streams which have undergone some type of physical alterations. Non-native cutthroat trout were first introduced into Utah in 1899, the rainbow trout in 1883, the brook trout in 1875 and the brown trout prior to 1900 (Sigler and Miller 1963).

Another significant impact on the survival of S. c. utah is man's physical alterations of its habitat. The Bonneville cutthroat, like other interior cutthroat trout, has been unable to readily adapt to modifications in its habitat. The types of habitat changes that have had the most impact on S. c. utah are livestock grazing, irrigation practices and climatic conditions. Most of these impacts are not usually individually responsible for the reduction of large numbers of cutthroat trout, but in combination with other factors they have been very effective. For example, habitat alterations usually favor the displacement of native fish by more tolerant, introduced species.

Livestock grazing imposes a serious and subtle threat to the survival of the cutthroat trout, especially in the arid regions of the Great Basin where livestock tend to concentrate in riparian vegetation along stream banks. Many studies have shown that livestock grazing destroys and degrades riparian vegetation and steambank soil stability, resulting in alterations of channel morphology, loss of cover, and a reduction in numbers and biomass of fish, particularly older and larger trout (Behnke 1978b; Duff 1978). Livestock interests in the Bonneville basin have been little concerned with protecting streams! The Bureau of Land Management in Utah and Nevada has been involved in riparian-aquatic rehabilitation projects involving streamside fencing and instream habitat improvement structures to protect the riparian habitats of streams containing S. c. utah from continued livestock damage (Goshute Creek, Nevada, Birch Creek, near Beaver, Utah and Trout Creek, Juab Co., Utah).

Droughts and violent thunderstorms may have historically eliminated cutthroat populations from some of the high gradient streams, since natural recolonization could not be effective after desiccation of Lake Bonneville. This may account for the high number of barren streams found in certain regions of the Bonneville basin prior to rainbow trout introduction. The 1977 drought killed up to 50 percent of the pure populations of S. c. utah in some streams in the southern portion of the Bonneville and in eastern Nevada (Personal communication with Mr. Leroy McLelland, Nevada Fish and Game Dept., Ely, Nevada, Nov. 7, 1977).

Past impacts from mining have been slight and of short duration, the main damage resulting from road construction and equipment movement to and from the mine site. Recent mining activities in some regions of the Bonneville basin have caused concern over the future impacts of mining to the resources of the fragile ecosystem.

Exploitation, though probably not a limiting factor by itself, can reduce the number of adults and may act to favor other exotics such as the brook and rainbow trout and hybrids. It has been documented that cutthroat trout are highly vulnerable to angling mortality (Behnke and Zarn 1976). McPhee (1966) found that 32 hours of angling removed 50 percent of the cutthroat trout, 152mm (six inches) or more in size, from 3.9 km (2.4 mile) section of Rochat Creek, Idaho. My own angling observations with native interior cutthroat trout in streams indicate that they are readily caught.

Carter (1969) cited five principle reasons for the decline of cutthroat trout in Utah Lake: "(1) fishing methods used, (2) the inadequacy of the laws regulating fishing and the lack of strict enforcement of the existing laws, (3) irrigation practices, (4) chemical changes in the water and (5) the introduction of new species of fish."

The use of the streams flowing into Utah Lake for irrigation purposes was partially responsible for the extinction of *S. c. utah* in Utah Lake and its tributaries. When the trout descended the streams after spawning, much of the water was diverted to irrigation ditches. In referring to the latter part of the nineteenth century, Mr. George Madsen reported that he saw over 500 trout from 152 to 203mm (six to eight inches) long taken out of one irrigation penstock in 12 hours. "They literally clogged the ditches and were considered a nuisance rather than a blessing." (The Salt Lake Tribune, June 17, 1923). Irrigation practices also aided in the chemical change of Utah Lake by leaching the surrounding land of its salts and increasing the salinity of the Lake. Other streams in the Bonneville basin were dewatered by irrigation methods. This had a pronounced affect on the ecology of trout populations and low water levels made them susceptible to predation and exploitation.

Utah Lake's fish fauna has gone from one dominated by trout to a warm water community. In the lake proper, 229km (142 sq. mi.) , no Salmonidae are found today.

The extinction of pure *S. c. utah* from Bear Lake was caused by hybridization with non-native cutthroat trout (particularly

Yellowstone cutthroat trout) and rainbow trout (McConnell et al 1957). Unlike Utah Lake, Bear Lake has remained an oligotrophic lake; cutthroat trout still exist in the Lake today, but no pure (unhybridized) *S. c. utah* are found. The introduction of nongame fish into Panguitch Lake resulted in the decline of *S. c. utah*; evenutally the lake was rotenoned, because it was full of carp, and any remaining cutthroat trout were eradicated.

TAXONOMY

The cutthroat trout, Salmo clarki, is an example of a polytypic species, a species consisting of several geographically disjunct forms with a broad distribution and a great amount of genetic diversity. Because of the widespread distribution in interior waters, accompanied by much isolation and local variation, the systematic problems presented by the cutthroat series are complex. Many of the taxonomic problems result from the large amount of variability found in many characters of the cutthroat trout (even within a single population) and from their ability to exist under diverse and fluctuating environmental conditions, which may induce direct (non-genetic) environmental influence.

Early ichthyologists without an understanding of the range of morphological variability expressed within a single species named many species of cutthroat trout on the basis of local varieties.

Referring to the systematic confusion surrounding the genus, Salmo, Gunther (1866) wrote:

> "There is no group of fishes which offers so many difficulties to the ichthyologist, with regard to the distinction of the species, as well as to certain points in their life history, as the genus Salmo."

Suckley (1874) was aware of the problems in morphological variability expressed by members of the genus Salmo when he gave this warning:

> There is already too much confusion in the synonymy of the various kinds (of Salmonidae); and if the practice of describing and naming new species from characters of unidentified, immature individuals is not stopped, the study of the relations of the species will become so

> complicated that useful classification will be next to impossible, and the principal object and usefulness of scientific arrangement, such as simplifies the study of natural history in other branches, will be greatly impaired.

Unfortunately, Suckley could not overcome the problem that he identified; many of the different Salmo species that appear in his 1874 paper were based upon certain variation of age, sex and season and are no longer considered valid species names. Suckley named several dubious species of trout on very little basis, one of these was Salmo utah.

Jordan (1885) expressed the belief that "no group in our vertebrate fauna offers such difficulties (in taxonomy) as the Salmonidae." Later, Jordan and Evermann (1896) noted that coloration and morphology were subject to variation and that there were numerous forms of Salmo because many authors separated them using unreliable characters. Among the reliable characters they recommended for use in distinguishing various forms of Salmo were hyoid teeth (basibranchial teeth), scale counts, and pyloric caeca and gillraker counts.

Miller (1950) wrote: "The trouts of western North America have provided perplexing problems to the systematic ichthyologist." He mentioned introductions of non-native trouts; variability in coloration, morphology, and meristic characters; and reductions in number due to habitat destruction and exploitation as reasons for this systematic confusion among western North American trouts.

In coastal waters and in the Salmon and Clearwater drainages of the Columbia River basin of Idaho, cutthroat trout and rainbow trout (Salmo gairdneri) have historically coexisted without massive hybridization. This natural sympatric occurrence of rainbow and cutthroat trout, each maintaining its genetic integrity, provides the basis for recognizing Salmo clarki and Salmo gairdneri as two separate species. One of the major reasons for the taxonomic confusion surrounding subspecies of S. clarki is that, when rainbow trout are introduced into waters where only the cutthroat is native, mass hybridization has been the rule (Behnke and Zarn 1976).

Behnke and Zarn (1976) indicated that recognition of pure stocks of cutthroat trout is not a simple matter because of the presence of all degrees of hybridization:

> Although one can acquire sufficient familiarity with the subtle variations among the different species and subspecies of western trouts to distinguish the various taxa, the average field worker cannot be expected to accurately differentiate the true native trout of a given area from hybrid populations . . . . the sorting and evaluation of specimens collected during survey work to determine the status of a native trout and to locate pure populations remains an involved process of detailed examination and comparison of many characters.

Because of the lack of clear-cut differentiating characters, S. c. utah has had a confusing taxonomic history (Table 2).

The first description of the Bonneville cutthroat trout was made by Suckley (1874) from explorations made in the late 1850's. The name "Salmo utah" was proposed by Suckley specifically to distinguish the trout of Utah Lake from the other Bonneville trout, which Suckley called Salmo virginalis, in the streams of the Bonneville basin. Suckley wrote (1874):

> A variety of the Salmo virginalis occurs in Lake Utah, a large sheet of freshwater about fifty miles south of Salt Lake City. The fish are less spotted than those caught in the mountain streams nearby, and attain a much larger size. . . . For this variety or kind we will, for the present, apply the provisional name of Salmo utah.

Table 2. Specific and subspecific names which have been applied to the cutthroat trout of the Bonneville Basin.

Salmo utah Suckley	(Suckley 1874)
Salmo virginalis Girard	(Yarrow 1874)
Salmo pleuriticus Cope, Salmo virginalis Girard	(Cope 1875) (Cope & Yarrow 1875)
Salmo clarki aurora Girard	(Jordan 1878)
Salmo purpuratus Pallas	(Jordan and Gilbert 1881)
Salmo purpuratus virginalis Jordan	(Jordan 1885)
Salmo purpuratus Pallas, S. spilurus Cope, S. pleuriticus Cope	(Goode 1888)
Salmo pleuriticus Cope	(Bean 1888)
Salmo mykiss virginalis Jordan	(Jordan 1889)
Salmo clarkii virginalis Jordan	(Jordan and Evermann 1898)
Salmo virginalis Girard	(Jordan and Evermann 1902, 1916)
Salmo utah Suckley	(Snyder 1919; Jordan 1920)
Salmo clarki utah Suckley	(Jordan 1927)
Salmo utah Suckley	(Jordan, Evermann and Clark 1930; Tanner 1931, 1936; Hatton 1939)
Salmo clarkii utah Suckley	(Schrenkeisen 1938)

Suckley intended the name utah only for the cutthroat trout of Utah Lake, which he believed to be larger and more silvery than the darker, more heavily-spotted stream trout that he was familiar with from the Provo, Weber and Bear Rivers. The distinctive characteristics of Utah Lake cutthroat trout were probably almost wholly a reflection of direct environmental influence caused by the conditions of Utah Lake and not due to genetic differentiation. Jordan (1891) felt the distinctive appearance of Utah Lake specimens was due to the alkaline conditions in that body of water.

Dr. Girard (1856) described S. virginalis from specimens collected by Lt. Beckwith's party from "Utah" Creek (now Ute Creek) and at Sangre de Cristo Pass, tributaries of the Upper Rio Grande del Norte, Colorado. Subsequent authors erred in thinking that Girard's (1856) description was from a tributary of Utah Lake. This error was not recognized until Snyder (1919) and Jordan (1920) pointed out that "Utah" Creek, the type locality of S. virginalis, is a tributary of the upper Rio Grande, with no relation to Utah Lake or the state of Utah.

Although Suckley's description of Salmo utah is inadequate for separating utah from any other form of cutthroat trout, this published account of Salmo utah (Suckley 1874) fixes the name utah as the earliest name applied solely to trout of the Bonneville basin. The spotting pattern and coloration of adult trout from Utah Lake are atypical of S. c. utah; therefore, it is unfortunate that Jordan (1891) used it to describe and illustrate the characteristics of the Bonneville cutthroat trout.

Yarrow (1874) applied the name Salmo virginalis to the specimens he collected from Utah and Panguitch Lakes in 1872.

Cope (1875) and Cope and Yarrow (1875) believed that two species, Salmo virginalis and Salmo pleuriticus, occurred in the Bonneville basin. Cope (1875), referring to specimens of S. virginalis collected from Utah Lake, said:

> (Salmo virginalis) maintains its distinctiveness from S. pleuriticus, Cope, from the streams which flow from the mountains on both sides (Wasatch mountains) in its more slender form of head and body.

Jordan and Copeland (1876) and Jordan (1878) recognized Utah trout as Salmo clarki aurora, with S. virginalis and S. utah being synonymous with aurora. Between the years 1876 and 1930, Jordan and co-authors recognized over ten different scientific names for the cutthroat trout of the Bonneville basin, changing names virtually every other year (Appendix A).

Jordan and Gilbert (1881) used the name Salmo purpuratus for trout that the authors collected from Utah Lake. They noted that the trout were very abundant in the Lake and that they did not differ in any visible respect from trout taken in the salt waters of Puget Sound, Washington. Jordan and Gilbert indicated that S. purpuratus was apparently the parent stock from which many other species of Salmo in North America had recently differentiated. Jordan and Gilbert's usage of purpuratus, a species of Kamchatkan trout described by Pallas (1814), was probably adapted from Gunther (1866), who considered the American cutthroat trout (S. clarki) a synonym of S. purpuratus. Goode (1884 and 1888), following Jordan and Cope, listed S. spilurus, S. pleuriticus and S. virginalis for trout in Utah. He believed that S. spilurus was a recent descendent of S. purpuratus and that S. pleuriticus was closely allied to S. purpuratus.

Garman (1885) listed trout from Utah as *Salmo virginalis*, which produced an immediate response by Jordan (1885). In reference to Garman's usage of *virginalis* as a full species, Jordan wrote:

> Thus he (Garman) writes '*Salmo virginalis*' and says below, 'a variety of *S. clarkii*'. If *virginalis* be named at all, I prefer *Salmo clarkii* subsp. *virginalis*, or var. *virginalis*, or, still better, in accordance with current American usage, *Salmo clarkii virginalis*. To place such forms in co-ordinate paragraphs with the unquestionable species is productive of confusion. This again, however, is a matter of taste or convenience.

Unfortunately, Jordan didn't follow his own advice of recognizing several subspecies of the species *clarki* (a method used since 1938); in this same paper he lists the trout of the Utah basin as *Salmo purpuratus virginalis*.

Jordan (1891) collected trout in the Bonneville basin in 1889 that he considered as *Salmo mykiss virginalis*. This name was given for all of the trout in the lakes and streams west of the Wasatch range, in the Bonneville basin, where he found them especially abundant in the Bear, Provo, Jordan and Sevier Rivers and in Utah Lake. Jordan listed all of the cutthroat trout as subspecies of *Salmo mykiss*; explaining his reason for changing from *purpuratus* to *mykiss*, Jordan (1894), in a footnote, said:

> By the laws of scientific nomenclature, the oldest name of any species is its right name, all questions as to which name is the best or sounds the best being disregarded. The cutthroat trout was called *Salmo mykiss* in Kamchatka by Walbaum, in 1792, *Salmo mykiss* by Schneider in 1810 *Salmo purpuratus*, by Pallos, in 1814, his specimens being also the *mykiss* of Kamchatka. It was named *Salmo clarkii*, by Richardson, in 1836 from Columbia river specimens.

Jordan and Evermann (1898), realizing that the name *Salmo mykiss* should be restricted to the Kamchatkan species, which is different from any trout in the United States, changed the name of the cutthroat trout to Salmo clarkii based upon Sir John Richardson's 1836 description from the Cathlapootl River (now North Fork of Lewis River), in the Columbia River drainage. Behnke (1966) noted that Salmo mykiss has a closer relationship to Salmo gairdneri than to Salmo clarki and concurred with Jordan and Evermann's analysis that Salmo mykiss and Salmo clarki are quite distinct. In this same paper (1898), Jordan and Evermann considered the trout from Utah as Salmo clarkii virginalis, the name Jordan had suggested 13 years before.

Jordan and Evermann (1902, 1916) chose to list all cutthroat trout as full species; thus, the Utah cutthroat were recognized as Salmo virginalis, the name used by Yarrow 28 years before.

The first published account that I am aware of to point out the error in using virginalis for the cutthroat trout of the Bonneville basin was by Snyder (1919) in a footnote to his paper on the whitefish of Bear Lake. In referring to the trout of that lake, he used the name Salmo utah; justifying this choice in a footnote in that paper, he said:

> Through some oversight the name Salmo virginalis has been wrongly applied to the trout of the Salt Lake basin, which should be called Salmo utah, the name given it by Suckley. Salmo virginalis is the trout of the Rio Grande.

In a later paper, Snyder (1922) reiterated the point that S. utah is the correct name for Bonneville trout.

Jordan (1920), in a short note in Copeia, mentioned that the name of the trout of the Bonneville basin that he had previously referred to as Salmo mykiss virginalis should be changed to Salmo utah. He had confused Girard's type locality for *virginalis* (Utah Creek) with a locality in the state of Utah.

While discussing the distribution of fish in the Great Basin, Jordan (1927) chose to list the Utah trout as *Salmo clarki utah*, because it was derived from *Salmo clarki*. Jordan changed his mind later (Jordan, Evermann and Clark 1930) and listed the Utah cutthroat as *Salmo utah*. This practice was followed by Tanner (1931, 1936) and his student (Hatton 1939). Schrenkeisen (1938) recognized the cutthroat trout of the Bonneville basin as *Salmo clarkii utah*. Current practice is to recognize one species of cutthroat trout, *Salmo clarki*, and several subspecies, with the Bonneville cutthroat as *Salmo clarki utah* (Behnke and Zarn 1976; Behnke 1976).

To add to the confusion of scientific naming, several common names for *S. c. utah* are found in the literature: Utah trout, Lake trout, brook trout, speckled trout, spotted trout, blue-nose trout (Bear Lake), River trout and Bonneville trout (Cope and Yarrow 1875; Tanner 1936). The common names used most frequently today are Bonneville and Utah cutthroat trout. I prefer the usage of Bonneville, since *S. c. pleuriticus* (native to the Colorado River drainage) and the large-spotted upper Snake River cutthroat trout (Raft River drainage) are also native to portions of Utah outside of the Bonneville basin (Behnke 1976a).

Because there is broad overlap in taxonomic characters of the various subspecies of *Salmo clarki*, no characters or techniques are presently known which can be used to positively identify an individual or a sample as pure *S. c. utah*. The overlap exists due to the lack of long and complete isolation needed to evolve unique genetic differences in the various subspecies. However, there are well-defined average differences between S. c. utah and non-native trout which have been previously introduced into the Bonneville basin and could hybridize with the native trout. From evaluations of the characters of the samples used in this study, an inference can be made on the degree of non-native genetic influence in the present populations.

Methods and Materials

The taxonomic analysis of the specimens used in this study were completed by the author, Dr. Robert Behnke and several of his students. Most of the trout analyzed are now located at Colorado State University under the care of Dr. Behnke. They represent the largest collection of the various subspecies of *Salmo clarki* and are maintained for future reference and comparisons.

Systematic analyses were first made on several samples from the Bonneville basin collected by the Bureau of Land Management (in Utah, Wyoming and Nevada), Wyoming Fish and Game Department, U.S. Forest Service, Utah Division of Wildlife Resources and the author. Those populations that were determined to be pure S. c. utah were then compared with other samples of the genus *Salmo* collected by the author (Hickman 1977; Hickman and Duff 1977; Hickman and Miller 1977) or from Dr. Behnke's collections and analysis of museum specimens made by Dr. Behnke during the past 20 years.

To determine the magnitude of differences between subspecies of cutthroat trout and other members of the genus *Salmo*, distinguishing characters must be established which allow separation of the subspecies.

Mayr (1969) defined a taxonomic character as: "any attribute of a member of a taxon which it differs or may differ from a member of a different taxon."

Each of the fish collected was subjected to various meristic and mensural analyses, which, unless otherwise noted, were made according to methods suggested by Hubbs and Lagler (1967). Where applicable, all counts and measurements were made on the left side of the fish. The mensural data were converted to thousandths of the standard length to allow for standardization for comparisons between fish of different sizes.

Of the meristic characters selected for taxonomic analysis, basibranchial teeth, pyloric caeca, gillrakers and scales in the lateral series and above the lateral line have the most diagnostic power in separating various species and subspecies of Salmo (Behnke and Zarn 1976) and are largely under genetic and not environmental influences (Wernsman 1973).

Several authors have presented a review of the effect of changes in the environment and its effect on meristic characters (Schreck 1969; Wernsman 1973; Murphy 1974).

The gillrakers were counted on the upper and lower rami of the first gill arch; they were stained with alizarin to expose all rudiments and to facilitate counting. The raker situated at the junction of the upper and lower rami was included with the lower count. Values for gillraker numbers for subspecies of Salmo clarki are quite variable, ranging from 17-24; samples from S. c. henshawi can range higher (Behnke and Zarn 1976; Hickamn 1978). Higher numbers of gillrakers and basibranchial teeth and more even distribution of spots on the body are typical lacustrine traits and may be found in cutthroat trout from Yellowstone Lake, Lahontan basin (*S. c. henshawi*) and the Snake Valley region of the Bonneville basin (Behnke 1978a).

Pyloric caeca counts were made by removing every complete tip from the anterior region of the intestine. Caeca with two separate tips, but with a common base, were counted as two caeca. Pyloric caeca can be very useful for distinguishing between species and subspecies of *Salmo*; Wernsman (1973) indicated that pyloric caeca were the most stable character (not influenced by the environment) among the meristic characters used in trout taxonomy. *Salmo clarki* typically have pyloric caeca counts ranging from 27-50 (*S. c. henshawi* counts may go to 80).

In the genus *Salmo*, basibranchial teeth are found only in cutthroat trout and are therefore the best character for separating *S. clarki* from *S. gairdneri* (Behnke 1978a). All teeth located on the basibranchial plate were counted. To facilitate counting, alizarin stain was used and, where necessary, as much epidermal covering as possible was removed. Basibranchial teeth, incorrectly called hyoid teeth in early literature, typically range from 1-30 in *S. clarki*, with one population of *S. c. henshawi* (Independence Lake) and *S. c. utah* from Snake Valley (Hickman 1978) having considerably more (Behnke and Zarn 1976).

Scales in the lateral series and scales above the lateral line are probably the most useful taxonomic characters used to distinguish between the various subspecies of cutthroat trout. The epidermal covering was removed and malachite green was applied to the scales to facilitate counting. The lateral series count was made by counting the scales two rows above the lateral line from the first scale in contact with the pectoral girdle to the end of the vertebral column (hypural plate). Scale counts above the lateral line were made by counting the scales in an oblique row downward and backward from the anterior base of the dorsal fin to, but not including, the scale in the lateral line. In Salmo clarki typical ranges in scale counts above the lateral line are 33-60 and those in the lateral series range from 135-220. Because of the similarity between many species and subspecies of the genus Salmo, scales in the lateral line is not a useful taxonomic discriminator.

Branchiostegal ray counts were made from both the right and left sides and included rudimentary rays. No significant differences were found in the branchiostegal rays between comparisons of various species and subspecies of Salmo used in this study.

Pelvic fin rays were recorded for each specimen analyzed. Although pelvic fin ray counts are useful for distinguishing between rainbow trout (10 pelvic rays), cutthroat trout (8 or 9 pelvic rays) and their hybrids, they are of no value in separating various subspecies of cutthroat trout.

All meristic counts were made using a binocular microscope. Vertebra counts were not used in the taxonomic analysis between comparisons of various cutthroat trout subspecies and with rainbow trout because of the overlap in values that can be obtained. S. clarki vertebra counts range from 59-64 with an average of 61 or 62 (Zimmerman 1965); rainbow trout vertebra counts range from 60-65, typically averaging 62-64 (Personal communication with Dr. Behnke). Bonneville cutthroat trout average 62-63 vertebra (Behnke 1976a), and detection of hybridization with rainbow trout by a comparison of the vertebra number is not very feasible.

The following mensural characters were used for taxonomic evaluation in this study: head length, upper jaw length, distance from the snout tip to the dorsal origin, dorsal fin depressed length, dorsal fin basal length, adipose fin depressed length, and caudal peduncle depth and length. These characters did not indicate any significant differences between the subspecies of Salmo clarki or that of the genus Salmo because of the great natural variation and the susceptibility to non-genetic (environmental) variation and allometry (sex, age and growth rate).

Hybridization between various species and subspecies of Salmo usually can be detected in populations by noting the meristic characters. The effects of hybridization with rainbow trout is typically first detected by the reduction and absence of basibranchial teeth in specimens carrying Salmo gairdneri genes. As hybridization spreads and intensifies in a population, scale counts decrease, pyloric caeca and vertabral counts increase, the spotting pattern becomes erratic and asymetrical on the body, and spots appear on top of the head. Spotting pattern and coloration are very useful in distinguishing hybrid from pure populations of Salmo when used with meristic counts. To the trained eye, coloration and spotting pattern can be quite diagnostic in distinguishing closely-related salmonid populations from one another, as are similar phenotypic traits in human populations (Behnke and Zarn 1976). Caution should be used, however, in relying upon coloration. Coloration is related to both genetic and environmental factors (Hubbs 1927; Dymond 1932; Alm 1949; Ricker 1959) and is also affected by absorption of foreign materials (Evelyn 1967) and changes in dietary elements (Peterson et al 1966).

Fish hybrids are usually depicted by an intermediacy in the taxonomic characters between parental forms, except for some features that reflect hybrid vigor (Hubbs 1955). Intermediate values for trout are not uniformly expressed, as is the case with plant hybridization (Wernsman 1973). Ivankov (1973) found that offspring from a chum salmon x pink salmon cross had higher number of pyloric caeca than either parent. Hybridization in trout is generally recognized in a wild population by a deviation of values from the normal modes for meristic characters. Changes in spotting pattern are also a useful tool for detecting hybridization in trout.

Results

As a result of analysis of museum specimens and other samples collected from the Bonneville basin during the past century (Behnke 1976a) and the analysis of additional specimens in this study, a means of identifying pure populations of S. c. utah has been determined (Table 3). No single character is significantly different from values for the other cutthroat trout subspecies to support separation, but taken collectively these characteristics will usually distinguish S. c. utah from other cutthroat subspecies.

Using the data in Table 3 as criteria for pure S. c. utah, 14 populations from isolated headwater streams and one possible lake population are recognized (Fig. 2). A summary of information (origin,

Table 3. Characters used to distinguish pure populations of *S. c. utah*.

Genotypic

Character	Range	Mean
Scale Counts		
lateral series	133-183	160
above lateral line	33- 46	38
Gillrakers	16- 24	19
Pyloric caeca	25- 54	35
Basibranchial teeth	1- 50	Present in at least 90% of the population

Phenotypic

Coloration: One of the more somber hued cutthroat trout, it does not develop the brilliant colors of some cutthroat subspecies. Typically have orange cutthroat marks.

Spotting: Large, sparse spots evenly distributed over the body. The cutthroat trout of the Snake Valley region tend to have more spots.

A. Snake Valley drainage

1. Trout Creek
2. Hampton Creek
3. Hendrys Creek
4. Pine Creek
5. Clear Canyon Creek
6. Water Canyon Creek
7. Goshute Creek

B. Virgin River drainage

8. Water Canyon Creek
9. Reservoir Canyon Creek

C. Sevier River drainage

10. Birch Creek
11. Sam Stow Creek

D. Jordan River drainage

12. Willow-Creek

E. Thomas Fork drainage

13. Raymond Creek
14. Giraffe Creek
15. Lake Alice

Figure 2. Map of pure *S. c. utah* populations.

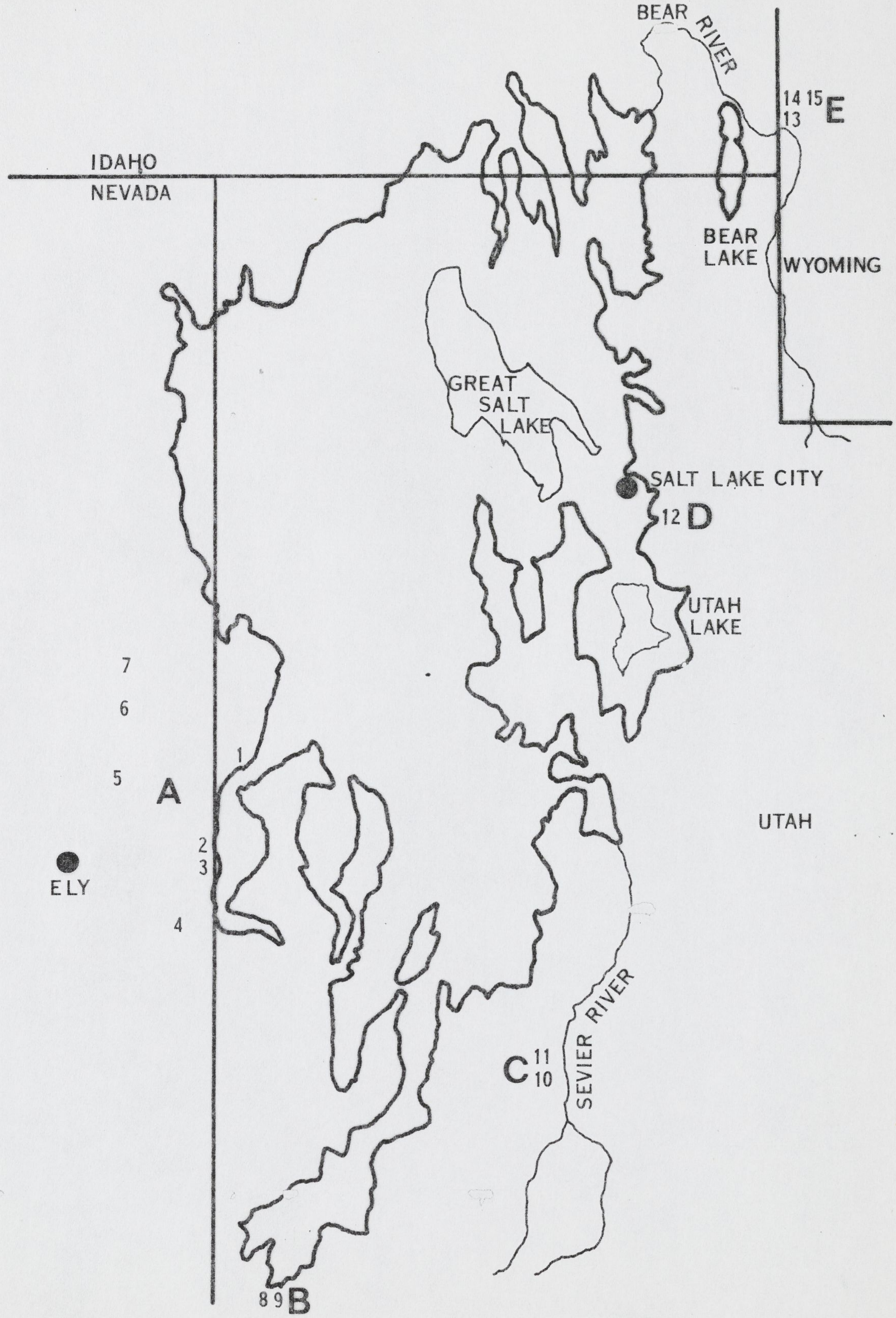
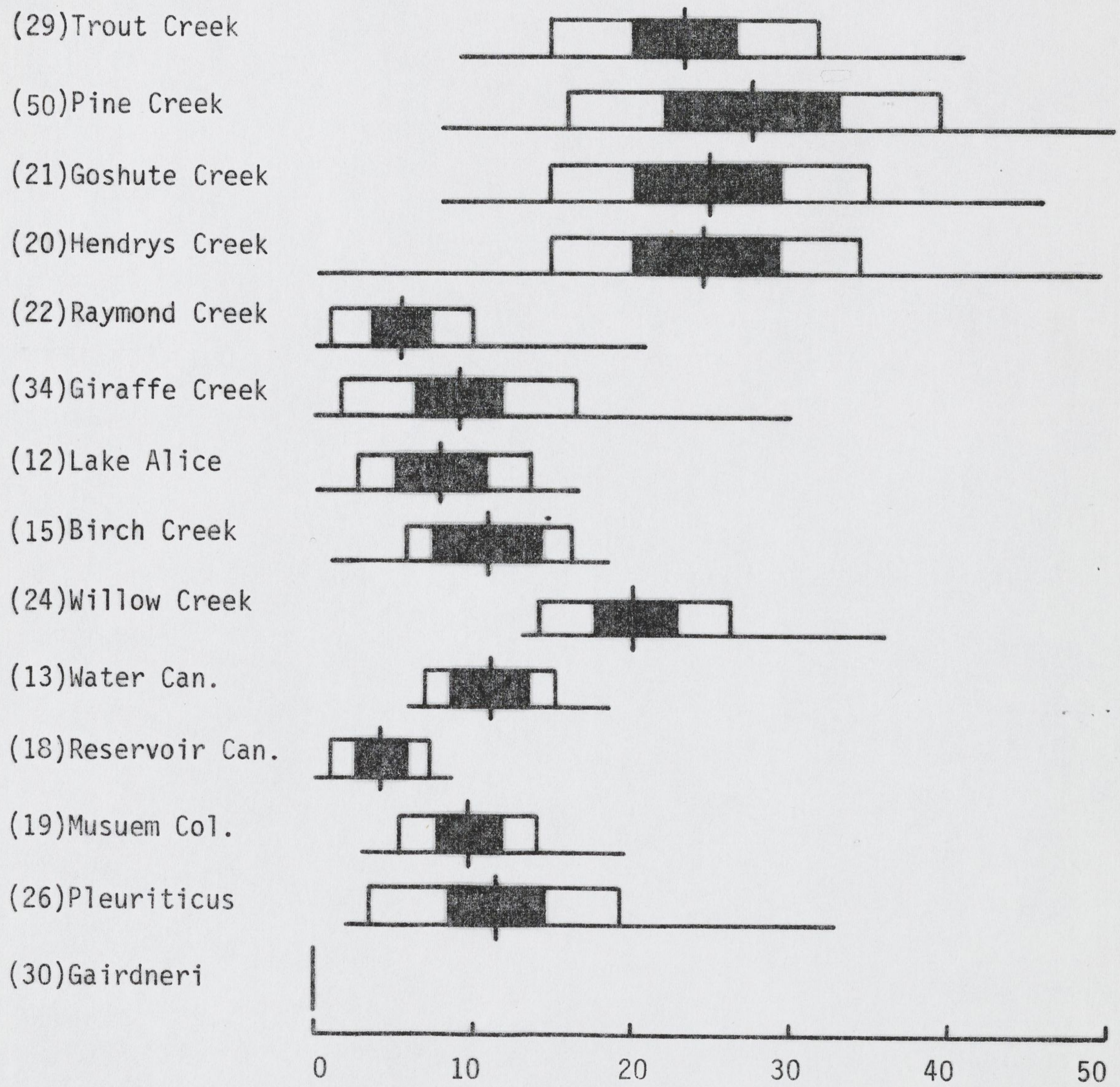

BEAR RIVER
14 15
13
E
IDAHO
NEVADA
BEAR LAKE
WYOMING
GREAT SALT LAKE
SALT LAKE CITY
12
D
UTAH LAKE
7
6
5
1
A
2
3
ELY
4
UTAH
SEVIER RIVER
C
11
10
8 9
B

Figure 3a. Hubbs and Hubbs diagrams of basibranchial teeth from 333 pure *S. c. utah* specimens collected from 1872 to 1977 and representatives of pure *S. c. pleuriticus* and *S. gairdneri* specimens.

The diagrams indicate the mean (center point), 95 percent confidence limits of the mean (black-lined rectangle), one standard deviation on either side of the mean (outer limits of open rectangle), and sample range (basal line).

The sample size is recorded in parenthesis prior to the name of the creek, species or subspecies.


(29)Trout Creek
(50)Pine Creek
(21)Goshute Creek
(20)Hendrys Creek
(22)Raymond Creek
(34)Giraffe Creek
(12)Lake Alice
(15)Birch Creek
(24)Willow Creek
(13)Water Can.
(18)Reservoir Can.
(19)Musuem Col.
(26)Pleuriticus
(30)Gairdneri
0
10
20
30
40
50

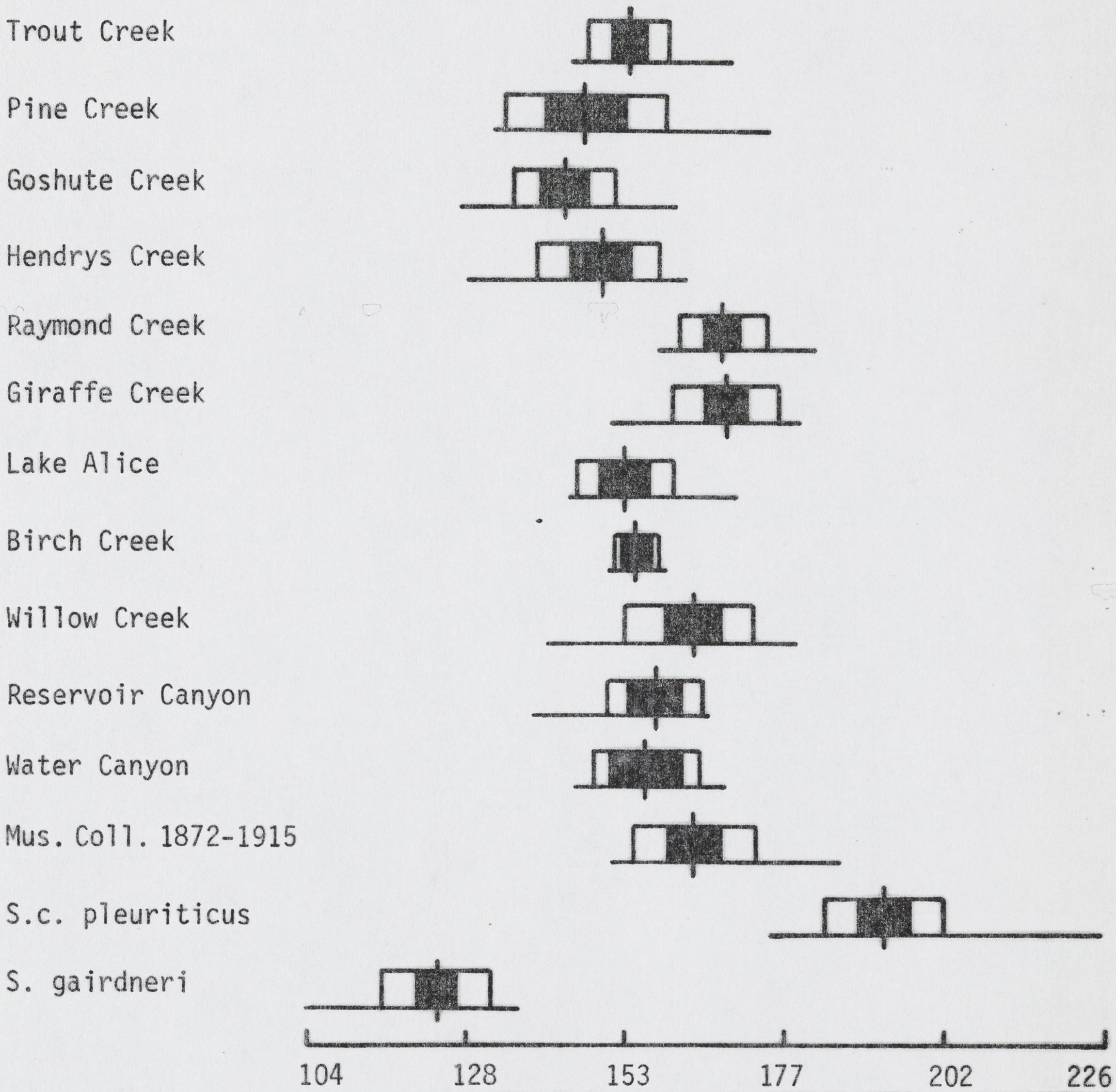


Figure 3b. Hubbs and Hubbs diagrams of scales in the lateral series from 333 pure S. c. utah specimens collected from 1872 to 1977 and representatives of pure S. c. pleuriticus and S. gairdneri specimens.

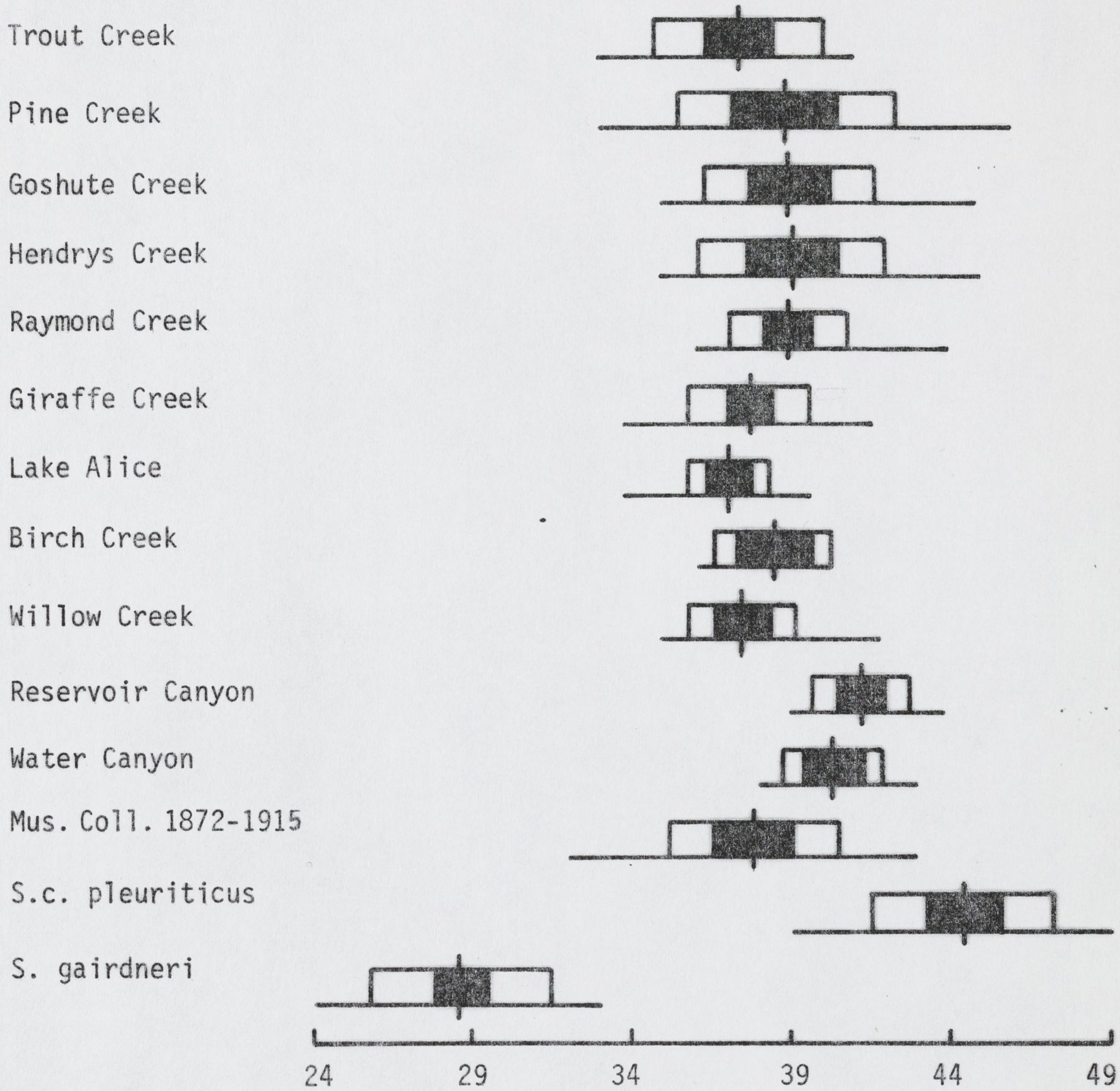


Figure 3c. Hubbs and Hubbs diagrams of scales above the lateral line from 333 pure S. c. utah specimens collected from 1872 to 1977 and representatives of pure S. c. pleuriticus and S. gairdneri specimens.

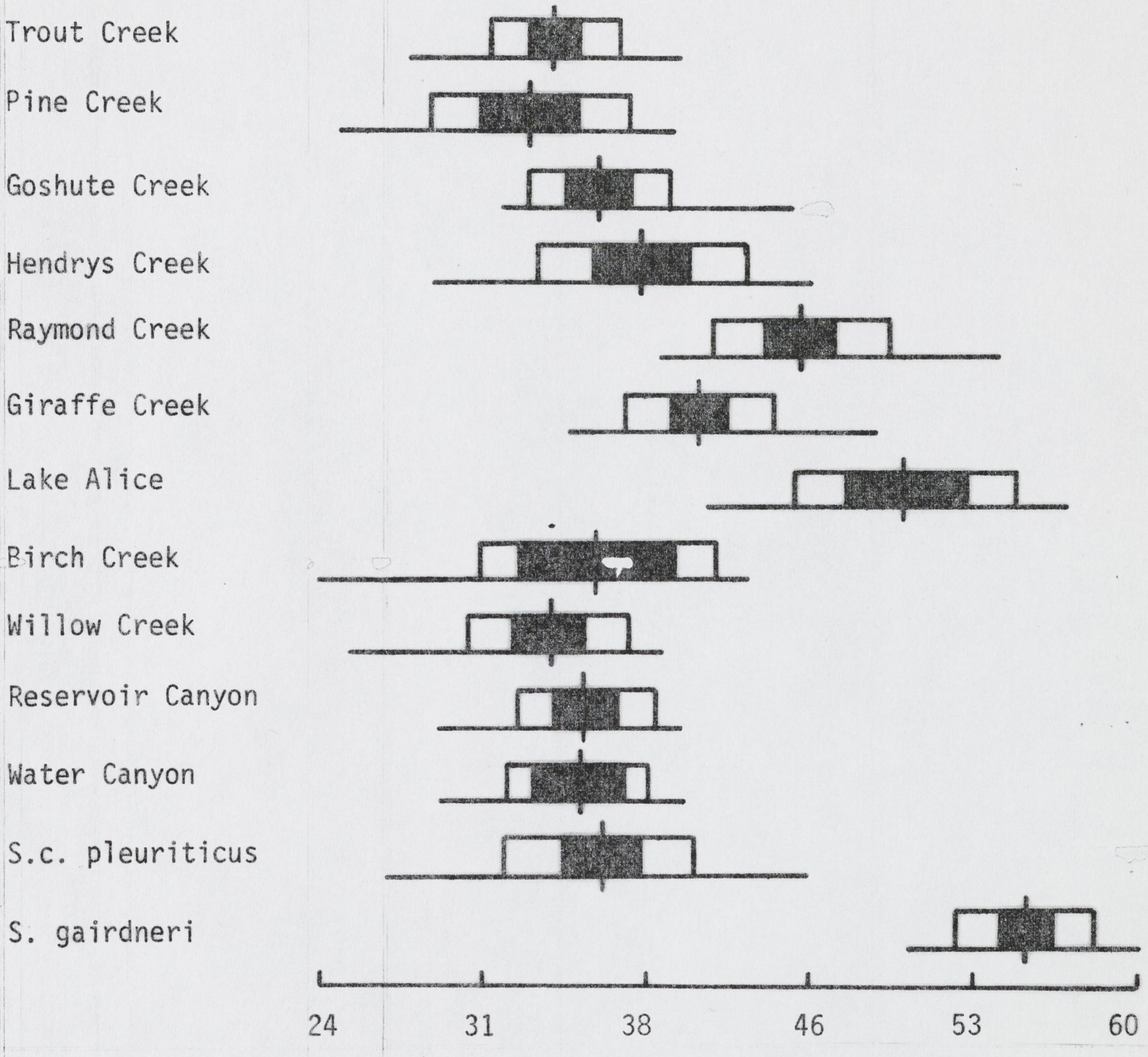


Figure 3d. Hubbs and Hubbs diagrams of pyloric caeca from 333 pure S. c. utah specimens collected from 1872 to 1977 and representatives of pure S. c. pleuriticus and S. gairdneri specimens.

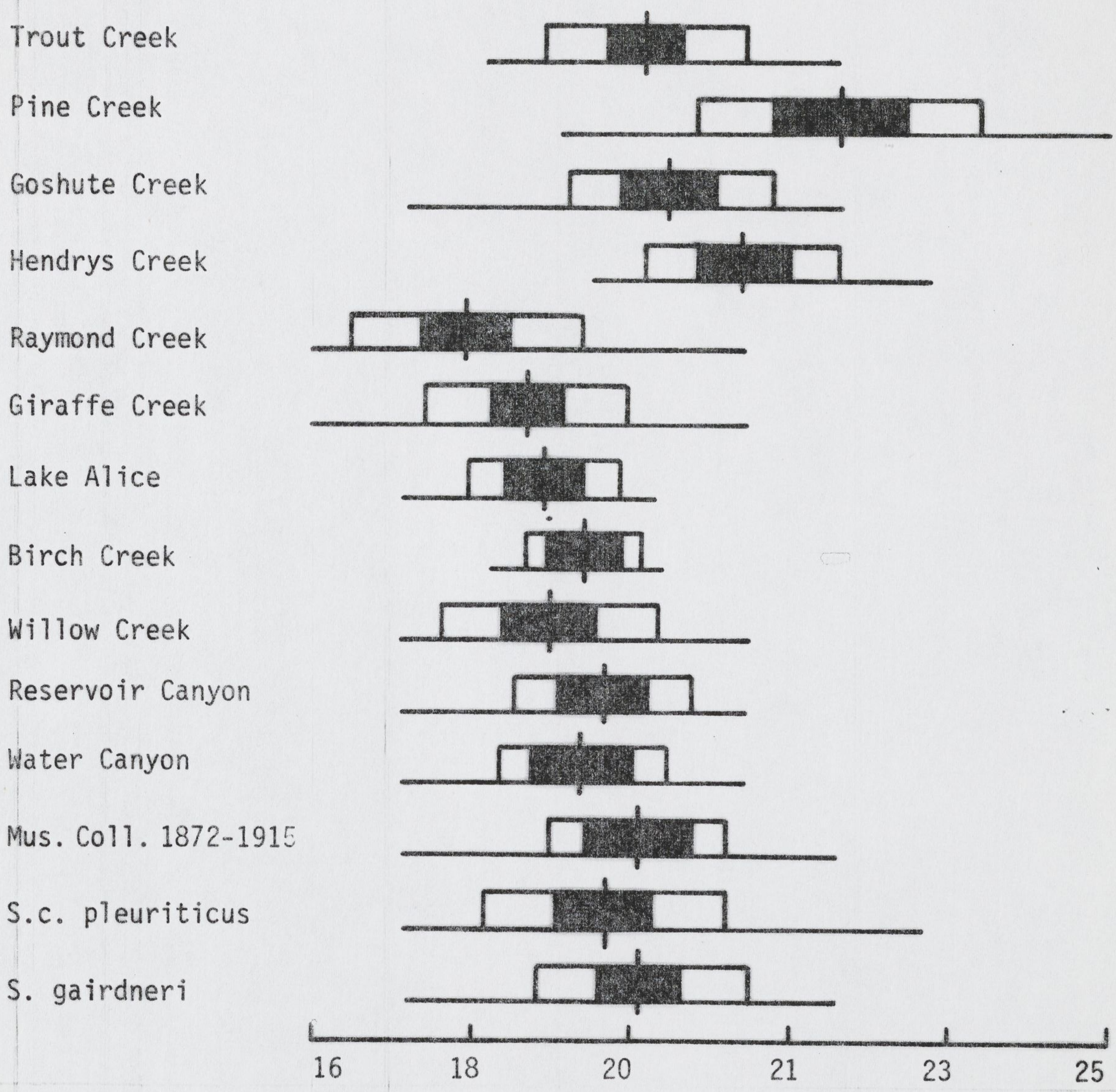


Figure 3e. Hubbs and Hubbs diagrams of total gillrakers from 333 pure S. c. utah specimens collected from 1872 to 1977 and representatives of pure S. c. pleuriticus and S. gairdneri specimens.

estimated abundance and threats) on these pure *S. c. utah* populations has been compiled (Appendix B).

To display the results of selected meristic analysis (pyloric caeca, scales in the lateral series, scales above the lateral line, gillrakers total and basibranchial teeth) of the pure populations of *S. c. utah* in a graphic comparison, a computer program for Hubbs and Hubbs diagrams was used (Andreasen 1976, Figs. 3a, 3b, 3c, 3d, 3e). The program was modified at Colorado State University by Mr. Steve Culver for use with a CDC 6400 computer.

The trout from the Snake Valley region (Trout, Pine, Goshute and Hendrys Creeks) exhibit typical lacustrine traits, with high basibranchial teeth (Fig. 3a), and gillraker total counts (Fig. 3e) and a more even distribution of spots on the body than the other trout endemic to the Bonneville basin. An exception would be the Willow Creek population, which also has a high basibranchial teeth count (Fig. 3a). The Willow Creek population has likely undergone microdivergence, probably from genetic drift, from the original ancestor of the Snake River cutthroat trout (personal communication with Dr. Behnke). The scale counts of the Snake Valley trout are lower than those of other Bonneville cutthroat trout (Figs. 3b, 3c). The trout from the Bear River drainage also show slight differences from other populations of *S. c. utah*; this can be seen in the low gillraker total counts (Fig. 3e) and basibranchial teeth counts (Fig. 3a) and the high pyloric caeca (Fig. 3d) and scales in the lateral series (Fig. 3b). This will be dealt with in more detail under the discussion on the Bear River drainage.

The present native trout populations of the Bonneville basin have been isolated from each other for thousands of years and should not be expected to be identical in all characters, but they do share a high degree of basic similarities which allow detection of the effects of hybridization and the separation from other subspecies of cutthroat trout. Variability is probably also increased in small populations isolated in small streams where genetic drift or unusual pressures may operate (Behnke 1976a).

ANALYSIS OF AREAS WHERE *S. c. utah* OCCUR

Snake Valley Drainage

The Snake Valley cutthroat trout may represent a group derived from a parental ancestor which became restricted to the western half of the Bonneville basin. This isolation may have been a result of some type of salinity barrier or geographical barrier resulting from fluctuations in the level of Lake Bonneville. The northern region of Snake Valley has a maximum elevation of about 1.6 km (5,100 ft). This high elevation would have been sufficient to prevent water from draining out of the Snake Valley area, after its separation from Lake Bonneville, during the desiccation of Lake Bonneville. The final desiccation of Lake Bonneville resulted in 10 or 12 independent basins, one of which was the Snake Valley region (Fig. 11).

The original large-spotted cutthroat trout, upon entrance into Lake Bonneville, radiated to all areas of the basin. The isolation and slight divergence of the Snake Valley cutthroat trout could have taken place prior to the desiccation of Lake Bonneville, allowing for time to differentiate from the other Bonneville trout. When a population is fractioned by some climatic, chemical or geological event into two or more populations and there is no genetic interchange for a long period of time, the isolated populations genetically diverge. A similar situation of divergence has occurred in the Lahontan basin between two subspecies of cutthroat trout native to that basin (Behnke and Zarn 1976).

Several studies have documented the isolation and subsequent speciation of fishes in the Snake Valley region. Wydoski et al (1976) conducted a study of the electrophoretic patterns of proteins in cutthroat trout located in the Bonneville basin, as well as with several other groups of cutthroat and rainbow trout. No protein was sufficiently unique or distinctive to differentiate _S. c. utah_ from other subspecies, but an unusual variation of muscle lactate dehydrogenase (LDH) was found in cutthroat from the Snake Valley region. This unusually-complex variation seems to indicate the presence of a variant allele. A unique evolutionary event, or series of events, occurred in the LDH enzyme of the Snake Valley cutthroat trout which would indicate long-term isolation from the rest of the Bonneville basin cutthroat trout.

Comparisons of samples of many cyprinid fishes in the western Bonneville basin adds credence to the assumption of incipient speciation in fishes isolated in Snake Valley. The Utah Chub, _Gila atraria_, found in the springs of Snake Valley, appear to be a dwarfed form, reproducing at 51 or 76mm (two or three inches) with fish over 102mm (four inches) rare. A dwarfed form of speckeled dace, _Rhinichthys osculus_, has also been noted from springs in the Snake Valley region (Hubbs et al 1974).

In 1952, Mr. Ted Frantz, Nevada Fish and Game Department, discovered a cutthroat trout population in Pine Creek on Mt. Wheeler, Nevada (Frantz and King 1958). Samples were sent to Dr. R. Miller, who indicated that they represented pure cutthroat trout, but he was unable to assign them to any described subspecies (Hickman and Duff

1977). Since Pine Creek drains into Spring Valley, White Pine County, Nevada, a basin originally barren of fish, it was assumed that these trout were introduced into Spring Valley by early settlers (prior to 1881) from the Bonneville basin, presumably from the Trout Creek drainage (Miller and Alcorn 1943; Hubbs et al 1974). This seems unlikely considering the many streams located closer to Pine Creek which contained native cutthroat trout (Lehman, Baker, Snake and Hendrys Creek). Behnke (1960, 1976a) indicated the most logical origin of the Pine Creek cutthroat was from Lehman Creek (which drains into Snake Valley from Mt. Wheeler) via the Osceola Ditch. This ditch was constructed to convey water from Lehman Creek around Mt. Wheeler for a gold mining operation in the 1880's. The Osceola Ditch extended around the east side of Mt. Wheeler to tap the waters of Pine Creek. Two specimens collected in 1938 from Lehman Creek are typical of the native cutthroat trout of the Snake Valley region of the Bonneville basin.

During 1953, the Nevada Fish and Game Department introduced 44 trout from Pine Creek into Hampton Creek, Nevada. A second transplant of 54 cutthroat trout from Pine Creek was made into Goshute Creek, Nevada, in 1960. Managing these cutthroat as pure S. c. utah, the Nevada Fish and Game Department closed Pine, Hampton and Goshute Creeks to fishing and listed S. c. utah as an endangered species in Nevada.

In 1972, Mr. F. Dodge of the Nevada Fish and Game Department found another population of cutthroat trout in the headwaters of Hendrys Creek (which drains into Snake Valley from Mt. Moriah) which resembled those found in Pine Creek (Behnke 1976a). Then several unsuccessful attempts were made by the Nevada Fish and Game Department to locate additional pure populations of cutthroat trout in the Snake Valley region of Utah and Nevada. It was believed that the native cutthroat trout of Snake Valley was extinct in its original range in Trout Creek drainage. This belief was based on fish collections made in the area by Dr. Carl Hubbs in the 1940's, Utah Fish and Game stream surveys in the Deep Creek mountains in the 1950's and an exhaustive effort to find cutthroat trout in Trout Creek and Deep Creek drainages in 1970 by Mr. F. Dodge and Mr. D. Cain, Nevada BLM (Dodge and Cain 1970).

In 1973, the Utah BLM began stream habitat surveys in the Deep Creek Mountain Range to define critical habitats and possible remnant populations of the cutthroat trout. In the spring of 1974, BLM biologists Mr. D. Duff and Mr. J. Warburton discovered cutthroat trout in the extreme headwaters of Trout Creek, Utah, above a natural barrier falls. Subsequent sampling and analysis by the BLM, Utah Division of Wildlife Resources and Colorado State Uniersity (the latter two under contract with the BLM) determined that Trout Creek specimens were pure Bonneville cutthroat trout native to the Snake Valley region (Hickman 1977).

Pure populations of S. c. utah native to Snake Valley are found in Pine, Goshute, Hendrys, Hampton, Water Canyon and Clear Canyon Creeks of White Pine County, Nevada and in Trout Creek, Juab County, Utah (Fig. 2 and Appendix B). Hybridized populations are found in Lehman, Muncy and Mill Creeks, Nevada, and Birch and Johnson Creeks, Utah (Behnke 1976b; Hickman 1977, 1978).

Goshute Creek probably has the highest number of Bonneville cutthroat trout with about 2,000 in 6.4km (four miles) of stream (McLelland 1975; Hickman 1978). The Nevada BLM and Nevada Fish and Game Department have been instrumental in protecting and enhancing the habitat in Goshute Creek. During the drought in 1977, Goshute Creek lost about 38 percent of its trout population. Because of these conditions the Nevada Fish and Game Department took 71 cutthroat trout from Goshute Creek and transplanted them into Water Canyon and Clear Canyon Creeks (personal communication with Mr. L. McLelland, Nevada Fish and Game Department, letter dated Nov. 7, 1977).

The basic problem of getting cutthroat established in this creek is one of habitat improvement. The creek has a history of large and rapid fluctuations in water levels which have resulted in scouring of the stream bottom, rendering the habitat poor for trout production. In 1955, a large cloudburst wiped out the stocked trout population in Goshute Creek, allowing for introductions, in 1960, of cutthroat trout from Pine Creek. The main impacts on this creek continue to be grazing practices allowed in the upper watershed and the susceptibility to flooding and droughts (largely a direct result of livestock grazing causing deterioration of the habitat).

Clear Canyon Creek, a previously-barren stream with fair to good trout habitat, is only 1.6km (one mile) in length from its spring source to its point of interception with Steptoe Creek. In October, 1977, approximately 20 cutthroat trout were transplanted from Goshute Creek (personal communication with Mr. McLelland). The cutthroat trout have not been in Clear Creek long enough to evaluate the success of the transplant.

Water Canyon Creek, a previously-barren stream located in the Egan Range, is approximately 6.4km (four miles) in length of fair to good trout habitat. In October, 1977, approximately 41 cutthroat trout were introduced into this creek from Goshute Creek. The creek had good fishing according to reports of old-timers; the original stream survey found rainbow trout present. The rainbow trout were probably eliminated by flooding (McLelland 1975).

Pine Creek, located on the Humbolt National Forest, is a very small stream with less than 3.2km (two miles) of trout habitat and is not capable of supporting many fish. Only about 200 cutthroat trout are presently inhabiting this creek. During the summer of 1976 approximately 91m (100 yards) of stream habitat were altered. The alteration work consisted of realignment and deepening the stream channel to facilitate water delivery to the ranchland in the valley floor below. The stream section altered was one that provided most of the fish that had been transplanted to other locations in the past. The drought in 1977 did not have a significant impact on the population of cutthroat trout in Pine Creek (personal communication with Mr. McLelland).

The upper reaches of Hendrys Creek is on the Humbolt National Forest, and the lower section is on National Resource lands. The creek has a limited carrying capacity for trout because of lack of undercut banks and adequate pools. Just above the mouth of the canyon, the stream traverses the mining property of Hatch Rock Quarry and then enters a concrete ditch. The stream is then carried across the benchlands to ranching property in Millard County, Utah, where it is used for irrigation purposes. The stream was stocked with rainbow trout and Yellowstone cutthroat trout above and below a barrier waterfall. A small population of native Snake Valley cutthroat trout, above the waterfalls in the headwater reaches, did not reflect hybrid influence from the introduced trouts. The remainder of the trout population in Hendrys Creek were a mixture of rainbow and cutthroat hybrids. In 1974, the stream above and below the waterfalls was retreated to eliminate the hybrids and rainbow trout and allow the Snake Valley cutthroat population to extend its range downstream. There are about 11.2km (seven miles) of potential trout habitat in Hendrys Creek, presently there are only approximately 400 cutthroat trout in 8km (five miles) of stream. The success of this population hinges on the idea that all of the non-native trout and hybrids were completely erradicated in 1974. The drought in 1977 erradicated about 50 percent of the population, entire sections of the stream dried up (personal communication with Mr. McLelland, 1977). According to testimony from an old-timer obtained by Frank Dodge, only Hendrys Creek originally contained the cutthroat trout, and several creeks, including Lehman Creek, were stocked with trout from Hendrys Creek (Dodge and Cain 1970).

Hampton Creek is located in the Humbolt National Forest and, like Hendrys Creek, drains into Snake Valley from Mt. Moriah. A garnet mine operation did considerable damage to the stream before the Nevada State Water Engineer's Office cancelled their water application in 1964. Hampton Creek, with only fair trout habitat, is smaller then Hendrys Creek and has the same problems regulating trout-carrying capacity. There are about 350 cutthroat trout in 4.8km (three miles) of stream. Hampton Creek also lost about 50 percent of its trout population during the drought in 1977 (McLelland 1975; personal communication with Mr. McLelland).

Trout Creek, located in the Deep Creek Mountain range, drains into the northern section of Snake Valley. About 800 cutthroat trout are confined to a 2km (one and a quarter mile) section of stream in the headwaters above a natural barrier waterfalls (Hickman 1977). In late October, 1977, the Utah Division of Wildlife Resources eradicated the rainbow trout inhabiting the stream below the barrier. Cutthroat trout were once found in several streams on the Deep Creek Mountain range, but since the introduction of rainbow trout in the area in 1928, the isolated population in Trout Creek is the only pure population remaining (Hickman 1977).

During 1977, one of the most significant items to take place in the Bonneville basin for the protection of native fishes and their environment, occurred in the Deep Creek Mountains. The Utah BLM filed for an emergency withdrawal of 10,927ha (27,000 acres) of an area of critical environmental concern within the mountain range because of increased uranium mining activity, which threatened to destroy many of the unique resources of the mountain area. The area was withdrawn from mineral entry on May 3, 1977, by the Secretary of the Interior under section 204 (e) of the Federal Land Policy and Management Act of 1976 (PL 94-579). This withdrawal stays in effect for a 3-year period to allow time for study of all resources to ascertain their values. The presence of the relict population of Bonneville cutthroat in Trout Creek was the major reason for justification of this action (Hickman and Duff 1977).

The potential impacts on Trout Creek are the presence of rainbow trout, which still exist in several streams on the Deep Creek Mountain range, and mineral exploration. Livestock grazing occurs on the lower reaches of Trout Creek and could affect the established cutthroat population in this area.

The cutthroat trout of Snake Valley were originally thought to represent an undescribed subspecies of S. clarki. Based upon analysis of cutthroat trout from Pine Creek, Drs. Miller and Behnke independently agreed that they could be differentiated from S. c. utah and all other cutthroat trout. Major differences were recognized in general morphology, number of basibranchial teeth and gillrakers, and spotting pattern (Behnke 1960, 1976b; Murphy 1974). With the analyses and comparison of subsequent populations of native cutthroat trout from Snake Valley and the rest of the Bonneville basin, the degree of differentiation between Snake Valley cutthroat trout and S. c. utah was not as distinct. This taxonomic confusion surrounding the Snake Valley cutthroat trout apparently inhibited the BLM from fully implementing their Goshute Creek habitat management plan to protect the habitat and increase the abundance of cutthroat trout in Goshute Creek. Pressures from local livestock interests prevented the implementation of grazing controls needed for habitat restoration and reduction of headwater erosion. The following year, the unstable headwater area was virtually destroyed by flooding and 60 percent of the cutthroat trout population was extirpated (Behnke 1976b). To avoid further taxonomic confusion and costly delays, the cutthroat trout native to the Snake Valley region of the Bonneville basin have been considered a relict form of *S. c. utah* (Hickman and Duff 1977). The addition of the Snake Valley cutthroat trout doubled the total known number of pure *S. c. utah* populations in streams from seven to 14.

The BLM in Utah and Nevada are interested in protecting and enhancing populations of *S. c. utah*. The BLM in Utah has developed a habitat management plan for Trout Creek and began implementation of this plan in 1977 using Sikes Act (PL 93-452) authorities. They have also funded a contract with the Utah Division of Wildlife Resources to provide for an inventory of the fisheries on the Deep Creek Mountain Range (Hickman and Duff 1977).

The Utah Division of Wildlife Resources plan to transport cutthroat trout from Trout Creek into the headwaters of Red Cedar Creek in the fall of 1978 and eventually to several other streams on the Deep Creek Mountain Range. In conjunction with this project, they intend to eradicate all of the rainbow trout from these streams (Hickman 1977; Hickman and Duff 1977).

The Nevada Fish and Game Department hope to reclaim two to four streams per year for the Bonneville cutthroat trout. Presently they have 20-25 streams identified for future introductions (personal communication with Mr. McLelland).

Virgin River Drainage

Reservoir Canyon and Water Canyon Creeks are headwater tributaries of the Santa Clara River (Virgin River drainage), located near Pine Valley, Utah. Although these streams are not in the Bonneville basin, *S. c. utah* probably extended its range into the Virgin River drainage by natural headwater transfers or from transplants by the early Mormon settlers of the Pine Valley area from the headwaters of the Sevier River of the Bonneville basin (Behnke 1976a). Miller (1961) related testimony from Mr. Bracken who saw the cutthroat trout in 1863 when he first came to Pine Valley. If these trout were transplanted by man, rather than gaining access via headwater transfer, it would have had to have been prior to 1863.

If cutthroat trout were native to the Pine Valley area in the Virgin River drainage, one would expect to find them throughout the Virgin River system. Based on the zoogeographical relationships of the native fishes of the Virgin River, a native trout would be expected to be derived from the Gila or Apache trout of the Gila River system and not from cutthroat trout (Behnke 1970a).

Behnke (1970) first collected and analyzed specimens from the headwaters of Reservoir Canyon Creek in 1959. Prior to 1973 Behnke felt that the Reservoir Canyon population was the only known pure population of S. c. utah existing at that time (Behnke 1973).

In 1973 samples were collected from Water Canyon Creek, adjacent to Reservoir Canyon Creek and they were also determined to be pure S. c. utah. Reservoir and Water Canyon cutthroat trout have the typical spotting pattern and taxonomic evaluations as the museum specimens of S. c. utah (Figs. 2a, b, c, d, e; Behnke 1976a).

Reservoir Canyon Creek probably has about 500 cutthroat trout, isolated above a barrier falls, in 3.2km (two miles) of stream. This headwater section is located on the Dixie National Forest. Rainbow trout and cutthroat rainbow trout hybrids are found below the barrier; this section of stream is on private land. In addition to the presence of non-native trout in the stream, other impacts include livestock grazing and small stream size which lends itself to rapid habitat deterioration, flooding and droughts.

Water Canyon Creek has approximately 200 cutthroat trout in an isolated .8km (one-half mile) headwater section. The same impacts noted for Reservoir Canyon Creek are prevalent in Water Canyon; the impacts are more detrimental to Water Canyon Creek because it is much smaller than Reservoir Canyon Creek.

At the present time I am unaware of any efforts to protect and enhance the cutthroat trout populations in these two streams.

Sevier River Drainage

Eight specimens of cutthroat trout were collected from Beaver River by Dr. Yarrow in the early 1870's; additional cutthroat trout specimens were collected from Mammoth Creek in 1915. The Beaver River samples were determined to be pure *S. c. utah*, while the Mammoth Creek population showed signs of hybridization. These streams no longer contain populations of *S. c. utah* (Behnke 1970). Going on a recommendation by a local conservation officer, Drs. Behnke and Stalnaker collected 12 specimens from Birch Creek in 1973 for taxonomic and genetic analysis. The taxonomic analysis indicated that this sample represented pure *S. c. utah* (Behnke 1976a). I examined 25 badly decomposed specimens, which had died during the drought in 1977, sent by BLM biologist Paul Peak. All of the specimens had basibranchial teeth ($\bar{x}$ of 8.8, range of 2-24), which indicates no rainbow trout influence and verifies Behnke's analysis that they are pure *S. c. utah*.

Birch Creek is a small tributary to the Beaver River and is located in the Tushar Mountains east of Beaver, Utah. The upper 9.7km (six miles) of the stream are on the Fishlake National Forest and the remaining perennial stream meters are on National Resource land. Presently there are approximately 200 cutthroat trout per 1.6km (mile) in 8km (five miles) of stream. An interagency habitat management plan for Birch Creek has been worked out by the BLM, Forest Service and Utah Division of Wildlife Resources. This plan calls for a system of drift fences to be constructed to exclude livestock use from the immediate stream vicinity. Stream habitat management will consist of instream improvement structures such as, installing trash catchers, log dams and gabions to provide for better trout habitat (Duff et al 1974). The stream is very small and is considered to have poor habitat for trout production; there is tremendous room for improvement of bank stability and erosion control. The cutthroat population suffered at least 30 percent mortality in 1977 due to drought conditions. Anticipating the effects of the drought, Utah Division of Wildlife Resources and other personnel transplanted between 50 and 100 cutthroat trout into a small stream, Sam Stow Creek, located in Beaver County, Sevier River drainage (Hickman 1978). The cutthroat trout have not been in Sam Stow Creek long enough to evaluate the success of the transplant.

Hybridized populations of S. c. utah occur in Deep Creek and Asay Creeks in the Sevier River drainage. Examination of 12 specimens from Deep Creek revealed an influence from rainbow trout hybridization; six of 12 specimens had no basibranchial teeth and low scale counts.

Phenotypically the Deep Creek population exhibited no indication of hybrid influence; the morphology and spotting pattern were typical of S. c. utah (Behnke 1976a).

Jordan River Drainage

In 1967, the Utah Division of Wildlife Resources sent 15 specimens to Dr. Behnke from Willow Creek for taxonomic analysis, and in 1973 Behnke received two specimens from Willow Creek sent by Mr. Jim Mullan, U.S. Fish and Wildlife Service. Behnke (1976a) noted that these samples contained no evidence of rainbow trout or Yellowstone cutthroat trout influence, but they had relatively low scale and pyloric caeca counts and smaller, more profuse spots. Behnke concluded that they were probably pure S. c. utah, but a larger sample was needed to accurately determine their taxonomic status. No stocking records for Willow Creek are known.

In 1977 Utah Division of Wildlife Resources send 22 specimens from Willow Creek to Colorado State University for taxonomic analysis. Both Dr. Behnke and I concluded that this sample represented typical S. c. utah, recognizing that they had evolved some unique traits, higher number of basibranchial teeth (Fig. 3a) and smaller, more profuse spotting pattern.

Willow Creek, a tributary to the North Fork of Little Cottonwood Creek, is located about .4 to .8km (one-quarter to one-half mile) off Wasatch Boulevard, east of Salt Lake City. The cutthroat trout population in Willow Creek is low in number and exists in a very limited habitat. They occur above a barrier falls at about a 1676m (5,500 foot) elevation. Probably the most significant impact to this stream is urban development in the area.

White and Sakamoto (1975) reported the discovery of a population of *S. c. utah* in Red Butte Canyon, a natural history preserve located east of the University of Utah in the Wasatch National Forest and on the Fort Douglas Military reservation (lower reach owned by the U.S. Army). Their conclusions were based upon spotting pattern, scale counts and coloration of 41 specimens.

Mullan (1974) indicated that brown, brook, rainbow trout and hybridized cutthroat trout occur in Red Butte Canyon Creek. Mullan's conclusions were supported by personal collections, fishermen creel surveys and stocking records. Cutthroat trout, probably from Yellowstone Lake, had been stocked on an annual basis, in Red Butte Canyon for many years. The U.S. Fish and Wildlife Service and U.S. Forest Service initiated plans to eradicate the trout from Red Butte Canyon Creek and stock it with *S. c. utah* from Willow Creek (Mullan 1974). Since the lower stream area is controlled by the U.S. Army, protection and enhancement could be given to the trout transplanted. The Army has been concerned about the effect trout eradication would have on the creek because it is used for the domestic water supply of Fort Douglas. This is their main concern and priority. If the water supply is not affected, the Army would look favorably upon considerations to establish the Bonneville cutthroat trout in Red Butte Canyon Creek (Letter from Mr. Phillip Glass, District Forest Ranger to the Forest Supervisor of the Wasatch National Forest, Feb. 27, 1978).

Bear River Drainage

The Bear River drainage of the Bonneville basin lies between the Snake River drainage to the north and the Green River drainage to the south on the Utah, Wyoming and Idaho borders. It is the largest river system of the Great Basin. The Bonneville cutthroat trout once inhabited all of the Bear River system; today only a few populations of pure _S_. _c_. _utah_ remain in Wyoming.

Dr. Behnke has analyzed trout from the Bear River drainage, collected by the Wyoming BLM and Wyoming Fish and Game Department, since 1973. I have also analyzed specimens collected in 1976 and 1977 by the BLM and Wyoming Fish and Game Department from the Thomas Fork and Smith Fork drainages of the Bear River system. The systematic results of studies of these fish collected since 1973 are included in this study.

Behnke (1976c) felt that Raymond Creek, of the Thomas Fork drainage, contained the only pure population of _S_. _c_. _utah_ analyzed to date. Many of the other streams contained slightly hybridized populations of _S_. _c_. _utah_, but based upon its isolation (only brook trout have been stocked into Raymond Creek), and the presence of basibranchial teeth in 30 of 31 specimens collected in 1976 (Fig. 3a), the Raymond Creek population was unhybridized. The Raymond Creek cutthroat trout have the typical appearance of _S_. _c_. _utah_ with large, pronounced round spots sparsely distributed on the sides of the body.

_S_. _c_. _utah_ in Raymond Creek are found in about 4.8km (three miles) of stream, located on National Resource land. Portions of the lower sections contain good stream habitat because of dense riparian growth which has prevented livestock from impacting portions of the stream. In this area of Raymond Creek, Wyoming Game and Fish Department sampled a 122m (400 foot) section of stream in June, 1977, to obtain a population estimate. They collected 44 cutthroat trout and 10 brook trout, which gave them an estimate of 747 trout per 1.6km (mile) (personal communication with Mr. Don Miller, fish biologist, Wyoming Game and Fish Department, Pinedale office, April 14, 1978). Based upon this data, an estimate of the cutthroat trout population for this section of Raymond Creek would be approximately 608 per 1.6km (mile). In the other sections of the stream, livestock grazing has resulted in degradation of the habitat, and cutthroat trout abundance is much lower. In the spring of 1977 approximately 250 cutthroat trout were taken from Raymond Creek to the Daniel Fish Hatchery in an attempt to establish a brood stock, which is expected to produce eggs by 1979 (personal communication with Mr. Joe White, Chief of Fish Division, Wyoming Game and Fish Department, Feb. 22, 1978). To date, these trout in the hatchery appear to be in good condition (personal communication with Don Miller). In the past, livestock grazing has been the major impact on Raymond Creek, but mineral (oil) exploitation is presently on the increase in this area. Wyoming BLM is actively involved with measures to rehabilitate the habitat of Raymond Creek to protect and enhance the cutthroat trout (personal communication with Mr. Neil Morck, BLM District Mgr., Rock Springs, Wyoming). The Wyoming BLM and Wyoming Game and Fish Department are in the process of attempting to get Raymond Creek listed as critical habitat for protection and improvement (personal communication with Mr. Joe White, Feb. 22, 1978).

Recent analysis of 34 specimens collected from Giraffe Creek in 1977 indicated that this was a pure population of S. c. utah. The headwaters of Giraffe Creek begin in Idaho on the Caribou National Forest, Bear Lake County, Idaho. The remainder of the stream, approximately 8km (five miles), is in Lincoln County, Wyoming. The upper 1.6

km (one mile) is on Bridger National Forest and the lower 6.4km (four miles) are on private property. The stream has been stocked from 1939 to 1957 with brook and cutthroat trout (possibly Snake River and Yellowstone cutthroat trout, personal communication with Mr. D. Miller, April 14, 1978). This stocking record explains why Behnke (1975) believed that Giraffe Creek specimens exhibited genotypic effects of hybridization with non-native trout. The specimens that he analyzed were collected in 1973 by Wyoming Game and Fish Department from the lower reaches of the stream.

The habitat in the upper section of the stream appears to be in good condition, and the cutthroat trout population is moderately abundant. The lower 6.4km (four miles) of the stream are heavily grazed by cattle, and the habitat is in poor condition (personal communication with Mr. D. Miller, April 14, 1978). Treatment of this lower section should be of high priority to prevent the hybrid influence from progressing upstream. This would also allow the cutthroat to extend their range downstream.

Analysis of 17 specimens collected from the south end of Lake Alice in 1977 by the Wyoming Game and Fish Department indicated a good possibility that a pure population of _S_. _c_. _utah_ occurs in this lake. Lake Alice is located in the Smith Fork drainage at an elevation of 2361m (7,745 feet) on the Bridger National Forest, Lincoln County, Wyoming. The lake is about 93.4ha (231 acres) in size, 3.2km (two miles) in length and .4km (one-quarter mile) wide. It was formed by a natural rock slide across Spring Lake Creek, a tributary to Hobble Creek. The lake has a natural fluctuation of about 3 to 6m (10 to 20 feet) per year (greater during times of drought) and a maximum depth of 53m (174 feet) (personal communication with Mr. D. Miller, April 14, 1978).

The taxonomic analysis of Lake Alice specimens indicate that they are typical S. c. utah (based upon character analysis, Table 3) but they show a small degree of variation from typical Bear River S. c. utah. The scale counts in the lateral series are lower than those from Raymond and Giraffe Creeks (Fig. 3b). The spotting pattern of the Lake Alice specimens appears to differ from that of Giraffe and Raymond Creek populations; the spots are concentrated posteriorly and are more round. Due to the environment of a lake (compared to a stream) and the isolation of Lake Alice, the variations noted in the taxonomic analysis may be natural and not a result of hybridization.

In 1939, 1940 and 1941, 45,700 trout fingerlings (25-51mm -- 1-2 inches -- long) were stocked into Lake Alice. The origin of these trout is unknown (personal communication with Mr. D. Miller, April 14, 1978). They may have come from Yellowstone Lake, nearby streams, or from Lake Alice itself. During the period of stocking, Wyoming Game and Fish Department was taking spawn from Lake Alice and hatching the trout in the fish hatchery at Cokeville, Wyoming. Eggs from other trout (cutthroat and rainbow) were also taken to this hatchery. The eggs and fry were probably indiscriminately mixed and then stocked out in the region; as a result the origin of the eggs planted in Lake Alice may never be known. Mr. Fred Eiserman (Coordinator of fisheries management for Wyoming Game and Fish Department) believed the trout stocked in Lake Alice could have originated from Henrys Lake in Idaho near West Yellowstone (personal communication with Mr. Don Miller, dated April 21, 1978).

If this were the case, they would have been Yellowstone cutthroat trout. No stocking records are known prior to, or since, 1939, 1940 and 1941 for Lake Alice. In 1964, a game warden reported that a fisherman had caught 16 brook trout from Lake Alice, but Wyoming Game and Fish Department has not found any brook trout in the lake.

The only attempt to obtain a population estimate for Lake Alice was in 1973, when two gill nets were set and 45 cutthroat trout, averaging 2.34mm (nine and two-tenths inches), were caught. Adequate natural reproduction occurs in the lake to sustain a good population of cutthroat trout (personal communication with Mr. D. Miller, April 14, 1978).

The Forest Service closed the only vehicle access to the lake (a jeep trail) a few years ago. The nearest open road is about 1.6km (one mile) downhill from Lake Alice on Hobble Creek.

Presently, S. c. utah is found in less than 30 acres of habitat; the addition of Lake Alice (231 acres) would increase the habitat by eight fold (to approximately 260 acres). Spawn from this lake could be used to stock an unlimited number of streams in the Bear River system, preventing the possible extinction of this subspecies in the Bear River drainage. Since there is a need to establish S. c. utah in a lake to analyze growth capabilities of this subspecies, to provide eggs for transplants, etc., Lake Alice could fulfill this need without tying up another lake; thus avoiding fishery management problems.

Samples from the Thomas Fork and Smith Fork drainages of the Bear River system are highly significant because they represent populations forming the greatest known concentration of an excellent phenotypic representative of *S. c. utah* (no external indication of hybridization). Despite habitat deterioration and large-scale introductions of non-native trouts, a trout identical in appearance to *S. c. utah* completely dominates the trout fauna in these areas of the Bear River drainage. With the cessation of widespread stocking of non-native trout into the Thomas and Smith Fork drainages, the trout populations are reverting to the native phenotype by a rejection of exotic genes under natural selection (Behnke 1976c). This ability to overcome and resist the effects of hybridization may be a result of thousands of years of stream adaptation by the cutthroat trout in the Bear River drainage. Bear River peripherially connected to Lake Bonneville, and the trout in this drainage never became lacustrine specialized like those that evolved for thousands of years in Lake Bonneville. This phenomenon probably accounts for the slight differentiation noted in *S. c. utah* from the Bear River system (discussed earlier in this study) compared to those from other regions of Lake Bonneville. Behnke (1976c) indicated that the trout endemic to ancient lakes developed an evolutionary heritage of specialization for large lacustrine environments which made them ill-adapted for life in small streams that they were forced into upon desiccation of ancient lakes. In the streams, these trout become vulnerable to displacement by introduced trout. An example of a stream-adapted cutthroat trout differentiating from a lacustrine-specialized cutthroat trout, analogous to that in the Bear River of the Bonneville Basin, has been noted in the native trout of the Lahontan basin. The Humboldt River cutthroat trout, native to a large river system, is more resistant to hybridization and displacement by non-native trouts and has become differentiated from the other cutthroat subspecies, S. c. henshawi, of the Lahontan basin (Behnke and Zarn 1976). Although S. c. henshawi and the Humboldt River subspecies have differentiated enough to merit subspecies recognition (personal communication with Dr. Behnke), those from the Bonneville basin have not.

Populations that are phenotypically good S. c. utah, but show genotypic signs of hybridization with non-native trouts, are found in the entire Thomas Fork and Smith Fork drainages in the Bear River system (Behnke 1976c). Cutthroat trout are not abundant in any part of the Bear River drainage examined. The major environmental problem limiting the abundance of trout populations is the lack of riparian vegetation resulting in accelerated erosion of the stream banks. Livestock grazing has virtually eliminated woody and herbaceous plants along much of the stream banks, and livestock have trampled the banks. As mentioned before, energy exploitations are on the rise in the Thomas and Smith Fork drainages and pose a serious threat to S. c. utah populations.

Possibilities exist that pure populations of Bonneville cutthroat trout may be found in other areas of the Bear River drainage. An example is Coantag Creek, located 4km (two and one-half miles) from Lake Alice. It is approximately 16km (10 miles) in length, is isolated and has never been stocked before. Coantag Creek is located on the Bridger National Forest and is a major tributary of Hobble Creek. There have been reports of cutthroat trout caught from this stream (personal communication with Mr. D. Miller, April 14, 1978).

The Wyoming Game and Fish Department and Wyoming BLM are very interested in the preservation of various subspecies of cutthroat trout in Wyoming. In the mid 1960's, the Wyoming Game and Fish

Department initiated a long-term study of endemic cutthroat trout in Southwest Wyoming. The goals of the study were to obtain information about the status of these cutthroat trout (Binns 1977).

The Utah BLM has proposed that several streams in Rich County, Utah, tributaries of the Bear River, be rehabilitated and S. c. utah populations be reintroduced into favorable habitat which will be protected from livestock grazing (personal communication with Mr. Don Duff, Utah BLM, May 15, 1978).

COMPARISONS OF S. c. utah WITH OTHER SUBSPECIES OF S. clarki AND WITH S. gairdneri

Hubbs and Hubbs Diagrams

Hubbs and Hubbs diagrams (Andreasen 1976) for selected meristic characters [basibranchial teeth (Fig. 4a), scales in the lateral series (Fig. 4b), scales above the lateral line (Fig. 4c), pyloric caecae (Fig. 4d), and total number of gillrakers (Fig 4e)] were used to compare S. c. utah with seven other subspecies of S. clarki and with S. gairdneri. An explanation of the program is given on page 40 of this study. All of the samples represent pure populations and were collected over the past 20 years and analyzed by Dr. Behnke; I also analyzed the more recent collections.

The diagrams indicate that S. c. utah can be differentiated from S. gairdneri by all characters used except number of gillrakers (Fig. 4e) and from S. c. stomias and S. c. pleuriticus by all except number of gillrakers and pyloric caeca (Fig. 4d). Of the meristic characters used, S. c. utah and S. c. henshawi show similarity only in scale counts. The Hubbs and Hubbs diagrams indicate that S. c. utah is most similar to S. c. lewisi, S. c. virginalis and S. c. clarki. In coloration and spotting, however, S. c. virginalis and S. c. clarki are very distinct from S. c. utah.

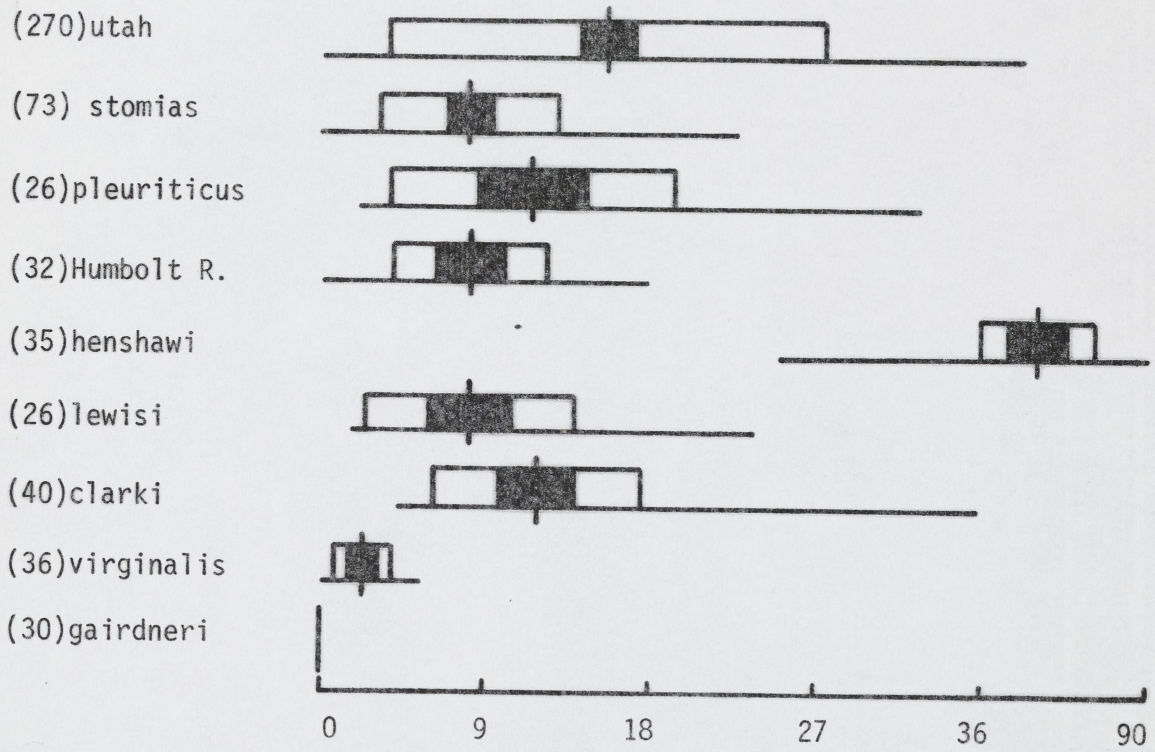
Multiple Discriminant Function Analysis

As a means of further substantiating and statistically verifying the results of Hubbs and Hubbs comparisons, and other morphomeristic analysis documenting the separation of various subspecies of S. clarki from each other and from S. gairdneri, the procedure of multiple

Figure 4a. Hubbs and Hubbs diagrams of basibranchial teeth from 568 specimens representing pure populations of eight subspecies of Salmo clarki and Salmo gairdneri, collected from 1872 to 1977.

The diagrams indicate the mean (center point), 95 percent confidence limits of the mean (black-lined rectangle), one standard deviation on either side of the mean (outer limits of open rectangle), and sample range (basal line).

The sample size is recorded in parenthesis prior to the species or subspecies name.


(270)utah
(73) stomias
(26)pleuriticus
(32)Humbolt R.
(35)henshawi
(26)lewisi
(40)clarki
(36)virginalis
(30)gairdneri
0
9
18
27
36
90

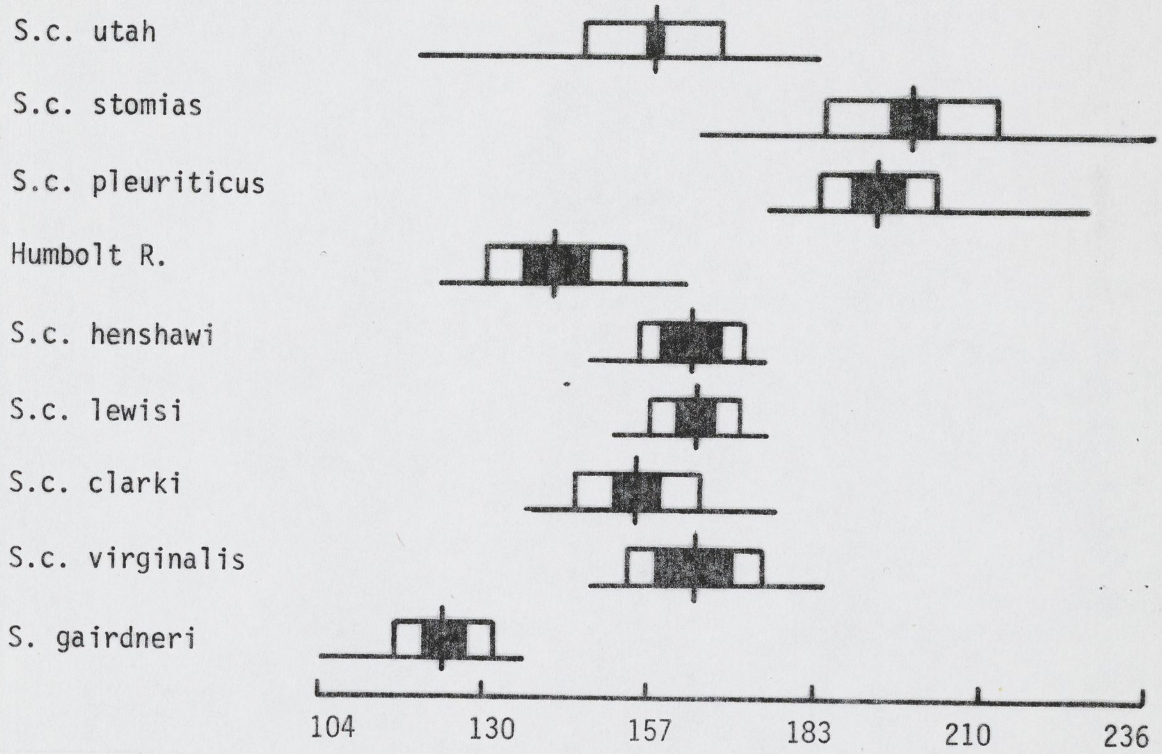


Figure 4b. Hubbs and Hubbs diagrams of scales in the lateral series from 568 specimens representing pure populations of eight subpsecies of Salmo clarki and Salmo gairdneri, collected from 1872 to 1977.

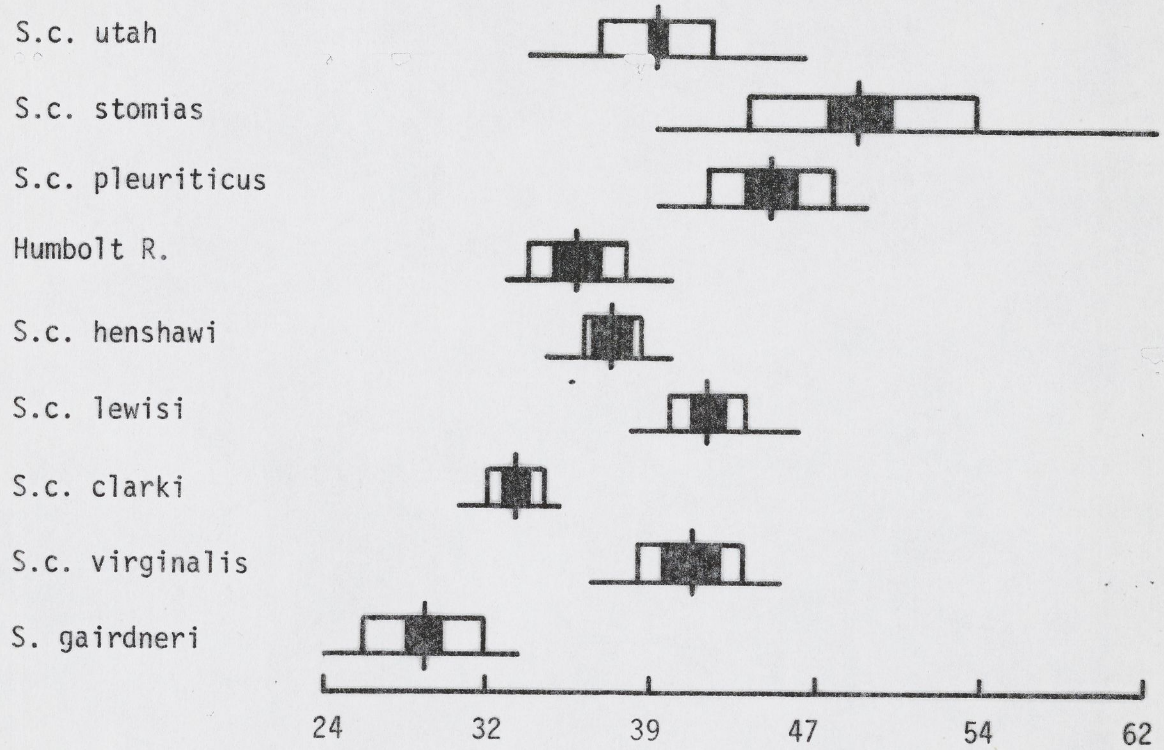


Figure 4c. Hubbs and Hubbs diagrams of scales above the lateral line from 568 specimens representing pure populations of eight subspecies of Salmo clarki and Salmo gairdneri, collected from 1872 to 1977.

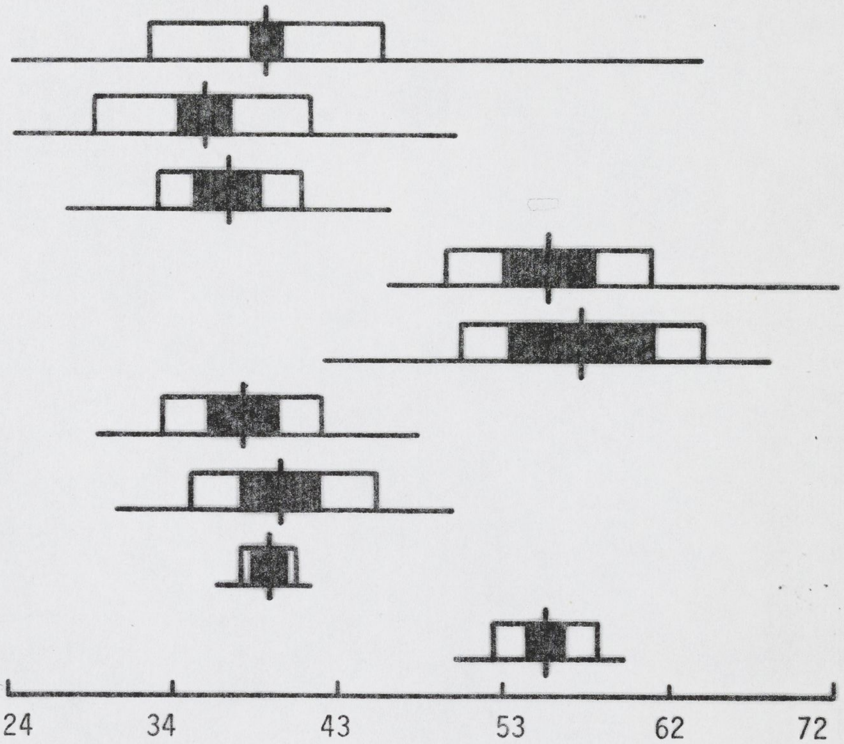


Figure 4d. Hubbs and Hubbs diagrams of pyloric caeca from 568 specimens representing pure populations of eight subspecies of *Salmo clarki* and *Salmo gairdneri*, collected from 1872 to 1977.

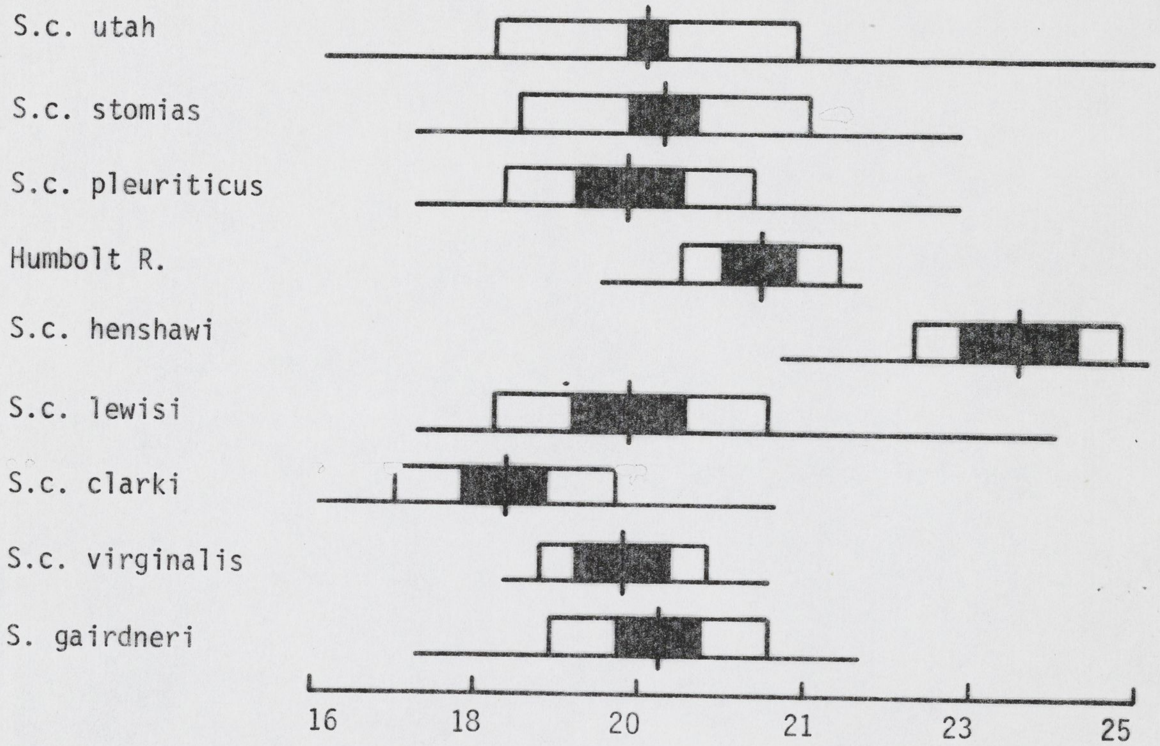


Figure 4e. Hubbs and Hubbs diagrams of total gillrakers from 568 specimens representing pure populations of eight subspecies of Salmo clarki and Salmo gairdneri, collected from 1872 to 1977.

discriminant function analysis was applied (Nie et al 1975). The program was modified for a CDC 6400 computer at Colorado State University by Mr. Steve Culver. Sixteen mensural and meristic characters (Table 4) from 560 specimens representing pure populations of S. c. utah, S. c. stomias, S. c. pleuriticus, S. c. virginalis, S. c. henshawi, S. c. lewisi, S. c. clarki, an undescribed subspecies from the Humboldt River drainage and S. gairdneri were utilized in the multiple discriminant analysis to compare the evolutionary affinities between the various groups. The mathematical objective of discriminant analysis is to weigh and linearly combine the 16 characters so that the groups are forced to be as statistically distinct as possible. Discriminant function attempts to do this by forming linear combinations of the discriminating variables (characters). The discriminant functions are of the form:

$$Di = di_1 Z_1 + di_2 Z_2 + \ldots. + di_p Z_p,$$

where "Di" is the discriminant score on discriminant function "i", the d's are weighting coefficients and the z's are the standardized values of the "p" discriminating variables used in the analysis.

In short, discriminant function analysis is a procedure for estimating the position of an individual on a line that best separates groups. Since one "best" line may not exhaust the predictive power of the characters, additional functions are calculated; this program is called multiple discriminant function analysis. The number of discriminant functions calculated is equal to the number of groups minus one or the number of characters used, whichever is less (White 1974; Nie et al 1975). In this study, the analysis was based on the

Table 4. Morphomeristic Characters Used in the Multiple Discriminant Function Analysis of 568 Specimens Representing Pure Populations of S. c. utah, S. c. stomias, S. c. pleuriticus, S. c. virginalis, S. c. henshawi, S. c. lewisi, S. c. clarki, an undescribed subspecies from the Humboldt River drainage and S. gairdneri, collected from 1872 to 1977.

Head Length
Upper Jaw Length
Snout Tip to Dorsal Fin Origin
Dorsal Fin Length
Caudal Peduncle Depth
Caudal Peduncle Length
Gillrakers Upper
Gillrakers Lower
Gillrakers Total
Branchiostegal Rays Right
Branchiostegal Rays Left
Scales In The Lateral Series
Scales Above The Lateral Line
Pelvic Fin Rays
Pyloric Caeca
Basibranchial Teeth

comparison of nine groups, thus eight discriminant functions were computed. Only the results of the top three functions were used to display the group separations (Table 5). This was based upon computations of eigen values, which measure the relative importance of the individual functions. The eigen values indicate that 81.7 percent (51.4% for function one, 15% for function two and 14.4% for function three) of the relative importance is placed on the first three functions (Nie et al 1975). Each character is weighted separately for each function, thus each specimen analyzed receives a score on each of the functions. In function one, scales in the lateral series had the most weight and were most responsible for group separation along this function (Table 5). In function two, it was gillrakers total and in function three it was basibranchial teeth.

Although the techniques of discriminant function were first introduced by Fisher (1936), it has only recently been applied to various studies in biology because of the availability of digital computers. White (1974) thoroughly reviewed the literature on the uses of discriminant function analysis, particularly on systematic studies.

To illustrate the group separation, the analysis for functions one, two and three are plotted in geometric space (Figs. 5 and 6). Since each discriminant function can be thought of as representing the axes of a geometric space, they can be used to study the spatial relationships among the groups in a more diagromatic manner. To obtain a more complete picture and better observe the separation among groups, the axes were rotated 90 degrees (Fig. 6).

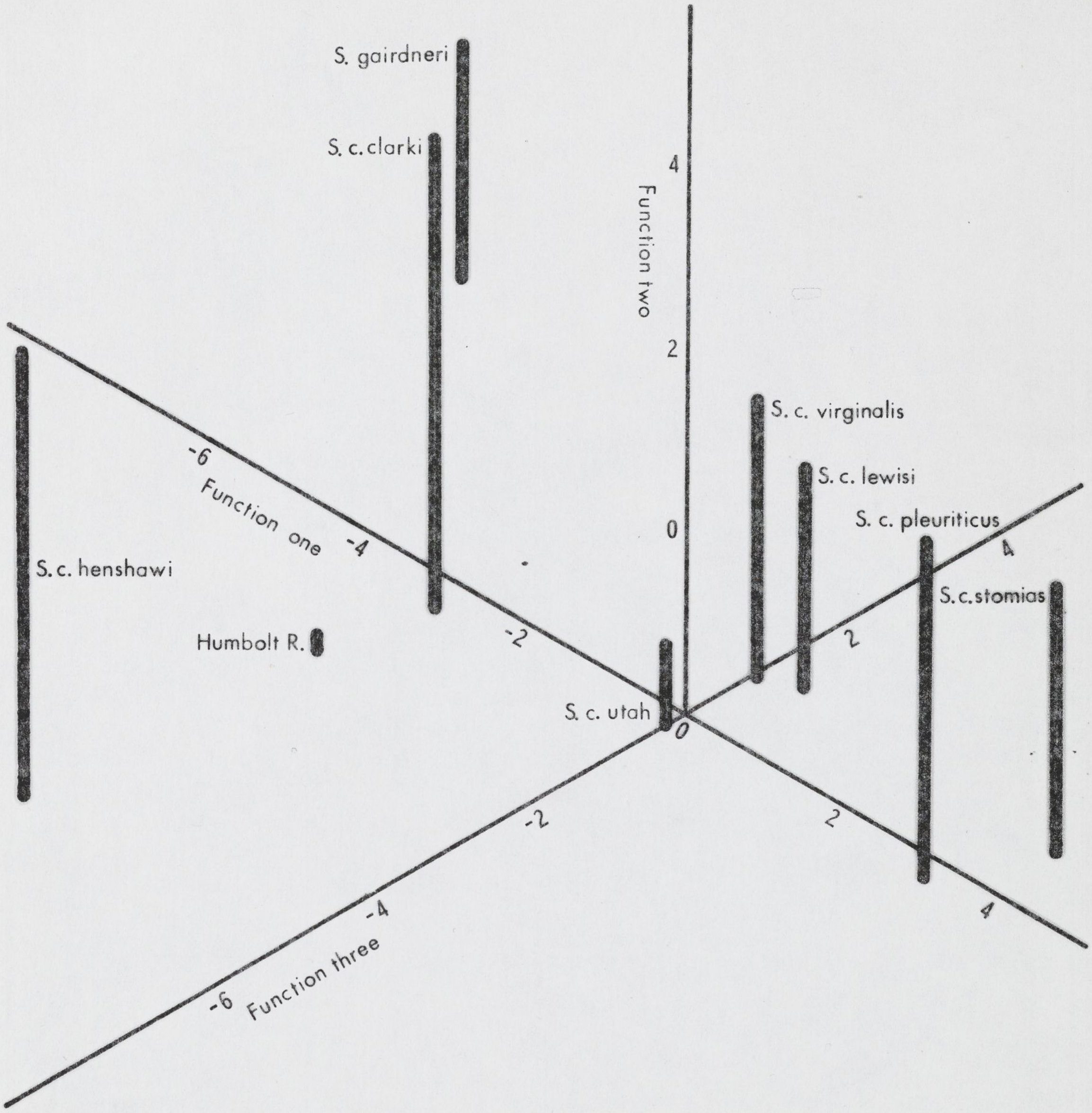
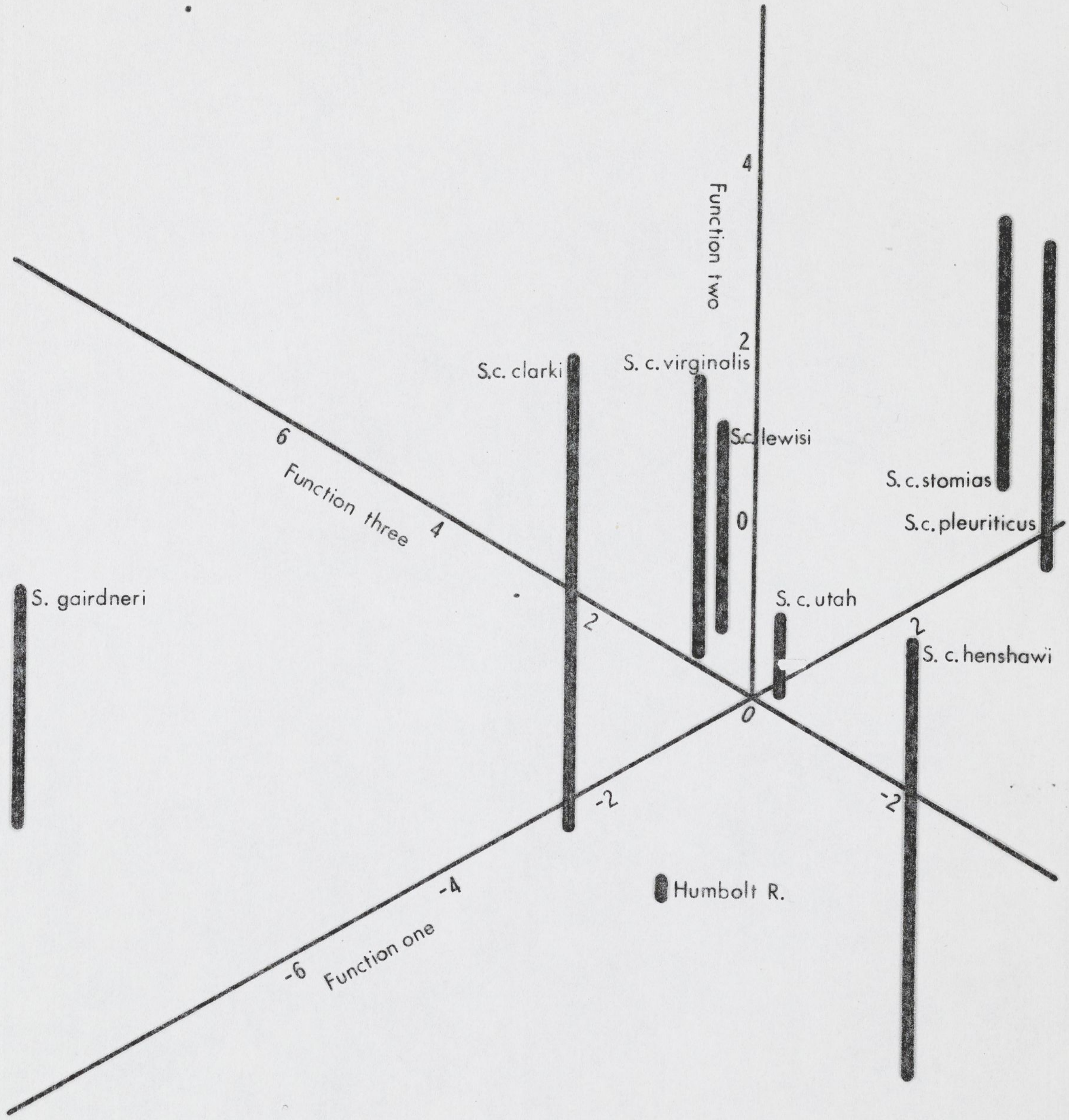

S. gairdneri
S. c. clarki
Function two
4
2
0
S. c. virginalis
S. c. lewisi
S. c. pleuriticus
S. c. stomias
S. c. henshawi
Humbolt R.
S. c. utah
-6
Function one
-4
-2
0
2
4
Function three
-6
-4
-2
2
4

Figure 6. Multiple discriminant function analysis plot, with the axes rotated 90°, for 568 specimens representing pure populations of *S. c. utah*, *S. c. stomias*, *S. c. pleuriticus*, *S. c. virginalis*, *S. c. henshawi*, *S. c. lewisi*, *S. c. clarki*, an undescribed subspecies from the Humboldt River drainage and *S. gairdneri*, collected from 1872 to 1977.



Function two
4
2
0
S.c. clarki
S. c. virginalis
S.c. lewisi
S.c. stomias
S.c. pleuriticus
S. gairdneri
S. c. utah
S. c. henshawi
6
Function three
4
2
0
-2
2
-2
-4
-6
Function one
Humbolt R.

In addition to the evaluation of similarities and differences between populations, multiple discriminant function analysis identifies the group to which each individual in the study is most closely related (Table 6). It is possible, from this information, to develop a model which can be used in the placement of questionable specimens if little or no overlap exists among the groups.

The most significant aspect of the computer results is that *S. c. utah* is distinctly separated from any other subspecies of cutthroat trout. Previous studies with multiple discriminant function analysis (Hickman and Duff 1977; Hickman and Miller 1977) have shown a closer relationship between *S. c. utah* and *S. c. virginalis* and *S. c. stomias* and *S. c. pleuriticus*, but with the analysis of function three these subspecies become more separated from each other. If phenotypic characteristics had been included in this computer analysis, the separation between *S. c. utah* and *S. c. virginalis* would have been even more distinct. *S. c. virginalis* have large spots concentrated in the caudal region and a brighter coloration. Murphy (1974), using a discriminant function and principle component analysis, compared several samples of Snake River and Yellowstone cutthroat trout with a few other subspecies of *S. clarki*. The Snake River cutthroat was more closely related to *S. c. utah* than to any other cutthroat subspecies. This is not surprising, since *S. c. utah* was derived from the large-spotted cutthroat trout of the upper Snake River.

Based upon the sixteen morphometric characters used in the computer analysis, *S. gairdneri* is very distinct from the various cutthroat subspecies; it is in a separate quadrant (Fig. 5 and 6). The computer

Table 6. Predicted Group Membership of 568 Specimens Representing Pure Populations of S. c. utah, S. c. stomias, S. c. pleuriticus, S. c. virginalis, S. c. henshawi, S. c. lewisi, S. c. clarki, an undescribed subspecies from the Humboldt River drainage and S. gairdneri, collected from 1872 to 1977.

	No. of cases	S. c. utah	S. c. stomias	S. c. pleuriticus	S. giardneri	Humbolt River	S. c. henshawi	S. c. virginalis	S. c. lewisi	S. c. clarki
S.c. utah	270	288	0	1	0	3	0	5	32	1
percent		84.4	0	.4	0	1.1	0	1.9	11.9	.4
S.c. stomias	73	0	70	1	0	0	0	1	1	0
percent		0	95.9	1.4	0	0	0	1.4	1.4	0
S.c. pleuri-ticus	26	0	0	26	0	0	0	0	0	0
percent		0	0	100	0	0	0	0	0	0
S. gairdneri	30	0	0	0	30	0	0	0	0	0
percent		0	0	0	100	0	0	0	0	0
Humbolt River	32	0	0	0	0	32	0	0	0	0
percent		0	0	0	0	100	0	0	0	0
S.c. henshawi	35	0	0	0	0	0	35	0	0	0
percent		0	0	0	0	0	100	0	0	0
S.c. virginalis	36	0	0	0	0	0	0	36	0	0
percent		0	0	0	0	0	0	100	0	0
S.c. lewisi	26	4	0	0	0	0	0	1	21	0
percent		15.4	0	0	0	0	0	3.8	80.8	0
S.c. clarki	40	0	0	0	0	0	0	0	0	40
percent		0	0	0	0	0	0	0	0	100

ZOOGEOGRAPHIC DISTRIBUTION OF CUTTHROAT TROUT

Of all living species of salmonid fishes native to Western North America, the cutthroat trout, Salmo clarki, has the broadest and most primitive distributional pattern. The magnitude of the geographical distribution and differentiation in the cutthroat trout is evidence that the species was already widely distributed in North America prior to the last glacial period which played a major role in the distribution and speciation of the present forms of cutthroat trout (Behnke 1972).

Ichthyologists in the late nineteenth century, influenced by Jordan (1894), thought the cutthroat trout originated in Asia. Jordan and Evermann (1896), following Jordan's earlier classifications, considered the Kamchatkan Salmo mykiss conspecific with the North American cutthroat trout and listed the various cutthroat trout as subspecies of S. mykiss. Jordan (1894) initially thought that the cutthroat trout (mykiss) had a continuous distribution from Kamchatka to Alaska, as a result of the ancient land bridge connecting Asia and North America (Bering Sea area). From Alaska, according to Jordan, the cutthroat extended its range southward to the upper Columbia River drainage, later migrating into the various interior river drainages. Later, after examining a specimen of Salmo from Kamchatka, Jordan and Evermann (1898) noted it was distinct from Salmo clarki and realized that the range of the cutthroat trout was not continuous to Kamchatka. It did not occur in the Bering Sea but extended northward only to Prince William Sound, Alaska. Based upon this evidence, they concluded that S. mykiss was not applicable to the cutthroat trout and that the results also compliment the findings of Behnke and Zarn (1976) that S. c. henshawi and the Humboldt River subspecies of the Lahontan basin are distinctly different from other subspecies of S. clarki. These subspecies probably represent an earlier divergence from the ancestoral cutthroat trout of the upper Columbia River drainage than those subspecies which were derived from the upper Snake River cutthroat trout located in a different quadrant (Figs. 5 and 6).

S. c. clarki, the coastal cutthroat trout, consists of migratory sea-run and nonanadromous stream and lake populations. Of the subspecies of S. clarki discussed in this study, only S. c. clarki is currently relatively abundant throughout its original range and is not in need of threatened or endangered species status to protect it from possible extinction. The most distinctive feature of S. c. clarki which was not used in the computer analysis, is its chromosome number. S. c. clarki has 2N = 68, while the other subspecies of S. clarki have 2N = 64 (Gold and Gall 1977). Gold and Gall showed that all cutthroat, rainbow and golden trout have 104 arms, only S. apache, and probably S. gilae, have 106 arms. The redband and golden trout have 2N = 58; the rainbow trout have 2N = 58-60; S. apache, 2N = 56; and S. gilae, 2N = 56-58. Another character which was not used in the computer analysis, and would differentiate S. c. clarki from other subspecies of cutthroat trout, is their spotting pattern.

Tanner and Hayes (1933) believed that their analysis of specimens of S. c. utah and S. c. pleuriticus indicated these two cutthroat trout subspecies were identical except for differences in size and coloration, which they attributed to environmental conditions. The scale counts (lateral series) that they obtained from cutthroat trout collected from Utah Lake and Bear Lake and headwaters of the Provo River (177-205) were consistent with what they believed Cope had given for S. c. pleuriticus (185-190). Tanner and Hayes (1933) remarked that the scale counts Jordan and Evermann (1923) gave for S. c. utah from Utah Lake were much lower than those that they had obtained from cutthroat trout of the Bonneville basin. Examination of pure S. c. utah specimens collected from the Provo River and Utah Lake, give scale counts lower than those of Tanner and Hayes, and more consistent with those of Jordan and Evermann (1923) (personal communication with Dr. Behnke). A striking difference noted in coloration and to a lesser extent in their spotting pattern is noted between mature S. c. utah and S. c. pleuriticus. S. c. pleuriticus are more brightly colored, with a tendency for red cutthroat marks (S. c. utah usually has orange cutthroat marks). The spots on S. c. pleuriticus are mainly concentrated more posteriorly than those on S. c. utah. Although the isolation of S. c. utah from S. c. lewisi and S. c. pleuriticus is probably less than from any other cutthroat subspecies in this study, they have developed significant differences in selected characteristics to merit separation (Figs. 5 and 6).

Based upon the assumption that when two or more characters are highly correlated only one will dominate in the separation of groups while the effects of the other characters are greatly reduced (Nie et al 1975), a multiple discriminant function analysis was run without gillrakers upper and lower, branchiostegal rays left, scales above the lateral line and caudal peduncle length. No significant differences in the group separations were noted.

Caution should be employed in the interpretation of any type of computer program used in systematic studies. The computer cannot create any new genetic information about the fish than that which has already been determined by standard taxonomic evaluations. Problems concerning artifacts from environmental (non-genetic) influence must be recognized. For example, if three groups of trout from the same parental stock were raised in three different environments (small stream, lake and a hatchery) their growth rates would likely produce consistent differences in morphology. The computer would depict these as three distinct groups.

Misinterpretations can also result from the use of too few specimens in the computer analysis. Because of the degree of isolation involved with each population of cutthroat subspecies and the high degree of intraspecific variability exhibited by these subspecies, there can be a large amount of genetic variation among populations of cutthroat trout. For example, if the populations from the Snake Valley region or Bear River drainage were used as representative of S. c. utah in a comparison among several subspecies of S. clarki, S. c. utah may appear more distinct because of some character unique to those populations but not to S. c. utah as a whole. This was pointed out by Hickman and Duff (1977) in which comparisons of S. c. stomias and other subspecies of S. clarki showed that an isolated population of S. c. stomias was as distinct from the other populations of S. c. stomias as it was for other subspecies.

Errors may also be committed when trying to determine which characters are most responsible for separation in the group discriminant process (Table 4). Any conclusions on the relative importance of the remaining characters (other than the top one or two in each function) concerning which have the next "most" discriminating power would be highly speculative and unsupported (see Nie et al 1975 for further discussion).

Although computer analyses are helpful in a systematic fish study and can be used to represent results in a graphic manner, the most useful means of separating various cutthroat trout subspecies is through an eclectic taxonomic and zoogeographic analysis.

MANAGEMENT OF *S. c. utah*

Habitat conditions existing in waters containing *S. c. utah* are marginal, and the streams are generally small. Yet, in many of these streams the cutthroat trout achieve good growth. Fisheries management programs with introduced non-native trout have proven unsuccessful, in many cases, in these small marginal streams. Although the idea of advocating fishing for a rare trout may seem contradictory, no rare or endangered trout has become so through overfishing (Behnke and Zarn 1976). A true native trout fishery can be ranked much higher than a hatchery trout fishery on a scale of values for cost-benefit analysis input for any potential development alternatives. Marshall (1973) determined that fishermen fishing for wild trout (self-reproducing population) placed a higher value on the opportunity to fish for wild trout than fishermen fishing for hatchery trout. Marshall compared wild brown and rainbow trout to catchable rainbow trout in the Cache la Poudre River and found that most trout fishermen preferred a wild trout fishery over a fishery based on fry or fingerling plants from the hatcheries. My analysis has shown that the *S. c. utah* populations in extremely small streams that are under a harsh environmental regime reach relatively large size. Under similar circumstances, rainbow and brook trout tend to stunt and only reach about half the size of the native cutthroat trout (Hickman 1977). McLelland (1975) cited an example of anglers preferring the native cutthroat trout over introduced rainbow trout:

> "Hendrys Creek has a very abundant population of stunted rainbows in the lower sections of the stream but the anglers who fished the stream did not fish for them;

> they walked to the headwaters area where they could catch the larger native cutthroat trout."

Early historical accounts are replete with the comments on the size attained by the cutthroat trout inhabiting the streams and lakes of the Bonneville basin. For fisheries management programs, serious consideration should be given to replacing non-native trout populations with native cutthroat trout within their historic native ranges to test the assumption that they will live longer and obtain a larger size than the non-native trout.

Behnke and Zarn (1976) outlined several steps in a native trout management program. Survey of waters and collection of specimens from suspected areas containing pure populations, while at the same time identifying potential sites for reintroductions, is the first priority in such a management program. The second step would be to conduct a taxonomic study of the samples to identify pure populations. Once the pure populations have been identified, protection and improvement of the habitat is usually necessary. To increase abundance of existing populations, introduction into barren or chemically treated waters isolated against contamination by non-native trouts, should be carried out before natural or man-caused catastrophes further decimate the remnant stocks. *S. c. utah* will hybridize with rainbow trout readily and cannot successfully coexist with brook or brown trout in most situations; thus potential sites for introductions must be barren of other trouts and protected from invasion. *S. c. utah* will likely thrive in virtually any stream capable of supporting other trouts.

The final step could be to establish a special regulation fishery if applicable. It is important to consider the necessity for special angling regulations for S. c. utah populations if the streams of the Bonneville basin are rehabilitated to a point where increased trout abundance attracts increased angling pressure. Without such protective measures, the first few anglers, exerting less than 50 hours of angling pressure per hectar on any stream, may catch 50 percent or more of all the catchable size trout, according to estimates of Behnke (1978a). Behnke estimated that 32 hours of fishing per ha (12 hours per acre) on Rochat Creek, Idaho, caught 50 percent of the cutthroat trout larger than 152mm (six inches). In the Poudre River 1898 hours of fishing per ha (769 hours per acre) per year caught, at most, 35 percent of the brown trout and 50 percent of the wild trout. Behnke (1978b) also indicated that in Dutch Creek, Alberta, 78 percent of all the cutthroat trout that were caught, tagged and released were caught again by anglers during the season, approximately 370 hours of fishing per ha (150 hours per acre) caught a minimum of 78 percent of the cutthroat trout. Under these circumstances, the first few anglers would experience a high catch per hour, but subsequent anglers would face a constant deterioration in catch and size of cutthroat trout throughout the season. The regulations should be designed to more equally distribute the size and abundance of the catch throughout the season for all anglers. The fishery developed through special regulations for native cutthroat trout of the St. Joe River, Idaho, has proved highly successful. The abundance of trout, the catch per man hour and number of large trout 330mm (over 13 inches) all dramatically increased after initiation of a minimum size limit of 330mm (13 inches) and a daily bag limit of two (Bjornn 1975, Behnke 1978b). The vulnerability of cutthroat to angling makes it an ideal species for a special regulation fishery (minimum size, restricted kill or no kill) where a high catch per hour is achieved by the catching and releasing of the same trout more than once in its lifetime. Many of the streams containing S. c. utah are too small to justify special angling restrictions which generally work best for a trophy fishery requiring moderate to large rivers or lakes where the trout can attain a large size (Behnke and Zarn 1976). This may produce incentive to establish populations of S. c. utah in large rivers or lakes where food supply and temperature do not limit growth.

State Fish and Game agencies should not be reluctant to enact special protective regulations to enhance the abundance of native cutthroat trout populations, but should consider the potential of establishing a unique type of quality fishery based entirely on natural reproduction (emulate the St. Joe River, Idaho, study) with little expense. When a management program for rare (sensitive) and native cutthroat trout involving restoration and enhancement projects is on federal lands, state and federal agencies should cooperate to improve the watershed to increase trout abundance and prevent further stream degradation from such impacts as mining, grazing, timber harvest, water diversion and road building. It is paramount that the state wildlife agencies and the federal land management agencies work closely together since habitat management is the key to a species survival.

If a propagation program for S. c. utah could produce large numbers of fry, their longevity and growth potential in cold waters should be an advantage over rainbow trout for stocking in mountain lakes lacking areas for natural reproduction.

STATUS OF _S. c. utah_

During the past decade there has been an awakening of interest in native fish fauna and a heightened awareness of man's stewardship responsibilities to the environment. This has been noted particularly among environmental action groups ranging from private conservation clubs to large established groups such as the International Union for the Conservation of Nature and Natural Resources.

The concept of human needs versus the protection of our natural resources is not new. In 1886 Congressman Lewis Payson of Illinois said: "I can't understand the sentiment which favors the retention of a few buffalo to the development of mining interests amounting to millions of dollars." (Segar 1978).

In 1966 the first specific piece of legislation dealing with endangered species, the Endangered Species Preservation Act, was passed. Its primary objective was to authorize and direct the Secretary of Interior to carry out a comprehensive program to conserve, protect, restore and, if necessary, establish populations of species threatened with extinction. It called for an official list of endangered species, allowing the use of Land and Water Conservation funds to purchase their habitats. It was apparent that this act was too limited in scope, and in 1969 the Endangered Species Conservation Act was passed. With this legislation, an animal must have been threatened with worldwide extinction to be listed by the Interior Department as "endangered". The only way a species could be afforded protection was to be classified as "endangered". In many cases a population could become so severely depleted before it was listed as endangered that even with concentrated efforts it could not be saved. In 1973 the Endangered Species Act (PL 93-205), was passed which gave protection to endangered species (any species in danger of extinction in all or a significant portion of its range), and to threatened species (species likely to soon become endangered). This act provided protection to a species before it was on the verge of extinction and called for protection, conservation and restoration of the ecosystem where the endangered or threatened species occurred.

In the Endangered Species Act of 1973, a species is defined as including subspecies, smaller taxa and viable segments thereof. Thus *S. c. utah*, despite any confusion over taxonomy, qualifies as a rare segment of *S. clarki*. Sufficient information is presented in this study to demonstrate that *S. c. utah* has suffered greater declines and is just as rare as (or more rare than) many species listed as endangered or threatened.

Beginning with the harelip sucker, the first United States fish known to become extinct as a result of man's activities, at least 11 other species and four subspecies of fishes have become extinct (Williams and Finnley 1977). The harelip sucker was last seen by biologists in 1893. Presently, 40 species and subspecies of fish in the United States are listed federally as threatened or endangered (Endangered Species Technical Bull., March, 1978).

Many fear the Endangered Species Act as a possible encroachment of states' rights. The problem of state vs. federal jurisdiction was the primary problem in enacting the Endangered Species Act of 1973. This was an obstacle in the 1960's, delayed the bills proposed in 1972 long enough to prevent their passage, and again caused considerable problems during all of the hearings on the 1973 bill. Historically, the state fish and game agencies have had jurisdiction over all resident, non-migratory species, regardless of whether or not they were found on federal lands. Any endangered species legislation had to take this into account, but it also had to initiate some kind of uniform policy to be effective. It would do the species in question no good if there were fifty separate sets of disconnected, unorganized policies in effect.

For any state agency to ignore the native trout or debate over the taxonomic validity of scientific names could be detrimental to the fish in question. It might be best to consider a species native to a particular geographical area as an evolutionary reality and a part of our biological heritage which should be preserved (Behnke and Zarn 1976). The object of the Endangered Species Act of 1973 is to increase the abundance of a species by environmental protection and improvement. Once a particular form of fish becomes extinct, problems of nomenclature, management and responsibility are meaningless. It is essential that emotional issues and lack of understanding, promoting confusion and conflict in an endangered species program, be avoided.

Presently, S. c. utah is not federally listed as threatened or endangered. This is based primarily on the U.S. Department of Interior's last version of the Red Book of Rare and Endangered Wildlife Species (1973), which considered it as "status undetermined." This listing was based mainly on the confused taxonomic status surrounding S. c. utah. The following organizations, agencies and individuals have recognized the precarious survival status of S. c. utah. The International Union for the Conservation of Nature listed it as rare (Vol. 4, 1969); Holden et al (1974), in a publication generated by the Bonneville Chapter of the American Fisheries Society, considered it endangered; the parent society of the American Fisheries Society, in its new listing, will consider it as threatened (personal communication with Dr. Deacon, Chairman of the Endangered Species Committee); Miller (1972) assuming S. c. utah was probably extinct, listed the Snake Valley cutthroat trout as threatened; the State of Nevada has considered it rare and is protecting the streams where it occurs; the State of Wyoming has also listed it as a rare species and considers it as a unique and distinct trout strain; the U.S. BLM in Utah, Wyoming and Nevada has considered it a sensitive species warranting special management consideration on public lands; Behnke (1973) treated it as rare with a highly restricted distribution; more recently, Behnke (1976c), according to the definitions of the Endangered Species Act of 1973, considered it as a threatened species. As a result of its limited distribution and present impacts, I would consider S. c. utah a threatened species.

The 1973 Endangered Species Act, which prohibits the taking of an endangered species, may interfere with meaningful restoration programs designed to increase the distribution and abundance of certain endangered trouts. Successful projects on endangered trouts have been carried out by re-introductions of the endangered trout into public waters. If all waters containing an endangered trout are closed to the public, the public agencies involved with these projects would stop further activity and restoration programs would be hampered. This problem is occurring with the endangered greenback cutthroat trout (Behnke and Zarn 1976; Hickman and Miller 1977). The status of "threatened" would allow S. c. utah to become a regular part of a fisheries management program, with the goal of increasing the distribution and abundance of this trout.

The main obstacle in securing federal protection for S. c. utah is the hesitancy of the state of Utah to consider it a threatened or endangered species. Many of the state's regional fisheries biologists are willing to initiate management programs for the protection and enhancement of S. c. utah, but the Utah Division of Wildlife Resources administrators are concerned about the difficulties the state might have with federal interference in regard to state control over resident fish. Mr. Don Andriano, Chief of Fisheries for Utah Division of Wildlife Resources said: "The present movement relative to preserving threatened, endangered and/or other nongame species, in our concerted opinion, is leaning considerably beyond what we would determine would be reasonableness and thus, our concern." (letter from Mr. Andriano to Dr. Behnke, dated Oct. 29, 1976). Of greater concern to me is that a rapidly-vanishing and potentially-valuable resource will be further eroded by arguing over matters of state and federal jurisdiction and the validity of scientific names. Programs to identify and manage the pure populations of S. c. utah, such as those being conducted by the states of Nevada and Wyoming, are the best insurance against federal encroachment of management with a state's native fishes.

Summary

A systematic study of the Bonneville cutthroat trout Salmo clarki utah was initiated to determine its taxonomic status and affinities with other cutthroat trout. Additional intentions of this study were to identify localities of pure populations and point out significant potential impacts which may affect these populations. The report is based on examination of more than 900 specimens from 64 localities.

The cutthroat trout, Salmo clarki, has the broadest and most primitive distributional pattern of all the salmonid species native to Western North America. Early ichthyologists thought the cutthroat trout originated in Asia. Dr. Jordan considered the Kamchatkan Salmo mykiss conspecific with the North American cutthroat trout and listed the various cutthroat trout as subspecies of S. mykiss. Jordan and Evermann later concluded that S. mykiss was not applicable to the cutthroat trout and that the Kamchatkan trout were distinct from any North American trout. The origin of the cutthroat trout is still uncertain.

The original distribution of cutthroat trout occurred in coastal streams from Prince William Sound, Alaska, to the Eel River in California. From the upper Columbia River basin the cutthroat migrated to several interior drainages. The trout of the Bonneville basin was probably derived from the cutthroat trout of the upper Snake River, which became isolated by Shoshone Falls from the cutthroat trout of the lower Snake and upper Columbia Rivers.

Lake Bonneville, which was located in the largest endorheic basin in the Great Basin, was formed during the late Pleistocene epoch. It went through several periods of fluctuation associated with wetter and drier climatic periods. The final desiccation occurred approximately 8,000 years BP (before the present), at which time the major drainages in the basin became isolated from contact with each other. The fish fauna of the Bonneville basin, although relatively depauperate, is the most extensive of the interior Great Basin drainages of the Western United States. The limited endemism exhibited by Bonneville fishes suggests that mixing of adjacent faunas occurred during Pliocene and Pleistocene times. The most obvious of these faunal connections was with the upper Snake River, above Shoshone Falls. There is one genus, seven species and one subspecies (S. c. utah) of fish endemic to the Bonneville basin.

S. c. utah, once one of the most characteristic and abundant fish, in comparison with other fishes in Utah, was of great importance to the Utah Indians as a source of food and to the early settlers both for sustenance and commerce. The former abundance of this trout has been vividly documented. The most detrimental factor causing the rapid decline of S. c. utah in the late nineteenth and early twentieth centuries, has been indiscriminate introductions of non-native trouts. Hybridization of rainbow trout and other interior subspecies of cutthroat trout with S. c. utah has resulted in almost complete elimination of pure populations. The presence of all degrees of hybridization has greatly confounded the taxonomy of S. c. utah.

Another significant impact to the survival of S. c. utah is man's physical alterations of their habitat. The types of habitat changes that have had the most impact on S. c. utah are livestock grazing, irrigation practices and climatic conditions.

The cutthroat trout is an example of a polytypic species, a species consisting of several geographically disjunct forms with a broad distribution and a great amount of genetic diversity. Because of the widespread distribution in interior waters, accompanied by much isolation and local variation, the systematic problems presented by the cutthroat series are complex. Early ichthyologists without an understanding of the range of morphological variability expressed within a single species named many species of cutthroat trout on the basis of local varieties. Many named several dubious species of trout on very little basis, one of which was S. c. utah. The first description of the Bonneville cutthroat trout was made by Dr. Suckley (1874) from explorations made in the late 1850's. The name Salmo utah was proposed by Suckley specifically to distinguish the trout of Utah Lake from the other Bonneville trout, which he called S. virginalis. Although Suckley's description of Salmo utah is inadequate for separating utah from any other form of cutthroat trout, this published account of S. utah (1874) fixes the name utah as the earliest name applied solely to trout of the Bonneville basin.

In 1856 Dr. Girard described S. virginalis from specimens collected from "Utah" Creek (now Ute Creek) tributary of the Upper Rio Grande in Colorado. Subsequent authors erred in thinking that

Girard's description was from a tributary of Utah Lake. This error was not recognized until Snyder (1919) and Jordan (1920) pointed out that Utah Creek is a tributary of the Upper Rio Grande, with no relation to Utah Lake or the state of Utah.

As a result of analysis of museum specimens and other samples collected from the Bonneville basin during the past century and the analysis of additional specimens in this study, a means of identifying pure populations of S. c. utah has been determined. No single character is significantly different from values for the other cutthroat trout subspecies to support separation, but taken collectively, several characteristics will usually distinguish S. c. utah from other cutthroat subspecies. Based upon analysis of these characteristics, 14 populations from isolated headwater streams and one possible lake population are recognized as pure or virtually pure S. c. utah. Appendix B summarizes the information on origin, abundance, and threats to these pure S. c. utah populations.

To display the results of selected meristic analysis of the pure populations of S. c. utah in a graphic comparison, a computer program for Hubbs and Hubbs diagrams was used. Hubbs and Hubbs diagrams were also used to compare S. c. utah with seven other subspecies of S. clarki and with S. gairdneri. As a means of further substantiating and statistically verifying the results of Hubbs and Hubbs comparisons, and other morphomeristic analysis documenting the separation of various subspecies of S. clarki from each other and from S. gairdneri, the procedure of multiple discriminant function analysis was applied.

Sixteen mensural and meristic characters from 560 specimens representing pure populations of eight subspecies of _S. clarki_ and from specimens of _S. gairdneri_ were utilized in the computer program to compare the evolutionary affinities between the various groups. Although computer analyses are helpful in a systematic fish study and can be used to represent results in a graphic manner, the most useful means of separating various cutthroat trout subspecies is through an eclectic taxonomic and zoogeographic analysis.

Habitat conditions existing in waters containing _S. c. utah_ are marginal and the streams are generally small. Yet, in many of these streams the Bonneville cutthroat trout achieve good growth. Fisheries management programs with introduced non-native trout have proven unsuccessful, in many cases, in these small marginal streams. For fisheries management programs, serious consideration should be given to replacing non-native trout populations with native cutthroat trout on a limited scale within their historic native ranges to test the assumption that they will live longer and obtain a larger size than the non-native trouts. When a management program for rare (sensitive) and native cutthroat trout involving restoration and enhancement projects is on federal lands, state and federal agencies should cooperate to improve the watershed to increase trout abundance and prevent further stream degradation from such impacts as mining, grazing, timber harvest, water diversions and road building. It is paramount that the state wildlife agencies and the federal land management agencies work closely together since habitat management is the key to success.

The Endangered Species Act of 1973 defined a species as including subspecies, smaller taxa and viable segments thereof. Thus S. c. utah, despite any confusion over taxonomy, qualifies as a rare segment of S. clarki. Many fear the Endangered Species Act as a possible encroachment of states' rights. For any state agency to ignore the native trout or debate over the taxonomic validity of scientific names could be detrimental to the fish in question. Of concern is that a rapidly vanishing and potentially valuable resource will be further eroded by controversy over matters of state and federal jurisdiction and the validity of scientific names. It might be best to consider a race native to a particular geographical area as an evolutionary reality and part of our biological heritage which should be preserved.

Presently, S. c. utah is not federally listed as threatened or endangered. This is based primarily on the U.S. Department of Interior's last version of the Red Book of Rare and Endangered Wildlife Species, which considered it as "status undetermined". This listing was based mainly on the confused taxonomic status surrounding S. c. utah. Several organizations, agencies and individuals have recognized the precarious survival status of S. c. utah. Despite recent discoveries and introductions an increase in abundance of S. c. utah has not been documented and the remaining pure populations lack the protection needed to insure survival of this unique trout. Sufficient information is presented in this study to warrant protective recognition for the few remaining populations. As a result of its limited distribution and present threats, I would consider S. c. utah a threatened species.

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APPENDICES

APPENDIX A

Jordan and co-author's views on
S. c. utah nomenclature.

APPENDIX A

Jordan & co-author's views on S. c. utah nomenclature.

Salmo utah, Salmo aurora, Salmo virginalis	(Jordan and Copeland 1876)
Salmo clarki aurora	(Jordan 1878)
Salmo purpuratus	(Jordan and Gilbert 1881)
Salmo purpuratus, Salmo spilurius, Salmo pleuriticus	(Jordan and Gilbert 1882)
Salmo purpuratus virginalis	(Jordan 1885)
Salmo mykiss virginalis	(Jordan 1889)
Salmo mykiss virginalis	(Jordan and Evermann 1896)
Salmo clarkii virginalis	(Jordan and Evermann 1898)
Salmo virginalis	(Jordan and Evermann, 1902, 1916)
Salmo utah	(Jordan 1920)
Salmo utah	(Jordan and Evermann 1923)
Salmo clarkii utah	(Jordan 1927)
Salmo utah	(Jordan, Evermann and Clark 1930)

APPENDIX B

Summary of information on pure populations of *S. c. utah*.

APPENDIX B. Summary of information on pure populations of S. c. utah.

STREAM	ORIGIN	ESTIMATED ABUNDANCE	THREATS
Nevada			
Hendrys Crk. Snake Valley Drainage (White Pine Co.)	Native	400 in 8km (5 miles)	Poor habitat (lack of pools, small size, etc.), suffered about a 50% mortality in 1977 due to drought conditions.
Hampton Crk. Snake Valley Drainage (White Pine Co.)	Introduced from Pine Crk. in 1953	300 in 4.8km (3 miles)	Poor habitat (low flow, lack of pools, small size, etc.), about a 50% mortality in 1977 due to drought.
Pine Crk. (White Pine Co.)	Derived from Lehman Crk.	200 in 2.4km (1.5 miles)	Irrigation (water fluctuations, channelization, etc.), not capable of supporting many fish due to small size.
Goshute Crk. (White Pine Co.)	Introduced from Pine Crk. in 1960	500/1.6km(mile) in 6.4km (4 miles)	Livestock, flooding, suffered a 38% mortality in 1977 due to drought.
Water Crk. (White Pine Co.)	Introduced from Goshute Crk. in 1977	41 in 6.4km (4 miles) (fall 1977)	Livestock, flooding, subject to drought conditions.
Clear Crk. (White Pine Co.)	Introduced from Goshute Crk. in 1977	20 in 1.6km (1 mile) (fall 1977)	Livestock, small stream subject to flooding and drought.
Wyoming			
Raymond Crk. (Thomas Fork Drainage, Lincoln Co.)	Native	300 - 800 in 4.8km (3 miles)	Livestock, mineral exploration, non-native trout introductions.
Giraffe Crk. (Thomas Fork Drainage, Lincoln Co.)	Native	300 - 600 in headwaters	Livestock, mineral exploration, non-native trout introductions.

APPENDIX B. (continued)

STREAM	ORIGIN	ESTIMATED ABUNDANCE	THREATS
Lake Alice (Smith Fork Drainage, Lincoln Co.)	Native	293.4 ha (231 acres)	Not determined.
Utah			
Trout Crk. (Snake Valley Drainage, Juab Co.)	Native	800 in 2.4km (1.5 miles)	Rainbow trout, mineral exploitation and exploration.
Water Canyon Crk. (Virgin River Drainage, Washington Co.)	Derived from Bonneville Basin	200 in .8km (.5 miles)	Rainbow trout, livestock, small stream.
Reservoir Canyon Crk. (Virgin River Drainage, Washington Co.)	Derived from Bonneville Basin	500 in 3.2km (2 miles)	Rainbow trout, livestock, small stream.
Birch Crk. (Sevier River Drainage, Beaver Co.)	Native	200/1.6km(mile) in 8km (5 miles)	Livestock, small stream poor habitat, suffered about 35% mortality in 1977 due to drought.
Sam Sto Crk. (Sevier River Drainage, Beaver Co.)	Introduced from Birch Crk. in 1977	50 - 100 in 2.4km (1.5 miles)	Small stream.
Willow Crk. (Jordan River Drainage, Salt Lake Co.)	Native	Small population isolated in less than 1.6km (1 mile)	Small stream, urban development.

Adapted from Hickman 1977.

LAKE BONNEVILLE AND ITS FISH FAUNA

I. History of Lake Bonneville

A. Named in honor of the early explorer -- B. L. E. Bonneville
B. Formed during late Pleistocene epoch (Wisconsin Age)
   1.) Geological and climatic conditions were involved in the origin and dessication of Lake Bonneville
C. Largest of the interior drainages of the Great Basin
   1.) 19,750 square miles
   2.) 346 miles in length
   3.) 145 miles in width
   4.) 1,050 feet at the extreme depth
   5.) 800 feet mean depth
   6.) 5,100 feet highest level
   7.) temperature of region 4.4° - 8.3°C cooler during late Pleistocene than today
D. Comparable in size, depth, regional air temperature and fish fauna to present Lake Michigan
E. Endorehic Basin
   1.) Bear River main inlet (supplied more than 50% of total inflow)
      a.) The remainder of inflow contributed by Weber & Jordan Rivers and other small streams and springs.
   2.) Red Rock Pass was the main outlet (lake never had an actual outlet until it spilled over at this point)
   3.) The outlet and inlet were both at the lowest points on the lake's rim.
F. Diversion of Bear River into Lake Bonneville
   1.) Ca 25,000 - 35,000 years ago
   2.) Diversion a result of basaltic lava flows in the Bear River Canyon
   3.) Resulted in a greatly augmented inflow into Lake Bonneville
   4.) Bear River Connection to Snake River lost
G. Overflow at Red Rock Pass into Snake River Plain
   1.) Ca 12,000 - 30,000 years ago
H. Lake Bonneville went through several periods of fluctuation
   1.) Water levels were closely associated with climatic conditions
   2.) Four low levels occurred between 8,000 and 20,000 years ago
      a.) Complete dessication and refilling (Ca. 11,000 years ago)
      b.) Final dessication (Ca. 8000)
I. Great Salt Lake is a remnant of Lake Bonneville
   1.) Too saline for fish life
   2.) Bear Lake, Utah Lake and various streams and springs provided refuga for fish fauna upon dessication of Lake Bonneville

II. Fish Fauna of Lake Bonneville

A. Limited endemism (refer to Table 1)
   1.) Suggests that there existed connections with one or more adjacent fish faunas
      a.) Headwater transfer from Colorado River System (<u>Pantosteus</u> & <u>Rhinichthys Osculus</u>)
      b.) Snake River (Columbia River Tributary) connection
   2.) As a result of the connections between Snake River and Lake Bonneville and subsequent mixing of the fish fauna, reference to endemism in Lake Bonneville includes the Upper Snake River fauna.

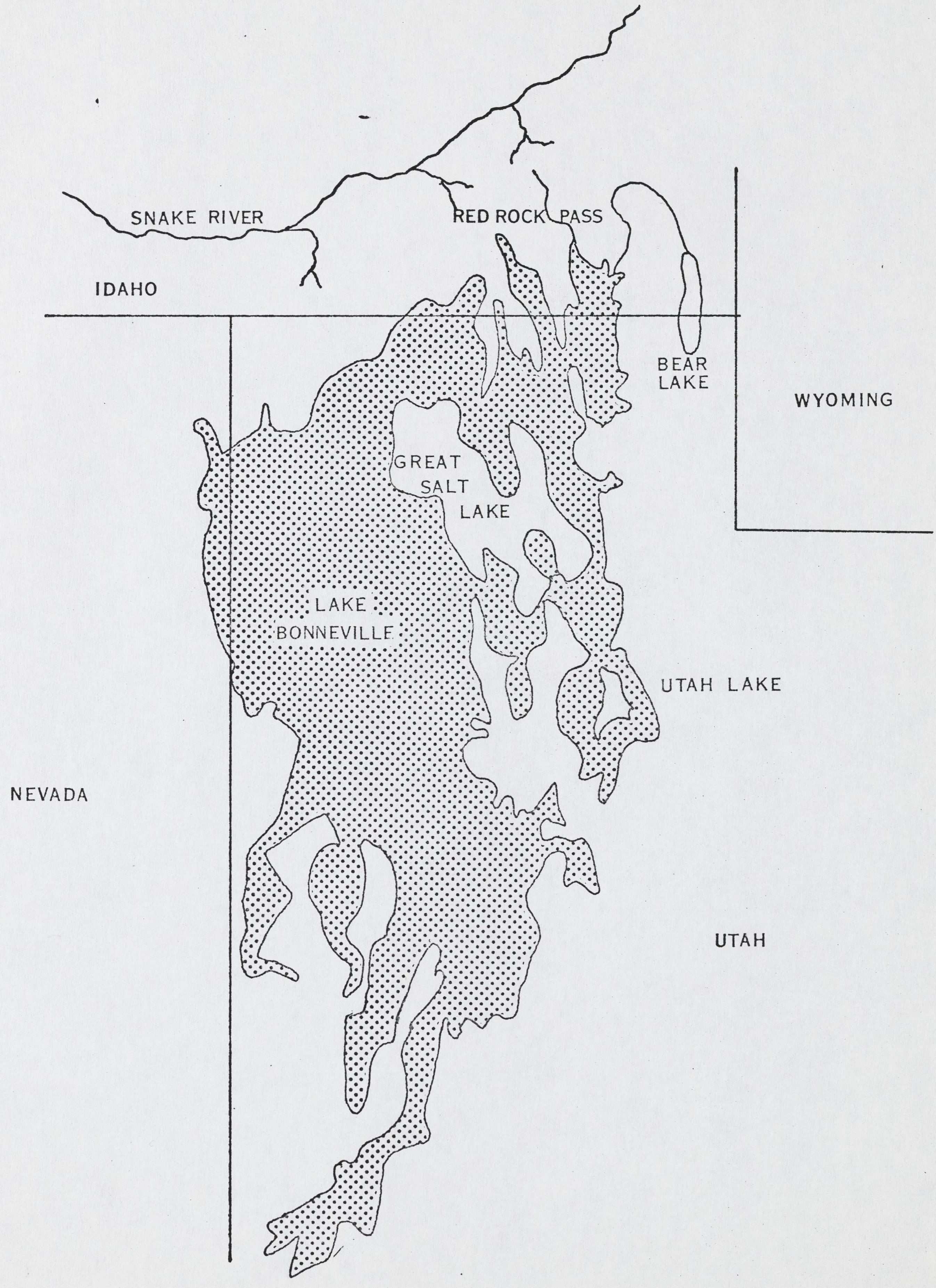
B. Pleistocene fossils from the Great Basin
  1.) are rare or little known.
    a.) Hinders interpretation of distribution and evolution of the recent fish fauna
  2.) Known fossil finds of late Pliestocene fishes in the Bonneville Basin all found in Salt Lake Co.
    a.) Salmo clarki (large specimen)
    b.) Prosopium gemmiferum
    c.) Prosopium spilonotus
    d.) Gila atraria
    e.) Catostomus ardens
    f.) Cottus bairdi
    g.) Cottus extensus
  3.) Other species may have existed but due to harsh environmental conditions they are not found today. May yet turn up in the fossil record.

C. Endemism in Bear Lake
  1.) Miller's theory on lacustrine speciation in the white fish
    a.) All four species co-exist because of differences in feeding habits, spawning time and place and behavior traits
  2.) Contradictions to theory
    a.) Fossil record
    b.) Upon dessication Bear Lake only refuga deep enough for Prosopium species.
    c.) Speciation occurred prior to dessication

D. Endemism in Utah Lake
  1.) Cottus echinatus probably descendant of extensus, differentiated in Utah Lake, which is shallow and fluctuating, not stable whereas Bear Lake is relatively unchanged and therefore no differentiation occurred.
  2.) Chasmistes liorus may have entered Bonneville Basin during Pliocene time.

E. Iotichthys phlegethontis
  1.) Only endemic genera
    a.) Ancestor present during Pliocene time?

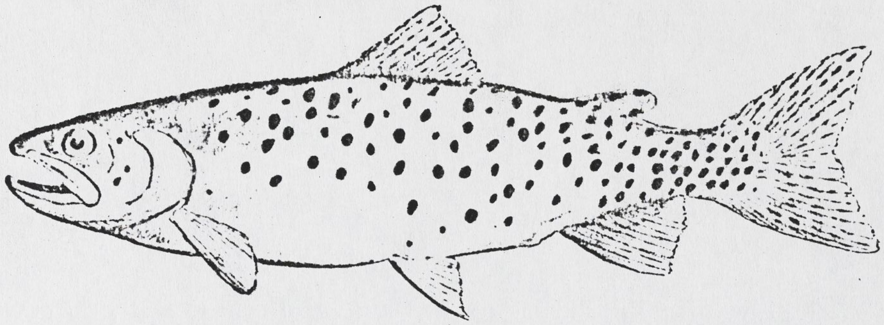
F. Salmo clarki Utah
  1.) Closely related to large spotted cutthroat trout of the Snake River
    a.) Probably entered Bonneville Basin at time of Bear River connection or during overflow into Snake River Plain
    b.) Since then has differentiated from large spotted cutthroat.


SNAKE RIVER
RED ROCK PASS
IDAHO
BEAR LAKE
WYOMING
GREAT SALT LAKE
LAKE BONNEVILLE
UTAH LAKE
NEVADA
UTAH

CUTTHROAT TROUT

***Salmo clarki* Richardson**

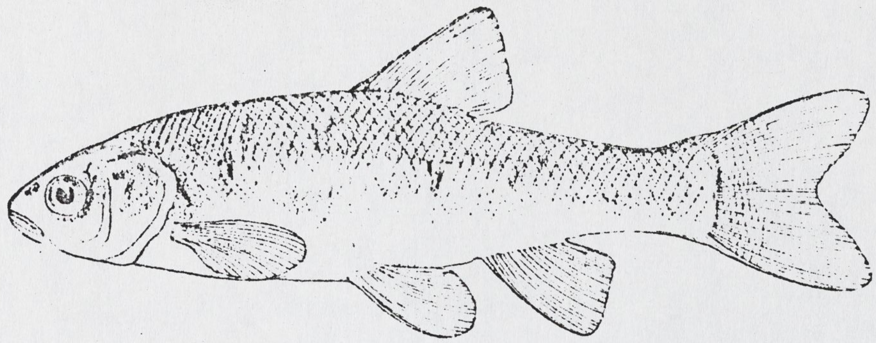
Common Names: Cutthroat trout, native trout, mountain trout.



UTAH CHUB

Gila atraria (Girard)

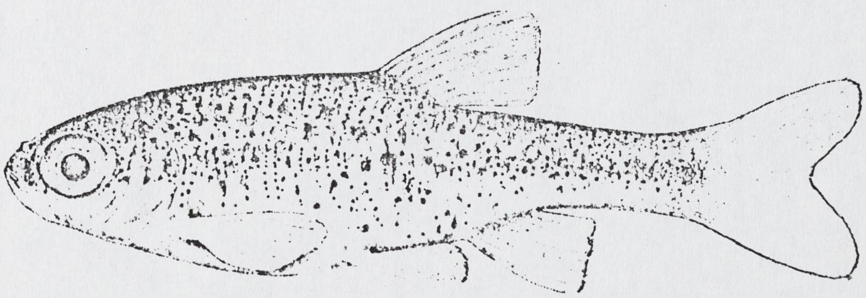
Common Names: Utah chub, great chub, chub.



LEAST CHUB

Iotichthys phlegethontis (Cope)

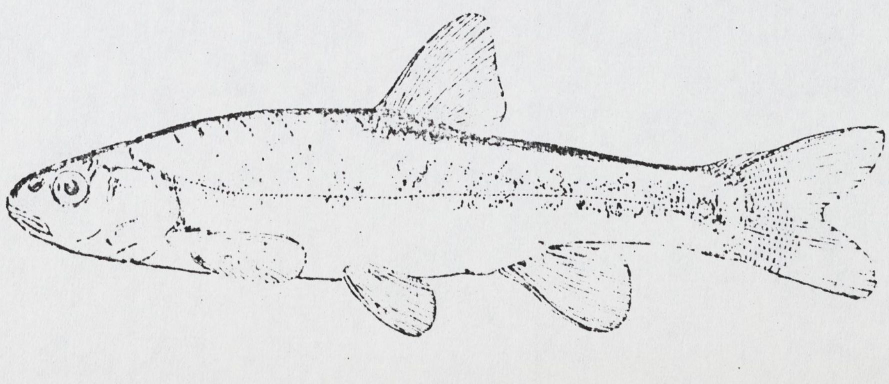
Common Name: Least chub.



LEATHERSIDE CHUB

Gila copei (Jordan and Gilbert)

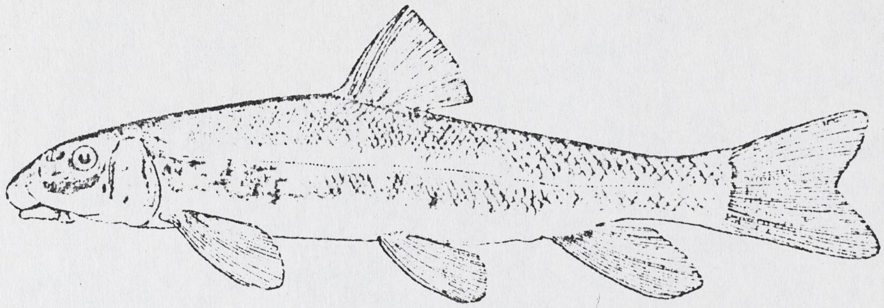
Common Names: Leatherside chub, leatherside minnow.



MOUNTAIN SUCKER

***Pantosteus platyrhynchus*, (Cope)**

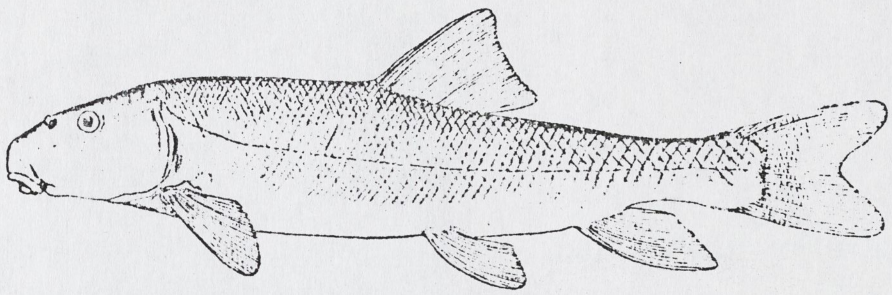
Common Names: Mountain sucker, Bonneville mountain sucker, mud sucker, flatnose sucker.



UTAH SUCKER

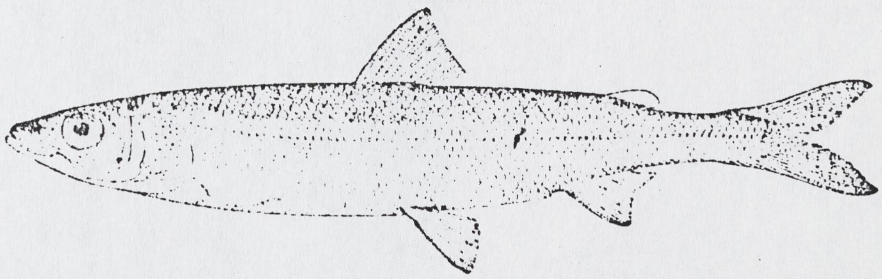
***Catostomus ardens* Jordan and Gilbert**

Common Names: Utah sucker, redhorse sucker, rosyside sucker, mullet.



BONNEVILLE CISCO

***Prosopium gemmiferum* (Snyder)**



BEAR LAKE WHITEFISH

***Prosopium abyssicola* (Snyder)**

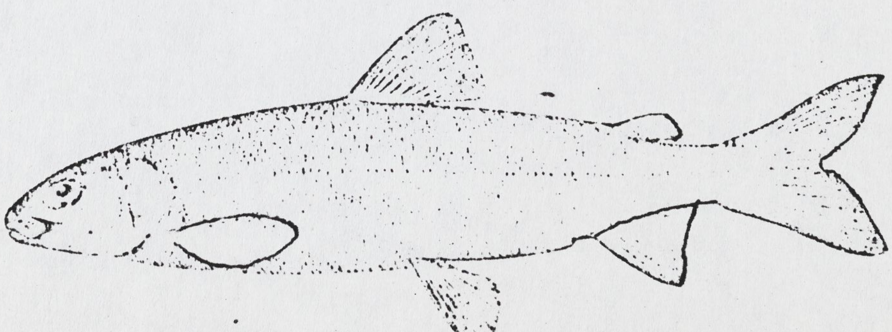


TABLE 1

Endemic to Lake Bonneville	(Common Name)	Present Location
Genera		
Iotichthys phlegethontis	(least chub)	isolated Springs in Bonneville Basin
Species		
Prosopium gemmiferum	(Bonneville Cisco)	Endemic to Bear Lake
spilontus	(Bonneville Whitefish)	Endemic to Bear Lake
abyssicola	(Bear Lake Whitefish)	Endemic to Bear Lake
Cottus extensus	(Bear Lake Sculpin)	Endemic to Bear Lake
echinatus	(Utah Lake Sculpin)	Endemic to Utah Lake (extinct?)
*Chasmistes liorus	(June Sucker)	Utah Lake (extinct?)
Subspecies		
Salmo clarki utah	(Bonneville cutthroat trout)	Few hd. streams in Bonneville Basin

Endemic to Lake Bonneville and Upper Snake River (Above Shoshone Falls)

Species	(Common Name)
Gila atraria	(Utah Chub)
Catostomus ardens	(Utah Sucker)
Catostomus platyrhchus	(Mountain Sucker)
Gila copei	(Leatherside Chub)

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* One specimen of Chasmistes spp. was found in Jackson Lake Wyoming, R. R. Miller thought it might be a separate species than liorus.

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Ariz. G.F.

- Border State [Soldier Crk]
- 60 -

John Rinne
USFS
Tempe
- Apache trout project -
- pure pop -

Ord Crk ~~[illegible]~~ antimycined → Aug. 77

→ Apache returned to stream

headwaters → above barrier

- 1-2% Apache trout -

John Rinne 261-4365
USFS: ~~Hydro~~ R.M.R.E.S.
For. Sci. Lab ASU
Tempe
85281

Li. Colo.
Paddy Crk - hybrids ~~[illegible]~~ ?

← Bonito Logging → ?
→