THE INFLUENCE OF FISH PREDATION ON PRODUCTION OF BOTTOM FAUNA

R. J. Behnke   Nov. 20, 1959

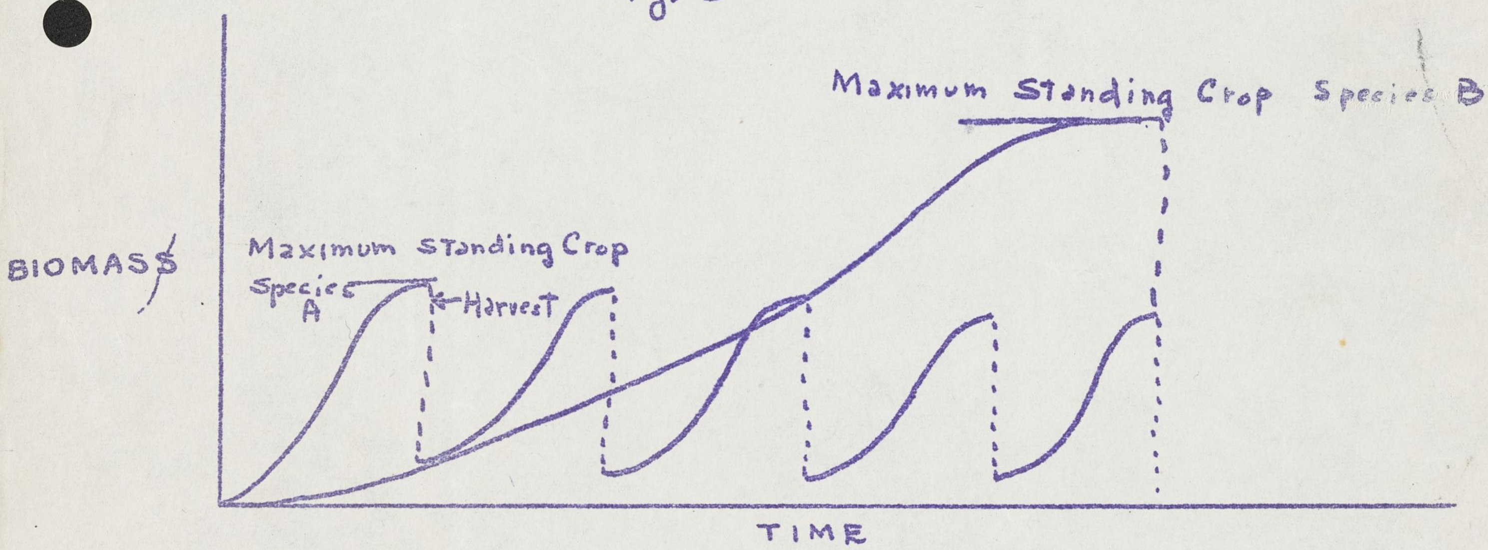
For our purposes, production is defined as the total biomass accumulated by a species during a unit of time. Consider all the members of a species living in a certain area as a unit. Each individual of the species contributes to the unit. Every bit of weight increase by an individual contributes to the production of the unit even though the individual dies or is eaten during the production period. Standing crop is the total weight at any one time of only the living members of the unit. The following analogy may help to clarify the distinction: Consider a water tank with a pipe leading into and out of it. The water flowing through the system is production, the level in the tank is standing crop. The level tells nothing about the rate of flow!

Hayne and Ball (1956) demonstrated that under fish predation, the standing crop of bottom fauna is decreased but the production rate is increased. A small standing crop of bottom fauna can support a much larger standing crop of fish because the production rate of the bottom fauna is much greater than that of the fish. Allen (1951) estimated that in a New Zealand stream, a heavily exploited bottom fauna replaced itself 100 times during a year.

Figure 1 shows how a species with a low standing crop but a high production rate will yield more biomass under exploitation than a species with a higher standing crop but a lower rate of production.

Production rates are complex and many uncontrollable factors must be considered. Little detailed work has been accomplished to date on production rates in aquatic environments. The work of Hayne and Ball (1956) on bottom fauna in ponds and the work of Allen (1951) on a stream's bottom fauna are the most comprehensive and useful for fishery science.

Fig. I



Species A with higher production rate but lower maximum standing crop, if properly exploited, will yield more biomass than Species B.

production – $\frac{250\text{-wght.}}{1000\text{ marked}} = \frac{2500\text{-wght}}{10,000}$

standing crop –

etc. –

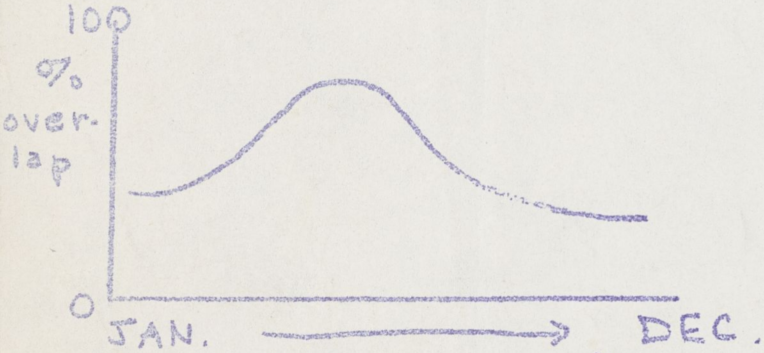
COMPETETION BETWEEN CLOSELY RELATED SPECIES OF FISH

R. J. Behnke Dec. 8, 1961

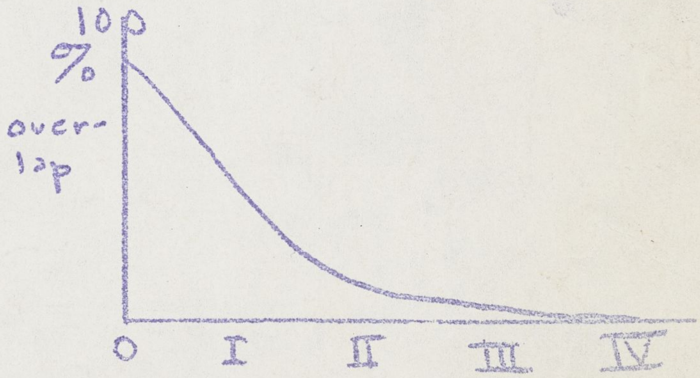
Gause's Principle that not more than one species can occupy the same niche, must be assumed to be a truism. During periods of superabundance of a food resource, more than one species may share in the feast, even those which may not be specifically adapted to the food. If the whole life cycle of an individual is considered, there must be some differences in this cycle between species if they are to coexist. These differences may be so subtle that cursory field work often leads an investigator to conclude that the requirements of the two species are identical. Fishery literature is rife with rash statements that this species of trout will out - compete that species of trout. If the niches are not distinct enough in an environment, then the species which is more highly specialized to fill the available niche will oust the other species. In another environment, however, the loser in the first case may prove superior or they may coexist and thus yield a more efficent exploitation of the environment.

The key to understanding the coexistace of closely related species is an understanding of basic evolutionary principles. When two evolving species come together, interspecific competition will favor those individuals which diverge so that a minimum degree of overlap in their requirements is attained. A new problem arises when species which did not evolve together are placed together such as brook, brown and rainbow trout. If they are able to coexist (Sagehen Creek) it is evident that their requirements are not identical. More refined thought on the matter reveals that withen a species there may be subspecies or populations which may be highly specialized to fill a specific niche; eg. Lahontan cutthroat trout (lacustrine predator) and very different results may be expected from certain environments that would not be predictable if one relied on a broad generalization based on the species as a whole (cutthroat trout).

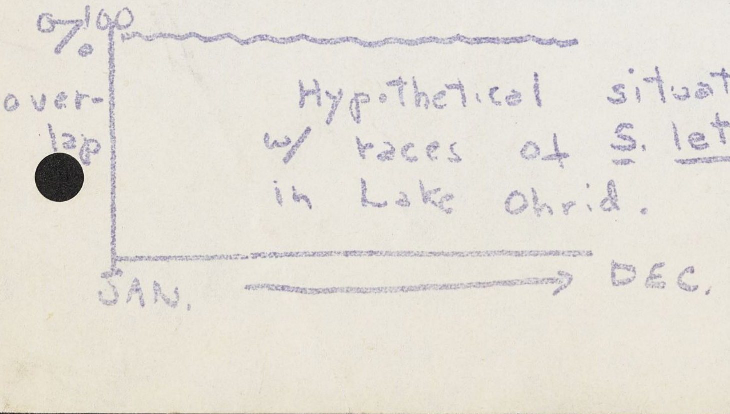
Recent work in Sweden demonstrates that two closely related species must be studied in great detail, both seasonally and annually if their ecological differences are to be understood. Species may behave differently when occurring allopatrically then they do when they are sympatric.



(Salmo - Salvelinus)



life of individual (redsided shiner - rainbow trout)



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RARE AND ENDANGERED SPECIES: THE RIO GRANDE TROUT
(*Salmo clarkii virginalis*)

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Introduction

The cutthroat trout native to the Rio Grande River basin, is listed as endangered by the Bureau of Sport Fisheries and Wildlife. So little is known about this trout regarding original distribution, taxonomy, or its present status, that perhaps the category "status unknown" would be more appropriate. Evermann and Kendall (1895) reviewed the scattered bits of information on the Rio Grande trout and concluded: "The distribution of the trout of the Rio Grande basin furnishes very interesting and proper subject for investigation." No such investigation has yet been attempted.

Virtually the whole taxonomic foundation of this trout found in present day keys and check lists can be traced to the comments of Jordan (1891), who examined two specimens from the Rio Grande at Del Norte, Colorado, in 1889. The original distribution, characters distinguishing it from other cutthroat trout, and variability of populations is not known. Drastic environment changes wrought by the use and misuse of water; the introduction of exotic fish species, particularly rainbow trout and other subspecies of cutthroat trout which hybridize with the native trout, make an evaluation of the present status of the Rio Grande trout a difficult task.

Relatively few specimens of native Rio Grande trout were collected and permanently preserved in museum collections, and these were from a rather restricted geographical area. Thus, there is little available material representing the original Rio Grande trout for comparative taxonomic studies.

Some interesting fragments of information have been accumulated and data obtained from 68 specimens of Rio Grande trout to provide a summary of the present knowledge of this trout. Mainly, however, the goal of this report is to stimulate an interest to know more about the Rio Grande trout, hoping to generate more information and the collection of specimens, allowing a thorough evaluation and an authoritative statement on its present status and taxonomic position.

Historical Considerations

The name

Reference to the Rio Grande cutthroat trout is probably the earliest mention of trout in the New World. An account of Coronado's expedition in 1539 related that: "There were very good trout in the upper Pecos River" (Rostlund, 1952:25).

In 1852 the U.S. Army established Fort Massachusetts on Utah Creek (now Ute Creek) in Costilla County, Colorado. Ute Creek flows westward from the Sangre de Cristo Mountains, joining Sangre de Cristo Creek which then enters Trinchera Creek, tributary to the Rio Grande in the San Luis Valley. Fort Massachusetts was abandoned in 1858 and replaced by Fort Garland, six miles to the south and closer to Sangre de Cristo Creek. In 1853 a Pacific Railroad Survey expedition made the first collection of Rio Grande trout for scientific purposes. These trout were taken from Ute Creek at Fort Massachusetts. On examining these specimens, Girard (1856) described a new species, "*Salar virginalis*." Additional specimens were later collected and sent from Fort Garland. Cope (1872) studied the specimens from

Fort Garland and also described a new species, "Salmo spilurus." The type locality for spilurus is listed as Sangre de Cristo Pass (probably from Sangre de Cristo Creek). Cope knew of Girard's description of virginalis from approximately the same locality, but at that time the typologist concept and criteria of a species was prevalent in systematic work. Trout with their great variability in color, spotting, and general morphology were especially susceptible to the naming of a rash of invalid species. Cope decided that spilurus was a distinct species because it was: "not so slender" as virginalis. He believed "S. pleuriticus" (the Colorado River cutthroat) also occurred in the Rio Grande basin and listed it from Fort Garland (Cope and Yarrow, 1875). For several years thereafter the name spilurus was applied to Rio Grande cutthroat trout and virginalis erroneously used for Bonneville basin trout. The name virginalis given by Girard in 1856, clearly is the first valid scientific name used for Rio Grande trout. There is no contention at present that the Rio Grande trout is a member of the wide ranging cutthroat species, Salmo clarkii. If the Rio Grande trout is sufficiently distinct from other cutthroat trout to warrant subspecific designation, the name Salmo clarkii virginalis should be used.

Distribution

Cope (1886) reported receiving two black spotted trout, resembling a cutthroat trout, with: "teeth on the basihyal bones," from southern Chihuahua, Mexico. Subsequently, most published distributional records extended the range of the Rio Grande trout south to Chihuahua. These two Mexican specimens mentioned by Cope have significance concerning the original distribution of Rio Grande trout and for trout systematics and zoogeography in general. Unfortunately, the fate of these specimens and their precise collection locality are unknown. The locality given by Cope: "streams of the Sierra Madre, at an elevation of 7,000 and 8,000 feet, in the southern part of the State of Chihuahua near the boundaries of Durango and Sinaloa," could be in the Rio Conchos drainage which is tributary to the Rio Grande in Chihuahua, or it could refer to streams draining westward into the Gulf of California. Needham and Gard (1959) described trout collected from the Pacific Coast streams (Rio Fuerte, Rio Sinaloa, and Rio Culiacan).

A distinctive golden colored trout inhabits these streams; it was named *Salmo chrysogaster* by Needham and Gard (1964). *Salmo chrysogaster* does not appear to be derived from, or closely related to, the Rio Grande cutthroat trout. Needham and Gard (1959) compared a sample of trout collected from the headwaters of the Rio Casas Grandes in northern Chihuahua, a disrupted tributary of the Rio Grande. These trout are not of the cutthroat species, but are almost identical to the trout of the Rio Yaqui, tributary to the Gulf of California. The Rio Yaqui and Rio Casas Grandes have many species in common (Miller, 1958). The Rio Yaqui and Rio Casas Grandes trout appear intermediate between the Mexican golden trout, *S. chrysogaster*, and the Gila trout, *S. gilae*, but are not closely related to Rio Grande cutthroat trout. The probability remains that during the colder periods of the Pleistocene, cutthroat trout did range throughout the Rio Grande system into Mexico and may yet persist in isolated colonies in the Rio Conchos. Cope's calling attention to the "basihyal" teeth on the Mexican specimens indicates that these specimens were true cutthroat trout and not the "golden trout" from the Pacific drainage of Chihuahua. The basihyal bone to be anatomically correct is the bone forming the base of the tongue and sometimes tongue teeth are called basihyal teeth. However, since all trout have teeth on the tongue, Cope's specific reference to basihyal teeth probably means basibranchial (=hyoid) teeth which distinguish cutthroat trout from other species of the genus Salmo. At present, this is the only evidence that a Rio Grande cutthroat occurred south into Mexico. No specimens of cutthroat trout have been collected from Mexico since Cope's note of 80 years ago. Just how far south in the Rio Grande basin the native cutthroat ranged has not been accurately determined. Clark Hubbs (1957) said there are no authentic records of native trout ever occurring in Texas, and at present only one stream, McKittrick Creek in the Guadalupe Mountains, maintains a self-reproducing population of introduced rainbow trout.

There are some old reports relating tales of native trout from far outside the present known distribution. Daniel (1878) in a letter to the sportsmen's journal, Forest and Stream, recalled his fishing experiences while serving as Assistant Surgeon in the Second Texas Rifles during the Civil War. He believed he remembered catching trout at San Felipe Springs (tributary to the Rio Grande near Del Rio on the Mexican border, Val Verde Co.). Daniel had a "distinct recollection" of taking "speckled trout" from the Devil's River while stationed at Fort Hudson (tributary of Rio Grande, Val Verde Co.). He claimed to have caught many trout from the Limpia River (tributary of Pecos R., Jeff Davis Co.) during his duty at Fort Davis in Texas. In southern New Mexico, at Fort Stanton, Daniel recalled trout in the Rio Bonito (tributary to the Pecos, Lincoln Co.). Daniel had lived in New Haven, Connecticut, and wrote that he was familiar with the eastern brook trout (Salvelinus fontinalis); he thought the trout he saw in Texas and New Mexico to be the same.

Another correspondent to Forest and Stream (Taylor, 1878) supplied further information on trout in Texas. Inquiry was made with Dr. D.I. Hunter, a Confederate Army surgeon, who was stationed at Fort Davis on the Limpia River during the Civil War. A fish, believed to be the eastern brook trout (Salvelinus fontinalis) was said to be abundant in the Limpia and in streams to the north. The Limpia was described as a clear, cool, sparkling stream flowing through a region about 5,000 ft. elevation. A buffalo hunter told Taylor of catching "wagon loads" of "speckled trout" in the Panhandle region of Texas, from headwater streams of the Canadian and Red rivers. Major D.W. Hinkle formerly with Emory's Boundary Survey and familiar with the Panhandle region, verified the Buffalo hunter's story according to Taylor. At that time the Texas border extended the Panhandle region of Texas westward into part of present day New Mexico and would have included suitable trout habitat in the Canadian River basin. The report of trout in the Red River basin, I would consider, more dubious. Another correspondent to Forest and Stream, Johnson (1880), was doubtful of the existence of trout in Texas, he wrote: "There may be genuine trout in Texas, but if so they are very far from the limits of civilization for I have fished Texas waters since 1848 and never saw a speckled trout other than what is called in the South, "Salt water trout" and in the North, "weakfish."

The existence of native trout in the Canadian River system has not yet been authoritatively demonstrated. A job completion report of the New Mexico Department of Fish and Game on fish surveys in the Canadian River basin from 1953 to 1956 lists many excellent trout waters among the headwater tributaries of the Canadian River in the Sangre de Cristo Mountains. Introduced brown, brook and rainbow trouts inhabit most of these streams but the report states: "native cutthroat still dominate most of the uppermost headwaters." The use of the term "native trout" is misleading, however, because the report mentioned that no attempt was made to differentiate Yellowstone cutthroat from Rio Grande cutthroat, both of which have been widely introduced. Thus, it is not known if "true native" trout occurred before the introductions by man. Fowler (1912) lists three "cotypes" of Salmo stomias (the greenback cutthroat of the Arkansas and Platte rivers) from Ute Creek, Camp Garlan, New Mexico, tributary of the Canadian River, in the collection of the Philadelphia Academy of Science. There are many errors in the locality records of the specimens collected by early explorers, perhaps these specimens came from Ute Creek at Fort Garland, Colorado, the type locality of the Rio Grande cutthroat, on the other side of the Sangre de Cristo Mountains. There is a Ute Creek which is major tributary of the Canadian River in New Mexico; it traverses a course of more than 100 miles, mainly between elevations of 6,000 to 4,000 ft. According to the above mentioned Job Completion Report, Ute Creek supports only warm water species today. Another Ute Creek, in the Canadian River system, a small tributary in the Sangre de Cristo Mountains, is listed as a trout stream.

Considering the topography of the upper Canadian River basin with the interdigitation of headwater tributaries with Rio Grande tributaries in the Sango de Cristo Mountains, and the proclivity of trout to utilize headwater stream transfer, would suggest the strong possibility that trout were native to the Canadian River system. Koster (1957) mentioned the fish fauna of the upper Pecos River have closer affinities to the fishes of the upper Canadian River than they do to the fishes of the upper Rio Grande.

In November, 1966, Terrence Merkel, Fisheries Biologist of the Bureau of Sport Fisheries for the Mescalero Apache Indian Reservation in southern New Mexico, collected 8 specimens of cutthroat trout from Indian Creek, a small stream tumbling off the west slope of Sierra Blanca Peak in the northwest section of the reservation in Otero Co., New Mexico. Indian Creek is tributary to Three Rivers whose waters disappear in the desert of the Tularosa Valley, north of the White Sands National Monument, an independent desiccating basin long isolated from the main Rio Grande. Hubbs and Miller (1948) discussed the Tularosa Valley and stated that the only fish known from this basin is a species of Cyprinodon confined to Malpais Springs. The trout obtained by Merkel represents the southernmost collection of Rio Grande cutthroat trout known to exist. The probability that the trout found on the Mescalero Indian Reservation are truly native and not introduced is discussed in the following section on systematics.

Several desiccating basins isolated from direct connection to the Rio Grande system occur in the arid country between the Rio Grande and the Pecos River and between the Rio Grande and the Gila River. Cold, spring fed, mountain tributaries of these disrupted segments of the Rio Grande basin may yield important discoveries of native cutthroat trout which should make significant contributions to our knowledge of past distribution and to the systematics of Rio Grande trout.

The statement mentioned in the introduction by Evermann and Kendall in 1895 that: "The distribution of the trout of the Rio Grande basin furnishes very interesting and proper subject for investigation" seems especially true today.

Systematics

Published accounts pertaining to Rio Grande trout are of little value for the recognition of a subspecies or to serve as a basis allowing separation of Rio Grande trout from other cutthroat trout. Many of the early reports grouped trout referred to as virginalis and spilurus from the Colorado River and Bonneville basins as well as the Rio Grande; and taxonomic information consisted of general comments on morphology and spotting pattern which are essentially worthless for distinguishing the Rio Grande populations from any other geographical group of the highly variable cutthroat trout species.

Most of the specimens obtained for museum collections came from Ute Creek and Sangre de Cristo Creek, near Fort Garland, Colorado, tributaries to the Rio Grande in San Luis Valley. Suckley (1874) mentioned a specimen at the Smithsonian Institution from Santa Fe, New Mexico.

This is the southernmost record of a Rio Grande trout known to be preserved in a collection; but Santa Fe is about 200 miles north of the recent collection from the Mescalero Indian Reservation.

The description of specimens collected by Jordan (1891) from the Rio Grande at Del Norte, Colorado, provided basis for virtually all subsequent taxonomic descriptions of the Rio Grande subspecies. Jordan stated that the Del Norte specimens had rather large spots ..."more or less confined to the dorsal and caudal fins and region between them, though often in the young, extending on the head." He added: "This form is apparently wholly identical with var. pleuriticus, except that in the specimens examined the scales are less crowded forward, so that the number in a lengthwise series is less. I count 155 to 160 in Rio Grande specimens; 185 to 190 in those from the Colorado." Two figures of Rio Grande trout were reproduced in Jordan's publication. Figure 7 listed as adult is profusely spotted with small, pepper-like spots; figure 8 is listed as young and has larger spots, corresponding to the above mentioned description. The scale counts of 155 and 160 were made on only two specimens. This scale count, however, is still quoted as the main distinguishing character of the Rio Grande subspecies. Ellis (1914) described specimens taken from the Rio Grande at Creede, Colorado, in 1912 as silvery fish with small black spots and a pale rose-red lateral band. Actually, the total amount of information that can be abstracted from all the available literature on Rio Grande cutthroat trout, provides no real basis for recognizing this trout as a group distinct from the cutthroat trout of the Colorado River, the Bonneville basin or of Yellowstone Lake, without a large measure of imagination and faith on the part of the observer.

Specimens Examined:

Counts and measurements were made on six specimens collected by Jordan in 1889 from the Rio Grande at Del Norte, Colorado, now in the collections of Stanford University and the California Academy of Sciences. Variability in spotting was noticeable, but none of the counts and measurements of this small sample indicated any character which would serve to separate them from other subspecies.

In August, 1958, Howard Tanner, Wayne Seaman, and Carl Welsh of the Colorado Fish and Game Department, collected cutthroat trout from two streams tributary to San Luis Valley in Costilla County, Colorado. Specimens were taken from the Rito Seco, tributary to Culebra Creek, 5-6 miles northeast of the town of San Luis; and from Indian Creek, a tributary of Sangre de Cristo Creek about 5 miles northeast of Fort Garland and approximately 15 miles north of the Rito Seco. Most of these specimens were sent to the University of Michigan and only 5 retained at C.S.U. I have data from 30 specimens now in the University of Michigan collections.

Jack Dean and Croswell Henderson, Bureau of Sport Fisheries Biologists, collected specimens from the Rio Chiquito, a Rio Grande tributary in Carson National Forest, east of Taos, New Mexico, approximately 75 miles south of Fort Garland, Colorado. Two specimens collected in May by Mr. Dean and 18 taken by Mr. Henderson in June, 1966, were donated to the Colorado Cooperative Fishery Unit's collection.

When the Rio Chiquito specimens are compared with those from the Rito Seco and Indian Creek, a high degree of homogeneity is apparent. This indicates these disjunct populations have diverged little from the ancestral cutthroat that once widely ranged throughout the upper Rio Grande basin. They may be considered as representative of the type material on which the names virginalis and spilurus are based.

The most obvious character which tends to distinguish these trout from other cutthroat trout is an adipose fin rimmed with a black border. The basibranchial teeth are exceedingly minute; not visible above the mucous membrane covering the basibranchial plate, and observable only under magnification and much eye straining probing with a needle.

Feeble development of basibranchial teeth is not uncommon among cutthroat trout populations, but it is a useful character to distinguish these trout from Yellowstone Lake stock.

The cutthroat trout native to Yellowstone Lake is the source of most of the cutthroat trout used for introductions throughout the west. Thus, to evaluate the relative purity of a suspected native population, comparisons should be made with trout whose ultimate origin was Yellowstone Lake.

The trout taken from the Rito Seco, Indian Creek, and Rio Chiquito, all differ from Yellowstone trout in the adipose fin marking and there is good separation in the development of basibranchial teeth and gillrakers. The gillrakers in Yellowstone trout are, typically all distinctly developed with visible development of several rakers on the posterior portion of the first gillarch.

The specimens from the upper Rio Grande basin have medium sized spots mostly concentrated in the posterior region. Anterior to the dorsal fin the spots are less numerous, smaller, and mainly located above the lateral line. Moving posteriorly from the dorsal fin the spots are progressively larger and more evenly distributed above and below the lateral line. Some of the specimens collected in June, 1966, from the Rio Chiquito still retain some color. Yellowish-orange shades the ventral region, and a reddish-orange lateral band is visible. The lower fins have reds and orange colors and a bright reddish-orange cutthroat mark is present. The anterior tip of the dorsal fin has a faint orange hue. Parr marks are distinct on all specimens (size range, 5-10 inches).

No meristic characters such as number of gillrakers, scales, branchisstegal rays, fin rays, vertebrae, or pyloric caeca, appear to have much efficacy to separate the upper Rio Grande trout from most other interior cutthroat trout. On the basis of the homogeniety among the three samples, particularly in sharing the black bordered adipose fin I conclude that these populations represent pure stock of native Rio Grande Trout. There is no evidence of hybridization with either rainbow trout or Yellowstone Lake cutthroat trout.

The 8 specimens from Indian Creek, on the Mescalero Indian Reservation, are quite different in appearance from the upper Rio Grande specimens. Their spots are larger, fewer, and mostly restricted to the region of the caudal peduncle. The adipose fin does not have a black border, and the pelvic appendage (the fleshy lobe adjoining the first pelvic ray) is much larger in the Mescalero specimens, being one-third to one-half the length of the first pelvic ray, whereas in the specimens from the Rio Chiquito, Rito Seco, and Indian Creek in the north, the pelvic appendage is less than one-fifth the length of the first pelvic ray. All color was lost from the Mescalero specimens by the time they arrived at C.S.U.

If trout were native to Indian Creek on the Mescalero Indian Reservation they should be expected to show divergence from upper Rio Grande populations. The streams draining westward from Sierra Blanca Peak are tributary to Tularosa Valley, which in the late Pleistocene contained a large lake, probably tributary to the Rio Grande (Hubbs and Miller, 1948). Apparently, there has been no connections of the waters of Tularosa Valley to the Rio Grande for several thousand years. If trout once ranged throughout the Rio Grande southward into Texas and Mexico during the Pleistocene, access to the Tularosa basin would have populated the tributary streams such as Indian Creek. As mentioned earlier, trout were reported from the Rio Bonito during the Civil War period. The Rio Bonito drains the west slope of Sierra Blanca Peak, tributary to the Pecos River. Westward flowing streams such as Indian Creek, may have received introductions of Pecos basin trout carried over by man, or natural headwater stream transfer may have been a source of trout from the Pecos drainage channeled into the Tularosa Valley side of the divide.

The spotting pattern of the trout found on the Mescalero Reservation and a comparison of gillrakers and basibranchial teeth indicates that these trout are not derived from Yellowstone Lake stock.

Almost nothing is known of the trout native to the Pecos River division of the Rio Grande system. No taxonomic accounts have been published, nor are there any specimens in museum collections that I am aware of. Collections of pure populations of native trout from the Pecos basin would be a most important contribution toward a better understanding of the range of variation possessed by the trout of the Rio Grande system.

Summary

Evaluation of the status of the native trout of the Rio Grande is difficult due to the paucity of published data and the few specimens in museum collections. The original distribution is not known, although some evidence suggests populations occurred as far south as Chihuahua, Mexico.

Three recent samples from southern Colorado and northern New Mexico represent the native trout of the northern Rio Grande basin. A sample from a desiccating basin in southern New Mexico is not identical to the northern samples.

Comparisons with Yellowstone Lake cutthroat trout demonstrate that the samples studied were not the result of introductions of Yellowstone Lake stock.

No published information is known on the taxonomic characters of the trout native to the Pecos River division of the Rio Grande basin. The occurrence of indiginous trout in the Canadian River basin has yet to be demonstrated.

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COMPARISON OF RIO GRANDE AND YELLOWSTONE LAKE CUTTHROAT TROUT

LOCALITY	GILLRAKERS			SCALES lateral series and above lateral line			BASIBRANCHIAL TEETH			PYLORIC CAECA AND VERTEBRAE		
	N	range	mean	N	range	mean	N	range	mean	N	range	mean
UPPER RIO GRANDE REGION												
Rio Chiquito, New Mexico coll. 1966	20	17-22	18.8	17 15	154-180 39-44	165.4 41.1	13 3	1-7 no teeth	3.9	16 No vertebral counts	28-40	34.8
Indian Crk., Rito Seco (combined) Colorado coll. 1958	34	18-21	19.5	26 5	146-186 39-43	164.3 40.8	28 5	1-6 no teeth	3.2	caecal counts of: 30,31,35,37,47 30	 61-63	 61.8
Rio Grande at Del Norte, Colo., coll. 1889	4	19-22	20.0	3	35-40	38.3	4	1-9		No caecal counts 6	 61-63	 62.0
MESCALERO INDIAN RESERVATION												
Indian Creek	8	16-21	19.0	6 6	168-180 38-41	173.0 39.0	8	1-12	7.6	5 No vertebral counts	33-39	35.8
YELLOWSTONE LAKE												
S.c. lewisi	30 all rakers more fully developed and greater development of posterior rakers on first arch	19-23	20.6	30 30	149-202 36-48	170.3 41.9	29 Typically larger teeth, prominently seen without removing tissue	1-27	13.7	10 30	28-51 60-63	38.0 61.5

[ca 1967]

RARE AND ENDANGERED SPECIES: THE GILA AND APACHE TROUTS

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A native "yellow belly" trout once widely occurred in the Gila River system of Arizona and New Mexico. After the coming of the white man, this trout suffered such a drastic decline in its range that by the time R.R. Miller described it as a new species, *Salmo gilae*, it was on the verge of extinction (Miller, 1950).

The species *Salmo gilae* was based on a population inhabiting Diamond Creek, Sierra County, New Mexico in the Gila National Forest. Since Miller's description of *Salmo gilae*, populations of native trout were found in headwater tributaries of the White River, Apache County, Arizona, part of the Salt River drainage of the Gila basin. These "Apache" trout have been considered as *Salmo gilae*, but examination of specimens reveal obvious distinctions from *S. gilae* of Diamond Creek. No real taxonomic data on the Apache trout has been published but Miller plans to describe them as a separate entity: *Salmo apache* or perhaps *Salmo gilae apache*.

Recent collections of the Apache trout by J. Andersen and R. Behnke allowed comparisons of samples from several localities with the specimens of Diamond Creek Gila trout.

Some degree of judgement is now possible on the distinguishing characters separating Gila and Apache trouts; on similarities these two trout share differentiating them from rainbow and cutthroat trouts; and on the relative purity of various populations suspected of contamination by rainbow or cutthroat hybridization.

The Arizona Fish and Game Department and the Bureau of Sport Fisheries and Wildlife have held the opinion that only Ord Creek, on the Fort Apache Indian Reservation contains a pure population of the native "Apache" trout. Examination of specimens from Firebox Creek, Deep Creek, and the headwaters of the East Fork of the White River of the White River system, and from Paddy Creek, in the Little Colorado basin, indicates that pure populations of "Apache" trout also occur in these streams. Specimens from several other streams will be evaluated in the near future.

Comparison of Characters

The characters shared in common by the Gila and Apache trouts distinguishing them from cutthroat and rainbow trouts are more impressive and basic than the characters differentiating them from each other.

It is clearly understood that body proportions are influenced by age, sex, growth rate, and habitat, and several morphometric characters are allometric. This was demonstrated in Miller's paper by a comparison of Gila trout from Diamond Creek and Gila trout raised in a hatchery. When comparisons are made, however, with data compiled on approximately 2,000 specimens of rainbow and cutthroat trouts representing 130 samples collected throughout their range, and it is observed that such measurements as head and jaw lengths, position of the dorsal fin, and lengths of the dorsal and adipose fins clearly separate out from all rainbow and cutthroat samples, it may be assumed that these characters are genetically determined to an extent that phenotypic variability is still beyond the range expressed in the rainbow and cutthroat species.

Two anatomical characters suggest a more clear-cut separation from cutthroat and especially rainbow trouts. Ranges and means of pyloric caeca counts (22-42 [28.1-34.9]) for Gila and Apache trout samples are significantly lower than typically found in rainbows (50-60) or cutthroat (35-50). Vertibrae number fewer in Apache and Gila trouts also. More complete information on vertebrae number will be available soon when the Colorado Cooperative Fishery Unit's newly acquired x-ray machine is in operation. Only the Colorado greenback cutthroat, _S. clarkii stomias_ approaches the Gila and Apache trouts in the low number of caeca and vertebrae.

The Apache and Gila trouts are chunky appearing, deep bodied trout with long heads and jaws, long fins and with the origin of the dorsal fin slightly more posterior than one-half the standard length. They have moderately small scales, with the Apache trout typically having more scales than the Gila, especially in the count above the lateral line. The Apache trout have a slightly longer dorsal fin than the Gila trout, while the Gila typically has a longer adipose fin; but, both have longer dorsal and adipose fins than cutthroats or rainbows. The number of gillrakers does not differentiate the Gila or Apache trout from rainbows or cutthroats, but the mean value of Diamond Creek specimens is slightly lower than Apache samples. Other meristic characters such as the number of fin rays, and branchiostegal rays are not useful in separating Gila, Apache, rainbow or cutthroat trouts.

In most characters the Gila and Apache trouts resemble the cutthroat species more than the rainbow; but in the absence of basibranchial (hyoid) teeth they are similar to rainbows.

Coloration and Spotting. The most obvious distinction between the Gila trout of Diamond Creek and the Apache trout is the smaller more profuse spots found on the Gila trout, especially on the dorsal and caudal fins. The only trout I have examined with a similar spotting is the cutthroat native to the upper Snake River system in Idaho and Wyoming. The Apache trout has a spotting pattern suggestive of other interior cutthroats.

The Apache and Gila trouts both have a pale yellow cutthroat mark and the dorsal, anal, and pelvic fins have a grayish-white or yellow tip. Well defined parr marks were observed only on small specimens (less than 6 in.) of Apache trout - parr marks appear to be slightly more pronounced in the Gila trout. Fresh specimens of Apache trout show variable colors, typically a dull, brassy, yellow-olive base with purple and pink tints seen in certain lights on some specimens. The coloration is suggestive of interior cutthroat trout but there are no bright red, yellow or orange shades apparent on the Apache trout as is common with cutthroat. Black pigmentation on the iris of the eye gives a mask-like effect. This pigment fades during preservation.

Evaluation of all data demonstrates that the affinities of the Gila and Apache trouts are closer to each other than they are to any known form of the cutthroat or rainbow species. The degree of difference between the Gila and Apache trouts suggests taxonomic recognition at the subspecies level, i.e., *Salmo gilae gilae* for Gila trout and *Salmo gilae apache* for Apache trout. It is recognized that the species *gilae* is not a good "biological species" because neither the Gila trout nor the Apache trout maintains reproductive isolation from rainbows or cutthroats when they occur together. The Gila and Apache trouts show affinities to both rainbows and cutthroats and they can not authoritatively be assigned as a subspecies to either of these species at the present time.

The closest affinities to other described forms, I believe, lie with the California golden trout, *Salmo aquabonita*, and the Mexican golden trout, named *S. chrysogaster*, by Needham and Gard (1964). In the future, when sufficient critical analysis of western North American trouts allows a more confident evaluation, the genus *Salmo* may be considered as two major phylogenies, the cutthroat species and the rainbow species with a third, intermediate, evolutionary line of "golden" trouts.

Systematic Problems

The main problem in understanding more about the systematics of Gila and Apache trouts is the paucity of material. More specimens from other waters than Diamond Creek and the close-knit group of tributaries in the headwaters of the White River are needed to evaluate the validity of the distinctions between the Gila and Apache trouts. The key area is the White Mountains of Arizona where headwater tributaries of the San Francisco and Salt river divisions of the Gila River basin and of the Little Colorado River, radiate out like spokes from the hub of a wheel.

Regan (1966) mentioned that S. gilae is also found in Eagle Creek, tributary to the Gila River, Greenlee County, Arizona; Spruce Creek, Catron County, New Mexico, in the San Francisco River watershed; and in McKenna Creek, tributary to the west fork of the Gila River, Catron County, New Mexico. I have examined no specimens from these waters nor has anyone, to my knowledge, critically evaluated specimens from these populations for comparison with S. gilae of Diamond Creek. It would be important that the Colorado Cooperative Fishery Unit collection obtain specimens from these and any suspected pure gilae populations for such an evaluation.

Trout were once indiginous to the Verde River system of the Salt River division in Arizona. It is not known if these trout were identical to the Apache trout found in the White River. It is hoped that some remote tributaries in the Verde system may be found with the original trout. Such a discovery would add greatly to our knowledge of the whole Gila basin trout complex.

The collection of "native" trout from Paddy Creek in the Little Colorado River basin raises some questions concerning the trout found originally in the Little Colorado. Were they truly native, or were they introduced from the White River side of the White Mountains?

Jordan and Evermann (1896:496) mentions specimens from the Little Colorado which they believed to be similar to the Colorado River cutthroat, Salmo clarkii pleuriticus. These specimens from the Little Colorado, mentioned by Jordan and Evermann were probably collected by H.W. Henshaw in 1872 as part of the Wheeler Survey. Cope and Yarrow (1875), describing the fish of this expedition, list two samples of trout referred to as "a variety of Salmo pleuriticus," one from the White River and the other listed only as from the White Mountains, Arizona, but probably from the headwaters of the Little Colorado where this expedition collected the type specimens of the Little Colorado spinedace, Lepidomeda vittata. I have examined the three specimens collected from the White River in 1872, and R.R. Miller (1961:389) has examined the Little Colorado specimens referred to as pleuriticus by Jordan and Evermann. These specimens are actually Apache trout; Colorado River cutthroat trout evidently did not occur naturally in any waters of Arizona, at least in historical times.

Miller (1961, 1964) believed, however, that the Apache trout was not native to the Little Colorado drainage, but were introduced by man. I believe if trout were found in the Little Colorado in 1872 they were probably indigenous. Miller (1961:390) relates information originating from Gustav Becker, who came to Arizona in 1876 and remembered the "yellow-bellied" trout from both the headwaters of the Little Colorado and from the White River. On the basis of the topography of the contiguous drainage basins, natural headwaters transfers into the Little Colorado would be expected.

A comprehensive collecting trip is planned for 1967 to fill in the gaps of our knowledge on the systematics of the Gila and Apache trouts. The cooperation, advice, and assistance of various government agencies and the Arizona and New Mexico Fish and Game Departments will be necessary for the success of such a venture.

Suggestions

At present, Ord Creek and Diamond Creek are closed to fishing. The very headwaters of Ord Creek holds only Apache trout while brook and brown trout occur with the Apache in lower sections. Based on samples from Ord Creek in September, 1966, the Apache trout appears to be holding its own in competition with brook and brown trout. This section of Ord Creek offers a fine site for study on delineating the ecological factors which may allow Apache trout to coexist with other species. Deep Creek and Firebox Creek are minute, brushy rivulets which do not attract much fishing pressure and the populations are in no danger of being fished out. All streams with native populations should be rigorously protected from introductions, this should also include any lakes tributary to such streams. Lakes, barren of fish and isolated from contamination, should be stocked with Apache or Gila trout, if suitable spawning facilities are available for maintaining a population. Limited sport fishing should be allowed to popularize these rare trout and make the public aware of them. The value of such a unique trout fishery will be much greater than that provided by common rainbow trout, and will appeal to the more discriminating and adventurous sportsmen.

For Apache trout brood stock, I would consider Ord Creek, the E. Fork White River, Deep Creek, and Firebox Creek to contain pure populations. These waters, because of their small size and limited environmental diversity probably promote quite a homozygous gene pool among their populations. It would be of interest if one lake received some fish from each of the pure Apache populations. The "inter-racial hybridization" resulting from such an experiment under conditions where natural selection is operating should quickly provide a more heterozygous gene pool and perhaps insure greater success for widespread introductions into new waters of diverse environments. Offspring of such "inter-racial" mixtures, however, should, under no circumstances, be introduced into any of the streams now inhabited by Apache trout.

Simon (1964, Ph.D. Thesis) found the California golden trout, _S. aquabonita_, to have a diploid number of 58 chromosomes; rainbows have 60; coastal cutthroats 70 and interior cutthroats, 64. Chromosome counts on Gila and Apache trout could yield some interesting insights into the evolution and relationships of the group, but must be considered only as supplementary evidence and not an absolute criterion. At present, serological studies leave much to be desired in establishing confident arrangements showing natural relationships among species and subspecies. One of our students, Richard DeLong, is now attempting to work out a refined technique which will be useful in interpreting true affinities.

ANNOTATED REFERENCES, PUBLISHED AND UNPUBLISHED

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Cope, E.D. and H.C. Yarrow. 1875. Report upon the collections of fishes made in portions of Nevada, Utah, California, New Mexico, and Arizona during the years 1871, 1872, 1873, and 1874. Report Geog. and Geol. Explor. and Surv. W. 100th Merid. (Wheeler Survey), vol. 5: 635-703. Two collections of trout made from White Mountains Arizona; one is listed from the White River, the other has no specific locality. They are referred to as a "variety of _Salmo pleuriticus_." This is the first mention of native trout in the scientific literature.

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Moheela, S. 1965. Arizona's unique arbitrary trout. Arizona Wildlife Views. Mentions studies done by James Bruce in surveying streams on Apache Indian Reservation; only Ord Creek considered pure population of Apache trout, Ord Creek stock taken to Sterling Springs Hatchery in 1963; problems of hatchery rearing; first successful artificial propagation. Mentions differences found by Regan between Gila and Apache trouts.

Mulch, E.D. and W.C. Gamble. 1956. Game fishes of Arizona. Arizona Fish and Game Dept.:19 pp. Color plate of Apache trout, referred to as Salmo gilae. Erroneously lists Colorado River cutthroat as once occurring on Mt. Baldy (Little Colorado River).

Needham, P.R. and R. Gard. 1959. Rainbow trout in Mexico and California with notes on the cutthroat series. Univ. Calif. Publ. Zool., 67(1): 1-124. Describes but doesn't name Mexican golden trout; taxonomic data on S. gilae.

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________. 1964(b). Ecology of the Gila trout. M.S. thesis CSU: 57 pp. Mainly on ecological studies on Diamond Creek Gila trout. Some meristic and morphometric data presented on 25 specimens.

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Simon, R. 1964. Cytogenetics, relationships and evolution in Salmonidae. Ph.D. thesis, Univ. Wash.: 72 pp. Chromosome numbers and configurations presented for S. gairdnerii, several groups S. clarkii, and S. aquabonita.

Whitaker, R.E. 1965. New hope for the Gila. Field and Stream, August issue: 48-49. Popular article fishing trip to Ord Creek, color photograph of Apache trout called Gila trout by the author.

LOCALITY	GILLRAKERS			PYLORIC CAECA			SCALES lateral series and above lateral line			VERTEBRAE		
	N	range	mean	N	range	mean	N	range	mean	N	range	mean
"APACHE" TROUT												
Little Colo. drainage Paddy Cr. coll. 1966	10	18-21	19.6	10	27-40	(31.7)	10 8	136-161 33- 40	149.2 37.1		--------	
White R. drainage E. Fork White R.coll.1950	20	18-21	19.5	2	30,31		20 20	144-168 32- 36	155.4 34.2	20	58-61	59.5
Ord Creek Collected 1966	12	19-21	20.3	10	22-35	28.1	11 9	139-163 34- 39	150.5 36.6		--------	
Firebox Creek collected 1956	6	19-21	19.5	8	30-37	32.9	8 8	147-172 34- 37	161.5 35.6		--------	
Deep Creek collected 1956	20	18-21	19.4	20	23-34	28.1	10 10	139-168 35- 40	156.2 37.3		--------	
3 specimens coll. 1872 White R. Ariz. USNM	3	18-19	18.7	------	------------	------	2 2	141,-158 37, 40		3	58-60	59.0
"GILA" TROUT												
Diamond Creek, New Mexico, Miller (1950)	25	18-20	19.0	10	31-42	34.9	23 16	131-151 24- 29	141.2 -----	20	59-62	60.2
Needham and Gard 1959	17	18-21	19.1	------	------------	------	17 17	138-153 28- 35	146.0 31.8	25	59-63	60.7
Regan 1964	------	------------	------	25	28-38	32.0	25 25	130-159 25- 33	143.0 29.0		--------	
Behnke specimens collected by Regan	34	18-21	19.2	------	------------	------	29 31	134-164 29- 35	148.0 31.8		--------	
RAINBOW												
Typical variability found in populations California - Alaska		17-22(18-21)			40-70(50-60)			120-140(125-135) 25- 31			62-65(63-64)	
CUTTHROAT												
		16-20 (S.c. clarkii) 18-22 (S.c. lewisii) 21-28 (S.c. henshawii)			30-60(35-50)			140-200(160-180)			60-63(61-62)	

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COMMENTS ON RARE AND ENDANGERED FISH SPECIES

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A study of the official lists of rare and endangered fish and wildlife of the United States issued by the Bureau of Sport Fisheries and Wildlife, reveals obvious deficiencies in the fish list compared with the other vertebrates. The lack of professional advice from ichthyologists is evident. There is little conformity between designated categories; the inclusion or exclusion from one year to the next often has little or no basis for such action; and the systematics of several forms are poorly known. The contributions of many persons specializing in various groups and in various geographic areas will be necessary for an authoritative list backed with solid data.

Based on personal knowledge and current studies I can offer the following information for improvement of the present lists:

Salmo evermanni is listed as an extinct species. Benson and Behnke (1961. Calif. Fish and Game, 47(3):257-259) demonstrated the *evermanni* is a synonym of *Salmo clarkii henshawi*.

The cutthroat trout native to Waha Lake, Idaho, named *Salmo bouvieri* is extinct, but from examination of museum specimens and other information, I would consider *bouvieri* as part of *Salmo clarkii lewisi*. This points out an important area for further consideration. Several species and even subspecies have a wide geographical range - as does *Salmo clarkii lewisi* - throughout this range there may be distinctive populations restricted to certain drainages which are threatened. Every effort should be made to protect these interesting units of a species or subspecies for future studies, even if they have not been officially endowed with a scientific name. This has already been done with the "Apache" trout of Arizona and the "Montana westslope" cutthroat. Both of these forms are now being propagated and their ranges expanded.

Taxonomic investigations by the Colorado Cooperative Fishery Unit demonstrated that the Apache trout is a well defined group recognizable at least as a subspecies, but distinct from cutthroat and rainbow trout. The chromosome number of Apache trout (2N=58) is identical to California golden trout, Salmo aquabonita. A mimeographed bulletin on Apache and Gila trout is available from the Colo. Coop. Fish. Unit. The Montana westslope cutthroat is presently under study. Preliminary examination of specimens received from the Creston National Fish Hatchery indicate this trout should be considered part of the polytypic Salmo clarkii lewisi and not deserving of recognition as a distinct species or subspecies.

The cytological evidence cited to bolster the contention that the Montana westslope cutthroat is a distinct species, is erroneous. Dr. Ray Simon, Leader, Oregon Cooperative Fishery Unit, found the Montana cutthroat has a diploid number of 64, typical of all other interior cutthroat examined. His communication on this matter was misinterpreted.

There is, however, a distinctive, but undescribed cutthroat in certain segments of the upper Snake River drainage in Wyoming and Idaho. This trout is easily distinguished by a profusion of tiny, pepper-like spots on the body and caudal fin; somewhat suggestive of a coastal cutthroat. Recently chromosome counts were made which indicate its origin and affinities are with interior cutthroat (2N=64) and not with the coastal cutthroat (2N=70). The range of this trout is completely circumscribed by the typical large-spotted interior cutthroat. Its native distribution in the upper Snake basin is not readily explained. A trip to Two Ocean Pass, Wyoming, in August 1967, only heightened the mystery of this unusual distribution when we found only the typical large-spotted Yellowstone trout in both Atlantic Creek and Pacific Creek on both sides of the Continental Divide. We have no evidence that the fine-spotted Snake River cutthroat intergrades or occurs sympatrically with the large-spotted form. The limits of the original distribution are not known. The Snake River cutthroat is propagated in both federal and state hatcheries.

At present, the greatest threat to maintaining pure stocks of our rapidly dwindling native cutthroat populations is the introduction of rainbow trout and of the widespread use of Yellowstone cutthroat as "native" trout. The Yellowstone cutthroat is the main source of hatchery stock distributed in waters throughout the range of the subspecies described as virginalis, utah, pleuriticus, and stomias. It can be definitely stated that all of these subspecies are rare. The problem confronting a systematic study of our native cutthroat trouts is how to distinguish them from the closely related Yellowstone cutthroat. Samples of suspected pure populations of the above mentioned subspecies have been collected and we are in the process of comparative analysis.

A biochemical method of micro-immunoelectrophoresis, relatively untried in fish taxonomy, is being tested for its efficacy in detecting slight genetic differences allowing separation of Yellowstone Lake cutthroat from other native forms.

All state fish and game departments and all organizations which may distribute fish must be made aware that to introduce rainbow trout or other cutthroat trout into waters where access is available to suspected pure populations of a native cutthroat will result in losing the native strain.

A history of cutthroat trout propagation is being compiled to indicate the diverse sources used to collect eggs and to what extent mixing of various forms took place. An indication of man's inimical influence is found in the first propagation of cutthroats in a federal hatchery. The hatchery at Leadville, Colorado, took eggs of the "greenback" cutthroat from Twin Lakes, Colorado, in 1890 to initiate the federal program of cutthroat propagation. By 1890, the greenbacks of Twin Lakes were already hybridizing with rainbows introduced in the 1880's. Thus, from the very beginning, contaminated stocks were used.

The Colo. Coop. Fish. Unit is making an effort to save the few remaining greenbacks. Black Hollow Creek, a small tributary to the Poudre River, west of Fort Collins, contained a small population of what appear to be relatively pure greenbacks. Eastern brook trout were rapidly replacing the cutthroat in this stream. In 1966, 55 adult specimens were transferred to a previously barren stream. In 1967, a barrier dam was installed on Black Hollow Creek, the brook trout eliminated with rotenone, and 24 adult greenbacks re-introduced. Other current studies underway include a systematic evaluation of the status of the trouts endemic to the upper Kern River basin, California. Field work in 1967 examined the waters of Sequoia National Park. Preliminary analysis revealed the past indiscriminate introductions of hatchery rainbows and golden trout has produced a medly of hybrid populations. No pure populations of the Kern River rainbow, S. gairdnerii gilberti, was found and this distinctive genotype may now be extinct.

Collections in the Kern basin and in McCloud River tributaries, California, uncovered well differentiated trout populations previously undescribed.

These specimens yielded much new information significant for understanding the taxonomy, speciation, and distribution of western trouts. It now appears certain that interior cutthroat trout once inhabited the Sacramento River system and a few populations still persist in isolated tributaries around Mt. Shasta. Dr. Donald Seegrist of the Rocky Mountain Range and Experiment Station, Berkeley, collected samples from several streams in the Mt. Shasta region in 1967. Except in isolated headwaters of remote areas, introduced rainbows have thoroughly hybridized with these relict cutthroat populations. Although as yet unrecognized with a scientific name, every effort should be made to determine the distribution of this unique trout in the upper Sacramento system and measures taken to insure their perpetuation. For most streams it is already too late.

Other interesting undescribed trout once occurred in the desiccating basins of southern Oregon. Dr. Carl Bond of Oregon State University believes some populations still exist and, hopefully, examination of this region can be undertaken in 1968.

Further Comments on the Bureau of Sport Fisheries and Wildlife List of Rare and Endangered Fish Species.

The Piute trout, *Salmo clarkii seleniris*, is typical of Lahontan cutthroat, *S.c. henshawi*, in every character except for the complete lack of spots on the body. This trout is certainly rare, but its present abundance and distribution is greater now than ever before. The native range of the Piute was restristed to about 4 miles of the headwaters of Silver King Creek above Llewellyn Falls, Alpine County, California. This trout was on the verge of extinction as a pure form in 1964 due to hybridization with introduced rainbows. Pure Piutes were found above barriers in tributaries to Silver King Creek and were introduced into Silver King Creek after the hybrids were eliminated. It has since been introduced into several new localities outside its original range.

Salmo clarkii henshawi, the Lahontan cutthroat, listed as endangered in the 1965 and 1966 lists exemplifies the difficulties of preserving pure cutthroat populations once man "helps out."

The main source of Lahontan cutthroat used in propagation is Heenan Lake, California. The Heenan Lake population was derived from near-by Blue Lakes. Lahontan cutthroat were stocked in Blue Lakes in 1864 but two subsequent introductions of rainbow trout into Blue Lakes resulted in hybridization and the present hatchery henshawi has a slight rainbow influence in a predominantly cutthroat genotype.

Pure Lahontan cutthroat populations are extremely rate. I know of 4 tiny isolated streams in California with small populations besides Independence Lake, California, and Summit Lake, Nevada. The Lahontan cutthroat is the most markedly differentiated of the many recognized subspecies of cutthroat trout. The lacustrine influence on its phylogeny is evident in the increased number of gillrakers (4-6 more than other subspecies). Their physiological adaptation to highly alkaline waters allow them to thrive in waters lethal to other trout - a cogent argument for the practicality of preserving diverse genotypes of our trouts.

The Humboldt River system of the Lahontan basin of Nevada, has a native trout differentiated from the typical Lahontan cutthroat by about 3 fewer gillrakers and 20 fewer scales. The Humboldt cutthroat appears to be a hardy trout, holding its own in several headwater tributaries in the Humboldt drainage in Elko County, Nevada.

The category peripheral is defined in the 1966 list to include those species and subspecies whose limited distribution in the United States is only a small segment of their total range but: "....special attention is necessary to assure retention in our nation's fauna." Yet the grayling, Thymallus arcticus, and the Atlantic salmon, Salmo salar, are considered in the respective categories of rare, and endangered in the 1966 list; these species clearly conform to the stated definition of peripheral.

The blueback trout listed as Salvelinus oquassa and the Sunapee trout as S. aureolus should, more correctly, be considered as subspecies in the Salvelinus alpinus complex.

A study in progress on the genus Gila of the Colorado River basin, based on the few specimens of Gila cypha and sparse data available, indicates the rare humpback chub is not sharply separated from the bonytail chub, G. elegans. Examination of many specimens of bonytail (elegans) and roundtail chub (G. robusta), collected over a wide range allows a more confident assessment of their systematic status. I can state with some authority that elegans and robusta, based on sympatric occurrence and constant differences in several characters, are two valid species and not "ecosubspecies" as considered in current literature. Probably, the now extremely rare Gila intermedia is also a valid biological species.

On May 4, 1967, I attended a meeting in Tempe, Arizona, with Drs. W. Minckley and J. Deacon. We discussed rare and endangered fishes of the Southwest. It is evident from the detailed data collected by Minckley and Deacon that several species, particularly the endemics associated with the lower Colorado River basin, although not presently rare or endangered by definition, are in need of constant surveillance. Whenever dams are built and sport fishing waters created, the red-sided shiner, Notropis lutrensis, is introduced by bait fishermen and within a few years the endemic cyprinids disappear. The introduction of mosquito fish, Gambusia affinis, has the same devastating effect on endemic cyprinodont fishes.

A need for life history studies is apparent from our lack of knowledge concerning the rapid increase in humpback suckers and squawfish in the large lakes created in the lower Colorado basin followed by the gradual disappearance of these species due to complete failure of reproduction.

Hopefully, from the accumulated information from many workers we can build a foundation of facts more accurately assessing the taxonomy and ecology of our fishes, providing a more realistic and judicious basis for setting guidelines and recommendations to assure the perpetuation of all our native "gene pool banks" representing all the natural diversity of our ichthyological heritage.

November, 1967

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PROGRESS REPORT: CUTTHROAT TROUT OF THE RIO GRANDE AND COLORADO RIVER BASINS

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June, 1968

Since the previous report summarizing information on Rio Grande cutthroat trout (January, 1967), several additional samples of cutthroat trout from the Rio Grande and Colorado River basins have been examined. All of the desired meristic counts are not yet completed for all specimens, but because of several urgent requests for information on these trout, this present report discusses some opinions based on current available data.

Essentially what was said about the description and nomenclature of Rio Grande trout is true for the Colorado River cutthroat. In 1872, E.D. Cope described "*Salmo pleuriticus*" in Hayden's Geological Survey of Wyoming. The name *pleuriticus* was based on specimens from the Green, Platte, and Yellowstone rivers, and from streams in Idaho and Montana. A type specimen was not designated, but because the trout of the other mentioned localities had already been named, the name *pleuriticus* became associated with the Green River of the Colorado basin. The distinguishing character of *pleuriticus*, according to Cope, was a ridge on the mid line of the skull. Unfortunately, this keel-like structure is an artifact due to the method of preservation which contracted the frontal bones. No one since Cope's time has discovered any characters really useful in distinguishing the cutthroat of the Colorado basin from other interior cutthroats.

The cutthroat was native to the Green and Colorado drainages as far south as the San Juan River, but was not found in the Grand Canyon and below.

Although every major drainage basin has a subspecies of cutthroat trout named for it, most of these subspecies do not form neat taxonomic units which can be segregated with any consistency on the basis of spotting, coloration, or meristic characters. The cutthroat trout native to the upper Missouri, Columbia, Bonneville, Colorado, and Rio Grande basins exhibit as much variability between populations within a single basin as they do between disjunct basins. The subspecies lewisi, utah, pleuriticus, and virginalis have some utility to designate the native trout of a particular area, but have little meaning concerning taxonomic distinction. This is true because many populations within each basin have been isolated from each other for thousands of years allowing independent divergence. Also, the proclivity of trout for headwater areas allows inter-basin transfers via headwater stream capture preventing rigid isolation between basins.

Systematic studies of cutthroat trout should provide information useful for the recognition of remnant populations of pure, indigenous genotypes. This is difficult to accomplish for specimens from the Rio Grande and Colorado basins because the distinguishing characteristics of the native trout are not known. It is possible to evaluate the complex of characters from a sample of a population for evidence of hybridization with rainbow trout. If the sample is judged to be pure cutthroat, then it can be compared with Yellowstone Lake cutthroat, the main source of introductions. Before the early years of this century, however, a variety of cutthroat trout, representing all the subspecies, were indiscriminantly mixed by fish culturists and widely distributed. Thus, although it can be stated with some authority that a population is pure cutthroat, it is virtually impossible to know if it represents the original trout of a given locality. If several samples are obtained from many disjunct localities in a drainage basin, and these samples all reveal a high degree of homogeneity, the assumption that they represent the original genotype can be made with some assurance. Of the present samples reported on in this paper, only the specimens from the Trinchera Ranch, collected from several localities in 1960 and 1967, meet this criterion. These specimens were well preserved and the spotting and coloration could be accurately determined. They represent a uniform group essentially of the genotype on which the name virginalis was based. The specimens from the Rio Chiquito, further downstream in the Rio Grande basin, also have identical spotting and coloration. These specimens and the ones from Peralta Canyon are pure cutthroats and probably represent the original populations of their area. The differences in the number of pyloric caeca and vertebrae can be attributed to slight genetic divergence from the upstream populations during a long period of isolation. The two specimens from Holden Prong, tributary to Animas Creek are judged to be pure cutthroats, but are so typical of a generalized interior cutthroat, it can not be assumed that they are truly native to the stream. The Indian Creek specimens, discussed more fully in the previous report, are pure cutthroats and are not from Yellowstone Lake, but are quite distinct in appearance from the Trinchera Ranch virginalis. Indian Creek may have been stocked by early settlers from the Pecos River basin. It would be important to examine samples of native cutthroats of the Pecos basin for comparison. Further collections of cutthroat trout from tributaries to the lower Rio Grande, Rio Mimbres and Pecos River should be most valuable in determining the systematic status of Rio Grande basin cutthroats.

It had been reported in the early literature that the Rio Grande and the Colorado basins both contained a fine spotted and a large spotted trout. All of the present specimens are medium to large spotted. I would be much interested in obtaining a sample of fine spotted cutthroat.

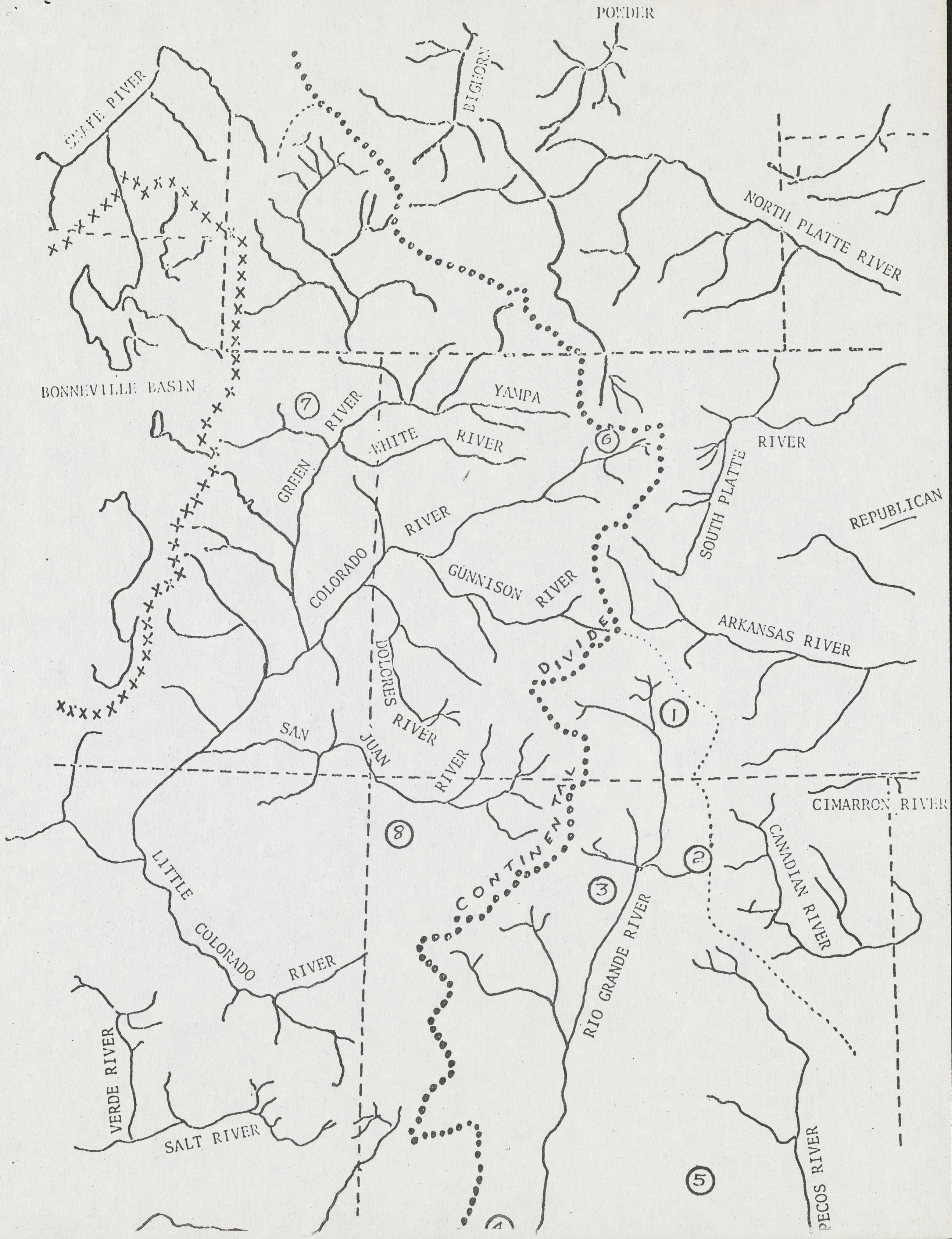
The three collections from the Colorado basin exhibit the diversity expected from such disjunct localities. The specimens from Stillwater Creek at the headwaters of the Colorado, have the smallest and most profusely distributed spots of any of the samples. They have the highest caecal and vertebral counts and the lowest gillraker number. These trout have the appearance of good cutthroats, but I expect there has been some small measure of rainbow introgression in this population. The specimens from Pole Creek on the Uinta Indian Reservation, tributary to the Green River, could be used as a model for the generalized interior cutthroat. I judge them to be pure cutthroat but will not venture an opinion concerning their origin. The collection from the South Fork of Wheatfield Creek, tributary of the San Juan River in San Juan County, New Mexico, is the southern-most population of cutthroats I have record of in the Colorado basin. The specimens appear as typical interior cutthroats in their spotting and coloration, but have a higher gillraker count. This gillraker count is similar to that found in Yellowstone Lake specimens and suggests an origin from an introduction of Yellowstone stock. These specimens will be investigated more thoroughly with the use of alizarin stain to compare basibranchial teeth development. Yellowstone trout have more basibranchial teeth than the typical interior cutthroat. These teeth are extremely minute and it is a tedious procedure to stain and count them.

It is possible that the higher gillraker count in the San Juan basin specimens is the result of an evolutionary lacustrine history in a Pleistocene lake. If this is the case then other populations in the upper San Juan basin should also indicate this lacustrine heritage.

In conclusion I would like to encourage further collections of supposed native cutthroat trout or information documenting their occurrence in the Rio Grande and Colorado River basins. Particularly, I am interested in finding fine spotted populations and populations in the lower Rio Grande - Pecos basins and from tributaries of the San Juan River. Also, as part of a comprehensive study of Rocky Mountain fishes, specimens of flannelmouth sucker, *Catostomus latipinnis* of the Colorado basin are desired.

Comparisons of samples of cutthroat trout from the Rio Grande and Colorado River basins with Yellowstone cutthroat and rainbow trout

LOCALITY	GILLRAKERS			VERTEBRAE			PYLORIC CAECA			SCALES, LAT. SERIES		
Rio Grande Basin	N	Range	$\overline{X}$	N	Range	$\overline{X}$	N	Range	$\overline{X}$	N	Range	$\overline{X}$
1. Several tributaries to Trinchera Crk. Trinchera Ranch, Costilla Co., Colo.	34	18-21	19.5	67	60-63	(61.7)	38	33-59	(46.0)	26	146-186	(164)
2. Rio Chiquito, Taos Co., New Mexico	18	17-22	19.7	18	60-62	(60.9)	20	28-42	(35.6)	17	154-180	(165)
3. Peralta Canyon, Sandoval Co., N.M.	3	18-19		6	61-63	(61.2)						
4. Holden Prong, trib. Animas Creek, Sierra Co., New Mexico	2	18-19		2	61-62		2	33-39				
5. Indian Crk (Tularosa basin) Otero Co., New Mexico	10	17-21	(19.0)	13	61-63	(62.1)	14	31-41	(36.7)	8	168-180	(174)
6. Colorado River basin. Stillwater Creek, Grand Co., Colorado	22	17-20	(18.2)	14	61-63	(62.4)	17	33-58	(47.2)			
7. Pole Creek, Uinta Indian Reservation, near Roosevelt, Utah				10	60-62	(61.6)	10	29-43	(36.1)			
8. S. Fk. Wheatfield Creek, San Juan Co. New Mexico	17	19-23	(21.0)	10	60-63	(61.3)	17	32-43	(37.4)			
Yellowstone Lake cutthroat	47	18-23	20.7	42	60-63	(61.6)	31	31-51	(41.2)	30	150-200	(170)
Typical rainbow trout		18-21	19.		62-64	63 - 63.5		40-70	(55)		120-140	(125-135)


POWDER
BIGHORN
SNAKE RIVER
NORTH PLATTE RIVER
BONNEVILLE BASIN
YAMPA
GREEN RIVER
WHITE RIVER
SOUTH PLATTE RIVER
REPUBLICAN
COLORADO RIVER
GUNNISON RIVER
ARKANSAS RIVER
DOLORES RIVER
DIVIDE
SAN JUAN RIVER
CONTINENTAL
CIMARRON RIVER
CANADIAN RIVER
LITTLE COLORADO RIVER
RIO GRANDE RIVER
VERDE RIVER
SALT RIVER
PECOS RIVER
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This note re: the discovery of greenback in Como Crk.

RARE AND ENDANGERED SPECIES: THE GREENBACK TROUT
Salmo clarki stomias Cope
Sources for Introductions and a Recent Discovery of a Probable Pure Population

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October, 1969

Investigations, collections and critical evaluation of specimens of eastern slope Colorado cutthroat trout revealed that the indigenous trout of this area, *Salmo clarki stomias*, is indeed rare and pure populations are virtually extinct.

Samples from numerous cutthroat trout populations were examined and the taxonomic data indicate that most present populations of cutthroat trout in the South Platte River basin are a mixture of two or more subspecies often introgressed with rainbow trout.

This report summarizes information on populations believed to most closely represent the original greenback trout and relates the recent discovery of what may be a pure population of this trout.

Comparison of museum specimens collected by D.S. Jordan in Colorado in 1889 and of representatives of other subspecies of cutthroat trout demonstrate that certain characters such as the pattern and size of spots, the number of vertebrae, scales and pyloric caeca and the degree of development of posterior gillrakers on the first gill arch can be useful for distinguishing *S. c. stomias* and to estimate the effects of hybridization between various subspecies of cutthroat trout and between cutthroat trout and rainbow trout.

The population of cutthroat trout in the headwaters of the Big Thompson River in Forest Canyon of Rocky Mountain National Park, appear to be "good" greenbacks. Despite known introductions of non-native cutthroat trout and possible contamination from tributary lakes, the characters of the Forest Canyon cutthroat trout closely approximate the synthesized, hypothetical "ideal" *S. c. stomias*. However, the vertebral counts of 31 specimens (60-62 mean of 60.6) is slightly higher than expected for pure *S. c. stomias* and probably is the result of slight introgression of introduced cutthroat trout genes into the native gene pool. The mean values of other subspecies of cutthroat trout typically are 61-62; rainbow trout are typically 63-64. Forest Canyon can be reached by a rather arduous hike from Trail Ridge Road in Rocky Mountain National Park. A Colorado Cooperative Fishery Unit project in 1965 took live specimens out of Forest Canyon by helicopter and transported them to the Leadville National Fish Hatchery. Attempts to obtain fertilized eggs from these trout were unsuccessful because the males and females did not mature in synchrony under hatchery conditions.

The remaining fish were moved from Leadville to the Uinta Indian Reservation, Utah, and stocked into a barren headwater tributary. It is not known yet if these Forest Canyon trout have successfully reproduced in their new environment.

Another essentially pure greenback population is found in the headwaters of North Boulder Creek above Island Lake (including Island and Goose Lakes) of the Boulder Municipal watershed, Boulder County, Colorado. These waters are isolated from upstream migration of introduced trouts and have long been protected from the general public and introductions. A record is known, however, of 5000 cutthroat trout stocked into Goose Lake in 1915. This introduction, probably of Yellowstone cutthroat trout, most likely resulted in a slight contamination of the original *S. c. stomias* genotype. The vertebral counts of 56 specimens from Island Lake and its tributary, North Boulder Creek, are 59-62 (60.4). If the sanction of the City of Boulder's water board can be had, the trapping of spawning trout from Island Lake could provide an abundant source of eggs for introductions of what can be considered an "almost pure" *S. c. stomias*.

Albion Creek (called North Boulder Creek on the U.S. Geological Survey topographical map of Ward, Colorado) a tributary to North Boulder Creek, via Silver Lake, also on the Boulder Municipal Watershed, probably had an uncontaminated population of *S. c. stomias* which is now probably extinct. The vertebral count of 39 Albion Creek cutthroat trout collected from 1957-1964 are 58-62 (60.1). It was known that eastern brook trout introduced into lakes on Albion Creek were rapidly expanding their population in the short section of stream (less than 1 mile) containing the native cutthroat trout. In August, 1968, the entire stream section was electrofished and 10 cutthroat trout were found among hoardes of eastern brook trout. It appeared obvious that the cutthroat trout was doomed in Albion Creek and these 10 specimens were transported alive and introduced into Black Hollow Creek, a tributary to the Poudre River, Larimer County, Colorado. The U.S. Forest Service and Colorado Game, Fish & Parks constructed a barrier dam on Black Hollow Creek in 1967 and the Colorado Cooperative Fishery Unit, eradicated the eastern brook trout above the barrier to create a barren section of stream to be used as a greenback sanctuary. Two surveys of Black Hollow Creek in 1969 failed to find any of the Albion Creek cutthroat trout or any evidence of reproduction. Efforts were renewed to find a pure greenback population to introduce into Black Hollow Creek.

On September 10, 1969, a small (about 1 cfs), unnamed stream tributary to North Boulder Creek, Boulder Co., flowing through the University of Colorado's Arctic and Alpine Research Institute in Roosevelt National Forest at about 9300 ft elevation was investigated and 6 specimens collected for examination. The taxonomic data from these specimens were typical of *S. c. stomias* and on September 22, sections of this stream were electrofished and 60 specimens from 3-11 inches were transported alive to Fort Collins. Eight of these were preserved for examination and 52 introduced into a vacant pond of the Colorado Cooperative Fishery Unit's bait rearing project on the Foothills Campus.

The combined data from 14 specimens are:

	Range	Mean
vertebrae	59-61	60.2
pyloric caeca	24-42	29.4
scales, lateral series	174-205	189.3
scales, above lateral line	46-53	48.4

Posterior gillrakers well developed on first arch. The low vertebral and pyloric caecal counts and the high scale counts are quite distinct from other subspecies of cutthroat trout and considerably different from rainbow trout. There is no indication in any character that this population has hybridized.

The topography of the drainage basin of the small, unnamed stream containing the probable *S. c. stomias*, is ideal for the preservation of a pure population. There are no lakes or ponds in the drainage basin. Lakes have always been a prime target for introductions of exotic trouts and a source of contamination of watersheds. The stream drops 500 ft in a distance of one half a mile before joining North Boulder Creek. Although this precipitous section was not personally observed, it seems certain that there are barriers against upstream migrations from North Boulder Creek, because of the absence of eastern brook trout, rainbow trout and hybrids in our collections. The inconspicuous nature of this tiny stream, mostly overgrown by dense vegetation, would not likely attract the attention of persons stocking trouts.

Originally it is likely that this stream was barren of fish above barrier falls. Probably miners or prospectors in the area carried greenback trout from North Boulder Creek around the turn of the century or earlier, prior to introductions of non-native cutthroat and rainbow trouts into that stream.

This stream is readily accessable via Forest Service road and the University of Colorado's Arctic and Alpine Research Station. It is reasonable to assume that another 100 trout could be taken by electrofishing next spring if a suitable site for introduction is available.

The 52 specimens now being held in the Cooperative Fishery Unit's pond on the Foothills Campus appear to be in good condition and no mortality has yet been observed. Plans are to hold them through the winter and introduce them into Black Hollow Creek, above the barrier, probably in April, 1970. These trout are extremely wild and feeding attempts have not been successful as yet. Live fly maggots, kindly made available by Dr. Byron F. Miller, Dept. of Avian Science, Colorado State University, will be introduced into the pond to stimulate active feeding. If this is successful, trout pellets will be added to their diet. It is hoped that growth and gonadal development can be increased to help insure successful reproduction and establish a self sustaining population in Black Hollow Creek.

FIELD TRIP NOVEMBER 22, 1969

Demonstration of Sampling Gear

The purpose of the demonstration is two fold: To practice the use of various sampling gear and to evaluate the information gathered in our investigation to predict the potential of this body of water to produce a trout fishery.

Some considerations pertinent to trout production are:

1. Water Quality

   a. Temperature regime throughout the year at various depths; might there be periods of lethal temperatures (above 75° F) at all depths where trout could live? What is the source of water supplying the pond? How will this influence summer and winter maxima and minima? How much of the total pond area, for how much of the year might contain optimum temperatures for trout growth (50-70° F)?

   b. Oxygen. Will the pond develop a thermocline in the summer with oxygen depletion in the hypolimnion? What are the possibilities of a winter-kill due to O_2 depletion under the ice? Of a summer-kill due to decomposing vegetation? Probable answers to these questions can be had from observation on the morphometry of the pond, its substrate and water source.

   c. Nutrients. Are there sufficient inorganic nutrients to produce high levels of biological productivity? By what pathways might these nutrients pass into trout via the food web? Could there be an excessive concentration of nutrients causing excessive algae and plant growths thus increasing the danger of summer-kill and winter-kill?

   d. Toxicity. Can pollution or pesticides get into the pond in harmful quantities.

Our water quality observations will not be quantitative; i.e., we will not do water analysis. We don't have the equipment available and at this time of year (November) the water quality will be ideal for trout - but the critical period for trout production will be in mid-summer; we can make an educated guess at what may happen then.

2. Competition, Predation, and Food Supply.

Hopefully, our sampling will reveal what species of fishes (if any) already inhabit the pond. How will populations of non-trout species interact with introduced trout?

A straightforward and obvious problem would be the presence of large predators such as largemouth bass or northern pike. Such large predators would make fingerling stocking quite wasteful (unless the object was to fatten the predator).

Actually, in most situations, more serious interference with realizing the maximum potential of a body of water to grow trout is from competitor species which compete for a common food supply or modify the environment by causing turbidity.

We must know something about the life history and food habits of the competitor species and something about the morphometry, substrate, limnology and food resources of the pond to estimate the degree of competition to be expected between the trout and the "wild" species. For example, carp are not usually compatible with trout - not because they eat trout but because they scour the bottom, rooting out benthic organisms, destroying vegetation and habitat for valuable trout food organisms. This activity results in muddy water reducing photosynthesis and raising maximum summer temperatures. If, however, the mud bottom littoral zone of a pond is small or non-existant and the major zooplankton - then the negative effects of carp-trout interaction would be reduced and it may be possible to achieve a high degree of success from a plant of small trout on top of an established carp population. Species such as crappie and certain minnows like the creek chub would be serious competitors for zooplankton.

There are some fundamental biological principals which tie all the factors together, helping to develop concepts for an overall evaluation.

Consider the whole aquatic ecosystem; the energy flow begins (disregarding chemosynthetic bacteria) with the fixation of the sun's energy by green plants (algae and higher plants), from here the energy flow proceeds by various and devious pathways (rotifers, protozoa, crustacea, insects, annelids, mollusks, small fish, etc.) throughout the whole aquatic environment from burrowing organisms in the benthic zone, crawling and attached forms, palagic, free swimming species and organisms associated with the surface film. Now, the basic aim is to most effectively channel this energy flow of the food web into desired fish flesh - in this case, introduced trout. How much of this energy, potentially available to trout, will be diverted into undesired species? Would it be economically justified to poison all fish species and manage the pond for trout only? What is the probability of a complete kill? How could undesired species re-enter the pond?

Based on the natural food supply, how much trout production can be expected with "wild" fishes present? How much increase would be expected if these species were removed?

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RARE AND ENDANGERED SPECIES REPORT: THE NATIVE CUTTHROAT TROUT OF THE COLORADO-GREEN RIVER BASIN, *Salmo clarki pleuriticus*

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December, 1970

In a previous report (Progress Rept: cutthroat trout of the Rio Grande and Colorado River basins. Colo. Coop. Fish. Unit., 1968), I reviewed the systematic status of the Colorado-Green River cutthroat trout pointing out that the total information in the literature is too vague to provide a firm basis for recognition of the cutthroat trout known as *Salmo clarki pleuriticus* allowing its separation from other subspecies of *S. clarki*.

The great amount of natural isolation found between various populations of this cutthroat trout, particularly between those associated with tributaries of the Colorado River and those of the Green River (another salmonid fish, *Prosopium williamsoni*, is native only to the Green River division of the Colorado system) would suggest that great taxonomic variability exists in this subspecies and no combination of characters will serve to separate all the native cutthroat trout populations of the Colorado-Green River basin from other subspecies of other major drainages. However, as a starting point it was decided to learn more about the native cutthroat trout of the upper Green River drainage because that is the type locality for the specimen on which the name *pleuriticus* is based (near Fort Bridger, Wyoming). The plan of study consisted of examining and recording data from samples of possible pure populations of cutthroat trout from the upper Green

River basin and then compare and evaluate the data for consistency between samples which would indicate that these samples represent remnants of the cutthroat trout once inhabiting the whole upper Green River watershed.

Collections made in 1969 and 1970 by Wyoming Game and Fish Dept., U.S. Forest Service and U.S. Bureau of Sport Fisheries and Wildlife were examined and pertinent data is presented in Table 1. The amount of material is not sufficient to arrive at an absolutely authoritative opinion on the taxonomic diagnosis of *S. c. pleuriticus*, but it does indicate the range of variability and allows a basis for judgement on probably pure populations. From this data a composite, hypothetical trout can be deduced approximating a representative example of the original native cutthroat trout of the Green River drainage.

Based on these recent collections from the Green River drainage, *S. c. pleuriticus* is characterized as follows: Large, round, pronounced black spots, typically concentrated posteriorly on the caudal peduncle and anteriorly above the lateral line with similar spots on the dorsal, adipose and caudal fins - the spotting pattern is somewhat similar to most other subspecies of interior cutthroat trout. Colors, particularly in the spawning season, are generally brilliant, almost gaudy, often with crimson suffusing the whole ventral region, a pink-red tinge on the side overlaying a bronze-gold background - typically males exhibit brighter colors than females. I noted similar coloration in the Arkansas-Platte greenback cutthroat trout (*S. c. stomias*) but it does not appear to be so highly developed in Yellowstone Lake cutthroat trout and other subspecies. Vertebral counts, 61-63, typically 62; gillrakers, typically 19-20; pyloric caeca, typically 35-40 but this can be a highly variable character within the same subspecies; scales above lateral line, typically 38-50; scales in lateral series, 170-200 - scale counts are also typically highly variable.

On the basis of these meristic characters, on uniform appearance and other characters such as number of pelvic rays and development of basibranchial teeth, the first 3 samples listed in Table 1 - Douglas Creek, Little West Fork and North Fork of Beaver Creek - are judged to most probably represent essentially pure populations of S. c. pleuriticus. The physical isolation of the populations in these streams from which the samples were drawn is not complete, however, and I suspect that a very small amount of rainbow trout and/or Yellowstone cutthroat trout introgression could have infiltrated into these populations. Although these streams are geographically remote, the three samples share strong similarities with each other, suggesting that they are good representative remnants of the once widely distributed native trout of the upper Green River area. The remaining samples indicate in one or more characters that some hybridization with rainbow trout and/or other subspecies of cutthroat trout has influenced their genotype. Trapper's Lake is a major source of cutthroat trout eggs for the state of Colorado. Large numers of Yellowstone Lake cutthroat were formerly introduced into Trapper's Lake and it is the general belief that the native genotype has been largely replaced by Yellowstone fish. My evaluations indicate that this is not true. Probably due to several thousand years of existence in Trapper's Lake, the native genotype is somewhat unique and apparently is highly adapted to conditions of Trapper's Lake so that hybridization has been resisted by negative selection against hybrids.

It is important that federal and state agencies take action to save remnant populations of S. c. pleuriticus. Pure populations are rare. The attached form was prepared for the rare and endangered species list of the International Union for the Conservation of Nature and the U.S. Department of the Interior. The major obstacle to make a valid claim for a rare status of S. c. pleuriticus is that so little was known of its taxonomy - how could they be recognized if they were found? A purpose of this paper is to provide some basis to answer that question. The introduced rainbow and brown trouts are now the major trout species in the Green River and its larger tributaries. Introduced eastern brook trout have crowded out the native cutthroat trout from many of the smaller tributaries. In the few areas where a trout occurs with predominantly cutthroat trout phenotype - critical examination reveals most of these are rainbow x cutthroat hybrids or hybrids between the native cutthroat trout and introduced Yellowstone or Snake River subspecies. Pure populations of the original S. c. pleuriticus are indeed rare. Rapid action will be necessary. The population in the Little West Fork in the Wasatch National Forest, Utah, will almost certainly be lost unless a barrier is constructed to isolate the stream from upstream migration. A dam is under construction on the Black's Fork which will back up water to the lower reaches of the Little West Fork and the new reservoir will be stocked with massive numbers of rainbow trout, a situation which inevitably leads to hybridization. The streams on BLM land are in severely overgrazed and eroded country resulting in very limited habitat - a highly precarious situation that will eventually eliminate the cutthroat trout unless better land use practices and habitat improvement are instituted soon.

It is hoped that remnant populations of S. c. pleuriticus receive the necessary protection of federal and state agencies, not only for the esthetics of preserving our biological heritage, but also to learn more about their ecological qualities and specializations with a view toward their potential in future fishery management programs.

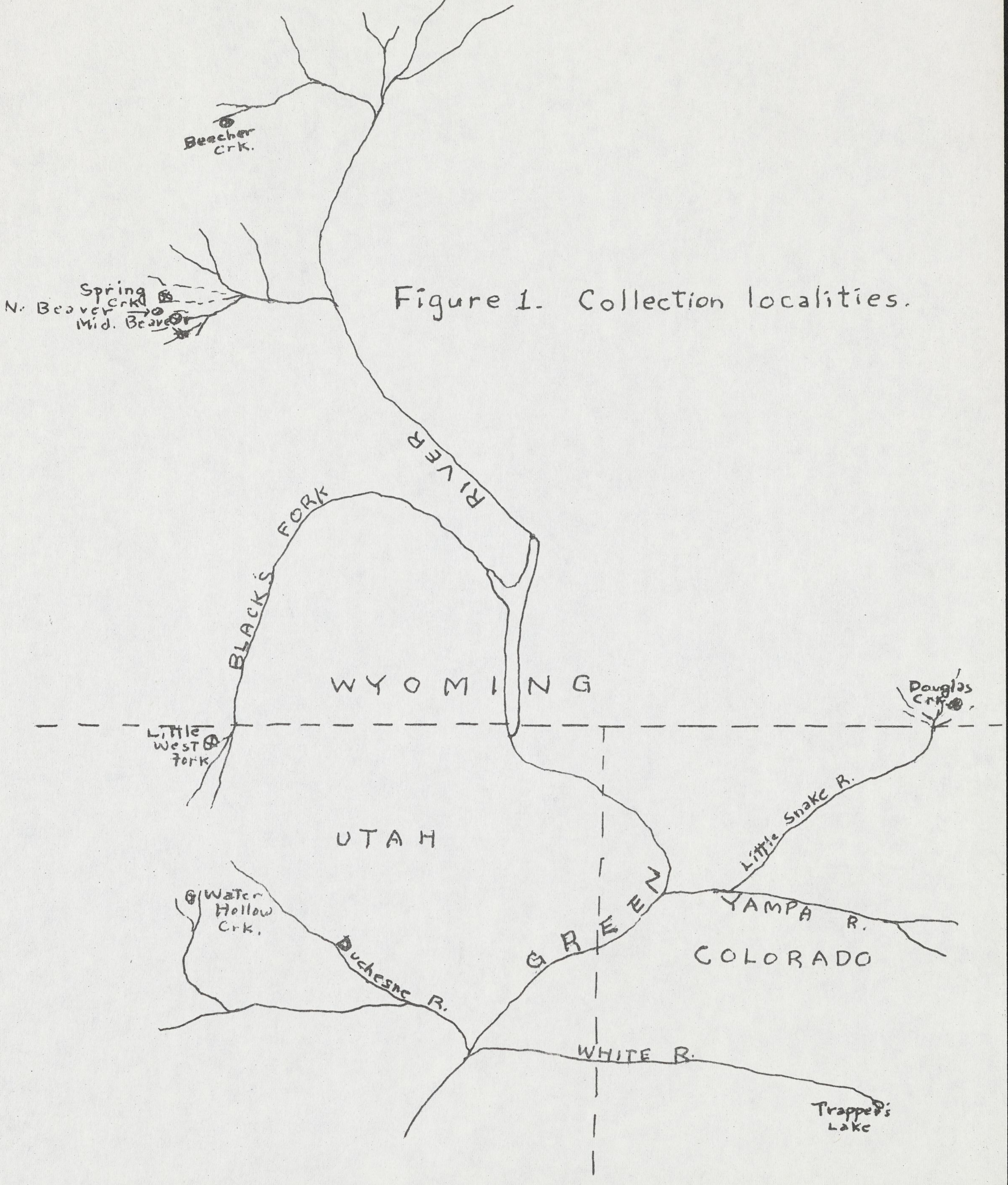

Figure 1. Collection localities.

TABLE 1. Some meristic characters of samples of Green River cutthroat trout.

Locality and Federal Agency Controlling Land	Vertebrae	Gillrakers	Pyloric caeca	Scales above lateral line	Scales, lateral series
Douglas Creek, Wyoming - U.S.F.S.	N = 41 61-63 (62.0)	N = 14 18-21 (19.4)	N = 14 31-42 (37.1)	N = 14 38-44 (41.4)	N = 14 159-197 (178.6)
Little West Fork Black Fork Utah - U.S.F.S.	N = 41 61-63 (62.2)	N = 14 18-21 (19.1)	N = 10 32-41 (37.4)	N = 10 39-47 (43.7)	N = 10 164-204 (185.4)
North Fork Beaver Creek, Wyoming - B.L.M.	N = 14 60-62 (61.4)	N = 15 18-22 (20.2)	N = 15 35-44 (39.4)	N = 15 42-52 (47.0)	N = 15 163-197 (182.3)
Middle Fork Beaver Creek, Wyoming - B.L.M.	N = 4 62-64 (62.8)	N = 5 19-20 (19.4)	N = 5 35-42 (39.2)	N = 5 38-46 (42.4)	N = 5 163-188 (173.4)
Spring Creek, Wyoming - B.L.M.	N = 8 62-64 (63.3)	N = 10 18-21 (19.4)	N = 10 34-42 (38.3)	N = 8 41-49 (44.8)	N = 8 163-190 (174.8)
Beecher Creek - B.L.M.	N = 5 60-63 (61.6)	N = 10 18-21 (19.4)	N = 10 40-52 (44.5)	N = 10 43-49 (46.0)	N = 10 136-180 (161.3)
Water Hollow Creek, Utah - U.S.F.S.	N = 22 60-64 (62.1)	N = 10 18-20 (18.7)	N = 10 29-43 (33.0)	N = 10 39-45 (41.4)	N = 10 162-182 (170.1)
Trapper's Lake, Colorado - U.S.F.S.	N = 24 59-63 (60.5)	N = 15 18-22 (20.1)	N = 10 32-41 (37.4)	N = 10 39-47 (43.7)	N = 10 162-204 (185.4)

RARE AND ENDANGERED SPECIES REPORT: THE BONNEVILLE CUTTHROAT TROUT, *Salmo clarki utah*

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Introduction

Detailed information concerning the classification of the cutthroat trout native to the Bonneville basin is virtually non-existent. When requested to render decisions on the relative pureness of certain populations, it became apparent to me that there is no valid information in the literature pertaining to diagnostic characters possessed by *S. c. utah* useful for authoritative recognition. Can the native trout of the Bonneville basin be readily separated from other subspecies of cutthroat trout by a combination of characters?

Examination of ancient museum specimens and recent specimens from the western part of the basin indicates that two distinct forms of cutthroat trout may be native to the Bonneville drainage in Utah and Nevada. The typical *S. c. utah*, indigenous to the Bear, Jordan, Provo, and Sevier river drainages is virtually indistinguishable from the widespread *S. c. lewisi* of the upper Missouri and Columbia river basins. A trout, evidently once native to the Snake Valley segment of the Bonneville basin and now found in a few small streams on Mt. Wheeler and Mt. Moriah appears to be consistently differentiated from *S. c. utah* by some meristic and morphological characters and in the profuse development of basibranchial teeth.

Historical Review

Suckley (1861) wrote: "A variety of the *Salmo virginalis* occurs in Lake Utah, a large sheet of fresh water about fifty miles south of Salt Lake City. The fish are less spotted than those caught in the mountain streams near by, and attain a much larger size. For this variety or kind we will, for the present, apply the provisional name of *Salmo utah*." Suckley intended the name *utah* only for the cutthroat trout of Utah Lake, whose distinctive characters were probably almost wholly a reflection of direct environmental influence caused by the conditions of Utah Lake, and not due to genetic differentiation.

Although Suckley's description of "*Salmo utah*" is inadequate to separate *utah* from any other form of cutthroat trout, the published account of *S. utah* fixes the name *utah* as the earliest name applied solely to trout of the Bonneville basin. Current practice now includes all cutthroat trout in a single species, *Salmo clarki*, with subspecies recognition designating major drainage basins or geographical areas. The Bonneville cutthroat trout is usually listed as *Salmo clarki utah*, but the fact remains that an adequate description establishing the validity of *utah* allowing its separation from other subspecies has never been published.

There are now almost insurmountable obstacles for conducting a definitive taxonomic study on the native trout of the Bonneville basin. Massive introductions of rainbow trout, *S. gairdneri*, throughout the basin along with alteration and degradation of habitat has led to the virtual elimination of cutthroat trout from most of their original range. More insidious, however, from the point of view of systematic research, has been the promiscuous mixing of different forms (or subspecies) of cutthroat trout to an extent that when a remote and isolated population of cutthroat trout is found today - how can it be known if it represents the original Bonneville cutthroat trout or an introduced Colorado River trout (S. c. pleuriticus), Yellowstone Lake trout (S. c. lewisi) or a combination of two or more races of cutthroat trout? Utah Fish and Game Department, as other states and federal agencies propagating cutthroat trout historically have not attempted to maintain the integrity of populations native to specific geographical areas. Eggs are taken from readily available sources. In Utah, cutthroat spawn is mainly from Strawberry Reservoir where the original trout would have been S. c. pleuriticus, but subsequent introductions of Yellowstone Lake cutthroat trout and intensive stocking of rainbow trout certainly has influenced the genotype of the trout now widely stocked in Utah as "native" trout in both the Bonneville basin and the Colorado River drainage.

Miller (1950) stated: "S. clarki utah of the Bonneville basin of Utah and Idaho is believed to be extinct." Cope (1955) also believed the native Bonneville cutthroat trout was extinct. Because of the abundance of small, isolated streams, in remote areas of the Bonneville basin, it seems likely to me that some pure populations of the original Bonneville cutthroat trout should persist. But the question again is raised - how would they be recognized if they are found?

Systematic Status

To answer the question concerning possible uniqueness possessed by the original trout of the Bonneville basin, I examined and recorded data on more than 30 museum specimens collected from 1872 to 1915 from various parts of the Bonneville basin. This data was then compared with data on other subspecies of cutthroat trout to evaluate the degree of differentiation present in the original Bonneville trout and to examine the diagnostic value of particular characters. My conclusions are that there is nothing really unique about S. c. utah - it appears to be quite typical of interior cutthroat trout in general such as the forms grouped under S. c. lewisi and S. c. pleuriticus. There is a trend for lower scale counts in S. c. utah (typically 145-180 vs. 160-200) and higher vertebral counts (61-65 typically 62-63 vs. 61-62 in most other cutthroat trout) but there is broad overlap in these characters.

This lack of obvious differentiation in Bonneville cutthroat trout is somewhat surprising considering the thousands of years of isolation in a large lacustrine environment afforded by the geologic history of the Bonneville basin and Pluvial Lake Bonneville. Other Bonneville fishes exhibit a high degree of endemism. The Lahontan cutthroat trout, S. c. henshawi, theoretically at least, under similar geological and evolutionary histories reveal marked differentiation, possessing 4-6 more gillrakers than is found in other groups of cutthroat trout.

In 1959 I made two collections of cutthroat trout of probably Bonneville origin, outside the basin. A sample was collected from a population of reputed "native" trout from the Virgin River drainage, in the headwaters of Reservoir Canyon near Pine Valley, Utah. I was interested in these trout because the Virgin River drainage was not known to have native trout. If trout were native to the Virgin River, on zoogeographical grounds, they should have been derived from the Gila trout or Apache trout of the Gila River system and not from cutthroat trout. The trout in the headwaters of Reservoir Canyon are typical interior cutthroat trout. They are not derived from Yellowstone Lake cutthroat trout, however, and the scale counts appear typical of S. c. utah. Evidently these trout were transplanted by the early Mormon settlers of the Pine Valley area from the headwaters of the Sevier River of the Bonneville basin and probably represent one of the few remaining pure populations of the original Bonneville cutthroat trout. Below barrier falls in Reservoir Canyon, the population consists of rainbow x cutthroat hybrids.

The other population first investigated in 1959 is found in Pine Creek, on Mt. Wheeler, White Pine Co., Nevada. Pine Creek drains into Spring Valley. Hubbs and Miller (1948) mentioned that some originally barren streams in desiccating basins west of the Bonneville basin in Nevada were stocked with trout carried over from Trout Creek, Utah (in the Snake Valley section of the Bonneville basin). Expecting to find a population of S. c. utah in Pine Creek, I was surprised and baffled to encounter a cutthroat trout quite unlike any other I had ever seen. The long head and jaw positioned on a deep body with a short caudal peduncle presents an odd "chunky" appearance. The spotting pattern is more uniformly distributed over the body and not so concentrated posteriorly as in S. c. utah. The Pine Creek trout have higher gillraker numbers and a profuse development of basibranchial teeth - up to 50 or more can be detected after alizarin staining, whereas S. c. utah and other cutthroat trout typically have 1-15 such teeth.

There is a strong probability that some of the extreme phenotypic differentiation apparant in the Pine Creek trout is a non-genetic influence induced by living in the very small, limited habitat of Pine Creek as it tumbles off the slopes of Mt. Wheeler. The spotting pattern and particularly the gillraker number and basibranchial teeth development, differentiating these trout from S. c. utah, can be considered as virtually wholly under genetic control. This assumption is supported by comparison of descendants of Pine Creek trout introduced into Hampton and Goshute creeks (also in White Pine Co., Nev.). There is no doubt that the cutthroat trout in Pine Creek are genetically differentiated from S. c. utah and other cutthroat trout. The level of differentiation would warrant recognition as a new subspecies of Salmo clarki. More important, however, than taxonomic classification, is the evolutionary basis justifying this classification. Does the Pine Creek population represent a geologically recent local divergence in a single isolated stream (the unknown parent stream from which the original stock was introduced) or from the trout in a group of streams connected to Snake Valley which diverged rapidly after the desiccation of Lake Bonneville and the isolation of Snake Valley from the rest of the Bonneville basin? Or, do they represent a more ancient divergence in the cutthroat trout evolutionary lineage which co-existed with S. c. utah in Pluvial Lake Bonneville, but were then restricted to the Snake Valley area after the desiccation? I have found two examples where two forms of cutthroat trout are native to the same basin. In the Lahontan basin, S. c. henshawi is the native trout and even after several thousand years of isolation in the various river systems (Truckee, Carson and Walker) all S. c. henshawi populations remained practically identical. In the Humboldt River drainage of the Lahontan basin, however, another form of cutthroat trout is indigenous, and is consistently differentiated from S. c. henshawi by 2-4 fewer gillrakers and about 20 fewer scales in the lateral series. These two forms must have also been present when Pluvial Lake Lahontan allowed free communication between all the now isolated river systems, and in some unknown manner, genetic segregation was maintained between the two forms. At present, in the upper Snake River in Wyoming, two forms of cutthroat trout maintain genetic segregation. In the very headwater area, above Jackson Lake, and downstream from the present Palisades Reservoir site, a typical, large-spotted form is found - probably with very close affinities to S. c. utah of the Bonneville basin. Between these areas inhabited by the large-spotted cutthroat trout, a distinctive, fine-spotted form dominates the fishery of the Snake River. How do these two distinct types of cutthroat trout remain reproductively isolated in the essentially continuous environment of the upper Snake River? Why haven't they hybridized into a single homogeneous population? These two examples are cited to indicate that the possibility of two forms of cutthroat trout once co-existing in Bonneville basin and in Pluvial Lake Bonneville is not too remote. Unfortunately, the Pine Creek population (and their descendants in Hampton and Goshute creeks) are the only pure populations of this unique cutthroat trout known to exist. However, two specimens from Lehman Creek (on the Bonneville side of Mt. Wheeler) in the University of Michigan collection are identical with Pine Creek specimens and recent collections of trout from Mill Creek and Hendrys Creek, although slightly influenced by hybridization with introduced rainbow trout share basic similarities with the Pine Creek trout to support the assumption that this form of trout was indigenous to all the streams of the Snake Valley region. Mr. Frank Dodge, Biologist with the Nevada Fish and Game Department, and Mr. Don Cain, Wildlife Specialist with the B.L.M. (Ely, Nevada) have diligently collected specimens for this investigation. They checked Birch Creek, Trout Creek and Granit Creek, all tributary to the Snake Valley, Utah, on December 3, 1970, but found only rainbow trout. Before more authoratative conclusions can be made on the range of variability of the diagnostic characters of the Snake Valley trout and a definitive statement made on its classification, samples from more pure populations will be necessary. The most likely area where such populations may be found, is in the isolated streams in the Deep Creek Range on the Goshute Indian Reservation.

According to the testimony of an "old timer" cited in a letter from Ted Frantz of Nevada Fish and Game to Dr. R.R. Miller, University of Michigan, written October 19, 1953, only Hendrys Creek originally contained the native trout and several creeks, including Lehman Creek, were stocked with trout from Hendrys Creek. Thus, it is possible that all the trout samples included in Table 2 were ultimately derived from Hendrys Creek. It is recorded that Yellowstone cutthroat trout and rainbow trout, particularly the latter, have been stocked in Hendrys, Mill and Lehman creeks. All of the specimens collected in 1970 from Hendrys and Mill creeks, phenotypically resemble pure cutthroat trout and bear a strong similarity to Pine Creek specimens. The meristic data, however, particularly the lack of basibranchial teeth in several Hendrys Creek specimens and higher vertebral counts and lower gillraker number in Mill Creek trout, indicates that these populations have been introgressed with non-native trout. If the lower mean values for gill-rakers, basibranchial teeth and pyloric caeca in the Pine Creek stock introduced into Hampton and Goshute creeks is a reality and has a genetic basis, it is probably due to the "Founder's Principle". That is, the few individuals used to establish the new populations in these creeks did not represent the genotype producing the modal values found in the Pine Creek population, but were more towards the lower extreme of vari-ability for these characters.

Summary

The first group of specimens in Table 1, collected from 1872-1915 from the Salt Lake and Utah Lake drainages appear to be a relatively uniform group and can be used to characterize *S. c. utah*. They have large, round spots, typically more concentrated posteriorly, and anteriorly the spots are mostly above the lateral line. Such a spotting pattern is quite typical of interior cutthroat trout in general. Compared with neighboring subspecies, *S. c. lewisi* and *S. c. pleuriticus* I find only slight differences. The scale counts average about 10-20 fewer in *S. c. utah* and the vertebral count is about one more than in the typical *lewisi* and *pleuriticus*. The large spotted cutthroat trout in the upper Snake River (and Yellowstone Lake) although called *S. c. lewisi* on geographical grounds, probably share closer affinities with *S. c. utah* than they do with *S. c. lewisi* of the Columbia and Missouri river systems. The other samples indicate some variability was present among Bonneville basin trout, as would be expected after several thousand years of isolation, but none appear as extremely differentiated as the Pine Creek population, representing the Snake Valley trout. Besides the unusual morphology, the Snake Valley trout have fewer scales, more gillrakers, many more basibranchial teeth and a more uniform distribution of spots on the body. Based on the present material and state of knowledge, I can not state with any authority if the distinctive traits of the Snake Valley trout ultimately rests on a single differentiated population from one stream (Hendrys Creek?) or if this form of trout was once the native trout of the whole Snake Valley (and probably once co-existing in Lake Bonneville with *S. c. utah*). If the latter alternative is the case, then this trout should be described as a new subspecies. Hopefully, future collections, particularly from the Goshute Indian Reservation will help to provide the necessary information.

Considering new techniques which may yield valuable information on the origin and affinities of the Snake Valley cutthroat trout, I would like to obtain karyotypes of the Pine Creek stock and other possibly pure populations, to see if they are typical of other interior cutthroat trout so far examined - a diploid complement of 64 chromosomes with a total of 106 arms. At present biochemical taxonomy would have limited application, perhaps assessing relative pureness of populations by gene frequency data, but for a clearer picture of evolutionary affinities more must be known about variability in specific proteins in several forms of cutthroat trout - information that is not now available (See Behnke, 1970, for more details on these techniques and their applicability to systematic studies of western North American *Salmo*).

Salmo clarki utah is listed as a rare fish in the International Union for the Conservation of Nature's Red Data Book, vol. 4, 1969 (See attached sheet). In the U.S. Dept. of Interior's Red Book of Rare and Endangered Species (1968) *S. c. utah* is listed as "status undetermined." Taxonomically, I would agree, *S. c. utah* has a nebulous status. There is such broad overlap of characters between most of the recognized subspecies of cutthroat trout, that they lack validity as taxonomic units. There is no doubt, however, that pure, native populations of Bonneville cutthroat trout (both forms) are extremely rare and should receive all possible protection. For the preservation and management of rare forms of native trouts, the typological approach, treating them as taxonomic units can be unwise. More correctly the cutthroat trout species represents an array of unique genotypes, and each genotype may have special attributes, so that a single subspecies such as *S. c. utah* may contain a large amount of genetic variability and ecological divergence. Undoubtably, the lacustrine population of native cutthroat trout persisting until relatively recent times in Bear Lake, Utah - Idaho had special physiological and ecological adaptations shaped by the environment of Bear Lake - and superimposed on a longer evolutionary history in Lake Bonneville. I doubt that any other population of S. c. utah could be used to precisely duplicate the life history and behavior of the original Bear Lake cutthroat trout.

It can be concluded that the Pine Creek population represents a pure form of the Snake Valley form of Bonneville cutthroat trout, but a pure population of S. c. utah can not be cited with authority; probably the population in the headwaters of Reservoir Canyon, near Pine Valley is the most likely choice.

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TABLE 1. Meristic variation in samples of native Bonneville basin cutthroat trout

Locality	Vertebrae			Gillrakers			Scales above lateral line			Scales, lateral series			Basibranchial teeth			Caeca		
	N	Range	$\bar{X}$	N	Range	$\bar{X}$	N	Range	$\bar{X}$	N	Range	$\bar{X}$	N	Range	$\bar{X}$	N	Range	$\bar{X}$
Salt Lake-Utah Lake drainages coll. 1872-1915	19	61-65	63.0	19	17-22	19.7	19	32-43	37.8	10	150-186	165.0	14	3-13	7.9			
Isolated trib. to Little Cottonwood Cr., Salt Lake Co., 1967	4	62-63	62.2	10	18-22	19.1	5	34-37	35.4	5	148-163	154.4	3 more than 100 mm	7-12	9.3	15	27-39	32.1
Bear R., 1915 Fish Haven, Idaho				7	18-19	18.7	7	37-44	40.3	7	157-178	168.4	one no teeth 7	0-10	4.0			
Thomas Fork, Bear R., Wyoming. 1968	6	61-63	62.0	7	18-20	19.1	7	35-42	38.4	7	142-173	160.9	7	2-7	4.4	7	31-42	36.0
Beaver R., disrupted trib. Sevier R., 1872	8	61-63	62.3	8	20-21	20.5	7	37.40	38.9				one no teeth 8	0-19	8.6			
Mammoth Cr., trib. Sevier R., 1915				5	19-23	20.8	5	37-39	38.0				5	2-3	2.4			
Asay Cr., near Hatch, trib. Sevier R.	2	63,63		2	18,20		2	39,40		2	149,158		2	4,5			27,36	
Reservoir Canyon near Pine Valley (probably introduced from Sevier drainage.)	31	61-64	62.1	30	17-21	19.3	30	38-46	41.5	30	139-182	159.3	2 no teeth 31	0-9	4.3			

TABLE 2. Meristic variation in Pine Creek and Snake Valley cutthroat trout

Locality	Vertebrae			Gillrakers			Scales above lateral line			Scales, lateral series			Basibranchial teeth			Caeca		
	N	Range	$\overline{X}$	N	Range	$\overline{X}$	N	Range	$\overline{X}$	N	Range	$\overline{X}$	N	Range	$\overline{X}$	N	Range	$\overline{X}$
Pine Cr., Nev., 1959, 1970	37	60-64	62.3	41	19-23	21.4	29	37-44	39.1	35	133-156	142.1	40	13-55	30.1	10	30-47	39.7
Hampton Cr. (Pine Cr. stock), 1970				10	20-21	20.5	10	39-43	41.0	10	141-157	149.8	10	17-27	22	10	29-36	33.1
Goshute Cr., (Pine Cr. stock), 1970				10	19-21	20.1	10	38-52	40.2	10	135-160	143.1	10	11-30	19	10	31-37	34.6
Hendrys Cr., extreme head-waters, 1970				7	20-22	20.9	7	41-44	42.1	7	146-175	155.3	7	4 no teeth 3 with 13, 15, 16		7	33-46	39.0
Hendrys Cr., downstream, 1970	9	61-63	61.9	10	18-22	20.5	7	36-42	39.7	8	142-160	152.1	10	7 no teeth 3 with 1, 1, 6		8	35-47	41.0
N. Mill Cr., 1970	6	63-64	63.5	9	18-21	19.7	5	39-45	42.0	5	150-169	161.0	5	3-30	20	10	39-51	43.2
Lehman Cr., 1938	2	62, 62		2	20, 21		2	42, 42		1	148		2	17, 20				

Common name: Bonneville cutthroat trout | Scientific name: *Salmo clarki utah* Suckley

Order: Salmoniformes | Family: Salmonidae

Distinguishing characteristics:

Medium-large spots; scales in lateral series, 145-180; vertebrae 61-64; gillrakers 18-21.

Present distribution:

Pure populations unknown; the cutthroat trout population in the headwaters of Reservoir Canyon, near Pine Valley, Utah, in the Virgin River drainage may be the result of introductions from the Sevier River system of the Bonneville Basin.

Former distribution:

Bonneville basin - Utah, Nevada. There is evidence that two somewhat distinct forms of cutthroat inhabited the Bonneville basin. The name *utah* would apply to the populations of the Provo, Jordan, Bear, and Sevier river systems. Specimens from Mt. Wheeler on the western rim of the basin appear more similar to the cutthroat trout of the Humboldt River system, Nevada.

Status: Endangered?

Estimated numbers: Unknown; perhaps 200-300 trout inhabit the headwaters of Reservoir Canyon; rainbow-cutthroat hybrids occur in lower reaches.

Breeding rate in wild/Fecundity: Unknown

Reasons for decline:

Alteration of habitat, water diversion, hybridization with introduced rainbow trout and exotic subspecies of cutthroat, competition with eastern brook trout.

Protective measures taken: None

Measures proposed:

Continued systematic study to determine the relationships of present existing cutthroat populations and to investigate the differentiation within the basin.

Number in captivity: None

Breeding potential in captivity: Unknown

Remarks: The Bonneville cutthroat is so similar to the widely propagated Yellowstone Lake cutthroat (S.c. lewisi) that a large sample is necessary to distinguish them with any authority. The state of Utah propagates Strawberry Lake trout as the "native" trout in the Bonneville Basin. This population was originally Colorado River cutthroat (S.c. pleuriticus) but almost certainly is now a mixture of S.c. pleuriticus x S.c. lewisi and S. gairdneri.

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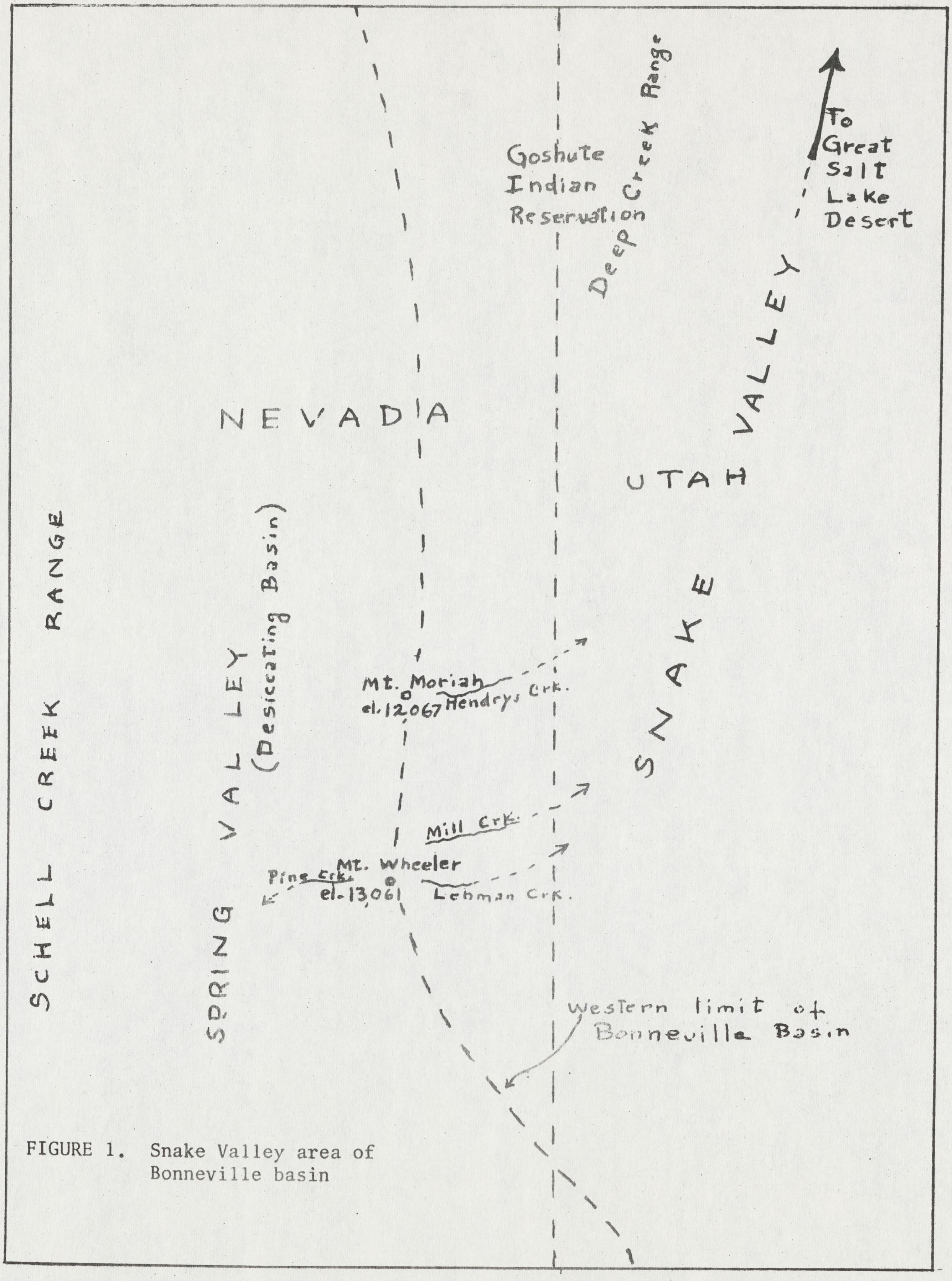

FIGURE 1. Snake Valley area of Bonneville basin

[ca. 1970]

THE LAKE OHRID TROUT, *SALMO LETNICA*,
AND ITS POTENTIAL AS A NEW NORTH AMERICAN SPORT FISH

Systematic Position: *Salmo letnica* (Karaman) is endemic to a single body of water - Lake Ohrid, on the Yugoslavian-Albanian border. Lake Ohrid has a surface area of 348 km^2 and is the oldest lake in Europe. Its lacustrine continuity from pre-glacial times has resulted in a unique composition of relict fauna (Stankovic, 1960).

Salmo letnica resembles the brown trout, *S. trutta* L.; the major distinctions are that *S. letnica* typically have fewer vertebrae and more numerous pyloric caeca and gillrakers than *S. trutta*. The chromosome complement of *S. letnica* is similar to *S. trutta*. I have discussed the evolutionary relationships of *S. letnica* in a previously published paper (Behnke, 1968).

Biological Notes

An interesting facet of the biology of *S. letnica*, suggesting a significant potential for fishery management, is the existence of four, distinct, reproductively isolated populations (or sibling species) separated by temporal and spatial differences during spawning. Three of the four races of *letnica* spawn in the lake itself and do not use tributary streams. The spawning seasons of the various races peak from December-February and in June and July. There are some small average differences in growth rate between the races, but the general maximum size of the commercial catch in Lake Ohrid is 2-3 kg. attained by 5-6 year old fish; although some much larger specimens are occasionally taken

In Lake Ohrid, *S. letnica* less than 40 cm, feeds predominately on crustaceans; above 40 cm, they become highly piscivorous. The cyprinid, *Alburnus albidus*, is the main forage fish utilized.

In Lake Ohrid, *S. letnica*, coexists with several species of cyprinids including the carp, *Cyprinus carpio*. Lake Ohrid supports an important commercial fishery with the total catch approaching 10 Kg. per hectare; *S. letnica* provides about one half of the total commercial yield.

During a visit to the Lake Ohrid Hydrobiological Laboratory, I was told that sport fishing on Lake Ohrid is restricted because *S. letnica* is relatively susceptible to exploitation by angling.

The popularity of *S. letnica* in Yugoslavia as a choice food fish has resulted in its introductions into many new reservoirs. It is believed that most introductions have been highly successful, but detailed published data are not available. Stankovic (1960) included considerable information on *S. letnica* in his book on Lake Ohrid. Stefanovic (1948) published the most comprehensive data on the systematics and ecology of *S. letnica*; an English translation of this publication is available.

The Possible Role of *S. letnica* in Fishery Management in North America

In 1965 the Division of Fish Hatcheries of the U.S. Bureau of Sport Fisheries and Wildlife imported eggs of the winter spawning race of *S. letnica*. A brood stock is now maintained at the Manchester, Iowa, federal hatchery.

S. letnica should be considered as an alternative to *S. trutta* in North American lacustrine environments - or as an addition to established *S. trutta* populations. Some of the possible advantages are: 1. A long evolutionary history of lacustrine adaptation and specialization. Highly specialized lacustrine forms of *S. trutta* have not been introduced into North America. The majority of *S. trutta* introductions were of fluviatile populations. Although the Loch Leven trout may have existed in Loch Leven, Scotland, for several thousand years, this is only a fraction of the time *S. letnica* has been evolving in Lake Ohrid. 2. Spawning in a lake without the necessity of suitable tributary streams for reproduction. 3. Co-existence with and utilization of cyprinid species. 4. Possibly more vulnerable to angling than *S. trutta*. 5. If more than one race of *S. letnica* could be established in a lake the total population should increase due to year-round recruitment and subtle ecological differences of the different races allowing for more efficient use of the environment.

There is need now for evaluation of *S. letnica* introductions into North American lakes and reservoirs. Cooperation between fish culturists to successfully raise *S. letnica* to fingerling size in large numbers and fishery biologists to select the waters and carry out the evaluation will be necessary.

As a preliminary study, Colorado Game, Fish and Parks received about 150,000 eyed eggs of *S. letnica* from the Manchester hatchery in February 1969. Fry mortality was high ~~Most of the fry perished~~ and perhaps only about 75,000 fingerlings will be available for introductions.

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[Ca 1970s]

ADDENDA TO GOLDEN TROUT REPORT

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Mr. Chuck Viox, Fishery Biologist, Wyoming Game and Fish Department, Lander, Wyoming, prepared a map and supplied some additional information on the original introduction of golden trout into the Alpine Lake basin.

The fish stocking records in the Lander office state that in 1938, Mr. Finis Mitchell stocked 3 "virgin" lakes along the Hay Pass trail with golden trout. Mr. Viox talked with Mr. Mitchell and established that the 3 lakes stocked in 1938 were: Lower Hay Pass, Carrol and Louise Lakes. These golden trout were from the Daniel hatchery of Cook's Lake origin. A self-reproducing population did not establish in Lower Hay Pass Lake due to lack of spawning areas. Golden trout now have an upstream distribution to Betty Lake, but several other headwater lakes are reputed to be barren.

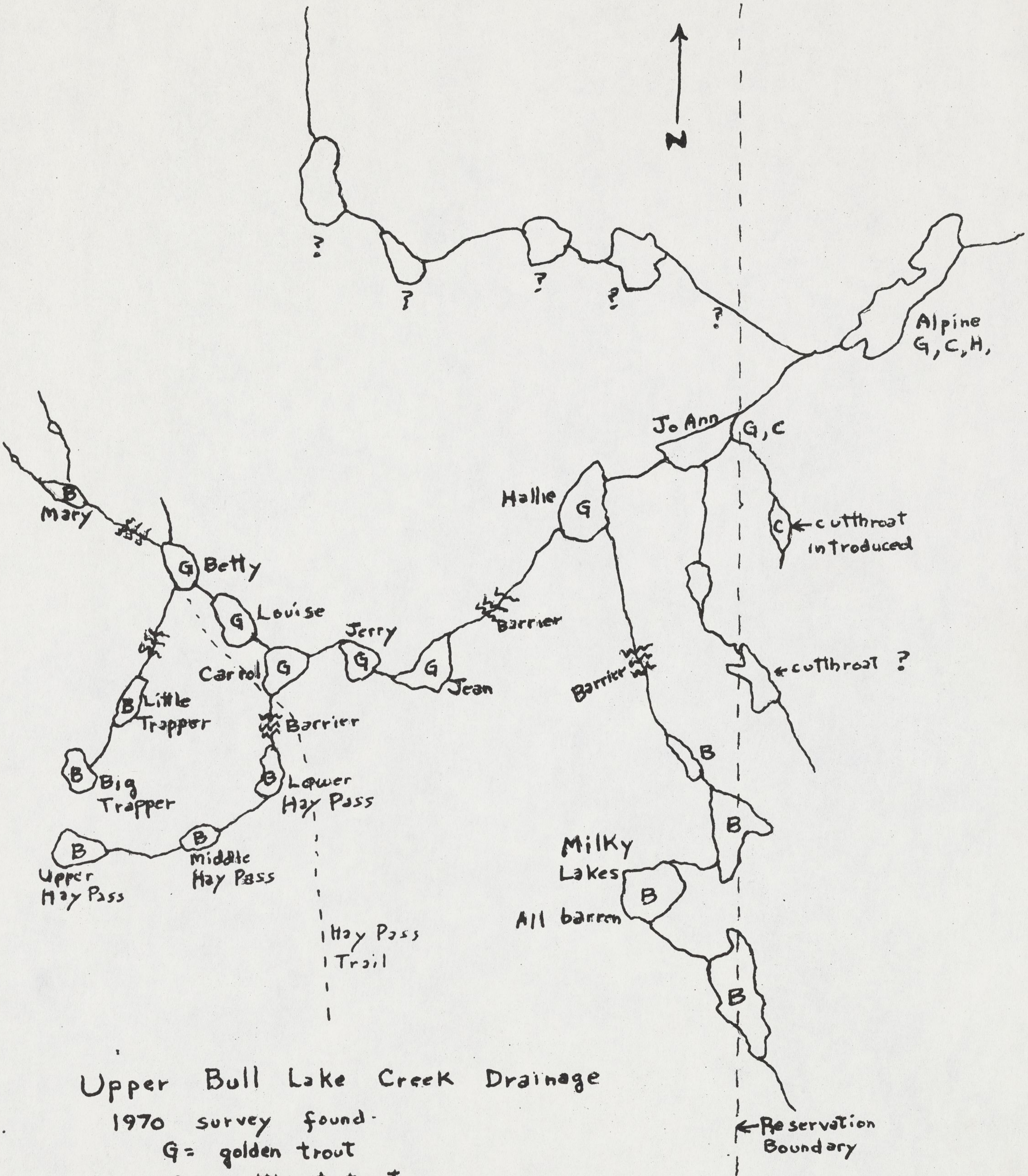
Other important information contributed by Mr. Viox helps to pin point the distribution of pure golden trout and hybrids. Observations on physical barriers to upstream migration indicate that natural upstream movement will be impossible between Hallie Lake and Jean Lake, but fish from JoAnn Lake might possibly make it to Hallie Lake. Cutthroat trout are entering JoAnn Lake from the inadvertent stocking of the tributary lake on the reservation. In 1970 a gill net set produced 27 golden trout and 1 cutthroat; however, I am confident that hybridization will occur and will intensify in the future. Only golden trout were caught in Hallie Lake in 1970, but if it is true that fish can move from JoAnn to Hallie, then eventually the hybrid genotype will introgress into that population also.

The probability is high that only pure S. aguabonita occur in the series of 5 lakes above the barriers upstream from Hallie Lake. There have been no other known introductions since the golden trout were stocked by Mr. Mitchell in 1938 and probably by Mr. Berg in 1940. In 1970 all the fish observed in these lakes were very typical S. aguabonita. However, to strengthen the degree of certainty that hybridization has not occurred, a sample of about 20-25 specimens from Jean Lake, the lowermost lake in the series above the barrier, should be sent to me for comparative examination. The major danger to preserving pure golden trout in these lakes is that someone will carry fish into some of the present barren lakes in the headwaters of the basin. Mr. Viox also mentioned that all of the lakes on the drainage joining Bull Lake Creek from the north below Alpine Lake are barren. This is highly inaccessable country but this large watershed should be investigated to establish the degree of physical isolation between sub-drainages. For example, barriers may effectively isolate all of the lakes in each fork of this drainage from each other. Such a situation would be ideal to establish rare and endangered forms of trout, besides the golden trout. Many of these lakes are on the reservation.

Recommendations

1. The barren lakes in the basin should be investigated for their suitability to establish self-reproducing populations of S. aguabonita. This would reduce the danger of unauthorized introductions. The stock for these introductions should be taken fron one of the 5 lakes now containing golden trout, after it has been satisfactorily demonstrated that they are a pure form.

2. A golden trout management program in the upper Bull Creek basin should be based entirely on natural reproduction. No matter how sincere the intentions and no matter how well planned and supervised over a period of years, due to the large number of people involved, another mistake such as the one responsible for stocking cutthroat trout into the tributary to JoAnn Lake, will eventually occur.



Upper Bull Lake Creek Drainage

1970 survey found-

G = golden trout

C = cutthroat trout

H = hybrid

B = barren of all fish

INFORMATION ON RECORD SIZE SPLAKE

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April, 1971

Inquiries were made regarding record size splake in order to establish the status of the 12 lb., 7 oz. specimen caught in Island Lake. Some interesting information was supplied by Mr. A. H. Berst, Ontario Dept. of Lands and Forests and Mr. J. J. Keleher, Manitoba Dept. Natural Resources.

It appears that no angling records for splake have been officially recorded because fishing contests or agencies recording prize fish have never established a splake category. Splake larger than the Colorado specimen have been taken in nets, but I found no reports of a rod and reel caught splake that exceeds the 12 lb., 7 oz. Island Lake fish.

An 8 year old splake of 78.7 cm and 7.5 Kg. (31 inches, 16.4 lbs.) taken by commercial fishermen south of Manitoulin Island in Lake Huron on November 8, 1969, is the largest known splake. Two 7 year old splake of 6.9 and 7.1 Kg. were taken in gill nets from Chrysler Lake, Ontario in 1960.

Ontario has an active program attempting to develop, by selective breeding, a deep-water splake for Lake Huron.

For those interested in splake and lake trout, the Fisheries Research Board of Canada has published a bibliography of lake trout by Marshall and Keleher (Tech. Rep. No. 176, 1970) and Mr. Berst is revising and updating an annotated bibliography on splake which should be available soon.

THE ZOOGEOGRAPHY, SYSTEMATICS AND MANAGEMENT OF CUTTHROAT TROUT

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The cutthroat trout, *Salmo clarki*, is an example of a polytypic species; that is, a species consisting of several geographically disjunct forms with a broad distribution and a great amount of genetic diversity. The potential of the cutthroat trout for fisheries management relates to their genetic diversity. Cutthroat trout are widely propagated and stocked into diverse habitats. The potential to utilize specific genotypes for specific environments and to create new types by intraspecific hybridization are fertile areas of fisheries management that have received scant attention. The native cutthroat trout has rapidly declined and has been completely eliminated from much of its original range in the interior waters of North America. Strong efforts should be made to preserve the remaining genetic diversity for its potential future use in fisheries programs. The practical aspects of utilizing genetic diversity in management programs is a most cogent reason for the support of an active and intelligent rare and endangered species program. Plant and animal breeding programs have abundantly demonstrated the value of utilizing a broad base of genetic diversity, accumulated by natural selection in ancestral stocks, to develop new useful races of plants and domestic animals.

Two important points must be emphasized. The first is that in fisheries management, as contrasted with the management of domesticated varieties of plants and animals, fish stocked in natural environments as fry or fingerlings must successfully survive and grow under the rigorous conditions of natural selection. That is why "wild" genotypes will be more successful than domesticated varieties developed by artificial selection. No sheepherders or predator control agents can accompany a plant and protect them from competition and predation.

The second significant fact is that physiological, behavioral and ecological differentiation, are not necessarily correlated with taxonomic recognition; that is, certain life history traits, important for fisheries management consideration, may not be reflected in morphological characters used for classification. These "non-taxonomic" traits can play a decisive role in the relative success of an introduction and emphasizes the need to recognize individual units or genotypes of a species or subspecies and not merely consider formal taxonomic categories in a rare and endangered fish program.

Millions of cutthroat trout are propagated each year in western states, and several sources of eggs are used. Past fish cultural practices have indiscriminantly mixed several different races of cutthroat trout, usually with some rainbow trout influence also. At present, virtually none of the sources of cutthroat trout used in propagation represent pure stock.

Distribution

The original distribution of cutthroat trout occurred in coastal streams from Prince William Sound, Alaska, to the Eel River in northern California. In the interior regions, the range included the South Saskatchewan drainage, the upper Columbia and upper Missouri basins, the Snake River segment of the Columbia drainage, above and below Shoshone

Falls, the upper Colorado and Rio Grande systems, the South Platte and Arkansas drainages in Colorado, and the Great Basin (Bonneville, Lahontan and Alvord basins).

In coastal waters the cutthroat trout and rainbow trout coexist without massive hybridization. This sympatric occurrence of the two trouts, each maintaining its genetic integrity, provides the theoretical basis for recognizing *Salmo clarki* and *S. gairdneri* as two separate species. Throughout most of the interior range of the cutthroat trout, the rainbow trout was not native, and introductions have almost invariably led to complete hybridization. There are areas, however, such as the Snake River system below Shoshone Falls where interior cutthroat trout and rainbow trout are both native and have been able to coexist without large scale hybridization. The precise mechanisms to explain how rainbow trout and cutthroat trout can live together without hybridizing are poorly understood; however, it is not due to genetic incompatibility - hybrids are fully fertile.

Taxonomy

Early ichthyologists without an understanding of the range of morphological variability that may be expressed within a single species, proceeded to name many species of cutthroat trout, based on local varieties. At present, because it is assumed that all populations of cutthroat trout could freely hybridize with each other, if given the opportunity, only a single species is recognized. Subspecies designation is commonly used to denote those populations of a certain geographical region or major drainage basin. On morphological grounds, most subspecies of *Salmo clarki* have little validity. No characters have much efficacy in distinguishing *S. c. lewisi*, *S. c. utah*, *S. c. pleuriticus*, and *S. c. virginalis*.

The coastal cutthroat trout, S. c. clarki, has a distinct chromosome number from other subspecies. The Lahontan cutthroat trout, S. c. henshawi, has more gillrakers and a unique spotting pattern. The Colorado greenback cutthroat trout, S. c. stomias, has more scales and larger spots.

There are four distinctive groups of cutthroat trout that are not yet officially recognized. These undescribed subspecies include: the indigenous trout of the Humboldt River system of the Lahontan basin, Nevada; a few relict populations of the Alvord basin, Oregon; a trout found in the Mt. Wheeler area of Nevada, apparently derived from western Bonneville trout, but quite distinct from S. c. utah; and a fine spotted cutthroat trout native to the Snake River below Jackson Lake, Wyoming.

The fine spotted Snake River cutthroat trout is the only interior cutthroat trout that has held its own despite massive introductions of exotic trouts, including other cutthroat trout. Preliminary information presented below indicates that this trout can be a most useful trout in fisheries management. The most baffling aspect of the existence of a fine spotted group of trout in the Snake River is the fact that typical large spotted populations occur above and below their range. How has hybridization and fusion into a single type been avoided in a continuous environment?

The Humboldt drainage subspecies in Nevada also appears to be an extremely hardy trout with desirable management characteristics - evidently influenced by its evolutionary history of the past several thousand years in a hostile and unstable environment.

For a more comprehensive perspective, the systematics of cutthroat trout must be considered within a framework of the evolution of western North American Salmo. The currently accepted notion that only two major evolutionary lines - S. gairdneri and S. clarki - are involved and that all western North American Salmo are derived from one or the other species, must be rejected. Based on morphology, zoogeography and supplemented with recent chromosome studies, it is now apparent that the ramifications of the evolutionary pathways leading to the living groups of western North American Salmo are not as simple and straightforward as previously thought. Several groups of trouts of dubious relationships, and not recently derived from S. clarki nor S. gairdneri, include the primitive Mexican golden trout, Salmo chrysogaster, the California golden trout, S. aguabonita, the Gila trout, S. gilae, the Apache trout, currently being described by Dr. R. R. Miller, and a diverse group of trout indigenous to several desiccating basins in southern Oregon and in parts of the McCloud and Pit river basins of northern California. I apply the name red-banded trout to these undescribed trout. Based on certain color characteristics and similarities in karyotypes, the red-banded trout appears to have relationships to S. aguabonita.

Much more information will be needed before we can do more than guess at how the connecting lines of a phylogenetic diagram of western North American Salmo should be plotted. It is evident, however, that many more major evolutionary divergences have occurred to produce the present diversity than has been generally believed.

Management

The most urgent need in cutthroat trout management is to initiate and carry out projects to preserve rare and endangered populations of pure, native genotypes. Examples of creating new habitat, eliminating non-native fishes and constructing barriers to upstream migration and introductions into previously barren waters have been used to modestly expand the range of the greenback cutthroat trout, the Gila trout and the Apache trout.

The major problem for rare and endangered trout programs is taxonomy. How can a pure, native population be recognized if found? The Colorado Cooperative Fishery Unit maintains a reference collection and has amassed data on the characters of thousands of specimens of western North American *Salmo* from throughout their range. Evaluation of any population can be made by comparisons with these data. Several reports summarizing the status of various rare forms of trout are available from the Colorado Cooperative Fishery Unit.

Information on ecology, behavior and physiology of cutthroat trout, necessary for scientifically based management programs, is sorely lacking. This information is basic to answer such questions as what form (genotype) of cutthroat trout best survives, grows and contributes to a fishery in different environments? Under what conditions are cutthroat trout more successful than rainbow trout or brook trout and why?

Unfortunately, the concept that slight genetic differentiation, not recognized taxonomically, can greatly influence the success of certain stocks in fisheries management is yet to gain wide understanding. The matter is more than mere hair splitting. The Lahontan cutthroat trout population once native to Pyramid Lake, Nevada, was probably the largest of all western North American *Salmo*. Maximum weight attained was 40-60 lbs. The average size of 195 specimens from the last spawning run from Pyramid Lake in 1938 was 20 lbs. The Pyramid Lake stock of *S. c. henshawi* was the last population representing direct continuity of evolution in a lacustrine environment for perhaps more than 50,000 years - as the only large predatory species among numerous minnows and suckers. The native

Pyramid Lake population became extinct after 1938 with complete blocking of spawning runs in the Truckee River. The trout raised as *S. c. henshawi* today has a very different evolutionary history and has been influenced by hybridization with rainbow trout. More important from a management point of view is the fact that the maximum size attained in Pyramid Lake by this trout is less than the *average* weight of the last spawning runs of the original native genotype. The state of Nevada and the U. S. Bureau of Sport Fisheries have ambitious programs to propagate Lahontan cutthroat trout and rehabilitate the Pyramid Lake fishery. Should some thought be devoted to the possibility that they are using the wrong trout? Might remnant populations of the original Pyramid Lake stock persist in some introduced populations? Millions of fry from Pyramid Lake parents were widely distributed in the early part of this century.

The only pure, native lacustrine stock of *S. c. henshawi* in California occurs in Independence Lake. Despite wide publicity given to the significance of the Independence Lake cutthroat trout, catchable rainbow trout were stocked into Independence Lake for "instant fishing" without regard to the possible consequences. This example illustrates the need to organize a rare and endangered fish program with firm and clear objectives and guidelines and to be certain all employees fully understand what is involved. If the Independence Lake cutthroat trout are lost through hybridization with the introduced rainbow trout who should be held accountable - the Director? The Chief of Fisheries? Or the biologist who made the introduction?

Example of Systematic Research Applied to Management

An ongoing systematic study of cutthroat trout has provided the basis for evaluating the amount of genetic divergence between various groups. The assumption that taxonomic differences should also be manifested in ecological differentiation provided the theoretical basis for a study being conducted by Colorado Cooperative Fishery Unit student John Trojnar. We were particularly interested in learning more about the fine spotted Snake River cutthroat and its role in fisheries management. The Snake River cutthroat trout is the only cutthroat trout that still is dominant over introduced trouts in its native range and has resisted hybridization with rainbow trout and other forms of cutthroat trout. The preliminary data based on the first three months of the 1971 field season from North Michigan Lake, Colorado, is presented in the following table.

	Snake River Cutthroat	Colorado Cutthroat
No. fry stocked 1968	24,000 (16%)	126,000 (84%)
1971 gillnet samples	38 (52%)	35 (48%)
1971 creel census	116 (78%)	32 (22%)

Although the sample size is small, the proportion of Snake River cutthroat trout in the anglers catch has been steadily increasing throughout the year. At present, the 16 fold increase in the catch from what would be expected based on the 1968 stocking ratios is not likely due to chance and we attribute it to the genetics of the trout involved.

Similar studies should be carried out in diverse environments with all of the stocks of cutthroat trout now being propagated to compile a "breeders handbook" on the genetics and ecological potential of *Salmo clarki*.

[Ca 1972]

RARE AND ENDANGERED TROUTS OF THE SOUTHWEST

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Introduction

A major problem in determining the status of native western trouts of the genus *Salmo* concerns the difficulties in providing a taxonomic diagnosis that allows recognition of various species and subspecies and to detect the often subtle effects of hybridization. We are dealing with a situation of rather closely related evolutionary lines where hybridization between species resulting in fertile offspring is a common occurrence. The fact that non-native rainbow trout have been stocked into virtually every stream in the Southwest and various mixtures of different subspecies of cutthroat trout (often hybridized with rainbow trout) were indiscriminantly distributed as "native trout" into headwater areas has caused the virtual extinction of pure populations of several subspecies of native cutthroat trout (*Salmo clarki*) as well as the Gila trout (*S. gilae*) and Apache or Arizona native trout (*S. apache*). It may be conservatively estimated that only a minute fraction of one percent of the original range of these species and subspecies are presently inhabited by pure populations.

My identification of pure populations depends on comparing several characters of large samples of specimens. Ancient museum specimens provide a basis for establishing the diagnosis of various taxonomic entities. Typically, no single character can definitely classify these trouts; mean values of several characters must be compared and evaluated. More important than concentrating on recognized taxonomic entities is the objective of preserving the remaining remnant pockets of genetic diversity of the western trouts.

The Native Trouts

Because of great phenotypic plasticity and local variability, the trouts are a confusing and difficult taxonomic group. It has been rather generally accepted that all western trouts of the genus *Salmo* can be classified as part of, or recently derived from, two species; the cutthroat trout, *Salmo clarki*, or the rainbow trout, *S. gairdneri*. More critical analysis of their systematics, including new information on chromosomes, reveals that the phylogeny of our western trouts is not as simple and clear-cut as formerly believed (Behnke, 1970,1972; Schreck and Behnke, 1971). Trout such as *S. gilae* of New Mexico and *S. apache* (that were virtually extinct before they were officially discovered) can not be readily alligned with either *S. clarki* or *S. gairdneri*, and represent evolutionary lines of long separation.

The most generally distributed trout of the Southwest is the cutthroat trout consisting of several subspecies (some undescribed) native to the different major drainage basins (Rio Grande, Colorado, Arkansas, South Platte and the Great Basin). All of the subspecies of native cutthroat trout of the Southwest are extremely rare in their pure form. I consider the following native trout of the Southwest as rare.

Rio Grande cutthroat trout, Salmo clarki virginalis. Native to the upper Rio Grande and Pecos River drainages of Colorado and New Mexico. Possibly once occurring also in the headwaters of the Canadian River of New Mexico and in the Rio Grande basin of Texas and Mexico. Now almost completely replaced by non-native trouts and hybrids. I have tentatively identified pure populations from a few streams on the Trinchera Ranch in Colorado and in isolated localities in New Mexico. Colorado Division of Wildlife has made some transplants and attempts are being made to establish a brood stock for propagation. Personnel of the Santa Fe and Carson National Forests have developed preliminary plans to protect and restore this trout.

Colorado River cutthroat trout, Salmo clarki pleuriticus. Native to the Green and Colorado River basin above the Grand Canyon in Wyoming, Utah and Colorado (possibly in San Juan system of New Mexico and Arizona); absent from Little Colorado drainage. Status is similar to Rio Grande cutthroat trout; pure populations have been identified from only four small streams in Wyoming and Utah.

Greenback cutthroat trout, Salmo clarki stomias. Native to the upper Arkansas and South Platte basins in Colorado. Once believed extinct, a population of about 100 adult trout was discovered in a tiny stream in Boulder County, Colorado, in 1969. Two transplants into barren streams have expanded the range of this highly colored trout.

Utah cutthroat trout, Salmo clarki utah. Native to the Bonneville basin of Utah, Idaho, Wyoming and Nevada. This trout has been declared extinct, but a population in a small headwater tributary of the Virgin River basin appears to be pure S. c. utah.

Mt. Wheeler cutthroat trout, Salmo clarki subsp. A cutthroat trout, well differentiated from S. c. utah once inhabited Snake Valley of the western Bonneville basin. This trout was introduced into several barren streams in desert basins in eastern Nevada, where it persisted in a single locality - Pine Creek, a tiny rivulet on Mt. Wheeler. The native trout is now extinct in Snake Valley, but two new populations have been established from transplants of the Pine Creek stock.

Lahontan cutthroat trout, Salmo clarki henshawi. Native to the Lahontan basin (except Humboldt River drainge) of Nevada and California. This trout represents the most divergent subspecies of Salmo clarki and was probably the largest trout native to western North America. Although "Lahontan" cutthroat trout are widely propagated in hatcheries, the source of the stock (Heenan Lake, California) has been hybridized with rainbow trout. The significance of this genetic contamination is evident from the fact that the maximum size attained by the Heenan Lake trout in Pyramid Lake is less than half that of the now extinct original Pyramid Lake cutthroat. Pure populations of S. c. henshawi are extremely rare. After several years of comprehensive surveys, I have identified only 6 populations as S. c. henshawi.

Piute cutthroat trout, Salmo clarki seleniris. Native only to a few miles above a falls on the very headwaters of Silver King Creek, Alpine County, California (Lahontan basin). The Piute trout is identical to S. c. henshawi (from which it is derived) except for the complete absence of spots on the body. Inadvertent introductions of rainbow trout and other cutthroat trout into Silver King Creek has produced a hybrid population in Silver King Creek. An earlier transplant of Piute trout persists in limited numbers in another stream.

Humboldt cutthroat trout, Salmo clarki subsp. Native to the Humboldt River drainage of the Lahontan basin of Nevada. This undescribed trout is differentiated from S. c. henshawi by 2-4 fewer gillrakers and about 20 fewer scales in the lateral series. Presently restricted to a few, small headwater streams; largely replaced by brook trout in most waters. One successful transplant into a barren stream has been made and others are planned.

Alvord cutthroat trout, Salmo clarki subsp. The large Alvord desert basin of northern Nevada-southern Oregon consists of two major segments with the two drainages evidently of long isolation. It is likely that two subspecies of cutthroat trout were present, but one is probably extinct and the other is limited to two streams (Willow and Whitehorse Creeks). The BLM has taken action to save this trout by protecting and improving the badly degraded habitat from overgrazing.

Gila trout, Salmo gilae. Native to the upper Gila River, New Mexico. When described in 1950, the only known population occurred in Main Diamond Creek. Since then I have identified three additional populations as S. gilae-South Diamond Creek, Spruce Creek and McKenna Creek. A transplant was made in 1970 into a rehabilitated stream in the Mimbres drainage.

Apache trout, Salmo apache. Native to the Black and White rivers of the upper Salt River drainage (Gila R. basin), Arizona, and probably to the headwaters of the Little Colorado River. This trout will be officially described by Dr. R. R. Miller this year. Its present distribution is limited to a few streams on the White River Apache Indian Reservation, but a proposed logging operation threatens the last stronghold of the Apache trout. Arizona Fish and Game Department propagates this trout in limited numbers and a few introductions have been made into its former range.

What Can Be Done?

A point I would like to emphasize is the relative ease and economy of initiating an action program and successful transplants of a rare trout into new habitat, thus expanding their range and abundance. Isolated streams above barriers presently barren of all fish are ideal for such transplants. With volunteer help, I have back packed live fish in plastic bags into new habitat at no expense. Some small streams provide ideal habitat but may be inhabited by non-native species such as eastern brook trout. All fish can be eliminated from a few miles of a small stream (2-3 c.f.s. flow) for a few dollars worth of rotenone. If a natural barrier is not present on a stream, one can be constructed.

The basic problem, however, is that of finding sources of pure populations to be used for transplanting. To make information avalilable on native trouts and to stimulate interest in action programs to perpetuate and expand these remnant populations, I have prepared a series of mimeographed reports, available from the Colorado Cooperative Fishery Unit. These reports summarize the status and taxonomic characters of the various species and subspecies.

In the past, ignorance, lethargy and inaction effectively prevented the launching of organized programs to save our native trouts from extinction. In recent years enthusiastic support from state and federal agencies give cause for optimism.

After relict trout populations are found and identified, the greatest threat to their survival centers on land use practices. The effects of grazing mining, and logging can completely eliminate a population in a small stream. Mine pollution can be sudden and complete. Grazing and logging result in more gradual degradation of habitat; loss of cover, erosion, siltation and rise in temperatures. I have observed many examples where native trout have held their own in virgin habitat only to be completely replaced by non-native trouts after habitat degradation. It is important, therefore, to document the distribution of pure populations of our native trouts so that watersheds can be given special classification and protection.

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ORIGINAL

THE RATIONALE OF PRESERVING GENETIC DIVERSITY: EXAMPLES OF THE UTILIZATION OF INTRASPECIFIC RACES OF SALMONID FISHES IN FISHERIES MANAGEMENT

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Fisheries biology has been hindered by a typological approach to species management. Considering the behavioral, physiological and ecological attributes of a population or of a generalized concept of a species to be representative of all populations of a species is highly erroneous and can lead to unsound management practices.

A rose may be a rose to most people, but rose hobbiests recognize a spectrum of size, shape and color, based on the genetic diversity of the species. So it is with fishes such as the Pacific salmons, the rainbow and cutthroat trouts; species of wide geographical distribution each consisting of an almost infinite variety of genotypes programmed by natural selection in response to different environmental cues. A polytypic species is not a homogeneous assemblage, but rather a grouping of a number of separate units with varying degrees of discreteness.

Some readily apparent manifestations of intraspecific genetic differentiation can be observed in migratory behavior (anadromous and resident populations), in the timing of the spawning run of anadromous stocks (summer and winter runs), in feeding and habitat preference and in different age structures and growth rates of different populations. I stress the fact that very significant behavioral and physiological differences may exist between different populations of a species without any apparent morphological differentiation. Thus, it may be highly important to recognize that certain stocks are characterized by different life history characteristics even though they are not given taxonomic recognition in a formal system of classification. Once this simple premise is accepted and comprehended, the typological approach can be more easily avoided.

The rationale of perpetuating native races and subspecies centers on the values of perpetuating genetic diversity; and for this we can draw analogies from the history of plant and animal husbandry. The source of genetic diversity necessary for developing new strains ultimately is derived from wild ancestral species. Fishes such as our native trouts are widely propagated but are in danger of losing the broad base of genetic diversity originally found in the species. Indeed, much of the cutthroat trout species, *Salmo clarki*, has already been destroyed. A conservative estimate would be that 99% of the original populations of *S. clarki* in the interior regions of the U.S.A. have been lost in the last 100 years. How many unique genotypes of potential management value have been lost with them? The cutthroat trout, native to Pyramid Lake, Nevada and probably the largest trout in North America, exterminated in the 1930's is but one example that can be mentioned.

We have domesticated strains of trout, and there is no doubt that man has modified the genotypes of these strains from their ancestral wild stocks to produce a more efficent trout for hatchery conditions. In making analogies between fish husbandry and the selective breeding of plants and animals, an important point is often ignored. This concerns the fact that unlike domesticated species which receive care and protection from their origin to the market place, sport fishes are stocked in a natural environment to compete and survive and return to a fishery over a period of time--perhaps several years. Under these circumstances the genetics of the fish play the major role in the total interaction of the organism with its environment governing the growth, survival and contribution to the fishery. To increase the survival potential of domesticated strains under natural conditions it may be necessary to modify the genotype by genetic infusion from wild populations.

Cordone and Nicola (1970) demonstrated that the survival and return to the creel of four strains of rainbow trout stocked into Beardsley Reservoir, California is inversely correlated with the degree of domestication of each strain.

Lake McConaughy and the North Platte River above it in Nebraska are noted for a large, steelhead-like rainbow trout. It was generally assumed that these trophy rainbows were the result of stocking hatchery rainbows in the tributaries of the North Platte. A study by Van Velson (MS. 1969) revealed that the Lake McConaughy rainbow were entirely a self-reproducing population completely separate from the hatchery rainbow, although massive numbers of hatchery trout were stocked in the same tributaries used by the wild stock for reproduction and nursery areas. Once it was established that the two races of rainbow trout (hatchery and wild) behaved as two completely separate entities in the North Platte drainage of Nebraska, a more intelligent and scientifically sound management program could be initiated to increase the valuable wild stock.

One of my graduate students recently completed a thesis on two races of cutthroat trout, both living together in the same lake (Trojnar MS., 1972). Mr. Trojnar's research concerned the dynamics of the interaction of the two races of cutthroat trout; how they partitioned the environment and the food resources and how they contributed to the fishery. This study suggests some implications for innovative fishery management practices, utilizing intraspecific genetic diversity to produce interactive segregation between two or more intraspecific races. Because two or more populations will make more efficient use of the total resources of a body of water than any one of them would alone, more biomass can be created by establishing populations from genetically diverse stocks of a species. By this technique we are emulating nature with its numerous examples of closely related, sympatric populations of salmonid fishes ("sibling species"). This interesting aspect of salmonid biology is covered more fully in a forthcoming publication, (Behnke, 1972. In press).

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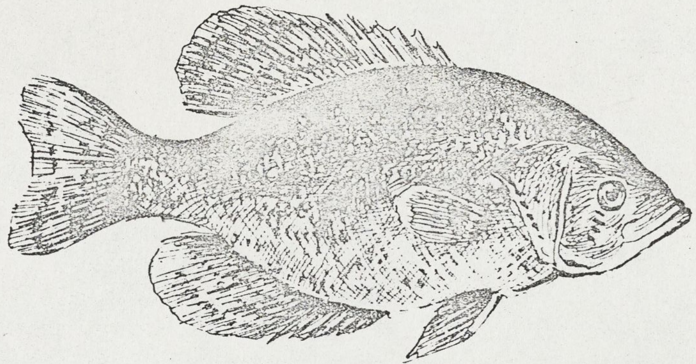

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THE RATIONALE OF PRESERVING GENETIC DIVERSITY: EXAMPLES OF THE UTILIZATION OF INTRASPECIFIC RACES OF SALMONID FISHES IN FISHERIES MANAGEMENT

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Fisheries biology has been hindered by a typological approach to species management. Considering the behavioral, physiological and ecological attributes of a population or of a generalized concept of a species to be representative of all populations of a species is highly erroneous and can lead to unsound management practices.

A rose may be a rose to most people, but rose hobbiests recognize a spectrum of size, shape and color, based on the genetic diversity of the species. So it is with fishes such as the Pacific salmons, the rainbow and cutthroat trouts; species of wide geographical distribution each consisting of an almost infinite variety of genotypes programmed by natural selection in response to different environmental cues. A polytypic species is not a homogeneous assemblage, but rather a grouping of a number of separate units with varying degrees of discreteness.

Some readily apparent manifestations of intraspecific genetic differentiation can be observed in migratory behavior (anadromous and resident populations), in the timing of the spawning run of anadromous stocks (summer and winter runs), in feeding and habitat preference and in different age structures and growth rates of different populations. I stress the fact that very significant behavioral and physiological differences may exist between different populations of a species without any apparent morphological differentiation. Thus, it may be highly important to recognize that certain stocks are characterized by different life history characteristics even though they are not given taxonomic recognition in a formal system of classification. Once this simple premise is accepted and comprehended, the typological approach can be more easily avoided.

The rationale of perpetuating native races and subspecies centers on the values of perpetuating genetic diversity; and for this we can draw analogies from the history of plant and animal husbandry. The source of genetic diversity necessary for developing new strains ultimately is derived from wild ancestral species. Fishes such as our native trouts are widely propagated but are in danger of losing the broad base of genetic diversity originally found in the species. Indeed, much of the cutthroat trout species, *Salmo clarki*, has already been destroyed. A conservative estimate would be that 99% of the original populations of *S. clarki* in the interior regions of the U.S.A. have been lost in the last 100 years. How many unique genotypes of potential management value have been lost with them? The cutthroat trout, native to Pyramid Lake, Nevada and probably the largest trout in North America, exterminated in the 1930's is but one example that can be mentioned.

We have domesticated strains of trout, and there is no doubt that man has modified the genotypes of these strains from their ancestral wild stocks to produce a more efficent trout for hatchery conditions. In making analogies between fish husbandry and the selective breeding of plants and animals, an important point is often ignored. This concerns the fact that unlike domesticated species which receive care and protection from their origin to the market place, sport fishes are stocked in a natural environment to compete and survive and return to a fishery over a period of time--perhaps several years. Under these circumstances the genetics of the fish play the major role in the total interaction of the organism with its environment governing the growth, survival and contribution to the fishery. To increase the survival potential of domesticated strains under natural conditions it may be necessary to modify the genotype by genetic infusion from wild populations.

Cordone and Nicola (1970) demonstrated that the survival and return to the creel of four strains of rainbow trout stocked into Beardsley Reservoir, California is inversely correlated with the degree of domestication of each strain.

Lake McConaughy and the North Platte River above it in Nebraska are noted for a large, steelhead-like rainbow trout. It was generally assumed that these trophy rainbows were the result of stocking hatchery rainbows in the tributaries of the North Platte. A study by Van Velson (MS. 1969) revealed that the Lake McConaughy rainbow were entirely a self-reproducing population completely separate from the hatchery rainbow, although massive numbers of hatchery trout were stocked in the same tributaries used by the wild stock for reproduction and nursery areas. Once it was established that the two races of rainbow trout (hatchery and wild) behaved as two completely separate entities in the North Platte drainage of Nebraska, a more intelligent and scientifically sound management program could be initiated to increase the valuable wild stock.

One of my graduate students recently completed a thesis on two races of cutthroat trout, both living together in the same lake (Trojnar MS., 1972). Mr. Trojnar's research concerned the dynamics of the interaction of the two races of cutthroat trout; how they partitioned the environment and the food resources and how they contributed to the fishery. This study suggests some implications for innovative fishery management practices, utilizing intra-specific genetic diversity to produce interactive segregation between two or more intraspecific races. Because two or more populations will make more efficient use of the total resources of a body of water than any one of them would alone, more biomass can be created by establishing populations from genetically diverse stocks of a species. By this technique we are emulating nature with its numerous examples of closely related, sympatric populations of salmonid fishes ("sibling species"). This interesting aspect of salmonid biology is covered more fully in a forthcoming publication, (Behnke, 1972. In press).

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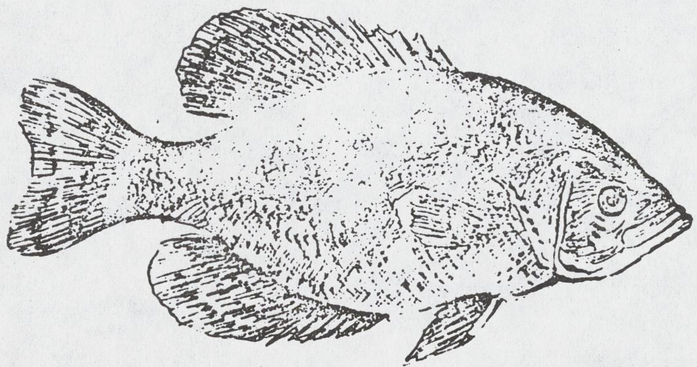

SYMPATRIC SIBLING SPECIES OF SALMONID FISHES WITH INFERENCES FOR FISHERIES MANAGEMENT

Seminar, Department of Zoology, University of Wyoming
February 22, 1973

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The currently accepted criteria for defining species emphasizing reproductive isolation has some serious limitations for the taxonomy of the family Salmonidae, where strong, innate, reproductive homing behavior may allow genetic segregation between two or more morphologically similar populations with only slight genetic differentiation.

Although the coexistence of closely related populations of salmonid fishes is a prime cause for taxonomic confusion and disagreement, this phenomenon suggests some innovative applications for fisheries management. In order for two or more populations to coexist in the same environment in nature, there must be some degree of ecological segregation to avoid direct competition. It then can be assumed that two or more coexisting populations will exploit the resources more effectively and produce more total biomass than either or any one could alone.

Examples in the literature exploring the nature of ecological segregation between coexisting salmonid fishes are limited to natural situations where the populations have been coexisting for thousands of years and the behavioral mechanisms for coexistence are probably incorporated into the genotypes.

The pertinent question for fisheries management application is: Can two closely related groups (for example, races or subspecies of a species) without genetic programming for coexistence in their evolutionary history, be introduced together and initiate ecological segregation?

Results from a study of two populations of cutthroat trout introduced in a small Colorado lake is enlightening. Their behavior is interpreted as an example of interactive segregation, whereby behavior patterns expressed in allopatry are modified in sympatry to avoid direct competition and allow coexistence. This, in turn, resulted in a striking difference in angling vulnerability between the two populations.

Proceedings of the Desert Fishes

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Robert Behnke; Colorado State University, Fort Collins, Colo.

Trouts of the Great Basin

At least two species and numerous subspecies of trout are native to the desiccating basins of the western United States.

The more ancient distribution is that of the cutthroat trout, Salmo clarki, native to the Bonneville, Lahontan and Alvord basins. In each of these three basins, the cutthroat trout was represented by two distinct groups (subspecies). Four of these subspecies are undescribed and one is extinct (the trout once found in Trout Creek and Virgin Creek, Nevada and Oregon, tributary to the Alvord Desert). The extant subspecies are all rare.

The desiccating basins of southeastern Oregon-Harney-Malheur, Catlow Valley, Fort Rock, Chewaucan, Warner Lakes and the Goose Lake systems have a trout I call the red-banded trout whose closest affinities appear to be with Salmo aguabonita, the California golden trout. The red-banded trout is also native to the upper Pit and McCloud rivers in California, to the upper Klamath Lake drainage of Oregon and California and to some isolated tributaries of the Owyhee River (Columbia River basin) of Oregon and Nevada.

The decline of the native trouts of the Great Basin is assoicated with degradation of habitat and introudction of non-native trouts. Both the cutthroat trout and the red-banded trout freely hybridize with rainbow trout. Current threats to remnant populations include mining activities and cattle grazing which can degrade habitat to an extent that all fish are eliminated from small streams.

Habitat protection and transplants to new waters are the major tools used to save the rare trouts of the Great Basin from extinction.

Top priority is given to intra-basin transplants, but if no suitable habitat is available within a basin, then transplants outside the basin should be made to perpetuate unique genotypes.

The Effects of the Newlands Project on the Pyramid Lake Fishery

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Introduction

Besides being the only place in the world where the cui-ui sucker, *Chasmistes cujus* is found, Pyramid Lake once attracted world reknown as the home of giant cutthroat trout, *Salmo clarki henshawi*, which attained a size greater than any other trout native to western North America.

The Piute Tribe of Pyramid Lake utilized both of these species in their economy and historically, to a large extent, the well-being of the tribe depended on the abundance of the trout and cui-ui.

The historical abundance of fishes in Pyramid Lake was due to three major factors: 1) The magnitude of nutrients in the lake water resulting in high fish productivity, 2) Access for the trout and cui-ui to the Truckee River for reproduction, and 3) The evolution of the fish fauna as a unit from 50,000 to 100,000 years in a continuous lake environment, resulting in efficient energy conversion and effective utilization of the total lake and river environments.

The extinction of the trout population and the effective loss of the cui-ui from the fishery occurred in 1939 after a long period of decline due to the diversion of Truckee River water at Derby Dam as part of the Newlands Project. The cutthroat trout is an obligatory stream spawning fish; it must have flowing water and gravel substrate for successful reproduction. The blocking of the Truckee River by Derby Dam and subsequent reduced flows into

Pyramid Lake doomed the native cutthroat trout. The last specimens were taken in 1938 and none seen thereafter. A valuable and irreplacable resource was lost forever. The cui-ui was able to maintain a drastically reduced and tenuous existence by spawning in freshened areas along the lake shore. However, their deepwater habit for most of their life cycle makes them unavailable to the tribal fishery, which formerly harvested them during the spawning runs in the Truckee River. The cui-ui is presently designated by federal law as an endangered species.

The following discussion estimates the magnitude of fish abundance in Pyramid Lake prior to Derby Dam. These data provide an approximation of what has been lost due to the Newlands Project. I estimate that when Pyramid Lake was at its long term historical level (3865-3870 ft.) during the period of 1860 to 1920, before massive diversion of the Truckee River occurred, and Winnemucca Lake was full, the total surface area of the combined lakes was about 200~~0~~,000 200,000 acres. The total biomass of the cutthroat torut population at that time is conservatively estimated at 2,000,000 lbs., from which about 1,000,000 lbs. could be potentially harvested annually in a sustained fishery.

The cui-ui probably maintained a population as large, or larger than the cutthroat trout. About 200 miles of prime spawning area was then available for reproduction of trout and cui-ui in the Truckee River drainage.

Historical Perspective

Pyramid Lake is a remnant of Lake Lahontan, a vast body of water covering a large area of Nevada during the last glacial epoch. As Lake Lahontan receded about 8,000 years ago, Pyramid Lake became the sump for the Truckee River. Water flows in but not out. The level is determined by the ratio of inflow to evaporation. This fact accounts for the high concentration of nutrients in the lake water--they enter, but are not flushed out by a through flowing river system as is typical for most lakes.

Historical information on the size and levels of Pyramid Lake (expressed as elevation above sea level of the lake surface) can be found in the following references: Harding (1962), Hardman and Venstrom (1941), Hutchinson (1937), La Rivers (1962), Sumner (1940) and Wheeler (1969). A brief summary of the data of the various authors reveals some discrepencies concerning dates, levels and size, but there is agreement on the trends of fluctuation. From 1860 to about 1920 there were natural fluctuations in lake level in relation to high and low run-off years of the Truckee River.

Because total fish production is related to total surface area of a lake, the following points are made for later reference.

The historical high level of Pyramid Lake was about 3880 ft. above sea level. At this level, the surface area of Pyramid Lake would be approximately 150,000 acres. The long term average from 1860 to 1920 was about 3865-3870 ft. A critical consideration is the 3863 ft. level, at which point water backs up to fill Winnemucca Lake. When full, Winnemucca Lake is roughly half the size of Pyramid Lake (Winnemucca completely dried in 1938). At long term, pre-diversion levels, Pyramid and Winnemucca lakes would comprise a surface area of about 200,000 acres (±10%). Winnemucca Lake, as Pyramid, was highly productive for trout and other fishes (Snyder, 1917) and also served as a national waterfowl refuge.

From about 1920 to 1966, intensive diversion of water from the Truckee River by the Newlands Project, caused a precipitous decline in the level of Pyramid Lake by 75 feet and Winnemucca Lake was lost completely (Wheeler, 1969). The cutthroat trout and cui-ui were able to enter the Truckee River for reproduction only sporadically after 1920 and these fishes suffered a drastic decline in abundance. Some reproduction was successful in 1929-30, which gave rise to the last spawning run of cutthroat trout in 1938. A drop in river flows eliminated successful reproduction in 1938, and no trout were seen thereafter. The ultimate extinction of the Pyramid Lake cutthroat trout can be placed in 1938-39 (Sumner, 1940).

The cui-ui, although not extinct like the trout, was not available to the Indian fishery in the lake because of their deep water existence and their planktonic feeding habits which make them impossible to catch with lures or bait. Thus, the cui-ui resource was also lost to the tribe after 1938.

Pyramid Lake, at its present level, is only slightly more than 100,000 acres in size or about one half of the total fish producing area originally existing when Pyramid and Winnemucca lakes were at their pre-diversion levels.

Originally, the Truckee River with its major tributaries such as the Little Truckee and Prosser Creek provided about 200 miles of large stream habitat for spawning and as a nursery area for the cutthroat trout. Considering the numerous smaller tributaries, the potential area for reproduction must be considered as super-abundant for the needs of the Pyramid Lake cutthroat trout. The closure of Derby Dam in 1906, blocked all access to the Truckee River about 30 miles above the lake resulting in a decrease in potential spawning area by at least 85%. The trout and cui-ui, however, evidently were able to maintain abundant populations with this limited spawning area until access to the Truckee River was sporadically blocked with increasing frequency from about 1920 on.

The Fishes and Fisheries of Pyramid Lake

The uniqueness of the Pyramid Lake fish fauna lies in the fact that the species have been co-evolving in a continuous lake environment for eons (50,000-100,000 years). Pyramid Lake is the only lake in the Lahontan basin that has maintained a direct continuity from pluvial Lake Lahontan of the last glacial epoch. The absence of the cui-ui from Walker Lake is evidence that Walker Lake has desiccated or became uninhabitable for fishes at sometime since the recession of Lake Lahontan.

The significance of the long coexistence of the original Pyramid Lake fish fauna is derived from fundamental principles of evolution. A faunal complex coexisting in a continuous environment for such a long duration, evolve specialized adaptive features in their behavior and physiology to maximize efficiency of energy conversion and utilization of the entire environmental resources. The end result is a highly productive fishery.

The native cutthroat trout of Pyramid Lake was specialized to a high degree to make most efficient use of the Pyramid Lake and the Truckee River environment, because of thousands of years of natural selection in this environment. The evolutionary selective factors acting to specialize the Pyramid Lake cutthroat trout for the large lake environment and to feed on the abundant schools of forage fish (which attain lengths of 15-18 inches) were responsible for making the Pyramid Lake cutthroat trout the largest trout native to western North America. The official record is 41 lbs. but reliable statements by Mr. Fred Crosby, a former commercial dealer for the tribal fishery, reveals that a cutthroat trout of 62 lbs was taken in 1916 (Wheeler, 1969).

The last spawning run of cutthroat trout entering the Truckee River in 1938 had an average weight of 20 lbs. (Sumner, 1940).

In my opinion, the extinction of the original Pyramid Lake cutthroat trout was the most significant irreplacable loss directly attributable to the Newlands Project. Although theoretically it would be possible to fill Pyramid Lake to its former level and make the Truckee River available for reproduction, the original cutthroat trout population is extinct and there is no possible way to completely duplicate all of the desirable attributes possessed by this trout, from any other source of Lahontan cutthroat trout.

The implications of what has been stressed above concerning the evolutionary heritage of the native Pyramid Lake cutthroat trout now becomes apparent. It was only the native trout, evolving for thousands of years in Pyramid Lake which could make such effective use of the forage and attain such a tremendous size. Although the Lahontan cutthroat trout is not extinct and various sources of Salmo clarki henshawi are propagated and stocked into Pyramid Lake, the current record size of these introduced trout is 19 lbs. 9 oz. (Len Hoskins, Nev. Fish and Game). Although a 19 lb. cutthroat trout is indeed a magnificent fish, it is less than the average weight of the 1938 spawning run and only one third of the maximum weight attained by the original population. It should be also noted that the relative light density at which trout are stocked in Pyramid Lake, provides a super-abundance of food and the expression of a maximum growth potential.

-24 lb. caught by troller

A taxonomic unit of classification such as a species or subspecies is a practical device to group organisms by morphological similarities and geographical areas. In reality a species or subspecies may consist of numerous diverse populations differing in behavior, physiology, ecology and life histories. Such a phenomenon is particularly evident in the fishes of a desiccating basin such as the Lahontan drainage where populations of each species have been isolated from each other in separate, non-connecting waters for several thousand years. The documentation of the reality of intraspecific genetic diversity and its implications for fisheries management can be found in publications by Behnke (1972a, 1972b) and by Ricker (1972). This local differentiation apparent in the Lahontan cutthroat trout, explains why no introduced race of this subspecies is ever likely to attain the maximum size of the extinct population of the native trout.

The Lahontan cutthroat trout most widely used stocking Pyramid Lake is now Summit L. from Heenan Lake, California. I investigated the origin of the Heenan Lake cutthroat trout (Behnke, 1960) and discovered that the original stock came from the Carson River (a river population, not a lake adapted stock), was introduced into Blue Lakes, California in 1864. Two introductions of rainbow trout (Salmo gairdneri) were made into Blue Lakes and hybridization between the two species occurred prior to establishment of the present population in Heenan Lake from Blue Lakes. The Heenan Lake cutthroat is not a pure Lahontan cutthroat. The evidence of hybridization can be detected in such characters as the number of scales and gillrakers and is supported by immunological evidence (Utter and Ridgway, 1966). The Walker Lake strain of cutthroat trout is propagated in Nevada, but my comparisons suggest the Walker Lake strain has also been exposed to hybridization and appears to be more similar to the Heenan Lake trout than to the original Pyramid Lake cutthroat The only pure population of Lahontan cutthroat trout used in propagation is from Summit Lake, Nevada. The reason why Summit Lake cutthroat trout will not attain a size of 40-60 lbs. in Pyramid Lake relates to the origin of Summit Lake and its cutthroat trout. Summit Lake was formed several thousand years ago by a lava dam across a Lahontan basin tributary. The cutthroat trout was (and still is) the only species of fish in Summit Lake. It has evolved for several thousand years in complete isolation from all other elements of the Lahontan fish fauna. Under these circumstances, evolution has worked to produce a trout eminently suited for the conditions of Summit Lake, but not for Pyramid Lake where it lacks the genetic programming for coexistence with and utilization of the Pyramid Lake fauna.

Although it has been suggested that the Summit Lake cutthroat trout might have been derived from an introduction of Pyramid Lake trout (Wheeler, 1969), I find their characters to be too divergent from the original Pyramid

Lake trout to accept this premise. La Rivers (1962) also recounted statements of an "old timer" who said trout were always present in the inlet stream of Summit Lake and would have been maintained if Summit Lake went dry (it may have desiccated at one time in the last 100 years).

The following figures illustrate the range and mean values for the number of scales and gillrakers of the original Pyramid Lake trout, the Heenan Lake trout and the Summit Lake trout to demonstrate the genetic differentiation between these groups.

	No. of scales	No. of gillrakers
Pyramid L. cutthroat (collected in 1913) (museum specimen)	156-179 (167.6)	21-27 (23.7)
Heenan L. cutthroat	128-157 (138.2)	20-26 (22.7)
Summit L. cutthroat	138-171 (155.4)	21-28 (25.2)

As mentioned above, the cui-ui has been able to avoid extinction by spawning in the lake, in reality, however, the cui-ui has been extinct in the tribal fishery since 1938. The abundance of the cui-ui can't be documented quantitatively, but the spawning runs up the Truckee River must have been immense. Trelease (1971) relates that the density of the schools of cui-ui could divert the Truckee River out of its channel. The cui-ui feeds on minute organisms strained from the water by its gillrakers. Fishes with this type of feeding (closer to the source of photosynthesis) would be expected to maintain higher abundance than a predator such as the trout. This is due to the loss of energy through each step of a food chain from plants to minute organisms feeding on plants to larger invertebrates to small fishes to large fishes. The cui-ui may have been more important as a source of food to the Piute Tribe than was the cutthroat trout. The Indian name for the Pyramid Tribe is "cui-ui eaters" (not trout eaters).

Documentation in quantitative figures on the former catch and abundance of trout is not available because no studies were made or systematic data collected prior to the Newlands Project. There are some insights in various reports, however, which indicate the once great abundance of the Pyramid Lake cutthroat trout and support my contention that Pyramid and Winnemucca lakes sustained at least 2,000,000 lbs. of cutthroat trout before Derby Dam influenced the fishery.

Mr. Mills, a former Fish Commissioner for Nevada, made an attempt to get some facts on the commercial catch in 1888-1890 and his statements are found in the Biennial Report of the Nevada Fish Commission for 1889-90. Mills checked the records of the railroads and Wells Fargo to discover that about 100 tons of trout were shipped from the Truckee River from Oct. 2, 1888, to April 20, 1889, and a similiar quantity the following year. This figure of 200,000 lbs. consisted only of what was shipped to distant markets and not what was sold locally or within about a 100 mile radius (Chinese entrepreneurs transported trout to mining camps and settlements around Nevada). Also, the Indian fishery is not included in these figures, nor the trout caught in Pyramid Lake, only what was taken from the spawning run in the Truckee River and shipped out.

From the above considerations it might be assumed then that in the period of 1888-90 a total catch of about 500,000 lbs. or more was harvested annually from the lake and from the spawning run in the Truckee River. Because of the size of the spawning area available to the trout in the Truckee River and their dispersion, it is not likely that more than one half of the spawners were taken by fishermen. This assumption is also supported by the fact that no evident decline was ever mentioned concerning the Pyramid Lake trout fishery until 1920. If the fishermen were taking more than surplus production and depleting the population, the effects would have been readily apparent and noted. From these considerations, I would estimate the total spawning run to consist of about 1,000,000 lbs. of cutthroat trout annually, in the 1888-1890 period. To support a spawning run of 1,000,000 lbs., the total biomass in the lake would probably have to at least be 2,000,000 lbs. This is based on the fact that cutthroat trout living in lakes do not spawn for the first time until they are 4 or 5 years old and then spawn for the second time (repeat spawners) two years later. Thus, all of the younger age classes and about one half of the older age groups (age 5 and older) did not participate in the annual spawning run but remained in the lake.

Sumner (1940) who detailed the decline and demise of the Pyramid L. cutthroat trout mentioned that 1920 was the last year the trout were in abundance in the Truckee River, but even in March, 1926, the tribal fishery were taking 1,500 to 2,000 trout in a single day. In 1935, after the continuous and drastic decline, the Tribe still sold 6,998 trout of an average weight of more than 10 lbs. and this did not include what was consumed on the reservation. Snyder (1917) described the tremendous schools of trout which left the lake to enter the Truckee River from November to April.

Comparision of life history data of other cutthroat trout which live in large lakes and spawn in large river systems above the lake (Flathead L., Montana, and Priest L., Idaho, for ex.) reveals that the young trout typically live for two years in the river before migrating to the lake. It can be reasonably assumed then, that a significant portion of the total biomass of the Pyramid Lake cutthroat population, was accumulated in and dependent on the Truckee River environment.

Even if the contribution from the river is ignored, it can be reasoned that to grow 2,000,000 lbs. of cutthroat trout, 20,000,000 lbs. of food is needed (conversion of 10-1). Considering the potential food supply available to the trout, the large invertebrate organisms and the forage fish, 20,000,000 lbs. would be a minimal figure for Pyramid Lake.

Most likely, the major source of food for large cutthroat trout is the lake tui chub, *Gila pectinifer*. This chub was also the main food of the pelicans on Pyramid Lake. Hall (1924) studied the relationships of the pelicans to the trout in Pyramid Lake to determine if the decline in the trout population could be attributed to predation by pelicans. Hall found that from April to September, 1924, the pelicans consumed 7,553,750 lbs. of fish, but virtually none of the pelican food was cutthroat trout. The largest component of the pelican diet was *Gila pectinifer* (4,418,944 lbs.). This same species was the major food in the diet of cutthroat trout, but Hall stated that he could detect no impact on the *G. pectinifer* population despite the great predation pressure from pelicans and trout--they swarmed everywhere in the lake in phenomenal numbers. The lake tui chub alone, must have provided at least 20,000,000 lbs. of potential forage for the cutthroat trout.

After viewing schools of large trout floundering and dying in dried up river channels above the lake, Hall had no doubt that the irrigation diversion was responsible for the decline in the trout fishery and not the pelicans.

Remarks on the Estimation of the Fishery to assess what has been lost to the Tribal Fishery by the Direct Effects of the Newlands Project

I will expand my discussion on some of the important considerations used to arrive at certain estimates.

Typically, comparative data on lake fisheries are expressed in lbs. of fish per surface acre of water. A concept called "standing crop" is the amount of fish per unit area existing at any one time. For example my estimate of 2,000,000 lbs. of cutthroat trout for Pyramid and Winnemucca lakes at a combined surface area of 200,000 acres would equal a standing crop of 10 lbs. per acre. The catch or yield of a fishery is that amount of fish removed by any means by fishermen in a certain time period (typically one year). This is often expressed in lbs. per acre and my estimates that originally Pyramid Lake could have supported a potential catch of 1,000,000 lbs. of trout a year (or 5 lb. per surface acre) and maintained a stable fishery, is based on the concept of surplus production. The term "production" refers to the total amount of weight (or biomass) accumulated by a fish population during a period of time (usually one year) and is a more elusive and difficult figure to obtain accurate estimates of. A stable fishery harvests the surplus production, allowing the standing crop to remain relatively stable through time. An analogy might be made with cutting a lawn. The surplus production is cut each week to stabilize the standing crop of grass and by the end of the year much more production of grass has been harvested than ever occurred as "standing crop."

The basic principles governing the production, standing crop and catch of a fishery are the same in water as they are with an agricultural enterprise - the amount of nutrients available for plant life and photosynthesis to initiate organic production and the climate which regulates temperatures and length of the growing season. For the trout and cui-ui fishery of Pyramid Lake, their dependency on the Truckee River for reproduction is also a critical consideration.

Productivity indices for lakes to predict their potential fishery is typically expressed as the quantity of total dissolved solids (TDS) or some aspect of TDS such as calcium carbonate, alkalinity, specific conductivity, etc. Most lakes considered highly productive in fish are in the range of 50-200 ppm TDS. Pyramid Lake at present has a level of about 5,500 ppm TDS. Admittedly, much of the Pyramid Lake TDS does not enter the food chain, but by any standard of lake "richness" - the nutrients necessary to produce life throughout a food chain - Pyramid Lake must rank as extremely high. Undoubtedly, if the TDS levels in Pyramid Lake continue to rise as they have since the initiation of the Newlands Project, fish life will be incompatible at some point. Precisely what ions will be lethal and at what concentration is not known.

Comparing the catch or standing crop of trout in other lakes (none with the basic nutrient levels of Pyramid Lake) allows some basis for the assumptions made for Pyramid Lake (10 lb. per acre standing crop and a potential 5 lb. per acre catch in a fishery per year). Crowley Lake, California, is 5,200 acres with a climatic regime comparable to the Pyramid Lake region. Crowley Lake is considered a rich and productive lake (187 ppm TDS). An annual angler catch of about 20-25 lbs. per acre of trout is estimated for Crowley Lake (Pister, 1965). Henry's Lake, Idaho, a body of water about 6,500 acres in size is also considered productive and has an estimated standing crop of cutthroat trout of 89 lb. per acre (Irving 1954). Fish Lake, Utah was estimated to produce a catch of 38 lb. per acre of trout (Hazzard, 1936). Lake Constance (Bodensee), a lake of about 100,000 acres in central Europe yields about 51 lb. per acre in a commercial fishery of which 20 lbs. per acre may consist of salmonid fishes (trout and whitefish) (Nümann, 1972).

These figures are provided to demonstrate that considering the nutrient levels of Pyramid Lake, the length of the growing season, the original availability of about 200 miles or more of stream environment for reproduction and as a nusury area for the cutthroat trout, the estimates of the original cutthroat trout population at 10 lb. per surface acre of lake (standing crop) and the availability of 5 lb. per acre annually of this population for a sustained yield fishery, should be considered as minimal.

Estimated Management Costs for the Pyramid Lake Fishery

Hypothetically, before the Newlands Project , any fisheries management program designed to maximize the catch of cutthroat trout and cui-ui would be of minimal expense. As stated above, the Truckee River provided a superabundance of reproductive area to maintain the lake populations at maximal levels. Any hatchery propogation would have been superfluous. All that might be useful would be some regulations of the catch to ensure adequate escapement of the spawning run to replenish the stock and a monitoring system to detect population trends and maintain catch statistics. If no natural reproduction occurs in the Truckee River to provide recruitment to the lake, then the entire Pyramid Lake trout fishery is dependent on hatchery propagation (which assumes the role formerly played by the Truckee River in the trout's life cycle) and for all practical purposes, hatcheries cannot raise enough fish to stock into Pyramid Lake to produce a potential fishery of 1,000,000 lbs. per year.

Since about 1950, Nevada Fish and Game Department has been stocking Lahontan cutthroat trout and rainbow trout into Pyramid Lake to sustain a fishery. The stocking rates have been about 15,000 lbs. of hatchery trout per year. The trout must be raised to a size of 6-8 in. to obtain significant survival, or about 5 trout per lb. = about 75,000 trout per year. The new Lahontan federal hatchery plans to raise about 50,000 lbs. of Lahontan cutthroat trout per year (ca. 250,000 trout). At the present reduced size of Pyramid Lake, the combined projected stocking rates would average only about 3 trout per surface area of the lake. If 10% of the stocked trout (at these projected stocking rates) survived and were caught at an average weight of 5 lbs., the total annual trout catch would be around 150,000 lbs., a small fraction of the actual potential. I have no figures available, but I doubt that the total annual catch from Pyramid Lake has exceeded 50,000 lbs. since prior to 1938.

The Lahontan cutthroat trout is the trout best suited for Pyramid Lake, even though the existing stocks are much less suited than the original population. Lahontan cutthroat trout are difficult and expensive to raise under hatchery conditions. It takes two growing seasons and a special high protein diet to raise this trout to 6-8 in. If accurate figures are available, it is probable that it costs $2.00 or more per pound (or about $.40 per 6-8 in. fish) to raise Lahontan cutthroat trout.

Allowing for maximum utilization of the potential food supply, I would estimate that a stocking density of 20 trout per surface acre is desirable--or 2,000,000 trout (400,000 lbs.) annually. No federal or state hatchery is available for that magnitude of production all directed to a single lake.

To sustain the Crowley Lake, California fishery (5,200 acres) 200,000 trout (10/ lb. = 20,000 lb.) are stocked annually at the rate of about 40 per surface acre.

To raise Lahontan cutthroat trout in sufficient numbers to restock Pyramid Lake at optimal rates would require, besides capital investment, operating costs in the range of one million dollars per year. If this money was available, there would yet be the problem of finding a suitable source of water to operate a hatchery of such a production capacity. It is doubtful that such a water source occurs within several hundred miles of Pyramid Lake.

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[Ca. 1975]

Statement of Objectives and Methods of Study

The possibility of obtaining seed money for a faculty research grant offers an opportunity to make use of available talent and equipment to launch a significant research project in evolutionary biology which I am confident can be developed into a major and greatly expanded undertaking.

The basic probem to be studied is: How can two species, fully able to hybridize, and producing fertile offspring, maintain differentiated populations in a continuous environment despite gene flow between the species?

A natural laboratory is available in the Poudre River drainage to study this phenomenon. Originally, only the cutthroat trout (Salmo clarki) was native to the Poudre River, but introductions of rainbow trout has largely replaced the native cutthroat trout in most of the drainage. In the headwaters of the Poudre River, at an elevation of approximately 10,000 ft., the fish are typical cutthroat trout in appearance. In lower reaches of the River (6,000 - 8,000 ft.) the trout resemble typical rainbow trout. A transitional series of hybrid fish is found at intermediate elevations.

My assumption is that natural selection operating mainly by favoring certain genotypes at different water temperatures is functioning to maintain the phenotype of the two species at the two extremes of trout habitat in the river, despite hybridization and gene flow between them. I have long contemplated a study of this interesting situation. The presence on campus of Dr. James Shaklee for the 1973-74 academic year, renewed my hope of obtaining detailed and quantitative data from a study of the genetics of trout in the Poudre River. Dr. Shaklee recently obtained his Ph.D. from Yale University under Dr. Clement Markert. His dissertation was on L.D.H. enzymes of fishes and he is an outstanding authority on the techniques of protein analysis of fish. My own research has been primarily that of a classical systematist, but I have been involved in biochemical and karyological aspects of systematics (Behnke, 1970) and with the use of computers to handle data (Legendre, Schreck and Behnke, 1972). Dr. Shaklee is housed in my laboratory in the Zoology-Anatomy building and our close association on this project should promote the verification of my previously published remarks to the effect that the most significant work in future systematic research will result from cooperative projects between classical systematists and biochemists (Behnke, 1970)

Methods of Study

Samples of trout will be collected from various elevations and frozen (the first sample of cutthroat trout from the headwaters was made October 6, in anticipation that the study will become a reality). Samples of blood and tissue will be used to obtain purified proteins (mainly enzymes). With the appropriate stain and buffer system, proteins form specific bands in the electrical field of an electrophoresis apparatus. A single gene codes for a single protein. Many proteins are polymorphic--that is, different genes (alleles) are present in a population to produce different forms of the same protein. This will allow the detection of a change in gene frequency for any polymorphic protein in samples of trout made at different elevations in the Poudre River and from this we can estimate gene flow between the two species. The specimens will also be analyzed morphologically (classical taxonomic procedures) and the two methods (biochemical and classical) compared for their relative information content.

We plan to have the samples analyzed and data evaluated during the present academic year. During this time, a major grant proposal, based on the preliminary results, will be developed for submission to N.S.F. to continue and expand the project.

This project has many significant implications for evolutionary biology--the speciation process, the effects of natural selection in maintaining certain phenotypes despite hybridization and gene flow, aspects of disruptive selection, etc. It is the type of research project that will demonstrate the efficacy of new techniques and equipment and should stimulate associated research by faculty and grad students. Publications arising directly and indirectly from this study will focus attention on C.S.U. as a significant research center applying biochemical techniques to studies of evolutionary biology. A comparable study has not yet been performed in nature (at least not published). All previous publications on the subject are based on laboratory experiments (mainly with Drosophila) or on theoretical models based on computer simulations.

Why Faculty Research Grant Funds?

Admittedly, the proposal seems somewhat grandiose to be covered by the relatively small amount of funds requested. The problem is that the Zoology Department has a highly sophisticated electrophoretic apparatus (the Bach and Lomb Spectrophore I) which can be used in this study, but the department does not have adequate funds to purchase the necessary chemicals and supplies to carry out the protein determinations.

I would also like to obtain a starch-gel apparatus which would increase the precision of the protein determinations.

My present research funds for this year: $5,000 National Park Service grant and $11,500 contract research for U.S. Bur. Sport Fish. and U.S. Forest Service, are committed to support three graduate students on specific projects and are not available for other uses.

Expenditures

Expendable Supplies

1 pk.	Beckman microfuge tubes (1,000 tubes)	$ 44.00
	Enzyme: cofactors (4g NAD; 1g NADP)	$130.00
	substrates (lactate, malate, 2-glycerophosphate, phosphocreatine, glutamate, etc.)	$100.00
	stains (4g NBT; 4g PMS)	$156.00
1X8 kg	Electrostarch	$ 55.00
		$485.00

Equipment

1 vertical gel mold (complete)	$ 91.00
1 lower electrode chamber	$ 38.00
1 upper electrode chamber	$ 38.00
1 gel stand	$ 50.00
9 staining boxes	$ 9.00
1 special 15 slot comb	$ 24.00
	$250.00

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Report on collections of cutthroat trout from Parachute Creek drainage, Garfield County, Colorado

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March, 1976

Introduction

Parachute Creek, a tributary of the Colorado River at Grand Valley, drains part of the Naval Oil Shale region and will likely suffer negative impact from oil shale development. Collections of cutthroat trout from the East Middle Fork, East Fork and Northwater Creek (tributary to East Middle Fork) were examined, analyzed and compared to evaluate relative purity of existing populations with special emphasis on determining if pure or virtually pure *Salmo clarki pleuriticus* might occur in the drainage.

Despite the fact that 19,000 cutthroat trout fry (probably from Trapper's Lake) and 1500 rainbow trout were stocked into Northwater Creek from 1960 to 1971 by the Colorado Division of Wildlife, samples of 19 specimens collected in 1972, 10 collected in 1973 and 12 taken in 1975 from Northwater Creek, indicate no sign of hybrid influence. The taxonomic characters of the Northwater Creek trout ideally approximate expected values of *S. c. pleuriticus* and they are one of the best representatives of this rare subspecies known from the state of Colorado.

The samples from the East Fork and East Middle Fork of Parachute Creek phenotypically resemble native cutthroat trout, but examination and evaluation of several characters reveals an influence from hybridization with rainbow trout. The hybrid influence is slightly less apparent in the sample from the East Fork.

Comparisons and basis of identification

I have discussed the problems involved in the identification of *Salmo clarki pleuriticus* in several previous reports. The subspecies has a large natural range: Green and Colorado River basin of Wyoming, Utah, Colorado and in parts of San Juan drainage of New Mexico and Arizona. Historically, the trout habitat was not continuous and native trout in many geographically disjunct areas of the basin must have been isolated from genetic continuity for thousands of years. Thus, the trout native to the upper Colorado River drainage would not likely be identical to the *S. c. pleuriticus* of the upper Green River system in Wyoming. It is probable that the cutthroat trout native to the headwater areas of the Colorado River in Colorado is genetically more similar to the greenback cutthroat trout, *S. c. stomias*, of the South Platte drainage, on the other side of the Continental Divide, than it is to *S. c. pleuriticus* from the upper Green River drainage.

During the past several years, numerous samples of cutthroat trout were examined from the Colorado River basin of Colorado and it was noted that the overwhelming majority of these populations were hybrid mixtures of native trout with rainbow trout and with non-native cutthroat. Evaluating all evidence, the native cutthroat trout of the upper Colorado River basin, is characterized by bright coloration, particularly in sexually mature males; medium to large roundish spots on body, larger and more concentrated on caudal peduncle area; spots absent from top of head; scales small, 40-50+ above lateral line and 180-200+ counted in a lateral series two rows above lateral line; pyloric caeca few (30-40). The color photograph of Colorado River cutthroat trout published by Baxter (1972) is an accurate representation of the typical spotting pattern.

The effects of hybridization with rainbow trout is typically first detected by the reduction and absence of basibranchial teeth in specimens carrying S. gairdneri genes. As hybridization spreads and intensifies in a population, scale counts decrease, pyloric caecal counts and vertebral counts increase and the spotting pattern becomes erratic and asymetrical on the body and spots appear on top of the head. At this stage, the population can be characterized as an obvious hybrid swarm. Between the pure population and the obvious hybrid, all transitional stages may be found. For management purposes, I have stressed the fact that because unhybridized populations of native trout are extremely rare in the Rocky Mountain region, those populations that do not exhibit any phenotypic expression of hybrid influence should be designated as "good representatives" of the native trout even though some characters such as lack of basibranchial teeth, indicates a hybrid influence.

I would hesitate to declare the Northwater Creek trout as a pure native population, particularly in view of known introductions and noting variability in spotting pattern which indicates at least a broad base of heterozygosity, possibly from non-native cutthroat trout stocking. Fortunately, however, the cutthroat trout fry stocked into Northwater Creek almost certainly came from Trapper's Lake stock, which is still a good representative S. c. pleuriticus (Behnke, 1974; Wernsman, 1973). It would be practically impossible to detect a slight influence of Trapper's Lake cutthroat trout in a population of trout native to the Parachute Creek drainage, but I am confident that the present population did not have its sole origin from planted Trapper's Lake trout. This is apparent in differences in gillrakers and pyloric caeca. Trapper's Lake trout have typical lacustrine gillrakers, well developed with distinct development of small rakers on the posterior part of the first gill arch - a condition not found in Northwater Creek specimens.

All 41 specimens examined to date have basibranchial teeth. Hybridization from the introduction of 1500 rainbow trout into Northwater Creek in 1965 should have been evident by 1975, if any of these rainbow trout survived and reproduced in Northwater Creek - hopefully this did not occur.

The samples from East Fork and East Middle Fork of Parachute Creek can also be considered as good representatives of native trout. They closely resemble the Northwater Creek specimens in appearance, but they have been influenced by past hybridization with rainbow trout as can be noted in absence of basibranchial teeth and in reduced scale counts. Pettus (1973) recorded typical hybrids and rainbow trout from the lower reaches of the East Fork of Parachute Creek and lists stocking records for 13,000 cutthroat trout and 2500 rainbow trout in the East Fork.

It is surprising to encounter such persistence of the native genotype (based on specimen examination) from the Parachute Creek drainage in light of stocking of non-native trouts and past and continuing environmental degradation of the watershed. The significance of the Northwater Creek trout may be emphasized by pointing out that Wernsman (1973) selected Northwater Creek, Cunningham Creek and the very headwaters of the Colorado River in Rocky Mountain National Park, as the three sites possessing the best known representatives of _S. c. pleuriticus_ in Colorado. Intensive collections from the headwaters of the Colorado River in 1974 and 1975 leads me to conclude that this population can be considered extinct (only 3 specimens found among a multitude of brook trout). Cunningham Creek is part of the Frying Pan - Arkansas diversion system and its trout may be lost.

Conclusions

Detailed data on identification, abundance, degree of isolation and characterization of Parachute Creek basin trouts would be useful not only for impact analysis in relation to oil shale development but also for consideration of habitat improvement in relation to livestock grazing controls.

The degree of isolation of trout populations in the basin is not known. I was informed by Dr. Dave Pettus who collected fishes from Parachute Creek basin in 1972, that an impassable falls exists on the East Middle Fork isolating the trout in Northwater and Trappers Creek above from hybrid contamination below. Other such barriers should be documented in relation to the purity of existing cutthroat trout stocks and a series of priorities can be established to focus attention on those populations best representing the native S. c. pleuriticus in need of protection and to locate situations where population enhancement would result from habitat improvement.

The stocking of brook trout, Salvelinus fontinalis, in headwater beaver ponds connected to East Middle and Middle Forks, occurred in 1971 (Pettus, 1973). The possible spread of brook trout in the basin should be watched, particularly in view of the threat posed of displacing cutthroat trout by the newly introduced brook trout - a common event in Rocky Mountain trout waters.

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Character analysis of cutthroat trout samples from Parachute Creek drainage compared with other pertinent samples (see text).

Locality	Vertebrae	Gillrakers	Pyloric caeca	Scales above lat. line and in lat. ser.	Basibranchial teeth
Northwater Crk. 1972 n = 19	60-62 (60.9)	17-20 (18.9)	23-46 (32.7)	44-50 (46.5) 172-201(184.0)	3-13 (7.3)
Northwater Crk. 1973 n = 10	60-62 (60.9)	16-21 (18.7)	32-42 (35.0)	43-51 (47.3) 175-206(186.7)	2-15 (7.3)
Northwater Crk. 1975 n = 12	-	18-21 (18.6)	30-38 (34.0)	44-50 (47.2) 182-201(189.3)	2-9 (5.6)
E. Middle Fork Parachute Crk. 1972 n = 20	60-63 (61.3)	17-21 (18.9)	24-42 (34.1)	44-54 (47.4) 166-183(169.2)	12 of 20 w/o teeth [8] 1-7 (3.1)
E. Middle Fork Parachute Crk. 1973 n = 11	60-62 (61.3)	18-20 (19.1)	32-43 (36.6)	42-53 (48.1) 164-191(175.7)	3 of 11 w/o teeth [8] 1-5 (2.3)
East Fork Parachute Crk. 1975 n = 12	-	17-19 (18.2)	29-35 (32.3)	43-48 (44.3) 170-197(182.9)	4 of 12 w/o teeth [8] 1-9 (4.3)
Cunningham Crk. (Roaring Fk. drainage) 1972 n = 9	61-62 (61.6)	16-19 (17.2)	32-40 (36.9)	42-47 (44.3) 182-202(193.7)	2-15 (7.9)
Cunningham Crk. 1973 n = 10	60-62 (61.1)	15-19 (16.8)	31-46 (39.1)	40-50 (44.4) 176-196(187.5)	1 w/o teeth [9] 1-13 (7.1)

Locality	Vertebrae	Gillrakers	Pyloric caeca	Scales above lat. line and in lat. ser.	Basibranchial teeth
Nickleson Crk. (Roaring Fk. drainage) 1973 n = 10	60-62 (61.2)	18-21 (19.2)	33-45 (38.7)	43-49 (44.2) 165-198(188.9)	1-12 (4.9)
Headwaters Colo. R. Rcky. Mtn. Pk. 1970 n = 14	61-63 (62.1)	18-23 (20.3)	32-43 (37.1)	44-49 (43.1) 187-226(195.1)	6-33 (14.0)
Baker Crk., head of Grand Ditch, R.M.N.P. 1975 n = 23	-	17-22 (20.3)	26-40 (34.8)	41-48 (43.1) 171-190(180.6)	2 of 23 w/o teeth [21] 1-22 (9.7)
Trapper's Lake 1971 n = 24	59-63 (60.5)	18-22 (20.1)	35-63 (42.7)	39-47 (42.7) 165-220(191.1)	2-16 (9.6)

A summary of information on a unique form of cutthroat trout
native to the Snake Valley section of the
Bonneville Basin, Utah and Nevada

Prepared for BLM
Salt Lake City, Utah
by
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March, 1976

Introduction

A cutthroat trout population discovered in 1953 in Pine Creek on the eastern slopes of Mt. Wheeler, Nevada, has been a most enigmatic fish. There is no doubt that the Pine Creek cutthroat is a pure population, uncontaminated by hybridization and undoubtedly it is not native to Pine Creek which drains into a desiccating basin originally devoid of fish. It has been assumed that the original range of the Pine Creek trout is Snake Valley, Utah, part of the Bonneville basin. The question, which until now, has not been satisfactorily answered is: Are the distinctive characters differentiating the cutthroat trout in Pine Creek from other Bonneville basin cutthroats (*Salmo clarki utah*), the result of local speciation in a single parental stock, or does it represent a more widespread divergence characterizing all of the native cutthroat trout of Snake Valley?

Recent collections allow for a more confident answer to this question and fully support the contention that the cutthroat trout native to Snake Valley is distinct from *S. c. utah*. Analysis of the data from several samples provides a basis to differentiate the Snake Valley cutthroat trout from *S. c. utah* and other subspecies of *Salmo clarki* and indicates the expected range of variability for identification of future collections. The high number of basibranchial teeth is the most diagnostic and stable taxonomic character of the Snake Valley cutthroat.

Historical Review

The cutthroat trout, classified as Salmo clarki utah, which once abounded in the Bonneville basin, suffered a catastrophic decline after white man settled the basin, altered the habitat and introduced multitudes of non-native trouts. Miller (1950), Cope (1955) and Sigler and Miller (1963) believed the native cutthroat trout of the Bonneville basin was likely extinct.

It was of some significance then, 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. It was believed that this trout was introduced from the Bonneville basin and represented S. c. utah.

A series of separate desiccating basins occur in Nevada west of the Bonneville basin and south of the Lahontan basin. These basins were originally barren of trout but early settlers began introducing trout into the mountain streams at least as early as 1876 (Miller and Alcorn, 1943; Hubbs and Miller, 1948; Hubbs, Miller and Hubbs, 1974). It has been assumed that these early introductions came from the Trout Creek drainage of the Snake Valley section of the western Bonneville basin. Widespread introductions of rainbow trout and Yellowstone Lake cutthroat trout were made for many years into both the native and introduced range of the Snake Valley cutthroat and it was commonly believed that none of the early introductions of Snake Valley cutthroat persisted as pure populations in Nevada until the 1953 discovery in Pine Creek. Pine Creek drains into Spring Valley, White Pine County, Nevada, a basin originally barren of fish (Hubbs, Miller and Hubbs, 1974). The nearest streams originally containing the native Snake Valley cutthroat trout are Lehman, Baker and Snake Creek on the eastern slopes of Mt. Wheeler and Hendrys Creek, immediately to the north on Mt. Moriah - all tributaries in the Trout Creek drainage of Snake Valley.

In 1953 specimens of Pine Creek trout were sent to Dr. R. R. Miller, University of Michigan for identification and I made my first collection from Pine Creek in 1958. The first introduction of 44 fish from Pine Creek was made into Hamptom Creek in 1953 and a new population became established.

Both Dr. Miller and I independently agreed that the cutthroat trout of Pine Creek was differentiated from _S_. _c_. _utah_ and all other cutthroat trout. The major differences are in general morphology and spotting pattern and in the number of basibranchial teeth and gillrakers.

It was not known, however, if the uniqueness of the Pine Creek trout was a reflection of very local speciation restricted to an unknown parent population from which the Pine Creek trout was derived or if their distinctive traits were characteristic of all of the native cutthroat trout of Snake Valley indicating a major genetic divergence of the trout of this area from the rest of the Bonneville basin.

A second transplant of Pine Creek trout introduced 54 fish into Goshute Creek in 1960. The new populations in Hampton and Goshute creeks provided an opportunity to compare specimens from these streams with the parental stock in Pine Creek and gain some insight into the variability and stability of certain distinctive characters of the Pine Creek cutthroat. In an earlier report (Behnke, 1970) I presented and discussed the data from specimen examination of the Pine Creek trout and its two derived populations along with data from a partially hybridized population in Hendrys Creek. My conclusions were that the Pine Creek cutthroat (and the original trout of Hendrys Creek) were consistently differentiated from _S_. _c_. _utah_ by fewer scales, more even distribution of spots, more gillrakers and particularly more basibranchial teeth. Evidence was still lacking, however, to draw any firm conclusion on the question of uniqueness of the native Snake Valley cutthroat which, at that time, I believed extinct as pure populations in its native range. These conclusions were essentially repeated in my last report on the Snake Valley cutthroat trout (Behnke, 1973b). 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 a determined effort to find cutthroat trout in the Trout Creek (and Deep Creek) drainage in 1970 by Frank Dodge, Nevada Fish and Game, and Don Cain, BLM, all failed to find native trout.

In 1974 BLM personnel conducted stream habitat surveys on several streams on the east slope of the Deep Creek Mountains. A population of native cutthroat trout was discovered by BLM biologists Don Duff and Josh Warburton in the headwaters of Trout Creek, Juab County, Utah. With this discovery, the Utah Division of Wildlife Resources (DWR) was requested by the BLM to sample adjacent streams. This cooperative effort resulted in the find of another population of native trout in the headwaters of Birch Creek by DWR personnel in 1975. Both Trout Creek and Birch Creek were reported to have only rainbow trout in the 1940's and Mr. Cain and Mr. Dodge found no indication of cutthroat trout in their collections from these streams in 1970 (Research & management of an undescribed cutthroat trout in eastern Nevada, a presentation by Dodge & Cain to the California-Nevada Chapter of the Wildlife Society, 1971). Evidently barriers to upstream migration had prevented rainbow trout from hybridizing with the native cutthroat trout in the headwaters of Trout and Birch creeks and these headwater areas were not sampled until 1974-75. A source was now available to compare with the cutthroat trout of Pine Creek (and its derivatives) and Hendrys Creek to more authoritatively determine the taxonomic status of Snake Valley native trout.

Mr. Frank Dodge of the Nevada Fish and Game Department devoted much time and effort to the study and protection of this trout and during his work he found a virtually pure population of cutthroat trout in the very headwaters of Hendrys Creek in 1972 and also collected an unusual cutthroat trout in Mill Creek (on the Bonneville side of Mt. Wheeler). Mill Creek is an extremely small stream - it must be one of the smallest natural habitats to maintain a self-reproducing population of trout and it is unlikely that these trout could have persisted for thousands of years since the pluvial period. Mr. Dodge believed Mill Creek was stocked with trout when the Osceola Ditch burst its bank above Mill Creek in 1905. The Osceola Ditch was constructed to convey water from Lehman Creek around Mt. Wheeler for a gold mining operation in the 1880's. Katherine Kaiser, U.S. Forest Service, Ely, Nevada, has called my attention to the fact that the Osceola Ditch extended around the east side of Mt. Wheeler to tap the waters of Pine Creek. Thus, the logical origin of the Pine Creek cutthroat trout is from Lehman Creek via the Osceola Ditch.

Taxonomy

For taxonomic evaluation and interpretation I have used samples from Pine Creek (assumed to be derived from Lehman Creek), its derivative populations in Goshute and Hampton Creek (to examine variability of a same genotype in different habitats), Hendrys Creek (headwaters population and hybrids from downstream), Mill Creek, Birch Creek, Trout Creek and a hybrid population from Muncy Creek (Schell Creek Range). Also included are data from museum specimens: 2 specimens from Lehman Creek, collected in 1938; 2 specimens from Trout Creek, collected in 1933; a single specimen collected in 1884 from Deep Creek, which strongly suggests that this same trout is also native to the Deep Creek drainage. (Trout Creek drains the east side of the Deep Creek Range and Deep Creek the west side, both are tributary to what is now the Great Salt Desert of the Bonneville basin).

The basic premise of a taxonomic study of a group of fish such as the Snake Valley cutthroat trout is to find unique or distinctive characters which differentiates this particular group from other groups derived from a common ancestor. When a population is fractioned by some climatic 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. Depending on the degree of difference in the environments and the selective factors involved, rates of divergence may be highly variable. The disruptive events initiated by the last glacial period, more than 50,000 years ago, were responsible for most of the subspecies of North American animals today. The differentiation of the Snake Valley cutthroat trout from the other cutthroat trout of the Bonneville basin cannot be readily explained by known climatic or geological factors. The isolation of the Trout Creek drainage of Snake Valley from other waters of the Bonneville basin dates only from the final desiccation of Lake Bonneville about 8,000 years ago. Thus, the native trout in the Sevier, Provo and Bear River drainages have been isolated from contact with each other as long as they have been isolated from the Snake Valley cutthroat trout and it would not be predictable from the hydrographic history of the basin to expect the degree of differentiation found in the Snake Valley cutthroat. The Snake Valley cutthroat may represent the original cutthroat trout of the Bonneville basin from pre-pluvial times, which was replaced by a later invader throughout most of the basin, or, more likely, the divergence was initiated by change in lake levels of Lake Bonneville during its long history as discussed by Broecker and Kaufman (1965). Isolation of the eastern part of the basin for a few thousand years could have initiated genetic divergence which was later maintained when lake levels rose, by the innate reproductive homing behavior to parent streams, characteristic of salmonid fishes

(Behnke, 1972). A similar situation exists with the cutthroat trout of the Lahontan basin. The Lahontan cutthroat trout, S. c. henshawi, is native to the Truckee, Carson and Walker river drainages, but the cutthroat trout native to the Humboldt drainage is consistently differentiated from S. c. henshawi by an average of 3 fewer gillrakers and about 25 fewer scales in the lateral series and represents an undescribed subspecies (Behnke, 1968). Thus, the parental cutthroat trout in both the Lahontan and Bonneville basins have diverged into two distinct groups, a generally distributed subspecies, S. c. henshawi of the Lahontan basin and S. c. utah of the Bonneville basin, and geographically restricted races - the Humboldt River drainage cutthroat in the Lahontan system and the cutthroat native to the Snake Valley area of the Bonneville basin.

Table 1 presents data from some selected meristic characters of samples of Snake Valley cutthroat trout and of S. c. utah.

Of prime importance is to determine if the trout found in the headwaters of Trout and Birch creeks in 1974 and 1975 represent pure populations of the native Snake Valley cutthroat. There is no indication of hybrid influence in such expressions as erratic spotting patterns, fish without basibranchial teeth or with abberrant and highly variable meristic characters. When compared with the Pine Creek and headwaters of Hendrys Creek samples, the Birch Creek and Trout Creek samples have fewer basibranchial teeth and fewer gillrakers but about the same number of scales and pyloric caeca. There is no way to know with absolute certainty that these differences are not the result of a slight hybrid influence, but this amount of variability is typically found in small populations of cutthroat trout subspecies where the populations have been isolated for thousands of years.

Most of the specimens from Trout and Birch Creek exhibit a profusion of basibranchial teeth in dense patches, typical of the trout in Pine Creek and Hendrys Creek. Also specimens were examined with teeth appearing on the hypobranchial segment of the gill arches, a highly unusual character, otherwise commonly found only in cutthroat trout from Pine Creek and Hendrys Creek. Biochemical analysis of many groups of cutthroat trout performed at Utah State University has provided cogent evidence of a unique genetic event occurring in the ancestral progenitor of the Snake Valley cutthroat after their separation from other Bonneville cutthroat trout, which is shared in common by the present Trout Creek and Pine Creek (specimens from Goshute Creek were used) populations, differentiating them from other Bonneville trout (and all other cutthroat trout tested).

The A form of the lactate dehydrogenase enzyme (LDH-A) of muscle tissue typically reveals a very stable and unchanging pattern in all cutthroat and rainbow trouts surveyed to date. In both the Pine Creek and Trout Creek cutthroat trout, an unusual banding pattern was exhibited, suggesting that one of the genes governing LDH-A expression functions in a most "abnormal" manner. Whatever the explanation of such a phenomenon, the unique LDH-A shared by the Pine Creek and Trout Creek populations, distinguishing them from all other trouts examined, supports the morphological data that the Snake Valley cutthroat trout represents an ancient divergence from S. c. utah. The biochemical analysis is reported on in an annual progress report, NMFS Project No. 1-87-R, June 1, 1974 - May 31, 1975 by Stalnaker, Klar, Braman, Kao and Farley. Utah Cooperative Fishery Unit, Logan, Utah.

The first collection of 17 trout from Trout Creek above the barrier made in 1974 were poorly preserved and a later collection was made. The last collection separated the specimens from three collecting sites (probably less than one mile apart): area 1 the extreme headwaters at an elevation of 8600 ft (6 specimens), area 2 at 8400 ft (6 specimens) and area 3 at 8200 ft (8 specimens). The first collection of 17 specimens was in area 3 or below to the barrier falls. The sample sizes are small but the headwater sample has more gillrakers but only about half the number of basibranchial teeth as the downstream samples. This phenomenon should be examined with more specimens to verify the reality of these differences. Typically cutthroat trout in small streams consist of highly localized populations with little movement between them. This is demonstrated in the Hendrys Creek data. Below a barrier falls in 1970 a typical rainbow x cutthroat hybrid occurred with 7 of 10 specimens lacking basibranchial teeth. Above the falls, the trout were phenotypically cutthroat in appearance but the effects of past rainbow trout introduction could be detected with 4 of 7 specimens lacking teeth. In 1972, 20 specimens were collected in the extreme headwaters of Hendrys Creek, about two miles above the barrier (and with no intervening barrier preventing mixing) and these appeared to be a virtually pure population with only one specimen lacking teeth and a mean tooth count of 24.5. Evidently the upstream diffusion of hybrid influence in Hendrys Creek was a very slow process and once this was discovered, attempts were made to eradicate the downstream hybrid population and repopulate the waters with the headwater population (personal communication from Frank Dodge and Leland McClellend, Nevada Fish and Game).

It is of interest to note that of all characters compared between samples from Pine Creek and the populations in Hampton and Goshute creeks derived from Pine Creek transplants, the only significant difference was found in the number of gillrakers - a character found to be genetically stable in my other studies.

I suspect that this difference may be due to the "Founder's Principle," where a new population is established from a few individuals and these individuals did not possess the modal values of gillrakers of the parent population. The unusual characters of the Mill Creek trout may also be explained in this manner, however rainbow trout and non-native cutthroat may have been introduced into Lehman Creek prior to the stocking of Mill Creek from the Osceola Ditch break.

The addition of data from Trout Creek and Birch Creek specimens somewhat lessens the magnitude of difference in the number of gillrakers and basibranchial teeth between Snake Valley cutthroat trout and S. c. utah. Besides typically possessing one or two more gillrakers and about twice the number of basibranchial teeth, the Snake Valley cutthroat have a distinctive morphology and spotting pattern. The spots tend to be more evenly distributed over the body in Snake Valley cutthroat trout when compared with S. c. utah and the body presents a more "chunky" appearance with a long head and long dorsal fin positioned more than half the distance from the snout to the end of the vertebral column. Hopefully, the discovery of other pure populations in the Deep Creek Mountains will provide the basis for deciding if the Snake Valley cutthroat consistently displays the degree of differentiation warranting subspecific designation or if it would be more judicious to consider them only as a differentiated group of S. c. utah. In any event, the Snake Valley cutthroat trout is the native trout of this particular geographical area, they are rare as pure populations and every effort should be made to preserve what is left and increase their abundance.

Status

As discussed above, the Snake Valley cutthroat trout has been extirpated from virtually all of its known original range. Most of the known existing populations are the result of introductions in Nevada outside of its native distribution. This trout does not appear on the official USDI list of endangered species, which has been in a state of flux. The Snake Valley cutthroat is recognized by Nevada Fish and Game Departments as one of their rare or endangered species (as S. c. utah). It was listed by Miller (1972) as one of the threatened fishes of the United States and the Bonneville Chapter of the American Fisheries Society considered it endangered (Holden, et al., 1974). Because of the recent discoveries of this trout in Trout and Birch creeks and the active interests manifested to preserve and increase its distribution and abundance, I would consider the Snake Valley cutthroat trout as threatened but not endangered at present.

It must be emphasized that the uncertainty of the taxonomic status of the Snake Valley cutthroat trout should not be confused with its survival status or its actual survival status with the current USDI list of endangered and threatened species.

This confusion apparently inhibited the BLM from fully implementing their Goshute Creek Habitat Management Plan to protect the habitat and increase the abundance of the Snake Valley cutthroat population in Goshute Creek (N-4 WHA-A1, Ely District, Nevada, Donald R. Cain, 1971).

Correspondence between Mr. William E. Ireland, Acting District Manager, BLM Ely office and myself in January, 1972, stated Mr. Ireland's concern and intentions to implement the Goshute Creek Habitat Management Plan but questions were raised on taxonomic status and official recognition on the USDI list of endangered species. Evidently, under pressure from local livestock interests, the grazing controls required for habitat restoration and reduction of head-water erosion were not instituted. The unstable headwater habitat conditions aggravated 1973 flooding which devastated Goshute Creek, cutting new channels, making much of the previous stream improvement devices inoperable and resulting in a 60% decline of the cutthroat trout population. This incident was one of the examples cited to demonstrate conflicts between livestock interests and multiple use management on BLM lands in Nevada in a 1974 Range Evaluation Report: Effects of livestock grazing on wildlife, watershed, recreation and other resource values in Nevada.

Protective Measures

As discussed above, a transplanting program from the Pine Creek population into barren streams established new populations in Hampton and Goshute creeks. Mr. Frank Dodge, Nevada Fish and Game, outlined a restoration program entitled: "Evironmental analysis of native cutthroat populations in White Pine County, Nevada" which he sent to me in January, 1974 with a list of 21 streams to be considered as potential sites of new introductions. Mr. Leroy McLelland, Mr. Dodge's successor as regional biologist in the Ely office of Nevada Fish and Game informed me (November, 1975) that new populations were introduced into Willard and Williams creeks. Also, the downstream area of Hendrys Creek was treated with antimycin in 1973 and 1974 in an attempt to eradicate hybrids.

The U.S. Forest Service, after the discovery of the Hendrys Creek trout, protected the headwater area from incursion by mining roads.

The Salt Lake District, BLM, is preparing a Habitat Management Plan to implement protective measures for the Trout Creek trout. Habitat surveys are planned for remaining streams in the Deep Creek Mountains in 1976-1977 by BLM.

Discussion

It was mentioned in my last report on Snake Valley cutthroat (Behnke, 1973a) that no detailed knowledge existed on the life history and ecology of the Snake Valley cutthroat - its food, reproduction or limiting factors. No significant ecological information has been obtained since then, but as a practical basis for restoration programs it can be assumed that their evolutionary heritage as a race of cutthroat trout allows some broad generalizations to be made. The Snake Valley cutthroat trout will hybridize with rainbow trout and probably cannot successfully coexist with brook or brown trouts in most situations - thus any potential sites for introductions must be barren of all other trouts and protected from possible invasion. The Snake Valley cutthroat trout will likely thrive in virtually any stream capable of supporting other trouts. The observed ability to reach a relatively large size (10-12 in.) in extremely small streams and under a harsh environmental regime such as is found in the headwaters of Hendrys Creek, Goshute Creek and in Mill Creek, under circumstances typically producing stunted brook or rainbow trouts, indicates a fisheries management potential for Snake Valley cutthroat trout. Their main limiting factor as a sport fish is likely to be a characteristic shared by most cutthroat trout - their vulnerability to over-exploitation by angling, where relatively light to moderate fishing pressure can effectively remove virtually all adults from a population. It is important, therefore, when considering the angling potential of Snake Valley cutthroat trout to estimate potential fishing pressure and design regulations accordingly to protect the bulk of the population (Behnke and Zarn, 1976).

Recommendations

In order of priority I would recommend:

1. Thorough survey and collections in all headwater sites in Deep Creek Mountain Range in both Trout Creek and Deep Creek drainages in attempt to document occurrence of other pure populations of native trout. This work should also:

   (a) characterize the habitat and identify actual and potential threats to habitat degradation.

(b) locate potential sites for new introductions.

(c) obtain some estimates of abundance, size and any life-history and ecological notes.

(d) identify watersheds where habitat management would be beneficial for increasing abundance of native trout including potential for stream improvement devices and possible pond or small lake construction sites.

2. Develop comprehensive species management plan incorporating this information designed to preserve and increase abundance of the native trout with a long-term view of making it available as a significant recreational resource.

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Character analysis of Snake Valley cutthroat trout and Bonneville (or Utah) cutthroat trout

Locality	Vertebrae	Gillrakers	Pyloric caeca	Scales above lat. line and in lat. series	Basibranchial teeth
Snake Valley cutthroat trout - - - - - - - - - -					
Pine Crk. 1959,1970,1972 n = 61	60-64 (62.3)	19-25 (21.8)	25-47 (33.9)	34-45 (39.1) 133-171 (148.9)	8-55 (27.3)
Hampton Crk. (Pine Crk. stock) 1970,1972 n = 32	60-63 (61.6)	20-23 (20.9)	28-39 (33.7)	35-45 (39.0) 136-162 (150.2)	5-47 (28.6)
Goshute Crk. (Pine Crk. stock) 1970,1972 n = 31	61-64 (62.3)	17-22 (20.0)	31-45 (35.7)	35-45 (39.0) 135-162 (145.4)	8-90 (28.6)
Hendrys Crk. very headwaters 1972 n = 20	61-64 (62.4)	18-23 (20.9)	29-46 (36.1)	35-44 (39.2) 129-163 (149.9)	1 of 20 w/o teeth [19] 14-19 (24.5)
Hendrys Crk. downstream, but above barrier 1970 n = 7	61-63 (61.9)	20-22 (20.9)	33-46 (39.0)	41-44 (42.1) 146-175 (155.3)	4 of 7 w/o teeth [3] 13-16 (14.7)
Hendrys Crk. below barrier 1970 n = 10 (obvious hybrids)	61-63 (61.9)	18-22 (20.2)	35-47 (41.0)	36-42 (39.7) 142-160 (152.1)	7 of 10 w/o teeth [3] 1-6 (3)

Locality	Vertebrae	Gillrakers	Pyloric caeca	Scales above lat. line and in lat. series	Basibranchial teeth
Mill Crk. 1970,1972 n = 30	60-64 (62.6)	17-22 (19.4)	34-56 (42.5)	35-43 (39.7) 139-175 (154.1)	2-30 (13.2)
Lehman Crk. 1938 n = 2 (UMMZ 141701)	62, 62	20, 21	-	40, 42 148	17, 20
Trout Crk. 1933 n = 2 (UMMZ 191644)	61, 63	19, 22	37, 41	38, 40 147, 149	10, 18
Deep Crk. 1884 n = 1 (FMNH 260)	-	at least 13 on lower arch 21-22? total	-	-	at least 32
Trout Crk. above barrier 1974 n = 17	-	18-22 (19.9)	25-40 (33.0)	37-44 (39.9) 137-168 (152.4)	2-39 (22.2)
Trout Crk. 1974, area I n = 6	62-64 (63.0)	20-22 (21.0)	26-39 (33.0)	39-42 (40.2) 145-164 (153.5)	2-27 (11.2)
Trout Crk. 1974, area II n = 6	61-64 (62.4)	18-22 (20.2)	30-39 (34.7)	38-41 (40.2) 145-159 (152.3)	14-37 (20.2)
Trout Crk. 1974, area III n = 8	61-64 (62.4)	18-21 (19.9)	31-40 (34.9)	38-42 (40.7) 144-163 (152.5)	9-39 (20.6)
Birch Crk. headwaters 1975 n = 14	-	18-22 (20.1)	31-47 (37.9)	37-42 (39.3) 141-168 (156.5)	2-36 (17.9)
Muncy Crk. 1972 n = 15 obvious hybrids	58-64 (60.9)	17-20 (19.1)	33-48 (36.3)	35-45 (37.1) 128-155 (134.4)	2 of 15 w/o teeth [13] 1-29(9.7)

Locality	Vertebrae	Gillrakers	Pyloric caeca	Scales above lat. line and in lat. series	Basibranchial teeth
Typical S. c. utah museum collections 1872-1915, Salt L. Utah L. drainages n = 19	61-65 (63.0)	17-22 (19.7)	-	32-43 (37.8) 150-186 (163.0)	3-20 (9.9)
Birch Crk. near Beaver, Utah 1973 n - 12	62-64 (62.6)	18-20 (19.1)	24-43 (36.3)	36-42 (38.4) 151-163 (156.3)	1-19 (11.2)
Reservoir Canyon and Water Canyon near Pine Valley, Utah 1958,1973 n = 30	61-64 (62.1)	17-21 (19.2)	29-40 (35.3)	38-45 (40.3) 143-176 (158.9)	6-19 (11.2)

Summary of information on the status of
the Utah or Bonneville cutthroat trout, Salmo clarki utah

Prepared for Wasatch National Forest
Salt Lake City, Utah

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Introduction

The cutthroat trout, Salmo clarki utah, native to most of the Bonneville basin, might be characterized as a victim of benign neglect. That is, its rapid decline in the Twentieth Century, has not been so much a result of direct destruction of habitat and fish, but rather an overwhelming emphasis on introduction of non-native trouts as a basis for fisheries management in the Bonneville basin. These introductions have caused replacement and hybridization to the point where S. c. utah appears to be virtually extinct as pure populations. Over the past 25 years, several authors have expressed their belief that this subspecies is extinct. Hopefully, they were somewhat premature in their judgement. Some probable pure populations are discussed in this report and their use to establish new populations and initiate a restoration program is considered.

A fundamental problem hindering concerted efforts to preserve this rare subspecies, increase its abundance and better document its survival status, has been the confusion surrounding its taxonomic status - or how can S. c. utah be identified?

Tanner and Hayes (1933) were frustrated in their attempt to study the native trout of Utah because of a lack of diagnostic criteria on which to base comparisons and hybridization with introduced cutthroat trout and rainbow trout. They stated: "The exact identity of the trout of this state as they existed when the first explorers entered it is still a puzzle and is becoming more difficult to solve because of the scarcity of native fish and the mixing of introduced forms." Needless to say, the situation has not improved.

Historical Review

It has been generally assumed that the native trout of Utah consisted of two subspecies of cutthroat trout: Salmo clarki utah of the Bonneville basin and S. c. pleuriticus of the Colorado River basin (Tanner and Hayes, 1933; Platts, 1957; Sigler and Miller, 1963). In the western part of the Bonneville basin in the Trout Creek drainage of Snake Valley, Utah and Nevada, a differentiated form of cutthroat trout is native. This trout may eventually be described as a new subspecies. In Utah, the Snake Valley cutthroat is known only from the isolated headwaters of Trout and Birch creeks (Behnke, 1976). In relation to native trout of Utah, other authors have neglected the fact that an area in northwestern Utah is drained by the Raft River, a tributary of the upper Snake River of the Columbia River basin. The native cutthroat trout of the Raft drainage is the large-spotted ("Yellowstone" type) cutthroat of the upper Snake River area - a trout of uncertain subspecific status. The only population of Raft River "cutthroat" trout presently known from Utah is a partially hybridized population in One Mile Creek, about 30 miles west of Snowville (Murphy, 1974). Pure populations of S. c. pleuriticus are not known from Utah, but the "best representative" population studied to date is found in the Little West Fork of the Black Fork (Behnke, 1970, 1974). Of all the collections I have examined of possible S. c. utah, only three appear to represent pure populations. Reservoir Canyon and Water Canyon creeks, headwater tributaries of the Santa Clara River, near Pine Valley, are typical

S. c. utah, although these sites are in the Virgin River drainage and not the Bonneville basin. Birch Creek, a tributary in the Beaver River drainage, southeast of Beaver, also holds a trout wholly typical of S. c. utah exhibiting no sign of hybridization.

Thus the native trout of Utah actually consists of three, possibly four, subspecies - all of them extremely rare as pure populations in the state.

The earliest record, of which I am aware, specifically referring to Utah native trout, is that of Townsend in 1833 on trout in the Bear River drainage. Townsend wrote that the trout were very abundant, averaging 15-16 inches with some much larger (Thwaits, 1907).

The native cutthroat trout, particularly S. c. utah, of Bear Lake, Utah Lake and Panguitch Lake, was of great importance to the early settlers of Utah, for both sustenance and commerce. S. c. utah was one of the first, if not the first, cutthroat trout artificially propagated by a public agency. Stone (1874) mentioned his visit to the Salt Lake City Municipal Trout Hatchery in 1872, discussing trout propagation with the Superintendent, Mr. A. P. Rockford. The trout propagated came from the Bear River.

The cutthroat trout fisheries were soon over-exploited in Bear, Utah and Panguitch lakes. Yarrow (1874), Siler (1884) and Woodruffe (1892) all mentioned the former abundance of cutthroat trout (3500-4000 lbs of trout to 15-18 lbs were reported for a single seine haul in Utah Lake in the 1860s) and their subsequent decline.

The rainbow trout was first introduced into Utah in 1883 (Sigler and Miller, 1963) and brook trout, brown trout and subspecies of non-native cutthroat trout soon followed. After the initial decline from over-fishing and habitat loss, the accelerated pace towards extinction of the native trout of Utah can be attributed to introductions of non-native trouts, particularly hybridization with rainbow trout and with other subspecies of cutthroat trout.

A variety of races and subspecies of cutthroat trout have been propagated and introduced throughout the western United States, but from the early 1900s to 1955, the cutthroat trout of Yellowstone Lake provided the overwhelming majority of eggs used in cutthroat trout propagation and Yellowstone Lake cutthroat trout were stocked in all western states as "native" trout. The term "native" trout can be a problem in semantics. Under the influence of a system of classification recognizing all cutthroat trout as a single species, *Salmo clarki*, Yellowstone cutthroat trout were stocked as "native" trout because they are part of the species, *S. clarki*.

Platts (1957) pointed out that the cutthroat trout caught in Utah were not the native trout but introduced Yellowstone trout and various hybrid mixtures. Platts mentioned that the brood stock used for Utah cutthroat trout propagation in Strawberry Reservoir, was started from Yellowstone cutthroat trout but hybridization with rainbow trout had occurred. My examination of Strawberry Reservoir "cutthroat" trout taken in 1971 revealed that they represent a Yellowstone cutthroat x rainbow trout hybrid with a predominance of cutthroat trout heredity. Although the Strawberry Reservoir "cutthroat" may be an excellent trout for the purposes it is used for, it is derived from non-native trouts and bears little resemblance to any of the native trout of Utah.

The taxonomy of *S. c. utah* is confused not only by the lack of clear-cut differentiating characters but also by the history of its nomenclature. A variety of specific and subspecific names have been applied to the cutthroat trout of the Bonneville basin (*mykiss*, *purpuratus*, *virginalis*, *spilurus*, *pleuriticus*). The most common name found in the older literature is *virginalis*. Jordan (1920) declared that the name *virginalis* is correctly associated with the cutthroat trout native to the Rio Grande basin and the earliest name for cutthroat trout of the Bonneville basin is utah. The name "Salmo utah" was proposed by Suckley (1874) to distinguish the trout of Utah Lake from "S. virginalis" in streams of the Bonneville basin. Suckley believed the larger, more silvery Utah Lake trout was a different species because it appeared so distinct from the darker, more heavily spotted stream trout he was familiar with from the Provo, Weber and Bear rivers. Although we now realize that the distinct appearance of the Utah Lake cutthroat was environmentally induced by life in a large, alkaline lake, the name utah is a valid name and is the currently accepted subspecific designation for the trout indigenous to the Bonneville basin.

Unfortunately, the trout of Utah Lake was used by Jordan (1891) to describe and illustrate the characteristics of Bonneville basin trout. The spotting pattern of adult trout from Utah Lake was quite atypical of S. c. utah because guanine deposition obliterated and altered the normal spotting pattern with a silvery sheen.

Because of a lack of diagnostic criteria for positive identification of S. c. utah and a long history of replacement and hybridization with non-native trouts, Miller (1950), Cope (1955), Platts (1957) and Sigler and Miller (1963) all believed that S. c. utah was probably extinct as a pure form.

As mentioned above, I believe three of the populations represented in Table 1 are pure populations of S. c. utah. Undoubtedly more such populations can be discovered by dilligent search. Pure populations of this cutthroat trout, however, are extremely rare. The recent collections listed in Table 1 for character evaluation and identification are not from populations randomly encountered, but largely from sites believed to potentially hold S. c. utah because of their remoteness, isolation and absence of known records of introductions.

The last version of the U.S. Department of Interior's "Red Book" of endangered species (1973) listed S. c. utah as "status undetermined." This classification was based mainly on the confused taxonomic status. The International Union for the Conservation of Nature lists S. c. utah as "rare." Holden et al. (1974) considered it endangered. In my summary on S. c. utah (Behnke, 1973) I treated it as rare with a highly restricted distribution.

A current cooperative project between the BLM, U.S. Forest Service, Utah Division of Wildlife Resources and the U.S. Fish and Wildlife Service is designed to protect and enhance the habitat of Birch Creek, a small tributary to South Creek in the Beaver River drainage (Duff, Gervais and May, 1974). I identified the Birch Creek trout as S. c. utah in 1973.

Taxonomy

There are no unique characters on which to base a positive identification of S. c. utah. The values of all of the characters studied overlap with values of other subspecies of cutthroat trout. There are differences in mean values of certain characters that are useful in recognizing S. c. utah and to detect the influence of hybridization with Yellowstone cutthroat trout and rainbow trout.

Murphy (1974) used a computer analysis of data comparing several characters of S. c. utah with other subspecies. Although expressing similarities and differences in a more quantitative framework, this study merely stated the degree of overlap in a more mathematical manner. Stalnaker, et al. (1975) made a study of the electrophoretic patterns of proteins in S. c. utah and several other groups of cutthroat trout and rainbow trout. No protein was unique or distinctive for S. c. utah but this research did find a unique LDH enzyme in the Snake Valley cutthroat trout, confirming other taxonomic data that the Snake Valley cutthroat represents an evolutionary line differentiated from S. c. utah. It would be expected that the isolation of the separate drainages in the Bonneville basin for thousands of years since the final desiccation of Lake Bonneville resulted in a large amount of variability among the various disjunct populations of S. c. utah. It is also expected that variability is increased in small populations isolated in small streams where genetic drift or unusual selection pressures may operate.

My first evaluation of the taxonomic characters of S. c. utah was based on examination of museum specimens collected in the Salt Lake and Utah Lake drainages from 1872 to 1915. When compared with other cutthroat trout subspecies, I noted a trend for higher number of vertebrae and lower scale counts in S. c. utah. Field observations in Reservoir Canyon and Birch Creek provided notes on living coloration and spotting pattern. S. c. utah does not develop the brilliant colors of S. c. pleuriticus, it is one of the more somber hued cutthroat trout. The spots are larger, more sparse and more evenly distributed over the body in S. c. utah in comparison with S. c. pleuriticus and most other subspecies of S. clarki. From Yellowstone Lake cutthroat trout, S. c. utah is distinguished by fewer scales, fewer basibranchial teeth, fewer gillrakers and slightly higher vertebrae counts.

The differences between S. c. utah and the Snake Valley cutthroat trout are mainly in morphology (longer head, deeper, more compressed body in Snake Valley trout) and fewer basibranchial teeth and gillrakers in S. c. utah (Behnke, 1976).

Recognizing that the variability inherent in a subspecies consisting of disjunct populations with thousands of years of isolation will result in some pure populations with "atypical" character values, the "best" diagnosis for S. c. utah, as a whole, is as follows: Mean values expected for - vertebrae, 62-63; gillrakers, 18-20; pyloric caeca, 30-40(?); scales above lateral line, 36-42; scales in lateral series, 155-170; basibranchial teeth present in at least 90% of population.

Historically, "unofficial" stocking by individuals, clubs and federal agencies (such as the U.S. Forest Service during the CCC period of the 1930s) occurred which were never recorded by state agencies. A remote and isolated stream with no records of introductions is no "sure thing" in regards to native trout. Deep Creek, an isolated tributary in the Sevier River drainage with no stocking records and containing a cutthroat-like trout was believed to have a high potential to contain S. c. utah by Bruce May, Regional Fisheries Biologist. Examination of 12 specimens from Deep Creek (Table 1) reveals an influence from rainbow trout hybridization (6 of 12 specimens without basibranchial teeth and low scale counts). Phenotypically, however, the Deep Creek specimens exhibit no indication of hybrid influence. The morphology and spotting pattern is typical of S. c. utah. Because of the rareness of pure populations, I have recommended, in similar circumstances in the Bear River drainage of Wyoming, that any population bearing a phenotypic resemblance to S. c. utah should be recognized as a "good representative" of the subspecies (Behnke, 1975).

A cutthroat trout deserving further study as a possible pure population of S. c. utah is found in an isolated tributary to Little Cottonwood Creek (Jordan River drainage), Salt Lake County. This trout is represented in Table 1 by three collections probably all referring to the same stream. One specimen in the University of Michigan collection (125054) is labeled "City Creek, Salt Lake Co., used for Salt Lake City water supply, no planting."

In 1967 I received 15 specimens for identification from Mr. Donald Andriano collected from an unnamed tributary to Little Cottonwood Creek between Little and Big Cottonwood canyons, elevation 5500 ft. The water of the stream is completely diverted where it leaves the mountains and no stocking records are known. In 1973, Mr. James Mullan sent two specimens from "Willow Creek," east of Salt Lake City, ¼-½ mile off of Wasatch Boulevard. The specimens in the three collections are similar in appearance. The spotting pattern appears more profuse and the spots smaller than expected in typical *S. c. utah*, but the specimens are small (only 4 of 15 specimens in the 1967 collection are more than 100 mm). The two specimens collected in 1973 (Willow Creek) are the largest (121, 160 mm S.L.) and have a large number of basibranchial teeth (16, 36). Typically basibranchial teeth continue to appear until a cutthroat trout is 100 mm or more in size. The four specimens over 100 mm in the 1967 collection have 6-13 basibranchial teeth, but otherwise appear identical to the "Willow Creek" specimens. Relatively low scale counts and pyloric caecal counts characterize these collections but there is no evidence of hybridization with rainbow trout or Yellowstone cutthroat trout.

A larger sample (15-20) containing some large (200 mm +) specimens should be preserved from this locality for analysis as a possible pure population of native trout. This could provide a source for introductions in northern Utah to initiate a restoration program for *S. c. utah* in its native range.

At present, as a source of *S. c. utah* for introductions I can only recommend the stock in Birch Creek, near Beaver, Utah and the small populations in the headwaters of Reservoir and Water canyons, near Pine Valley, Utah. Although Reservoir and Water canyon creeks are not in the Bonneville basin, *S. c. utah* probably extended its range into the Virgin River drainage by natural headwater transfers. If the present populations were introduced by man from the Bonneville basin, they must have been stocked by the very earliest settlers. Miller (1961) related testimony that cutthroat trout were in the streams around Pine Valley as early as 1863.

Recommendations

A restoration program for *S. c. utah* should be initiated, ideally this would be a cooperative venture between Utah Division of Wildlife Resources, U.S. Forest Service, U.S. Fish and Wildlife Service and BLM. Basically, such a program would consist of transplanting pure stock into new waters. The simplest type of project is to transplant into an isolated section of stream presently barren of all fish. Other suitable sites presently containing non-native trouts can be treated to eliminate all fish above a barrier and *S. c. utah* introduced. New ponds or reservoirs without fish might be considered. Such environments could establish a brood stock for future propagation.

Surveys of headwater tributaries should be made in an attempt to find new sources of *S. c. utah*. Some of this work might be carried out as part of environmental analysis, assessment or impact studies on U.S. Forest Service and BLM lands.

For fisheries management, serious consideration should be given to replacing stunted brook trout populations with native cutthroat trout to test the assumption that the longer life span and larger maximum size of the cutthroat trout will create a more valuable fishery. Behnke and Zarn (1976) reviewed the potential role of native cutthroat trout in sport fisheries.

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Table 1. Character analysis.

Locality	Vertebrae	Gillrakers	Pyloric caeca	Scales above lat. line and in lat. ser.	Basibranchial teeth
Museum collections 187201915 Salt L., Utah L. drainages n = 19	61-65 (63.0)	17-22 (19.7)	-	32-43 (37.8) 150-186(163.0)	3-20 (9.9)
Birch Crk., Trib. Beaver R. 1973 n=12	62-64 (62.6)	18-20 (19.1)	24-43 (36.3)	36-42 (38.4) 151-163(156.3)	1-19 (11.2)
Reservoir Canyon & Water Canyon Virgin R. drainage 1959,1973 n = 30	61-64 (62.1)	17-21 (19.2)	29-40 (35.3)	38-45 (40.3) 143-176(158.9)	6-19 (11.2)
Headwaters Thomas Fork, Wyo. (Bear R.) 1970 n = 7	61-63 (62.0)	18-20 (19.1)	31-42 (36.2)	35-42 (38.4) 142-173(160.9)	2-7 (4.4)
Raymond Crk., Wyo. (Bear R.) 1974 n=20	62-64 (63.0)	16-19 (17.1)	30-51 (45.1)	34-40 (36.1) 159-173(164.4)	4 w/o teeth 16 w/ 1-14(7.1)
Giraffe Crk., Wyo. (Bear R.) 1973 n=15	61-65 (62.8)	18-21 (18.5)	34-64 (48.3)	34-44 (38.1) 141-176(159.1)	2 w/o teeth 13 w/ 1-26(6.9)
Birch Crk., Trib. Smithfield Crk.,Utah (Bear R.) 1973 n=8	-	18-24 (20.5)	36-54 (44.5)	36-46 (42.5) 143-180(164.6)	5-14 (9.0)
Trib. Bear L., Fishaven, Id. 1915 n = 7	-	18-19 (18.7)	-	37-43 (40.3) 157-178(168.7)	1 w/o teeth 6 w/ 3-10(5.2)
Beaver R. 1872 n = 8	61-63 (62.3)	20-21 (20.5)	-	37-40 (38.9)	1 w/o teeth 7 w/ 2-19(8.6)

Locality	Vertebrae	Gillrakers	Pyloric caeca	Scales above lat. line and in lat. ser.	Basibranchial teeth
Headwaters Asay Crk. (Sevier R.) 1973 n = 16	61-64 (62.4)	16-19 (18.9)	32-44 (37.1)	38-42 (40.1) 141-179(161.9)	4 w/o teeth 12 w/ 2-16(4.8)
Trib. Little Cottonwood Crk. (Jordan R.) Salt Lake Co. 1967 n=15	62-63 (62.3) n = 4	18-22 (19.1)	27-39 (32.1)	34-39 (36.4) 140-167(156.7)	6-13(10.0) (4>100mm) 2-10(11<100mm)
"Willow Crk" (Jordan R.) Salt L. Co. 1973 n = 2	-	17,20	25,36	37,38 141,156	16,36
"City Crk." (Jordan R.) Salt L. Co. 1934 n = 1	63	20	-	36 149	8
Strawberry Res. (stock for propagation) 1971 n=10	60-63 (61.9)	17-21 (19.0)	37-51 (43.2)	38-43 (39.4) 138-185(168.9)	1 w/o teeth 9 w/ 1-19(8.5)
Strawberry Res. stock introduced in Sheep Crk. L. 1971 n = 10	59-62 (60.7)	16-22 (19.7)	31-63 (40.2)	39-44 (41.3) 158-189(172.1)	1 w/o teeth 9 w/ 3-31(13.3)
Deep Crk. (Sevier R.) 1975 n = 12	-	17-23 (19.7)	37-50 (42.2)	35-39 (36.8) 140-165(150.6)	6 w/o teeth 6 w/ 3-20(7.5)
Snake Valley cutthroat headwaters Trout Crk. 1974 n = 25	61-64 (62.4)	18-22 (20.2)	25-40 (34.0)	37-44 (40.2) 137-168(152.4)	2-39 (22.2)
Yellowstone Lake cutthroat n = 30	60-63 (61.6)	18-23 (20.6)	31-51 (41.2)	37-46 (40.6) 161-187(179.2)	9-46 (24.0)
"Typical" Colo. R. cutthroat, <u>S</u>. <u>c</u>. <u>pleuriticus</u> (expected mean values)	61-62	18-20	35-40	43-47 180-195	5-15

Identification of trout and environmental problems of Thomas Fork drainage, Wyoming

Prepared for BLM, Rock Springs District

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November, 1976

Introduction

The native trout of the vast Bonneville basin of Utah, Wyoming, Idaho and Nevada, suffered a catastrophic decline in abundance from habitat loss and alteration combined with introductions of non-native trouts. Taxonomic confusion surrounds *Salmo clarki utah* because of a lack of clear-cut diagnostic characters. There is little doubt, however, that pure populations (unhybridized with rainbow trout or other subspecies of cutthroat trout) have declined to a point of virtual extinction throughout the Bonneville basin and several authors have, prematurely, announced its demise (Behnke, 1973; 1975; 1976a; 1976b).

Salmo clarki utah is given the status of "rare" by the International Union for the Conservation of Nature. The Nevada Fish and Game Commission lists it as "endangered" and the Bonneville chapter of the American Fisheries Society also considers it endangered (Holden, et al., 1974). The U.S. Department of Interior does not include *S. c. utah* on its present list of endangered or threatened species, but when all of the present facts are known, it is likely to be listed as "threatened."

The samples of trout examined in the present study collected in 1976 from the Thomas Fork drainage, tributary to the Bear River, Lincoln County, Wyoming, are highly significant because they represent populations forming the greatest known concentration of, at least, an excellent phenotypic representative of *S. c. utah* (no external indication of hybridization) and, perhaps, a pure or virtually pure population of S. c. utah in Raymond Creek. All specimens observed from six localities in the Thomas Fork drainage with the exception of a single brook trout, Salvelinus fontinalis, from Raymond Creek, and one cutthroat trout from upper Salt Creek in Bridger National Forest, with a patch of erratic spotting, are wholly typical of S. c. utah in appearance. The abberrant cutthroat specimen is likely the result of past hybridization with introduced Snake River cutthroat trout.

Trout are not abundant, however, in any part of the Thomas Fork drainage examined. Habitat degradation, particularly from erosion and loss of riparian vegetation, keep populations well below the potential carrying capacity of the streams.

Trout habitat ranks from fair, in the canyon area of lower Raymond Creek, to non-existent (barren of trout) in Little Muddy Creek.

The following sections discuss the identification of specimens, environmental problems in the watershed and suggested actions for a habitat management plan.

Although the emphasis of this report is on the trout, its habitat and riparian vegetation, improvement of the diversity and abundance of vegetation on the watersheds as a whole and control of erosion would have an equally positive effect on wildlife and recreation values, on range and forage conditions and consequently on grazing allotments.

Taxonomy of S. c. utah and identification of samples collected in 1976

A total of 91 specimens collected in 1976 from nine sites were examined for recording taxonomic characters. Seven of these samples are from the Thomas Fork drainage, one sample is from the Smith Fork drainage (Howland or Coal Creek, no. 8, table 1) and one sample from a tributary of the Bear River south of Cokeville (Rock Creek, no. 9, table 1). All localities are in the Bear River system of the Bonneville basin in Lincoln County, Wyoming. Data from previous collections are presented and discussed to indicate that with the cessation of wide-spread stocking of non-native trout into the Thomas Fork and Smith Fork drainages, the trout populations are reverting to the native phenotype by a sorting out and rejection of exotic genes under natural selection.

As discussed in my previous reports, there are no characters or no techniques presently known which can positively identify an individual or a sample as pure *Salmo clarki utah*. However, there are well defined average differences between *S. c. utah* and non-native trout which have been previously introduced into the Bear River system to possibly hybridize with the native trout (rainbow trout, Yellowstone Lake cutthroat trout and Snake River cutthroat trout), and from an evaluation 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.

Study of the 1976 collections reveals a phenomenon not found previously with the native trout of the Bonneville basin, and that is a trout, entirely typical in appearance to *S. c. utah*, completely dominates the trout fauna of the Thomas Fork drainage, and probably, to a large extent, also the Smith Fork drainage. A long history of non-native trout introductions and habitat deterioration in the Thomas Fork and Smith Fork drainages are factors which have inevitably led to the demise of *S. c. utah* in other parts of the Bonneville basin.

Based on my studies of desert basin native trout, I have concluded that relics of ancient lake systems such as *S. c. utah* of the Bonneville basin, *S. c. henshawi* of the Lakontan basin and undescribed subspecies of the Alvord basin of Nevada and Oregon, are burdened with an evolutionary heritage of specialization for large lacustrine environments which make them not well adapted for life in the small streams they became restricted to on desiccation of the ancient lakes. This evolutionary heritage makes the native trout of desert basins extremely vulnerable to displacement by introduced trout.

I have noted one exception to this ease of displacement of native trout by non-native trout and that concerns the cutthroat trout native to the Humboldt River system of the Lahontan basin (Behnke and Zarn, 1976). The Humboldt cutthroat, I believe, is not a lacustrine specialized form but rather its evolutionary programming has been influenced by life in streams under a harsh and fluctuating environment and thus is much more resistant to hybridization with and replacement by non-native trouts in these streams.

An analagous situation may explain the predominance of a trout, phenotypically identical to S. c. utah in the Thomas Fork and Smith Fork drainages. The Humboldt River and the Bear River are the largest river systems in the Lahontan and Bonneville basins respectively. Even at maximum lake levels of Lake Lahontan and Lake Bonneville, these river systems provided a vast network of fluviatile habitat and it is reasonable to believe that a resident (non-lake-run) trout has always inhabited these systems. That is, it seems likely that the ancestors of the native trout of the Thomas Fork and Smith Fork were always stream fish and have little lacustrine influence in their evolutionary history. Whatever the reason, the fact remains that native cutthroat trout, with very slight influence of past hybridization, dominate in all areas observed in 1976 and this is a most unusual situation for the Bonneville basin.

The surprising aspect of the trout populations in the Thomas Fork drainage is that native cutthroat trout are found there at all. The streams appear to be marginal trout habitat because of the silty, turbid water and lack of bank stability. If any trout could persist in the drainage, I would assume the hardy and adaptable brown trout, Salmo trutta, would be the most likely candidate. Yet, no S. trutta were found in the Thomas Fork drainage and in the Smith Fork they appear to be restricted to Pine Creek and Hobble Creek, two tributaries with essentially pristine environments (well forested watersheds and clean water). Evidently, brown trout have not been able to become established in the more degraded main Smith Fork in the face of competition with the native cutthroat trout. The only obvious non-native trout encountered in the Thomas Fork drainage was a single brook trout, Salvelinus fontinalis, taken with a sample of 15 cutthroat trout in lower Raymond Creek. Brook trout were heavily stocked in Raymond Creek and throughout the Thomas Fork drainage in the 1950's (Don Miller, Wyoming Game and Fish Biologist). The environment of Raymond Creek, particularly the silted beaver ponds, is typical of hundreds of similar streams I have observed throughout the West where brook trout have replaced native cutthroat trout.

Comparing the specimens collected in 1970 with previous collections indicates that the influence of non-native trout is rapidly decreasing since wide-spread introductions have ceased. Samples collected in 1973 - 1974 from Salt and Huff creeks of the Thomas Fork drainage indicated more erratic spotting, leading me to assume an influence of hybridization with Snake River cutthroat trout being stocked at that time. In 1976, the only specimen with erratic spotting (a patch of small, irregularly shaped spots among the large, roundish spots) was found in upper Salt Creek in Bridger National Forest, below an area where Snake River cutthroat trout are still being stocked. In a collection made in 1969 from the Smith Fork at Hobble Creek, a site stocked with Snake River cutthroat at that time, 22 of 30 trout observed were of the Snake River variety. At the same site in 1976, 15 trout from the river and one in an angler's creel, were all typical of S. c. utah; no trace of Snake River cutthroat influence could be detected.

These observations suggest a significant fisheries management potential for the native trout of the Thomas Fork and Smith Fork drainages and a fisheries program based entirely on the native trout.

Table 1 lists five of the most important taxonomic characters used to base decisions regarding identification of samples and to evaluate their relative purity. Twelve other meristic and morphometric characters have been recorded on all specimens. This additional data will be statistically treated in comparison with other samples of native Bonneville basin trout in thesis research currently being conducted by Mr. Terry Hickman. When subsequent findings become available, the data will be forwarded to the BLM Rock Springs District Office. I am confident, however, that further refinement and comparisons will not alter the basic conclusions presented here on the relative purity of the populations in the Thomas Fork drainage, but will serve to better define the degree of differentiation between S. c. utah native to the Bear River system and S. c. utah native to other segments of the Bonneville basin.

The present samples confirm an indication in my previous reports on S. c. utah that the trout native to the Bear River drainage tend to have more numerous pyloric caeca than do populations in the rest of the basin.

The mean values of the meristic characters presented in Table 1 for the 1976 collections are highly consistent in their similarities, a situation not expected from hybridized populations. The degree of consistency makes difficult the evaluation of the effects of past hybridization. Except for the single specimen with an abberrent patch of spots from Salt Creek, all specimens appear to be typical of S. c. utah in spotting pattern and general morphology. The mean meristic values are those expected of S. c. utah native to the Bear River system: gillrakers 17-19; pyloric caeca 40-50; scales above lateral line 38-40; scales lateral series 160-170 and basibranchial teeth present (expected in at least 90% of specimens from pure populations). The sample deviating most from expected values ("mid" Coal Creek of Thomas Fork and Twin Creek, tributary to Bear River) are also the samples with the highest proportion of specimens lacking basibranchial teeth, indicating some genes from past hybridization with rainbow trout are present in these samples.

There is no difference in phenotypic appearance between the three samples from different segments of Coal Creek, and there are no real barriers preventing free mixing of all trout in Coal Creek.

The effects of past rainbow trout hybridization is probably reflected in the absence of teeth in one of five specimens from lower Coal Creek and three of nine specimens from a section at the end of a four-wheel drive trail ("mid" Coal Creek). All eight of the specimens taken about two miles further upstream have basibranchial teeth. Except for the single specimen from Salt Creek indicating a Snake River cutthroat trout influence in its spotting pattern, no other indication of past hybridization with either Snake River cutthroat or Yellowstone Lake cutthroat trout can be detected in the values of the meristic characters.

I would choose Raymond Creek as the most likely candidate of all streams sampled, to contain a pure population of native trout. I base this on the degree of isolation of Raymond Creek (all water diverted before it reaches Thomas Fork), the statement of Don Miller, Wyoming Game and Fish biologist, to the effect that all known previous introductions into Raymond Creek consisted of brook trout and the presence of basibranchial teeth in 30 of 31 specimens collected in 1976 from Raymond Creek.

Previously (Behnke, 1975), I stated that Raymond Creek trout were the "best phenotypic representative" of _S. c. utah_ known from the Bear River system, but I did not believe them to be a pure population because I found four of 20 specimens collected in 1974 lacked basibranchial teeth. In light of the present findings, the 1974 sample will be re-examined by removing the skin and staining the basibranchial plate on the four specimens reported to have no teeth (at present, my fish collection is in storage awaiting a move to new facilities scheduled for March, 1977).

A detailed examination of the 1976 specimen lacking basibranchial teeth from South Raymond Creek, revealed an aberrant condition of the basibranchial plate. The plate was ridged in the midline and tooth sockets were present on both sides but no tooth development. This is quite different from the typically smooth basibranchial plate caused from hybridization with rainbow trout. In any event, if, on re-examination, it is verified that four of the 20 1974 specimens lack basibranchial teeth, then of a total of 51 specimens from Raymond Creek, basibranchial teeth would be present in 46 (90%). I pointed out (Behnke, 1976) that basibranchial teeth are not invariably present in pure S. c. utah, because I found these teeth absent in one of eight specimens collected from the Beaver River, Utah, in 1872.

Attention should be called to the trout population in Howland Creek (USFS map, but called Coal Creek on BLM map), a tributary to the Smith Fork. There is no isolation of the population in this small stream from free interchange with trout in the Smith Fork, and because of the long history of non-native trout introduction in the Smith Fork, it is difficult to believe that a pure population of native trout could persist; but there is no indication of a hybrid influence in any character and all 17 of the specimens examined have basibranchial teeth.

In summary, the trout of the Thomas Fork and Smith Fork drainages represent the first known instance in the Bonneville basin where a cutthroat trout, identical in appearance to S. c. utah, persists and is the dominant element of the trout fauna despite habitat deterioration and large scale introductions of non-native trouts.

With the possible exception of the trout in Raymond Creek, the populations sampled are not wholly pure, but have resisted hybridization with rainbow trout and other subspecies of cutthroat trout to an amazing degree. It appears that the process of natural selection is working to restore the native genotypes by elimination of non-native genes resulting from past hybridization.

Identification of Environmental Problems of the Thomas Fork Drainage

The major environmental problem limiting the abundance of trout populations concerns riparian vegetation, or more precisely, the lack of riparian vegetation. Livestock grazing has virtually eliminated woody and herbaceous plants along stream banks on grazing allotments throughout the drainage. It is not likely that woody vegetation such as willow can initiate restoration without protection from grazing for at least a five-year period.

Stability of small streams is dependent on the stability of their banks. The dense root system of riparian vegetation provides this stability and at the same time acts to control erosion, shade the water and to create the most optimum of trout habitats--the undercut bank area (Wesche, 1973; White, 1973; White and Brynildson, 1967).

Loss of riparian vegetation and livestock trampling results in caved-in banks, erosion, temperature increase and stream channel alterations. Depending on soils, substrate, gradient and flow regimes, channel alterations typically tend to modify in one of two directions, both equally inimical to the well-being of a trout population. The stream channel may initiate down-cutting or trenching forming an arroyo-like trough or it may spread out into a braided network. Both types of alterations result in predominantly shallow riffle areas with high velocity flows. The loss of prime trout habitat, the pools and undercut banks, lowers the carrying capacity of the stream, or, as phrased by White (1973), the "shape of the container" may no longer be suitable trout habitat.

The South Fork of Raymond Creek is an example where spring sources provide a constant supply of high quality water at optimum temperatures to the stream, but we captured very few trout (six in about one mile of stream) because of the lack of suitable habitat in the chute-like trench the stream has cut after loss of riparian vegetation. Concomittant with channel alteration and loss of habitat, the stream will carry a higher sediment load, have higher maximum temperatures, greater diurnal variation in temperature and a decrease in diversity of the invertebrate forage resources (Cummins, 1973; 1974; Cummins et al., 1966; 1973; Lantz, 1976; Tebo, 1975).

Channel alterations induced by riparian vegetation removal are comparable to man-made channelization of streams in relation to impact on trout populations from loss of habitat, deterioration of water quality, flow and thermal regimes. Irizarry (1969) found an average decrease of 87% of trout biomass in 29 Idaho streams subjected to channel alterations.

Chapman (1933) reviewed studies of the late Nineteenth and early Twentieth centuries documenting the disasterous damage from floods and erosion caused by overgrazing during the period of the open range policy. There has been much improvement of range and watershed conditions in many areas of National Resource Lands in recent years. Virtually all of the emphasis of range research and management, however, has been devoted to improving range and forage conditions for livestock while ignoring the riparian community and its associated fishery, wildlife and recreation values. Herein lies much of the basis for the present conflicts in multiple-use management on federal lands.

The basic problem of livestock grazing in relation to riparian vegetation is the fact that livestock tend to concentrate along stream bottom areas. In arid and semi-arid regions where alternative water sources may be scarce and all green vegetation is restricted to the riparian community by mid summer, the problem becomes exacerbated. Except for fencing, no range management practice has yet provided an adequate solution to this problem. Historically, range managers have written off the stream bottom lands as "sacrifice areas."

Published data quantifying the effects of livestock grazing on trout populations is scarce, although it is currently becoming a popular topic and some current projects are listed in an appendix to this report.

A longterm study by the Montana Fish and Game Department on Rock Creek (Yellowstone River system) in southwest Montana, provides some data on trout populations in grazed and ungrazed sections of the stream (Gunderson, 1968; Marcuson, 1970). By 1970, the natural, ungrazed section of Rock Creek had 213 lbs./acre of wild trout and the grazed section had 63 lbs./acre. The habitat difference between the two sections consisted of loss of riparian vegetation in the grazed section with subsequent channel alteration resulting in a braided, shallow riffle environment.

The BLM EIS on livestock grazing impact on wildlife and recreation in Nevada (Anon. 1974) states that at least a five year period of complete protection from grazing will be necessary to initiate adequate regrowth of riparian vegetation. Dr. William Platts, U.S.F.S., Boise, Idaho, stated that the rest period of current rest-rotation grazing systems is insufficient to protect or restore woody and herbaceous riparian vegetation (Platts and Roundtree, 1972 and personal communication). Dr. James Johnson, formerly BLM fisheries biologist, Denver, Colorado, came to the same conclusion while working on the San Luis Valley EIS (Johnson, 1976 and personal communication).

Suggested Actions

The problem of degraded trout habitat from loss of riparian vegetation is caused by continued livestock grazing. The trend of deterioration cannot be reversed without changes in present livestock allotments and range management actions designed to protect riparian habitat and achieve a more uniform distribution of animals throughout the allotments during the grazing period.

The following alternatives are presented with an understanding that elements of all alternatives may be eventually incorporated into a comprehensive plan designed to restore trout abundance, improve wildlife habitat and recreational values and improve range conditions for better utilization of available forage by livestock.

1. Elimination of livestock grazing on all NRL of Thomas Fork drainage.

This is not a desirable objective for multiple-use management. Certainly, the production of livestock for the national economy is a valid use of forage on federal lands. If, however, such use is incompatible with other uses or with specific objectives then elimination of grazing should be considered for certain sections of the drainage. The significance of the trout population in Raymond Creek is a special case where if it is determined that exclosure of livestock from the riparian area by fencing is not practical and a better distribution of livestock cannot be achieved from range management practices, complete exclusion of livestock from the watershed would be warranted. The Raymond Creek watershed with the forested slopes of Raymond Mountain contains the greatest scenic and esthetic values in the Thomas Fork drainage and is a logical site for wild or primitive area designation.

2. Fencing to exclude livestock and allow re-establishment of riparian communities.

Adequate fencing is expensive but it does work. Certain streams and stream sections can be given priorities so that areas deemed to have the greatest potential for trout production can be treated first. The BLM fenced Northwater Creek, a tributary to Parachute Creek on Naval Oil Shale lands, Colorado, to protect a population of the rare cutthroat trout, S. c. pleuriticus. Off stream springs should also be fenced to prevent trampling and erosion sources.

To speed up restoration of the stream after protection from livestock, re-vegetation of banks by planting of willows and other plants can be carried out. It would be useful to compare the progress and direction of re-vegetation between sections planted by man and natural, unplanted sections.

Stream improvement structures designed to slow the velocity, create deeper water and provide clean gravel areas will greatly accelerate the restoration of suitable trout habitat.

Trenched streams such as South Raymond Creek present a particularly difficult problem for restoration. The cut banks may be 10-15 ft. above the wetted perimeter of the stream and only more xeric adapted plants can be re-established along the upper horizon. The steepness of the cut banks pose the threat of continued long term sloughing and cave-ins. The lower parts of the cut bank may require rip-rapping and staking of wire to accumulate organic debris for a suitable substrate to establish willows.

3. Range management techniques.

As stated previously the problem here is one of better distribution of the livestock throughout the allotments to improve vegetation of the watershed, reduce erosion and favor dispersion away from stream bottom areas.

Timing of entry and exit dates, reduced numbers, experimentation with rest-rotation patterns and development of off-stream watering and salting sites can be tested in relation to achieving the objectives.

I made several inquiries regarding the possibility of restoring riparian vegetation with plants unpalatable to livestock along streams not protected by fencing. Mammoth wildrye grass, Elymus giganteus, is a drought resistant plant commonly used to revegetate sandy soils. USDA Agriculture Handbook 170 lists it as "unpalatable" to livestock but Handbook 339 considers it as "moderately palatable." Mr. Dean Marriage, Biologist SCS, Portland, Oregon, stated: "I strongly feel some management will be necessary to establish and maintain any promising plant material on stream banks. The plant species that will resist grazing and stabilize the bank without any supplemental structural measures is yet to be found" (correspondence, August 24, 1976). The U.S. Forest Service, Rocky Mountain Forest and Range Experiment Station, Forest Hydrology Lab, Tempe, Arizona, has plans for studies of riparian vegetation in relation to livestock grazing (see appendix).

The Birch Creek Habitat Management Plan, a cooperative venture initiated in 1967 between BLM and Idaho Department of Fish and Game should be consulted as a guideline for developing and carrying out a Thomas Fork Habitat Management Plan. The Birch Creek HMP is designed to protect the riparian vegetation by fencing and assist the restoration of trout habitat by instream devices. The associated livestock management plan calls for development of 16 reservoirs and pipelines and water storage facilities to disperse livestock and better utilize available forage. Potential forage production increase is estimated to be 20%-30%. Wildlife and recreation values are also considered (Borovica, Culbertson and Jeppson, 1975). The creation of reservoirs suggests another alternative to be considered, that of mitigation.

4. Mitigation

If it is agreed that due to the impact of livestock grazing, the streams on NRL of the Thomas Fork drainage are presently supporting trout populations below their potential carrying capacity and measures will not be taken to restore the quality of stream habitat to reach their potential carrying capacity, then mitigation is justified in the form of creation of new habitats to support new trout populations approximately equal to the difference between the present biomass and the potential biomass of these streams if good habitat were present.

The obvious problem is that such a scheme calls for quantitative data on present biomass and potential carrying capacity biomass, which does not exist. It is possible, however, based on experience and observation and drawing from a wide range of fishery literature to arrive at some "ball park" estimates.

The best trout populations I observed were in the canyon area of Raymond Creek, below the junction of the north and south forks. I would estimate perhaps a biomass (standing crop) of 30-50 lbs/per surface acre of water in this section. The other streams examined have poorer habitat and would rank from zero (barren of trout) in Little Muddy Creek to about 10-25 lbs./acre in sections of Coal, Huff, Raymond and Salt Creeks. Considering all streams on NRL of the Thomas Fork drainage, the average trout biomass is probably on the order of 20 lbs./acre ± 50%.

The potential carrying capacity of these streams are projected to be in the range of 50-100 lbs./acre (fair-good classification). Dr. Allen Binns, Wyoming Game and Fish Biologist has gathered data on 20 Wyoming trout streams, correlating habitat quality indicators with biomass. The best stream sampled had a trout biomass in excess of 400 lbs./acre, but most streams were less than 100 lbs./acre. Windell and Burkhard (1976) reported trout standing crops of 65-271 ($\bar{X}$ 134 lbs./acre) for six Colorado trout streams.

As a conservative estimate, it may be assumed that with habitat quality, the streams in the Thomas Fork drainage would sustain trout populations of at least 50 lbs./acre, and this could be a minimum figure for a specific objective of a HMP.

A stream averaging eight feet in width equals one acre of surface water per mile. If it is determined that because of habitat degradation, there is a net deficit of 5000 lbs. of trout in all streams on NRL in the Thomas Fork drainage, then construction of 100 surface acres of reservoirs, suitable as trout habitat (to support a biomass of 50 lbs./acre) would mitigate for the loss. To maintain the intent of a native trout restoration program, such reservoirs should be stocked with trout derived from Raymond Creek.

The need for more quantitative data emphasizes the need for a cooperative plan making use of the resources of the Wyoming Game and Fish Department, particularly the expertise of Dr. Allen Binns. The Thomas Fork drainage would be an excellent opportunity to evaluate Dr. Binns' techniques of quantifying trout habitat by obtaining "habitat quality index" scores for the streams and measuring the effects of habitat improvement by means of habitat units (see appendix).

The experimental livestock exclosure planned on lower Huff Creek should yield valuable information on the response of riparian vegetation to livestock protection under the climatic regime of the Thomas Fork drainage. Comparisons might be made between areas planted to speed up recovery and areas revegetating naturally, particularly in relation to the establishment of willow. No striking changes in the trout and invertebrate fauna are expected in the enclosed area because of the condition of the upstream watershed will continue to produce the present silt loads and water quality. Special attention should be given to the progress of riparian vegetation restoration in relation to creating stable, undercut bank habitat.

The problem of personnel to systematically gather data from the experimental exclosure and for certain other aspects of data collecting on the drainage might be assisted by use of the BLM-Colorado State University Cooperative Education Program (see appendix).

Native Trout in Fisheries Management

The improvement of trout habitat and/or the construction of reservoirs containing trout will stimulate greatly increased angling pressure. Although this is a highly desirable goal, a serious problem arises when cutthroat trout are subjected to even light angling pressure (less than 50 hrs. per acre per year), and this concerns their vulnerability to angling (Behnke and Zarn, 1976). Cutthroat trout, at least in streams, are readily exploited. McPhee (1966) found that 32 hours of angling removed 50% (69 of 138) of the cutthroat trout six inches or more in size from a 2.4 mile section (2.6 acres) of Rochat Creek, Idaho. That is, only about 12 hours of angling pressure per surface acre of stream removed half of all the catchable size cutthroat trout in the experimental section. Typically, public trout streams are exposed to much greater annual angling pressure than 12 hours per acre. West Virginia ranks fishing pressure from "very light" (up to 50 angler hours/acre/year) to "very heavy" (more than 500 hours) (Bailey, Maughan and Whaley, 1975). Comparing the angling vulnerability of cutthroat trout with other trout species, the data of Marshall (1973) and Klein (1974) reveal that year-round fishing pressure of up to 768 hours/acre (1898 hours/ha.) on the Poudre River, Colorado, could not remove more than 35% of the wild brown trout population nor more than 50% of the wild rainbow trout population of catchable size (6 inches or larger).

It is important then to consider the necessity for special angling regulations on cutthroat trout fisheries if the streams of the Thomas Fork drainage are rehabilitated to a point which increases trout abundance and attracts increased angling pressure. Otherwise, the first few anglers, probably exerting less than 50 hours of angling pressure per acre, on any stream, would likely skim off the cream of the population (50% or more of all catchable size trout). Under these circumstances, the first few anglers would enjoy excellent fishing with a high catch-per-man-hour, but subsequent anglers would face a constant deterioration in catch and size throughout the season.

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 (over 13 inches) all dramatically increased after initiation of a minimum size limit of 13 inches and a daily bag limit of two (Bjornn, 1975; Behnke and Zarn, 1976).

The vulnerability (or stupidity) of cutthroat trout makes it the ideal species for a special regulation fishery where a high catch-per-man-hour is achieved by the catching and releasing of the same trout more than once in its lifetime.

The impact of angling on the cutthroat trout populations observed in this study is suggested by the scarcity of catchable size fish in samples taken from stream sections near roads (upper Salt River, Smith Fork at Hobble Creek and Howland Creek samples) where only 12 of 59 cutthroat trout electrofished exceeded six inches in total length. In an electrofishing sample from lower Raymond Creek, an area subjected to much less angler use, 8 of 15 cutthroat trout exceeded six inches.

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Table 1. Character analysis of collections of cutthroat trout from the Bear River system, Wyoming.

Locality	Gillrakers	Pyloric caeca	Scales above lat. line and in lat. ser.	Basibranchial teeth
1. Thomas Fk. drainage Upper Raymond Crk. 1976 n = 10	17.21 (18.1)	41-51 (44.6)	37-40 (38.1) 164-180 (169.2)	1-10 (4.5)
2. So. Fk. Raymond Crk. 1976 n = 6	16-19 (17.1)	39-46 (43.5)	37-44 (40.3) 156-183 (170.3)	1 w/o teeth 5 w/ 4-5 (4.4)
3. Lower Raymond Crk. 1976 n = 15	16-20 (17.8)	39-54 (46.4)	36-41 (39.2) 158-174 (166.4)	2-21 (6.4)
4. Upper Coal Crk. 1976 n = 8	18-19 (18.7)	38-47 (43.7)	36-41 (38.3) 155-178 (165.1)	2-15 (5.6)
5. "Mid" Coal Crk. 1976. n = 9	17-20 (18.3)	36-55 (41.6)	34-40 (37.8) 146-167 (155.8)	3 w/o teeth 6 w/ 4-14 (7.0)
6. Lower Coal Crk. 1976 n = 5	17-20 (18.2)	35-45 (39.2)	37-41 (39.2) 163-173 (167.0)	1 w/o teeth 4 w/2-20 (7.0)
7. Salt Crk. 1976 n = 14	17-21 (18.4)	37-55 (45.6)	38-44 (40.6) 154-175 (163.1)	2-12 (4.3)
8. Smith Fk. drainage Howland (or Coal) Crk. 1976 n = 17	16-21 (18.4)	38-56 (47.2)	36-40 (40.1) 142-186 (161.2)	1-11 (3.7)
9. Bear R. Tributary via Twin Crk. Rock Crk. 1976 n = 7	17-19 (17.8)	38-46 (42.2)	40-45 (42.4) 158-175 (162.5)	2 w/o teeth 5 w/ 1-5 (2.8)
Previous Collections Thomas Fk. drainage Raymond Crk. 1974 n = 20	16-19 (17.1)	30-51 (45.1)	36-42 (38.1) (recounted)	4 w/o teeth 16 w/ 1-14 (7.1) (to be recounted)

Locality	Gillrakers	Pyloric caeca	Scales above lat. line and in lat. ser.	Basibranchial teeth
Giraffe Crk. 1973 n = 15	18-21 (18.5)	34-64 (48.3)	44-44 (38.1) 141-176 (159.1)	2 w/o teeth 13 w/ 1-26 (6.9)
Huff Crk. 1974 n = 10	18-20 (19.1)	38-50 (42.8)	33-42 (38.3) 156-171 (162.7)	1-7 (4.1)
Salt Crk. 1973 n = 17	17-20 (18.8)	41-57 (48.1)	34-43 (38.4) 153-177 (165.1)	2 w/o teeth 15 w/ 1-15 (6.2)
Typical values of introduced Trouts				
Rainbow trout	18-21 (19-20)	45-75 (50-60)	25-30 120-135	absent
Yellowstone cutthroat	19-23 (20.5) (well developed)	30-50 (42)	38-45 (42) 160-200 (178)	2-45 (22)
Snake River cutthroat (fine-spotted)	18-22 (19.5)	32-50 (41)	36-48 (42) 145-185 (167)	5-30 (14)

APPENDIX

In gathering information and making contacts concerning the impact of livestock grazing on aquatic habitat, I recognized that although there is a paucity of detailed information, there is a current awareness of the need to obtain quantitative data and this has led to the initiation of research projects, management actions and planning development.

This appendix attempts to relate who is doing what and bring together bits of information useful in evaluating the present "state of the arts" on the subject matter.

Bureau of Land Management

Postland, Oregon Office. Mr. Bob, Borovica, the senior fisheries biologist of BLM has had much experience in federal-state projects designed to protect and improve fisheries habitat, including the protection from livestock grazing of a rare cutthroat trout, existing in only two streams in the Alvord basin of Oregon. The Birch Creek, Idaho, HMP has been cited in the present report. Mr. Paul Jeppson, Idaho Fish and Game Department, kindly sent reports and data documenting the success of riparian vegetation protection and in-stream improvements for increasing the trout population and angler use in the improved sections of Birch Creek.

Denver, Colorado Office. Dr. James Johnson, former BLM state fisheries biologist, was involved in writing the San Luis Valley EIS in regard to livestock impact on aquatic habitat. Dr. Johnson is presently employed by the U.S. Fish and Wildlife Service, Albuquerque. His replacement in the Denver office is Mr. Robert Gervais. Mr. Gervais was former fisheries biologist on the Fish Lake National Forest, Utah, where he participated in a four year study on Seven Mile Creek relating to the influence of livestock exclosures on water quality, substrate, bank stability and riparian vegetation. He also participated in the Birch Creek Interagency Project between BLM, USFS and Utah Division of Wildlife Resources, designed to enhance the survival of a population of S. c. utah.

Mr. Paul Cuplin, fisheries biologist, has been documenting the response of riparian vegetation to livestock removal on the headwaters of the Colorado River in Rocky Mountain National Park.

Mr. Ed Roberts, BLM State wildlife biologist, is experienced in matters of environmental-rehabilitation after livestock exclosure. Mr. Roberts cited to me a cooperative federal-state project he was involved with on Camp Creek, Prineville BLM District, Oregon, as an example of what can be done to benefit fisheries, wildlife and recreation values from watershed rehabilitation after fencing and revegetation.

Mr. Roberts suggested to me a potential study site on livestock impact on riparian vegetation, bank stability and fish habitat in open and protected sections of the same stream. South of Salida and north of Poncha Pass on highway 17, a stream meanders through a grazing allotment with the meanders alternating back and forth under a highway right-of-way fence which provides contiguous sections of stream open and closed to grazing.

Mr. Roberts expressed enthusiasm concerning the BLM-Colorado State University Cooperative Education Program whereby a student is employed by the BLM, typically for two summer periods. Student assistance has proved a valuable asset in research and data gathering projects. Dr. Dwight Smith, Department of Fisheries and Wildlife Biology, C.S.U. is the campus coordinator.

I recently discussed native cutthroat trout projects with Mr. Allen Brumsted, a CSU-BLM student employee currently working in the Craig District. Mr. Brumsted is writing a habitat evaluation for protection of trout habitat in the Douglas Creek watershed and we discussed possibilities of using Sikes Act funds for the construction of a lake to be managed for S. c. pleuriticus.

Cheyenne, Wyoming Office. Mr. Ron Gumtow, BLM state fisheries biologist, formerly with the U.S. Fish and Wildlife Service, has a broad background in fisheries habitat management and his experience with the rare trout, S. apache, in Arizona should be valuable to future Wyoming projects on rare, native trout.

Recently, I discussed with Dr. Morris Skinner the possibility of utilizing remote sensing aerial photography for rapid interpretation of habitat data for stream evaluation (riparian vegetation, bank stability, pool-riffle ratios, etc.) and he mentioned to me that the BLM has conducted remote sensing aerial photography for most of its lands in Wyoming and the films are at the Cheyenne office.

U.S. Forest Service

Dr. William Platts, Intermountain Station, Boise, Idaho, has extensive experience on the impact of grazing and other land uses on aquatic habitat. In 1975, Dr. Platts initiated a ten-year study entitled: "The effects of livestock grazing in high mountain meadows on aquatic environments, streamside environments and fisheries." Dr. Platts told me he was co-authoring a "state of the arts" paper on livestock impacts for the Journal of Soil and Water Conservation.

Mr. R. Gervais, BLM, Denver, related to me that the U.S.F.S. has been conducting tests of rest rotation grazing patterns in relation to their impacts on aquatic ecosystems (Ogden, Utah, office).

The Rocky Mountain Forest and Range Experiment Station, Hydrology Lab, Tempe, Arizona has hired two biologists, Charles Pase and Dr. John Rinne. Dr. Rinne is presently evaluating habitat criteria for the rare trouts, S. apache and S. gilae. Mr. Pase is studying the effects of grazing on riparian vegetation.

The Rocky Mountain Station recently initiated a cooperative research project with Colorado State University on the effects of grazing on water quality in Manitou National Forest. Dr. James Ward will assess the macroinvertebrate fauna and Dr. Stanley Ponce will study the watershed aspects.

As mentioned in Behnke and Zarn (1976), adequate guidelines have never been developed in relation to multiple use values and livestock grazing. It was mentioned however that Region 6 of the USFS would have such guidelines by July, 1976, as part of their fish habitat management policy.

Correspondence with Robert Phillips, Fisheries Biologist for region 6, revealed that the grazing guidelines are not completed, but "they are working to achieve the intent of that policy statement." Region 6 is currently evaluating a decision on where to place the administrative direction to implement riparian vegetation management.

Soil Conservation Service

Mr. Dean Marraige, SCS, Portland, kindly provided information on vegetation. The SCS has long experience in revegetation projects and any comprehensive habitat rehabilitation of such watersheds as the Thomas Fork or Smith Fork will necessarily entail the cooperation of private landowners and SCS involvement. The SCS Wyoming biologist is Mr. George Dern, Casper.

Wyoming Game and Fish Department

The Wyoming Game and Fish Department has a genuine interest in their native trout. Habitat Management Biologist, Dr. Allen Binns, is experienced in native trout restoration projects with the Colorado River cutthroat trout, *S. c. pleuriticus*. Dr. Binns presented a paper at the AFS meeting, Dearborn, Michigan, September, 1976, entitled: "Evaluation of habitat quality in Wyoming trout streams." Dr. Binns has developed techniques to better quantify trout habitat to put in terms of trout biomass what is lost when habitat is degraded or what is gained when it is improved. His "Habitat Quality Index" evaluates ten attributes best correlated with trout biomass. A "Trout Habitat Unit" is defined as the amount of habitat quality required to increase the trout biomass by one lb. per acre.

Symposia

The proceedings of a recent symposium (Sept., 1976) on Wildlife and America is scheduled for publication in the near future. This will include an outstanding paper by Dr. Federic A. Wagner, Utah State University, on the effects of grazing on wildlife.

The Sport Fisheries Bulletin, October, 1976, mentions a national symposium on classification, inventory and analysis of fish and wildlife habitat, scheduled for January 24-27, Phoenix, Arizona. The various sessions will cover: user needs; classification systems; ecological relationships; inventory procedures and geo-base management information systems.

Collection sites
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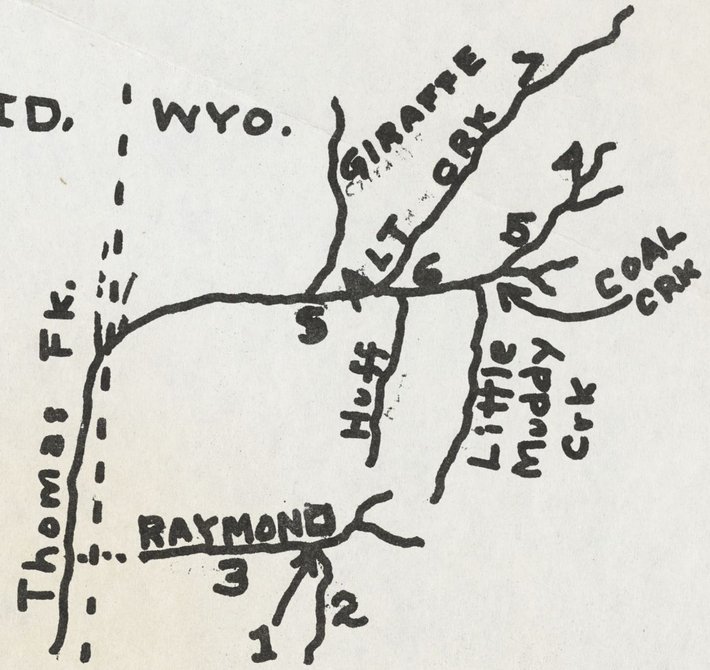

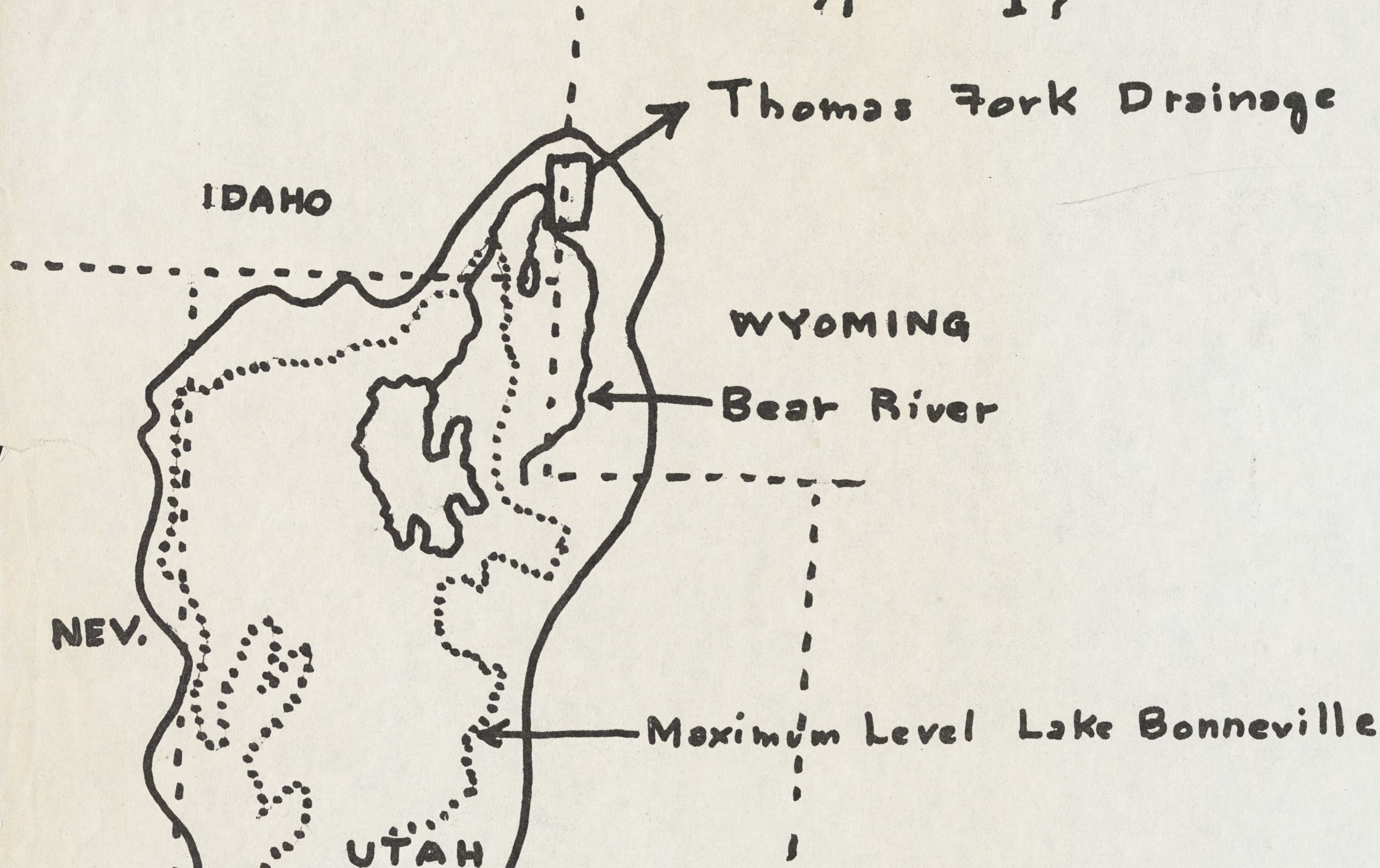

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GRAZING AND THE RIPARIAN ZONE: IMPACT ON AQUATIC VALUES

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Abstract.--Livestock grazing is a valid and valuable use of forage on public lands. Multiple use conflicts arise where grazing has long been a dominant use and other values have been neglected. Of special concern is the fact that livestock concentrate in riparian zones and this problem is particularly acute in arid and semiarid regions where the most ubiquitous and significant damage occurs to riparian vegetation. Historically, it has been a common practice of range management to consider the stream bottom lands as "sacrifice areas." Studies on four western streams, comparing grazed and ungrazed sections, revealed 3-4 times more trout biomass in the ungrazed sections per unit area. Removal and reduction of riparian vegetation causes a loss of bank stability triggering a change in channel morphology resulting in a negative change in the habitat. There is an obvious common ground concerning fishery, wildlife and recreation values to demand changes in grazing management where damage to the riparian vegetation occurs. The riparian zone contains the richest concentration of animal life and provides the most utilized recreation areas. The recognition of the significance of the riparian ecosystem is not a new discovery, but implementation of adequate riparian protection under multiple use management on federal lands has been a slow process. This is due to ambiguous wording of multiple use guidelines, often contradictory directions from Washington to the state or regional level concerning outputs from federal lands, and pressure exerted by user groups to influence land use decisions at the local level.

Litigation may be necessary to accelerate the implementation of better multiple use management of federal lands.

INTRODUCTION

It appears that a tremendous reawakening has occurred in recent times towards an appreciation of the true significance of the riparian ecosystem for fisheries, wildlife, recreation and water quality. Besides this present symposium on the subject, symposia were held at Tucson, Arizona in July 1977 (the papers were published in U.S. Forest Service Gen. Tech. Rep. RM-43: "Importance, preservation and management of riparian habitat"), in Sparks, Nevada, in May, 1977, on livestock and wildlife-fisheries interrelationships (symposium papers in press), in Washington, D.C., March, 1976, on improving fish and wildlife benefits in range management (published by USFWS; FWS/OBS-77/1), and future symposia include one on "grazing and riparian/stream ecosystems," sponsored by Trout Unlimited and several governmental and private organizations to be held in Denver, November 3-4, 1978, and a national riparian symposium scheduled for Atlanta, Georgia, December 11-13, 1978.

The significance and values of riparian communities have been and are being well documented. The problem is that this significance is not adequately taken into account as an integral part of revised livestock grazing plans on public lands at the local level.

With other potential multiple use conflicts, such as logging, riparian communities can be preserved if certain guidelines pertaining to buffer strips are followed. There are no such guidelines, or known range management techniques short of fencing, that can protect riparian vegetation from domestic livestock grazing. Livestock grazing continues to be the most ubiquitous and pervasive negative influence on riparian ecosystems.

About 48% of the total land area of the 11 western states is under federal control and more than 75% of this land is grazed by domestic livestock. I will state here my opinion that the use of public forage by private livestock is a valid and desirable use of public lands. Conflicts arise where this use destroys other more valuable resources, and this conflict is focused most intensely on the riparian zone. The problem is simply that livestock tend to concentrate along stream bottom lands. This problem is magnified in arid and semiarid foothill regions at lower elevations where the grazing season is longer and where, by mid summer, the only water and palatable vegetation is found along streams.

The historical aversion by federal agencies to protect the riparian zone by fencing, the common acceptance in range management practice that the riparian community is an unfortunate but unavoidable "sacrifice area," and the mass conversion to rest-rotation grazing systems, which increases the intensity of damage and prevents the establishment of woody riparian vegetation (such as willows), is leading towards legal confrontations.

Unfortunately, the issue is charged with emotion and opinions soon become polarized with a "choosing of sides." Hopefully, as more light and less heat are shed on the matter, progressive ranchers will realize that, in the long run, livestock interests have the most to gain from the reversal of the downward trend in the vegetative conditions of watersheds and from the restoration of grasslands to millions of acres of what is now essentially, barren arroyo gutted wasteland in the Southwest. In the last 100 years, the rate of "desertification" of the American Southwest has been far more rapid than in similar climatic areas of the world -- and overgrazing by domestic livestock has been the major cause of conversion of grasslands to barren wastelands.

THE PROBLEM

In areas where forage and water are well dispersed throughout a watershed and grazing intensity is moderate, livestock grazing is not harmful, and can even be beneficial to certain fishery and wildlife values. It is in the arid and semiarid regions where precipitation is sufficient to establish grasses and forbs, but not sufficient to promote rapid and vigorous growth of vegetation, where vegetation is highly susceptible to overgrazing. Once the vegetation canopy is removed, heavy rains are not absorbed into the soil but run overland causing erosion. When this occurs, the amplitudes of peak run-offs are tremendously increased. The loss of riparian vegetation results in destabilized stream banks. The energy created by the increased flood peaks causes the stream channel to trench down, creating an arroyo (or if bedrock is near the surface, the energy is dissipated by forcing the stream channel to spread out and braid). With a lowering of the stream channel to form an arroyo, the water table drops and former grasslands are converted to more xeric species of vegetation.

This pattern of dramatic changes in the watersheds and aquatic environments of the American Southwest during the past 100 years has been the major cause of the widespread replacement of native fishes by introduced species (Miller, 1961; Behnke, 1977). More specifically, trout populations are affected from the loss of riparian vegetation and destabilized stream banks by a modification of their physical habitat. Optimum trout waters are characterized by slow, deep water with abundant cover (typical of undercut bank areas). In such habitat, trout populations can expand to the limits of their food supply (abundance is food limited). Where riparian vegetation is destroyed, the banks trampled and caved-in, the stream will typically braid out or trench down and the habitat is characteristically composed of shallow, high velocity flows without adequate cover. In such situations the abundance of the trout population is limited by its physical habitat (abundance is habitat limited). In relation to the impact on trout abundance and growth, the effects of overgrazing in the riparian zone is comparable to stream channelization (Behnke and Zarn, 1976). In the paper I submitted to the symposium on livestock and wildlife-fisheries interrelationships (Behnke, 1978, in press), I pointed out that four case history studies comparing trout populations in grazed and ungrazed sections of the same stream, all agreed that trout biomass was 3-4 times greater in the ungrazed sections. The differences in the aquatic habitats between grazed and ungrazed areas, in all four studies, reflect the descriptions given above of food limited vs. habitat limited environments.

Although there is some contribution of terrestrial invertebrates (in some cases quite considerable) to the trout's diet, which is lost from destruction of riparian vegetation (Hunt, 1975; Erman et al., 1977; Meehan et al., 1977), the major detrimental influence of livestock on trout is not through modifications of the food supply, but by a modification of the physical habitat, changing the shape of the living space, and this effect is initiated by the destruction of riparian vegetation.

THE PAST

A point that must be understood is the differences between natural erosion and accelerated erosion. It is not commonly realized that millions of acres of land in the arid regions of the American Southwest, presently dissected by deep arroyos and characterized by mesquite, sagebrush, greasewood and cactus were grasslands less than 100 years ago. The transformation of these lands is an example of accelerated erosion. The primary cause of this erosion was overgrazing by domestic livestock, particularly in the late nineteenth century, during the days of the open range. Many persons refuse to accept this conclusion, but the evidence is overwhelming. There are three possible ways to stimulate accelerated erosion: 1, climatic change (greatly increased precipitation); 2, geological changes, tilting the earth's crust to increase gradients; and 3, vegetation removal on watersheds.

Briefly summarized, the evidence is as follows: There was no detectable changes in precipitation patterns in the Southwest during the late nineteenth century in areas subjected to accelerated erosion, nor were there changes in the geological landscape. Arroyo cutting began within a few years after an area was subjected to heavy grazing pressure. Comparable areas not grazed did not undergo accelerated erosion and arroyo cutting. Areas subjected to accelerated erosion and arroyo cutting have reversed the process -- the watersheds were revegetated with the arroyo scars healing, after many years of complete protection from domestic livestock. After reviewing many case histories and literature on the subject, Hastings (1959) concluded that arguing over the question -- if livestock grazing was the major cause of the accelerated erosion in the arid Southwest -- was "beating a dead horse." There is no other reasonable conclusion; the evidence is overwhelming.

Other man induced influences such as land cleared for agriculture, river channelization, clear-cutting, etc. have a synergistic effect with overgrazing to increase the rate and magnitude of accelerated erosion. Dissmeyer (1976) examined all causes of accelerated erosion on a watershed and concluded that 92% of it was due to livestock grazing.

A sequence of the events of accelerated erosion has been documented for the Douglas Creek watershed near Rangely, Colorado (Womack, 1975). In 1883, livestock grazing was initiated on a large scale. Mr. James Rector brought in 25,000 head of cattle to the Douglas Creek watershed. Later in his life, Mr. Rector reminisced that when he first came to the area, the Douglas Creek watershed . . . "was the best cattle country you ever seen -- no brush and deep gullies like today, but lush, grass up to the stirrups of a horse." Today, the watershed is a barren expanse of greasewood, dissected by deep arroyos. A cabin built by Mr. Rector, precariously teeters on the edge of a 40 foot arroyo channel cut by Douglas Creek.

THE PRESENT

The days of the open range came to an end with the Taylor Grazing Act. Substantial improvements in range conditions have been made in many areas, but comparable improvements in the riparian vegetation in areas exposed to livestock grazing has not occurred and they continue to decline in many grazing allotments. It is now known that areas protected from livestock grazing can be naturally restored with the establishment of good vegetative cover, stabilized stream banks, the transformation of intermittant flows to perennial flows with great reduction of sediment loads -- that is, the process of accelerated erosion can be reversed (Heede, 1976; Winegar, 1977). The papers presented at the Sparks, Nevada, livestock-wildlife-fisheries symposium, documented that stream sections protected from livestock responded rapidly with increases in trout biomass of 3-4 fold. Van Velson (1977) discussed the dramatic improvements resulting in Otter Creek, Nebraska, a small tributary to Lake McConaughy, after the riparian area was protected from grazing. Prior to 1969, Otter Creek suffered from overgrazing. The warm, shallow, silted stream was virtually barren of fish. In 1969 the Nebraska Game and Parks Commission leased the headwater area and fenced out livestock. Rainbow trout eggs were planted in Otter Creek in 1969. The stream rapidly recovered, riparian vegetation flourished, it stabilized the stream banks, deepened the channel, cooled the water and provided cover. The water ran cool and clean; gravel beds were exposed after lying for years under silt deposits. A migratory run of rainbow trout from L. McConaughy became established and produced 20,000 7-10 inch young fish to the lake fishery in 1974.

Winegar (1977) documented similar beneficial results to water flows and quality and to wildlife from the livestock exclosure zone on Camp Creek, Oregon. The abundance and diversity of wildlife in the protected riparian area is much greater than in contiguous areas, grazed by livestock (rattlesnakes are more abundant in the grazed area).

Merely by using the literature and reports generated by Bureau of Land Management employees, the values and significance of riparian communities can be well documented. Yet I have been dismayed to read recent draft environmental impact statements on BLM grazing allotments that reflect a "business as usual" attitude with neglect or even planned further degradation of riparian ecosystems. What is the cause of this apparent "bureaucratic schizophrenia?" The BLM has a long history of administrators rising in the ranks in an atmosphere of subservience to the livestock industry. Citizen advisory boards are made up of or dominated by user groups. When decisions are made at the local level regarding land use and management, livestock interests form a vocal and cohesive force; fisheries, wildlife and environmental interest groups are diffuse and ineffective in influencing a change in policy.

THE FUTURE

The BLM must prepare 212 environmental impact statements on the 150,000,000 acres of grazing lands it administers in the 11 western states. Some of the current draft EIS' I have seen or am familiar with, reflect the "business as usual" attitude in relation to livestock grazing. Heavy reliance is put on rest-rotation grazing to increase the AUM's (animal unit months). At the Sparks, Nevada symposium, previously referred to, it was brought out by fisheries biologists experienced with rest-rotation grazing, such as Dr. William Platts, USFS, that high livestock density at certain times, causes more damage to the riparian vegetation than former grazing systems. One or two years rest is not sufficient to restore the vigor of woody vegetation such as willows, which are so critical to maintain stable stream banks and channels. Thus, I predict that if the new BLM grazing proposals are instituted, a continued downward trend will occur in the riparian vegetation with further reduction in fishery and wildlife values.

The BLM is faced with conflicting, often incompatible and contradictory directives. For example, on one hand they are responsible for maintaining and enhancing fish and wildlife and their environments, and on the other, to increase the products from the land, such as red meat. When it comes to the bottom line, the environment continues to receive the lower priority.

The livestock grazing EIS' I have read are highly vulnerable to legal action under such federal laws as the National Environmental Policy Act and The Colorado River Salinity Control Act (if watersheds are in Colorado River basin) because of their overwhelming emphasis on increased grazing pressures, regardless of the loss of other values. I believe legal action or the serious threat of litigation will be necessary to remove the land management decisions, which are of national significance, from the local level and turn the situation around now.

The March, 1978 Readers Digest contained a laudatory article written by J. N. Miller on Secretary of Interior Cecil Andrus. The article is filled with optimism that at last the BLM is entering a new era of environmental enlightenment. As long as land use and management decisions are made at the local level, I foresee no dramatic change in the future. Indeed, as discussed, above, the long range plans of the BLM regarding livestock grazing calls for increased grazing pressures and a mass shift to the rest-rotation grazing system. Without fenced protective zones, the riparian communities and their fishery, wildlife and recreation values will almost certainly decline.

An obvious solution to this problem is to separate the riparian zones from regular grazing allotments and manage them with a different set of priorities (Behnke, 1977). The mechanism to do this is found in the Federal Land Policy and Management Act of 1976, which instructs the BLM to promptly develop plans for the protection of "Areas of Critical Environmental Concern" (ACEC). In multiple use conflicts, ACEC preservation is given the highest priority.

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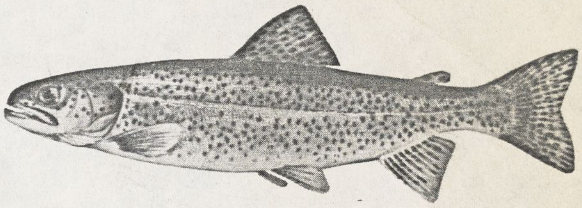
Salmo gairdneri Richardson
Rainbow trout

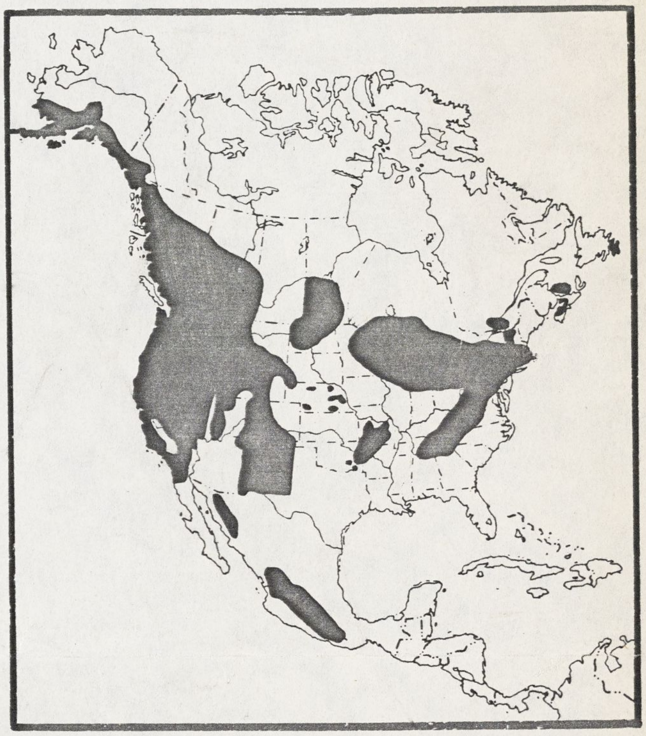
Order Salmoniformes
Family Salmonidae



(N.C. Wildl. Resour. Comm. and NCSM)

TYPE LOCALITY: Mouth of Columbia River at Fort Vancouver, WA (Richardson 1836. *Fauna Boreali-Americana*).

SYSTEMATICS: The "rainbow trout" is comprised of two major groups, coastal rainbow trouts and redband trouts. The redband trout native to headwaters of McCloud River, CA, is closely related to the golden trout of Kern River drainage, CA, *S. aguabonita*. Oldest name for any member of redband trout group is *S. newberryi*. Oldest name applied to any member of either group is *S. mykiss*, proposed by Walbaum in 1792 for the Kamchatkan trout. Many practical difficulties are involved if *gairdneri* becomes synonym of *mykiss*.



DISTRIBUTION AND HABITAT: *Salmo mykiss* occurs in Asia north from Amur River in Othotsk Sea basin, and on Kamchatka and Commander Islands. *Salmo gairdneri* group in North America ranges from Kuskokwim River, AK, to Rio del Presidio, Durango, Mexico. Interior distribution includes headwaters of Fraser River, BC, Columbia River basin to major barrier falls on Kootenay, Pend Oreille, Spokane, and Snake rivers; native to several desiccating basins of southern OR and a few headwater areas of Mackenzie River basin, Canada. "Kamloops" trout of BC considered to be redband trout. Anadromous ("steelhead") and resident redband trout occur east of Cascade Mountains in Columbia basin. Except for northern and southern extremes of range, anadromous populations occur in all coastal rivers. Resident stocks may inhabit small headwater streams or large rivers. There are several lacustrine specialized populations, especially in upper Columbia basin, and upper Fraser basin, BC ("Kamloops" trout). Widely introduced and established in suitable cold water habitats all over world.

ADULT SIZE: 250-750 mm TL; 1000 mm TL maximum.

BIOLOGY: As with cutthroat trout.

Compiler: R. J. Behnke. January 1979.

SUPPLEMENTARY REPORT ON AQUATIC BIOLOGY

OF THE CLIMAX AREA

Robert J. Behnke

February 16, 1979

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ABSTRACT

Supplementary information is provided to the October, 1978, report on aquatic biology of the Climax area regarding the identification, feeding habits, reproduction, and general well-being of the cutthroat trout in Clinton Reservoir. Additional information basic to the development of a sound fisheries management program for the reservoir is included.

INTRODUCTION

The October, 1978, report detailed the occurrence of two subspecies of cutthroat trout in Clinton Reservoir. Detailed examination of all of the specimens has now been completed and information concerning precise identification, feeding, reproduction, and general biology is given to supplement the incomplete data of the October report.

A hypothetical population structure of Clinton Reservoir trout was developed (Fig. 1) to facilitate a discussion of future management options designed to maximize the fishery potential of this body of water. Action should be taken to preserve the purity of the rare Colorado River cutthroat trout and utilize it in management of the reservoir. Introduction of forage organisms may be necessary to increase the efficiency of energy pathways from primary production into trout production and to provide large forage species necessary to produce trophy size trout.

OBJECTIVES

To obtain information on taxonomic characters, feeding habits, possible ecological segregation between subspecies of cutthroat trout, major forage organisms present in reservoir, disease and parasite problems, sexual maturation and general well-being of the trout after two years of reservoir life from a critical examination of specimens.

To synthesize and evaluate pertinent research data on trout lakes and trout populations from my personal work and that of my graduate students in addition to a literature survey as a basis for developing a generalized future scenario of trout population dynamics in relation to a discussion on management options and recommendations and to recognize possible future problems in the fishery, their causes and treatment.

METHODS

Eight specimens of cutthroat trout (five Colorado River cutthroat and three Snake River cutthroat) taken in Clinton Creek and Clinton Reservoir in June and August, 1978, were examined in detail. Several taxonomic characters were recorded and compared to detect differences between the subspecies useful to assess the degree of hybridization between the two subspecies in future years. Stomach and intestine contents were examined microscopically to identify food organisms, type of feeding (bottom, pelagic [open water], or surface), and possible ecological segregation between subspecies. Gonads were examined to note prior spawning and to identify specimens that would have spawned in 1979. General health and condition was assessed from examination of internal organs, degree of fat deposition and observations of indication of parasites or pathogenic organisms.

Personal data and literature concerning cutthroat trout biology and populations in lakes were assessed to abstract pertinent information in relation to the future course of the cutthroat trout population in Clinton Reservoir, its management, manipulation, exploitation, potential problems and their suggested solutions.

IDENTIFICATION OF SUBSPECIES

Several characters were counted, measured, and compared between the five specimens of Colorado River cutthroat trout and the three specimens of Snake River cutthroat trout. Although the sample sizes are small, three characters (number of scales in the lateral series and above the lateral line, and number of basibranchial teeth) showed clear-cut differences and will be useful to evaluate the degree of hybridization occurring between the two subspecies in future generations. As discussed and illustrated in the October report, there is an obvious difference in the spotting pattern that allows ready separation of the two subspecies. To assess the degree of hybridization in future years (first or second generation hybrids, backcrosses to either parental subspecies, etc.), additional characters are necessary.

The characters possessed by the five specimens of Colorado River cutthroat trout convince me that they are a pure population which should be perpetuated. I expect pure populations of this subspecies to average at least 180 scales in the lateral series (counting the diagonal rows of scales in a horizontal series about two rows of scales above the lateral line) and at least 43 scales above the lateral line (made from the origin of the dorsal fin in a diagonal row to the lateral line). The five specimens of Colorado River cutthroat trout collected from Clinton Creek and reservoir in 1978 have 192, 201, 212, 216, 217 (208) scales in the lateral series. This is the highest scale count I have yet found in this subspecies. The scale counts above the lateral line are 46, 47, 48, 48, 49 (48). In comparison, the three specimens of Snake River cutthroat trout have 172, 174, 178 (175) scales in the lateral series and 41, 41, 44 (42) scales above the lateral line. The number of basibranchial teeth (minute teeth that lie on the floor of the pharynx between the gill arches) are 2-8 (4.2) in the Colorado River cutthroat trout specimens and 13-22 (19.7) in the Snake River cutthroat specimens. There is an indication that the two subspecies also differ in the number of gillbrakers (bony protuberances on the gill arch). I found 18-20 (18.6) gillbrakers in the Colorado River cutthroat specimens and 20-21 (20.3) in the Snake River cutthroat specimens.

SEXUAL MATURATION

One of the three Snake River cutthroat trout examined (a male of 12.6 in. [320 mm] total length) had well developed testes and undoubtedly would have participated in spawning in 1979. Another male of 10.8 in. (274 mm) had only rudimentary testes and would not have been sexually mature until 1980. The third specimen of Snake River cutthroat trout (12 in. [306 mm]) showed no gonadal development. This specimen is probably a female which would not have spawned until 1980 or 1981. The five specimens of Colorado River cutthroat trout had all spawned in 1978. They exhibited only slight gonadal development by August. No more than one or two would have spawned again in 1979. Biennial (every other year) spawning is typical of cutthroat trout living in lakes. Those fish which survive spawning, generally require two years to accumulate sufficient energy to mature sperm or eggs again.

Some males and probably a few of the females of the Snake River cutthroat population will sexually mature and attempt to spawn in Clinton Creek in 1979 and hybridization is expected to occur.

FEEDING

Except for one of the spawned-out fish taken in Clinton Creek in June, which contained only a few tiny beetle larvae, the other stomachs and intestines were glutted with food. Although the small sample size and timing of the collection does not allow for firm conclusions, the growth rate (3-4 in. per year) and the great amounts of fat (storage of surplus energy) deposited in the viscera, demonstrate that excellent feeding conditions have existed since the reservoir was created.

The forage organisms in all stomachs overwhelmingly (> 99%) consist of only a few species of two groups (orders) of insects. Larvae, pupae and adult "midges" ("black gnats") was the sole or dominant food in two of three Snake River cutthroat trout and in three of four Colorado River cutthroat trout (the "fifth" Colorado River cutthroat specimen taken in June from Clinton Creek had virtually no food in its stomach). One Snake River cutthroat trout and one Colorado River cutthroat trout had fed almost exclusively on pupae and adults of a single species of mayfly. A detailed comparison of the "midge" component in the diets, definitely indicates some ecological segregation is occurring in the feeding habits between the Snake River cutthroat trout and the Colorado River cutthroat. The Colorado River cutthroat trout had fed mainly on the larvae form of the midge (occurring on the bottom) and the Snake River cutthroat fed predominantly on pupae or adult midges (near or on the surface).

No crustaceans ("water fleas," "shrimp," etc.) were found in the food, which suggests the possibilities for introductions of additional forage organisms as part of a management program (discussed under recommendations).

GENERAL WELL-BEING

No indication of disease or unhealthy condition was found. The specimens appeared to be in excellent condition when captured. Roundworm parasites were found in stomachs containing mayflies but I believe they are parasites of the insect, not the trout.

Some disease organisms and parasites are associated with all fish populations but rarely create serious problems in wild populations. The most serious parasite problem in Colorado trout lakes occurs in the North Park region where the larval stage of the eye fluke causes impaired vision and blindness in trout. Trout serve as an intermediate host of the eye fluke. Snails are the primary host and fish-eating birds act as the final host.

FISHERY CONSIDERATIONS

Figure 1 represents an idealized size-age structure of the Clinton Reservoir trout population at some future time and illustrates an excellent fishery potential. The figure is based on the assumptions that spawning success is strictly limited, natural mortality rates are relatively low, growth rates are high, survival and growth are relatively high after first spawning (to produce trophy size fish), and anglers remove only "surplus production" (overexploitation doesn't occur). The total biomass represented by all age groups in figure 1 is about 5000 lbs. or 50 lbs./acre (46 kg/ha). Virtually all of this biomass consists of catchable size (8 in. and larger) trout. This representation is the way the population structure might appear in September of any year (toward end of growing season).

In reality, figure 1 is a great oversimplification of nature. The processes determining size-age and biomass structure of a population are highly dynamic and influenced by many factors. The blocks representing the age classes are stationary only at a given moment in time. A more realistic view is to view them as pistons in an engine, constantly moving up (increasing) or down (decreasing) during a year and between different years.

Although figure 1 may not approximate the Clinton Reservoir trout population it can serve as a useful reference to facilitate an understanding of a discussion of the reservoir fishery in relation to potential problems, management options and special angling regulations. Some of the potential problems which may appear in the future, diminishing the quality of the Clinton Reservoir fishery, can be summarized as follows.

Problem: Fish are small (average size 10 in. [254 mm] or less), growth is slow. Such a population, in reference to figure 1, would exhibit a great skewing to the left side of the figure with most of the fish and biomass tied up in small size groups. Slow growth results in fish of 8-10 in. (203-254 mm) at age 3-4 and very few fish in the population exceeding 12 in. (305 mm).

Cause A: Overpopulation resulting from too much natural reproduction which causes severe competition for food supply, high mortality, and slow growth (the fish are stunted). Figure 1 provides for 20,000 fry hatching each year in July which, in turn, suffer a 75% mortality by September leaving 5,000 fingerlings of the zero age group in the lake. The early life history stages of a fish are vulnerable to several environmental influences and high mortality is generally encountered, particularly in the first few weeks after hatching. In natural environments, year to year fluctuations in survival can be enormous.

Assuming that 20,000 fry (newly hatched) is the best approximation of the quantity necessary to "stock" the reservoir each year to avoid overpopulation and to maintain an abundant and stable population of trout exhibiting good growth, this number of fry would be expected to be produced from a spawning of about 40,000 eggs (assuming 50% mortality of eggs before hatching). About 40 to 50 lbs. of female trout will spawn 40,000 eggs. For an assessment of the spawning potential of the hypothetical population depicted in figure 1, it is assumed that about half of the population of age 3 and older are females. About half of the females spawn for the first time at age 3 but only every other year thereafter. Such a situation would result in a potential annual fecundity of about 500,000-750,000 eggs--a tremendous surplus.

Treatment: Limit spawning. All trout must spawn in Clinton Creek. Presently there are few areas suitable for successful reproduction due to lack of suitable spawning gravel in the stream. This natural limitation may serve to prevent the problem from developing. If suitable spawning areas are limited to 40-50 $yd.^2$ (or m^2), overreproduction should not be a problem.

Cause B: Food supply deficient in forage organisms of diverse size. Ideally, the forage base should favor feeding segregation between young, small trout (age 0 and 1) and older, larger trout (age 2 and older) and to maintain a sufficient abundance of large food items to produce trout of trophy size and favor survival and growth after first spawning.

Treatment: If adequate diversity of forage organisms are not present in reservoir, they can be introduced. The present indication is that crustaceans of a size suitable for trout forage are lacking. If pelagic and benthic crustaceans can be established, the channelization of energy through the food web from primary production (plant photosynthesis) into the trout population will become more efficient and more "trophy" (15-16 in. and larger) trout will be produced (see recommendations for specific types of organisms for introduction). If a diversity of forage organisms can be established, and both subspecies of cutthroat trout are maintained in the reservoir, segregation between the subspecies, resulting in greater total production, will also be favored.

Problem: Catch is mainly of young fish; reservoir exhibits indications of being "fished out."

Cause: Overexploitation by anglers. Overexploitation occurs when anglers kill more fish than would have died from natural causes during the year if there was no angling mortality so that fewer fish are alive the following year than there would have been without angling mortality. In general, mortality factors in fish populations are largely compensatory. That is, the more fish killed by anglers, the fewer die from natural causes and vice versa. The hypothetical population illustrated in figure 1 shows a natural annual mortality (or surplus production) of 2500 catchable size (8 in. and more) trout. Under ideal conditions, anglers might account for 80% (2000 trout) of the total mortality without increasing the total mortality. Thus, the population in figure 1 might sustain an annual kill of 2000 trout before overexploitation occurs.

It must be recognized, however, that the most significant values associated with a wild cutthroat trout fishery in a mountain lake are not measured by the numbers and pounds of trout killed, but rather by the recreational experience and the quality of the fishery expressed in catch-per-man-hours (CPMH) and average size of the fish. As discussed in the October report, cutthroat trout are the most vulnerable trout species to angler overexploitation, but they are also the best species for special regulation fisheries because they are susceptible to being caught and released several times (they can maintain a high CPMH on a limited stock of fish). Thus, even though half or more of the cutthroat trout caught and released in any year may die of natural causes before the next year, they are maintained in the current fishery and contribute to a high CPMH by being caught again before their death.

As discussed in the October report, I believe that even light (20-40 hrs./acre) angling pressure under current Colorado Division of Wildlife regulations will result in overexploitation and "overfishing." Because of the accessibility of Clinton Reservoir, angling pressure may well exceed 100 hrs./acre/year. West Lake, one of the Red Feather Lakes, about 50 mi. (80 km) northwest of Fort Collins, received more than 2000 hrs./acre angling pressure in 1974, the last year of complete creel census on the lake. This extremely high angler use is maintained and encouraged by the stocking of catchable size rainbow trout. In 1973, as part of an experiment designed for learning more about the role of the Snake River cutthroat trout in fishery management, I stocked 1900 Snake River cutthroat trout fingerlings (about 2 in. in length and weighing 950/lb.) into West Lake. Survival and growth of this plant was excellent. In 1974, creel census data revealed that 847 of the 1900 (45%) introduced cutthroat trout were harvested by anglers. Strictly from a cost-benefit point of view, the 1900 fingerling cutthroat trout stocked in 1973 provided an excellent return in 1974 (2 lbs. stocked, about 350 lbs.

caught), but under the intense angling pressure, there were virtually no cutthroat trout which escaped angling mortality to become trophy size fish in 1975-76. On the other hand, brown trout fingerlings stocked into West Lake, remain in substantial numbers for two and three years in the fishery because the brown trout is much more resistant to catch (and overexploitation) than is the cutthroat trout.

Trappers Lake, Colorado, is a body of water of 280 surface acres (116 ha) in size with a maximum depth of 175 ft. (53 m). Cutthroat trout is the only fish in Trappers Lake. From 1960 to 1968 Colorado Division of Wildlife personnel collected much data on the cutthroat trout and its fishery in Trappers Lake. Angling pressure averaged about 11,000 hrs./yr. (or about 40 hrs./acre) and the catch ranged from 2172 to 7401 trout per year, averaging about 4500. Regulations regarding size and bag limits had no detectable effects on the Trappers Lake cutthroat trout population. That is, the angler's catch did not overexploit this population (they were removing only surplus production). This is due mainly to the size-age structure of the population, but may also be influenced by the large area of deep water where the trout may retreat and not be available to the fisherman. The Trappers Lake cutthroat grows reasonably well, reaching 11.1 in. (279 mm) to 14 in. (356 mm) at three to four years of age. However, due to a lack of large forage organisms, survival is poor and growth is very slow after first spawning. Of a total of 10,688 fish examined from spawning runs from 1960 to 1968, only 18 (1 of 600 or .2%) of the adult fish were 18 in. (456 mm) or larger. The largest specimen of the 10,688 trout examined was 20 in. (508 mm). Thus, under such a growth regime, it would be fruitless to attempt to create a trophy fishery in Trappers Lake by protecting younger, smaller trout in expectation that a significant number would reach "trophy" size.

Treatment: Institute special regulations regarding size, bag, and gear restrictions on the Clinton Reservoir fishery. In the October report I suggested a 14 in. (356 mm) size limit and a bag limit of two trout per day and also suggested a season on the fishery, opening July 1, with angling restricted to artificial flies and lures.

All angling regulations on waters open to public fishing must be approved by the Colorado Division of Wildlife, and I would urge the adoption of my suggested regulations. In the future, as indicated by the response of the Clinton Reservoir trout population, the regulations can be modified to adjust to existing situations.

The restriction of angling to artificial flies and lures is necessary for any fishery where large numbers of fish are returned to the water with an expectation that they will survive and be caught again. Bait caught trout (worms, salmon eggs, etc.) typically suffer 30% to 50% mortality based on numerous studies. This is due to the tendency for the trout to swallow the bait and be hooked deeply and fatally. Depending on temperature, fly and lure caught trout, typically suffer 2% to 10% mortality. There is little consistent difference in mortality between trout caught on flies (single hook) or lures (treble hook) or between barbed and barbless hooks. In a test conducted in a hatchery raceway in Colorado with catchable size rainbow trout (8.2-11.9 in. [209-303 mm], 3 of 233 trout caught on a single hook lure and 4 of 224 trout caught on a treble hook lure in April, died after being released. The mortality difference (1.3% and 1.7%) was not significant in April. The same test conducted in July, in warmer waters, resulted in a mortality of 28 of the 272 trout caught and released on the single hook lure (10.3%) and a mortality of 13 of 271 (4.8%) caught on a treble hook. The July test did show significant statistical differences in mortality--a higher proportion of the trout were killed by the single hook (because it was more likely to be taken into the mouth and fatally rupture the gills).

In Yellowstone Lake, bait caught cutthroat trout suffered a 40% mortality while only 3% of the cutthroat trout caught on barbless flies and 4% caught on barbed flies died after release (the difference between barbed and barbless hooks was not statistically significant).

Thus, any regulations regarding minimum size must also restrict angling gear to artificial lures or flies if it is to be effective.

RECOMMENDATIONS

1. Preserve the pure population of Colorado River cutthroat trout in Clinton Reservoir by artificial propagation and establishment of a brood stock. This recommendation is given in more detail in the October report. I have examined hundreds of specimens of Colorado River cutthroat trout from many sites and have never been as confident of the purity of the stock as I am with the Clinton Reservoir population. Populations of this trout uncontaminated by hybridization with rainbow trout or other subspecies of cutthroat trout are extremely rare--to the point of virtual extinction. Colorado Division of Wildlife should be willing to cooperate in taking eggs from the spawning run in Clinton Creek for propagation. Hybridization between the Colorado River cutthroat trout and the

Snake River cutthroat will begin in Clinton Creek in 1979. Year classes of Colorado River cutthroat trout born prior to 1979 are pure and they will continue to spawn into the 1980s (probably to 1984-85), but each generation produced from 1979 on will likely become increasingly hybridized. Eggs and sperm from pure Colorado River cutthroat trout can probably be taken until about 1984-85, but the largest numbers of pure Colorado River cutthroat trout should appear in the spawning runs from 1979 to 1982 (from those born from 1976 to 1978). The practical value of maintaining a source of the Colorado River cutthroat for propagation is that they can be stocked as fingerlings into the lake each year to maintain two groups of cutthroat trout (the native Colorado River cutthroat and the hybrid which will probably become dominated by its Snake River cutthroat ancestry) and create ecological segregation resulting in a more productive and higher quality fishery.

2. Introduction of forage organisms. As discussed, I found no evidence of crustaceans suitable as trout food in Clinton Reservoir in 1978. Crustaceans can make effective use of the pelagic (open water) and benthic (bottom) resources and supply a dependable source of food and also effect feeding segregation (avoidance of competition) between young, small trout and older, larger trout and feeding segregation between subspecies of cutthroat trout. I would break down the crustacea considered for introduction into three categories based on their sizes: Small (1-3 mm) species represented by copepods and cladocerans (water fleas) which are pelagic and are typically the "bread and butter" of young trout in most mountain

lakes. Trout can grow rapidly to a size of about 12 in. (305 mm) on these small organisms alone if they are abundant, but grow slowly beyond that size because of the energy expenditure required to capture sufficient quantities of such small organisms. Trappers Lake is an example of the basic food supply consisting of small crustaceans. Few trout exceed 14 in. (356 mm) in Trappers Lake, but there is an abundance of smaller trout.

Medium size species (3-15 mm) represented by freshwater "shrimp" or scuds and aquatic "sow bugs." The trout from lakes with an abundant "shrimp" population are characterized by rapid growth, excellent condition ("plumpness"), and red flesh color. "Shrimp" occur in many, but not all, mountain lakes in Colorado. Sometimes introductions of shrimp into waters where they did not previously occur are successful, sometimes not. The aquatic "sow bug," where it occurs, typically becomes abundant in fall and winter months, when it makes significant contributions to the trout's diet. They inhabit mud bottom areas and are abundant in Dillon Reservoir.

Large size (20 mm and larger) crustacean are largely restricted to crawfish and "possum shrimp" in Colorado lakes. The "possum shrimp" has been introduced into several Colorado lakes and is abundant in Twin Lakes. Since the establishment of "possum shrimp" in Twin Lakes, the small crustaceans (water fleas), once the most abundant trout food, has disappeared. This "trade-off" may not be beneficial to the trout population.

Crawfish are a prime food for large trout. In waters where crawfish are abundant (and of a species available to trout), trout growth curves show an interesting phenomenon. A size of about 14 in. (356 mm) is attained primarily on a diet of small crustaceans and insects in perhaps two to four years, then the trout start to feed almost exclusively on crawfish and their growth spurts rapidly. I have two small ponds (.5 acre) on my property in Fort Collins in which I raise Snake River cutthroat trout. After reaching a size of 13-15 in. (330-382 mm), the cutthroat trout start to feed intensively on the abundant crawfish population and the following year are 18-21 in. (457-533 mm) in length and weigh three to four pounds and more.

I have observed this same growth pattern in the Snake River cutthroat trout introduced into Towave Reservoir on the Uinta Indian Reservation, Utah, after crawfish became established in the reservoir. I do not know of any crawfish population existing at 11,000 ft. (3333 m), the elevation of Clinton Reservoir, and their successful introduction is doubtful, but as with the freshwater "shrimp," it is a "try it and see" situation.

3. Plan future management and monitoring of Clinton Reservoir trout population and fishery. Much useful information can be obtained from relatively little effort such as sampling of spawning runs, sampling anglers catch for size, age, growth rate, feeding habits, etc., but if detailed data regarding population dynamics, recruitment, catch, feeding, etc., are desired, an intensive research plan must be adopted. The most cost effective method to conduct intensive research would be the employment of a graduate student or students who would collect and analyze the data for thesis studies.

Figure 1. Hypothetical and idealized size and age structure of Clinton Reservoir trout population in September of some future year. Assumptions for this model are that natural mortality rates are relatively low, growth and production remain good to excellent, natural reproduction is limited to no more than about 10% of the potential fecundity of the population (to prevent overpopulation, slow growth and stunting), and anglers remove only surplus production (overexploitation does not occur).

The standing crop (total biomass) is about 5000 lbs. or 50 lbs./acre. There are 5775 trout of catchable size (ca. 8 in. or more); of these, 2500 will die within a year (surplus production).

Good growth and survival into the older age classes to produce "trophy" size trout is dependent on an abundance of relatively large forage organisms.

Overexploitation by anglers will occur if the number of trout removed by anglers equals or exceeds the numbers in the surplus production. Restrictive regulations aimed at creating a high catch-per-hour (bulk of trout caught and released) may be necessary if angling pressure approaches 50 hrs./acre/year.

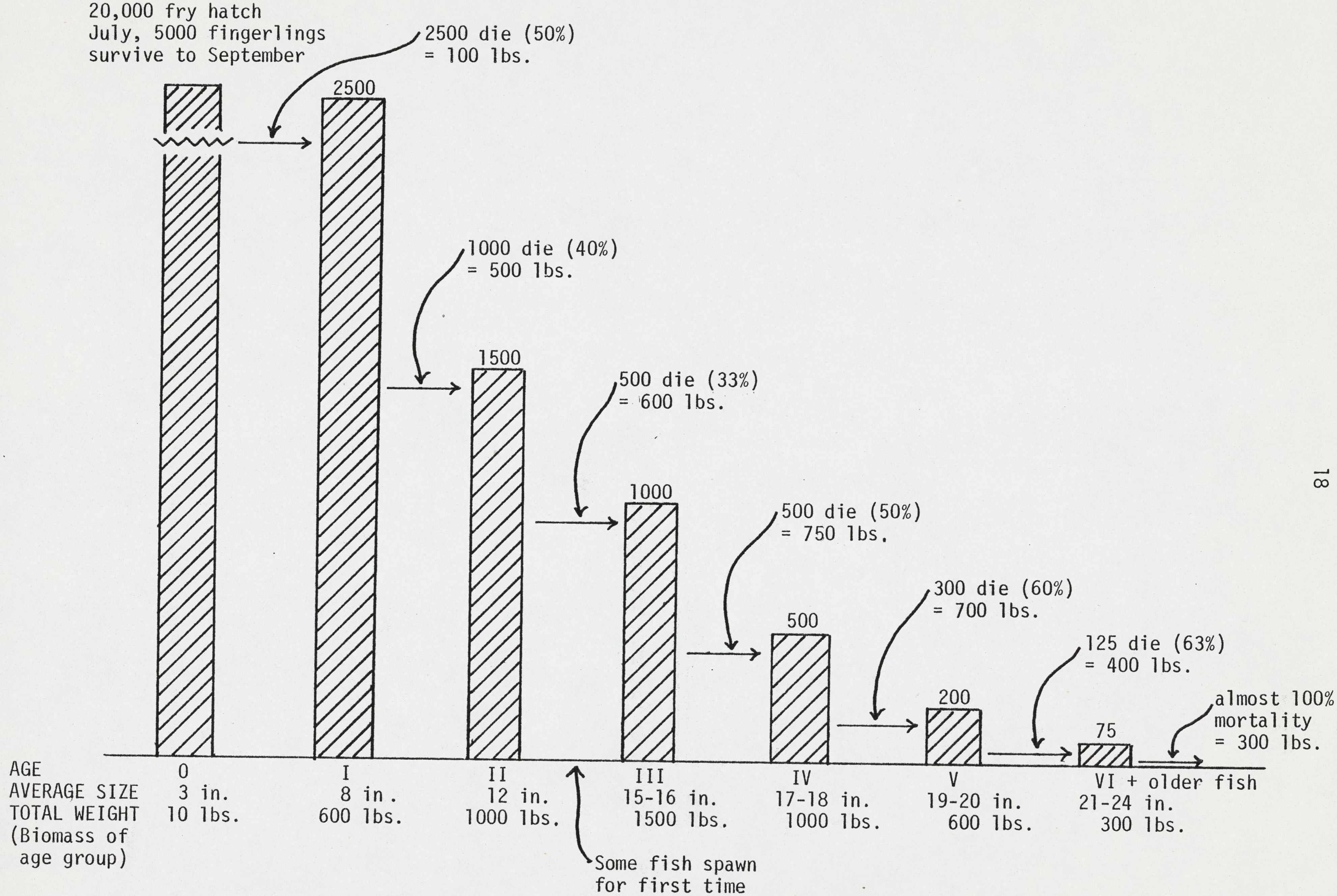
20,000 fry hatch
July, 5000 fingerlings
survive to September
2500 die (50%)
= 100 lbs.
2500
1000 die (40%)
= 500 lbs.
1500
500 die (33%)
= 600 lbs.
1000
500 die (50%)
= 750 lbs.
500
300 die (60%)
= 700 lbs.
200
125 die (63%)
= 400 lbs.
75
almost 100%
mortality
= 300 lbs.
AGE
AVERAGE SIZE
TOTAL WEIGHT
(Biomass of
age group)
0
3 in.
10 lbs.
I
8 in.
600 lbs.
II
12 in.
1000 lbs.
III
15-16 in.
1500 lbs.
IV
17-18 in.
1000 lbs.
V
19-20 in.
600 lbs.
VI + older fish
21-24 in.
300 lbs.
Some fish spawn
for first time

FIGURE 1.

APPENDIX I

LIST OF COMMON AND SCIENTIFIC NAMES USED

Common Name	Scientific Name
Colorado River cutthroat trout	*Salmo clarki pleuriticus*
Snake River cutthroat trout	*Salmo clarki* subsp.
Rainbow trout	*Salmo gairdneri*
Brown trout	*Salmo trutta*
Beetle	order Coleoptera
Mayfly	order Ephemeroptera
Midge or gnat	order Diptera, family Chironomidae
Crustaceans	class Crustacea
Copepods	order Copepoda, particularly the genus *Diaptomus*
Cladocerans or water fleas	order Cladocera, particularly the genus *Daphnia*
Shrimp or scud	order Amphipoda, genus *Gammarus*
Aquatic sowbug	order Isopoda, genus *Asellus*
Possum shrimp	*Mysis relicta*
Crawfish	order Decapoda, reference to *Oronectes virilus*
Roundworm parasite	class Nematoda
Eye fluke parasite	class Trematoda, genus *Diplostomum*

[ca 1979]

Probable Rediscovery of the Original
Pyramid Lake Cutthroat Trout

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Abstract: The circumstantial evidence is convincing that a population of cutthroat trout, inhabiting an unnamed stream in the Pilot Peak Range of Utah-Nevada, represents the original Pyramid Lake genotype of *S. c. henshawi*. This has considerable significance in regards to propagation, since the world record cutthroat trout was of this unique genotype.

Salmo clarki henshawi, the cutthroat trout native to the Lahontan basin of Nevada and California, evolved in pluvial Lake Lahontan, a late Pleistocene lake, comparable in size to present day Lake Erie.

As the only large predator among several potential cyprinid and catostomid forage species, the selective pressures determining the evolutionary divergence of *S. c. henshawi*, resulted in, perhaps, the largest and most highly predaceous trout native to western North America (Behnke and Zarn 1976). Only the population of Pyramid Lake, Nevada, continued to exist with the full array of the Lahontan basin fish fauna, after the final desiccation of Lake Lahontan about 8,000 years ago. After the final desiccation of Lake Lahontan, *S. c. henshawi* stocks persisting in streams of the Lahontan basin evidently were ill adapted by virtue of an evolutionary heritage as a large, lacustrine predator and rapidly disappeared after non-native trouts were introduced. Only a few, small, headwater streams isolated by barrier falls still contain *S. c. henshawi* and two native lacustrine populations still exist in Independence Lake, California and in Summit Lake, Nevada. Although "S. c. henshawi" has been propagated in large numbers since the 1950's, the bulk of hatchery produced Lahontan cutthroat trout are derived from Heenan Lake, California, from a stock originating from the Carson River, but which is slightly hybridized with rainbow trout (Behnke and Zarn 1976). The taxon S. c. henshawi was formerly recognized as an endangered species under the 1973 Endangered Species Act, but its status was changed to "threatened" in 1976 to facilitate management and to allow angling.

The uniqueness of the Pyramid Lake population lies in the fact that this stock persisted in a continuous lake environment for several thousands of years (50,000-100,000 years). Pyramid Lake is the only lake in the Lahontan basin that has maintained a direct continuity from pluvial Lake Lahontan. The evolutionary programming associated with a continuous environment endowed the native trout of Pyramid Lake with specialized adaptive features reflected in their behavior and physiology to maximize efficiency of energy conversion and utilization of the entire environmental resources.

The evolutionary selective factors acting to specialize the Pyramid Lake cutthroat trout for the large lake environment and to feed on the abundant schools of large forage fish which attain lengths of 375-450 mm (15-18 inches) were responsible for making this fish the largest trout native to western North America. The official world record cutthroat trout, taken from Pyramid Lake, weighed 18.6 kg (41 lbs), but it is a common belief among the older Paiute Indians around Pyramid Lake that much larger trout were once regularly caught by the Indian fishermen.

Wheeler (1969) reported a trout of 28.2 kg (62 lbs) taken in 1916 in the Indian fishery. Sumner (1940), observing the final spawning run of cutthroat trout from Pyramid Lake in 1938, recorded the average weight of the trout in the run to be 9.1 kg (20 lbs). Since 1955 millions of S. c. henshawi of Heenan Lake origin and in more recent years, supplemented by the offspring of Summit Lake trout, have been stocked into Pyramid Lake to support a trophy fishery, but relatively few specimens in excess of 9.1 kg (20 lbs) have been taken in the last 20 years.

The demise of the original Pyramid Lake trout began in 1906 with the closure of Derby Dam, part of the Bureau of Reclamation's Newlands irrigation project. This dam blocked the Truckee River, the only spawning stream tributary to Pyramid Lake, about 30 miles above the lake. In the 1920's more and more of the Truckee River was diverted at the dam and complete dewatering frequently occurred. Successful spawning became sporadic with the last known run leaving the lake during the high water year of 1938. No water was available in subsequent years and the unique Pyramid Lake genotype of this magnificent trout was believed extinct. The presumed extinction of the original Pyramid Lake cutthroat trout population with the loss of such a unique genetic resource has been cited by Trojnar and Behnke (1974) and Behnke and Zarn (1976) to illustrate the practical values of preserving genetic diversity within a species or subspecies.

Millions of eggs from Pyramid Lake cutthroat trout were taken by the Nevada Fish Commission and later by the U.S. Bureau of Fisheries during a period from about 1885 to 1930 (Behnke 1971). There is the possibility that an introduction of the original Pyramid Lake cutthroat may have persisted in some remote, unknown waters, and its discovery would again offer the opportunity to utilize this genotype in modern fisheries management.

We believe that an unusual cutthroat trout population discovered in a small stream on Pilot Peak, Nevada-Utah, in 1977, does represent an introduced population of S. c. henshawi of Pyramid Lake origin.

Pilot Peak lies at the western edge of the Bonneville salt flats on the Utah-Nevada border, north of the city of Wendover. Its maximum elevation is 3513 m (10,716 ft). Two perennial streams drain its eastern slopes, Bettridge Creek and an unnamed stream in Morrison Canyon called Donner Creek by Hickman and Duff (1978). The name was suggested by neighboring Donner Springs, the first source of freshwater found by the ill-fated Donner party in 1846 after crossing the searing desert floor of the Bonneville basin.

Donner Creek is the water supply for the city of Wendover and is diverted at about 5900 ft. elevation. Above the diversion point, Donner Creek is perennial for about 3.2 km (2 mi), with about half of this length in Nevada and half in Utah.

The first report of an unusual type of cutthroat trout in Donner Creek was by personnel of the Utah Division of Wildlife Resources during a BLM-UDWR cooperative survey of the Pilot Peak area in April, 1977.

The senior author, assisted by Mr. Donald Duff, BLM Utah State Fisheries Biologist, collected 17 specimens from Donner Creek in June and August, 1977 as part of a BLM funded research project on the native trout of the Bonneville basin (Hickman 1978a).

Although Pilot Peak is in the Bonneville basin, the trout of Donner Creek are Lahontan cutthroat trout, S. c. henshawi, not S. c. utah, the native trout of the Bonneville basin, and thus they are obviously introduced.

Fortunately, S. c. henshawi is the most conspicuously differentiated subspecies of Salmo clarki. Three characters, in particular, allow for positive identification of this subspecies: The more-or-less uniform distribution of moderately large, roundish spots over the sides of the body and onto the ventral surface; the high number of gillrakers (21-28 with modal and mean values typically 23-25 vs. typically 17-21 in other subspecies); and the high number of pyloric caeca (typically 45-80 in henshawi vs. 25-50 in other subspecies). A multiple discriminant function analysis compared 16 characters of the Donner Creek cutthroat trout with several other cutthroat trout subspecies, and clearly associated the Donner Creek specimens with S. c. henshawi (Hickman 1978a).

The typical henshawi spotting pattern is apparent on the Donner Creek cutthroat trout specimens (Fig. 1). The gillraker counts on 17 specimens range from 24-29 with a mean of 26.1. The number of pyloric caeca ranges from 57-77 with a mean of 66.0. The gillraker count is higher than that of any known sample of S. c. henshawi. Snyder (1917) reported gillraker counts of 22-27 (23.6) for 45 Pyramid Lake cutthroat trout from the Truckee River. It is possible that there is a direct environmental (non-genetic) component which increases the gillraker number in the present population in Donner Creek by about 10% above the assumed source stock, but we believe the largest part of the increased number of gillrakers is due to the "founder's principle", whereby a new population is started from a few individuals and these individuals carry skewed values toward one extreme or the other, rather than modal values in some characters such as gillraker number. Evidently, this has occurred in a subgroup of the Bonneville cutthroat trout, native to the Snake Valley region. The parent population in Pine

Creek, Nevada, averages 22 gillrakers, a population introduced into Hampton Creek averages 21 and a population in Goshute Creek averages 20 (Wernsman 1973), or about a 10% change between the Pine Creek parent population and a population derived from a few individuals transplanted from Pine Creek into Goshute Creek.

Although there is no possible method of taxonomic comparison to verify Pyramid Lake as the source of the Donner Creek population of S. c. henshawi, the circumstantial evidence is convincing that the original introduction was made from eggs collected from S. c. henshawi of Pyramid Lake.

The city of Wendover is partly in Nevada and partly in Utah. Evidently, many years ago a Nevada resident from the Wendover area had a shipment of trout sent to him by the Nevada Fish commission and some were stocked into Donner Creek, which, at the time, was barren of fish. Many small streams, similar to Donner Creek, in the Lahontan and Bonneville basin were barren of fish in historical times. This is due to the steep gradient of the watersheds making the small streams vulnerable to scouring and elimination of fish life from catastrophic floods. The above mentioned Hampton Creek and Goshute Creek are examples where the introduced rainbow trout populations were eliminated by floods about 1950, thereby providing the opportunity to introduce the rare Bonneville cutthroat trout and establish new populations (Hickman 1978b).

If the person who originally introduced trout into Donner Creek obtained the stock from the nearest natural source, he would have introduced the Bonneville cutthroat trout, S. c. utah (assuming the time period was sufficiently early, before brook, brown and rainbow trout replaced the native cutthroat trout from virtually the entire Bonneville basin). The nearest geographical source of native trout in the Lahontan basin is the Humbolt River drainage which has a native cutthroat trout differentiated from _S_. _c_. _henshawi_ by a lower number of gillrakers, averaging 21 instead of 23-25 (Behnke and Zarn 1976).

About 1955 the Heenan Lake cutthroat trout began to be propagated in Nevada as _S_. _c_. _henshawi_. Prior to this it appears that Pyramid Lake was the sole source of _S_. _c_. _henshawi_ propogated in Nevada. More than a million eggs of Pyramid Lake trout were shipped to several eastern Nevada counties in 1910 (Miller and Alcorn 1946). Apparently the last egg taking operation using Pyramid Lake trout was the 1929-1930 season when 3,000,000 eggs were taken as discussed in the Centennial Issue of Nevada Wildlife (Vol. 5, No.'s 4-7).

Mr. Howard Gibson, retired water master of Wendover, told the senior author that cutthroat trout were in Donner Creek when he commenced work in 1952. Mr. Patrick Coffin, regional fisheries biologist, Nevada Department of Fish and Game, wrote that there are no records of fish stockings for the Pilot Peak area.

Mr. Kendall Kimber, Conservation Officer with the Utah Division of Wildlife Resources at Snowville, Utah, wrote that Bettridge Creek (immediately to the north of Donner Creek) was stocked with rainbow trout in the early 1940's. In 1957 Mr. Kimber was told by Mr. Pete McKeller, an elderly rancher and long-time resident of the Pilot Peak area that Morrison Canyon (Donner Creek) "always had native trout."

We examined 22 specimens from Bettridge Creek and found them to be typical of rainbow trout with the exception that one specimen has a basibranchial ("hyoid") tooth -- a cutthroat trout characteristic and evidence that a previous cutthroat trout population had been hybridized and replaced in Bettridge Creek by rainbow trout. There is no evidence of rainbow trout hybridization in the Donner Creek specimens. All 17 specimens possess basibranchial teeth. A rainbow trout influence would not only decrease the basibranchial teeth number but would also decrease, not increase, the gillraker number.

It is relatively certain then that Donner Creek was stocked with *S. c. henshawi* long before 1950, during the time when the only source of *S. c. henshawi* used in propogation in Nevada was the cutthroat trout of Pyramid Lake.

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Figure 1. Cutthroat trout from Donner Creek exhibiting typical spotting pattern of Salmo clarki henshawi.

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Probable Discovery of the Original Pyramid Lake Cutthroat Trout

Salmo clarki henshawi, the cutthroat trout native to the Lahontan basin of Nevada and California, evolved in pluvial Lake Lahontan, a late Pleistocene lake, comparable in size to present day Lake Erie.

As the only larger predator among several potential cyprinid and catostomid forage species, the selective pressures determining the evolutionary divergence of *S. c. henshawi* perhaps resulted in the largest and most highly predacious trout native to western North America (Behnke and Zarn 1976). Only the population in Pyramid Lake, Nevada, continued to coexist with the full array of the Lahontan basin fish fauna after the final dessication of Lake Lahontan about 8000 years ago. Stocks of *S. c. henshawi* persisting in streams of the Lahontan basin evidently were ill adapted by virtue of an evolutionary heritage as a large, lacustrine predator and rapidly disappeared after nonnative trouts were introduced. Only a few small headwater streams isolated by barrier falls still contain *S. c. henshawi,* and two native lacustrine populations still exist in Independence Lake, California, and in Summit Lake, Nevada. Although "*S. c. henshawi*" has been propagated in large numbers since the 1950's, the bulk of hatchery-produced Lahontan cutthroat trout are derived from Heenan Lake, California, from a stock originating from the Carson River, but which is slightly hybridized with rainbow trout (Behnke and Zarn 1976). The taxon *S. c. henshawi* was formerly recognized as an endangered species under the 1973 Endangered Species Act, but its status was changed to "threatened" in 1975 to facilitate management and to allow angling.

The uniqueness of the Pyramid Lake population lies in the fact that this stock persisted in a continuous lake environment for 50,000 to 100,000 years. Pyramid Lake is the only lake in the Lahontan basin that has maintined a direct continuity from pluvial Lake Lahontan with a retention of the original fish fauna. The evolutionary programming associated with a continuous environment endowed the native trout of Pyramid Lake with specialized adaptive features reflected in their behavior and physiology to maximize efficiency of energy conversion and use of the entire environmental resources.

The evolutionary selective factors acting to specialize the Pyramid Lake cutthroat trout for the large-lake environment and to feed on the abundant schools of large forage fish, which attain lengths of 375-450 mm (15-18 in.), were responsible for making this fish the largest trout native to western North America. The official world record cutthroat trout, taken from Pyramid Lake, weighed 18.6 kg (41 lb), but it is a common belief among the older Paiute Indians around Pyramid Lake that much larger trout were once regularly caught by the Indian fishermen. Wheeler (1969) reported a trout of 28.2 kg (62 lb) taken in 1916 in the Indian fishery. Summer (1940), observing the final spawning run of cutthroat trout from Pyramid Lake in 1938, recorded the average weight of the trout in the run as 9.1 kg (20 lb). Since 1955, millions of *S. c. henshawi* of Heenan Lake origin (in more recent years, supplemented by the offspring of Summit Lake trout), have been stocked into Pyramid Lake to support a trophy fishery, but relatively few specimens larger than 9.1 kg have been taken in the last 20 years.

The demise of the original Pyramid Lake trout began in 1906 with the closure of Derby Dam, part of the Newlands Irrigation Project of the Bureau of Reclamation. This dam blocked the Truckee River, the only spawning stream tributary to Pyramid Lake, about 50 km (30 mi) above the lake. In the 1920's, more and more of the Truckee River was diverted at the dam and complete dewatering frequently occurred. Successful spawning became sporadic; the last known run left the lake during the high-water year of 1938. No water was available in later years and the unique Pyramid Lake genotype of this magnificent trout was believed to be extinct. The presumed extinction of the original Pyramid Lake cutthroat trout population with the loss of such a unique genetic resource has been cited by Trojnar and Behnke (1974) and Behnke and Zarn (1976) to illustrate the practical values of preserving genetic diversity within a species or subspecies.

Millions of eggs from Pyramid Lake cutthroat trout were taken by the Nevada Fish Commission and later by the U. S. Bureau of Fisheries during a period from about 1885 to 1930. There is the possibility that an introduction of the original Pyramid Lake cutthroat may have persisted in some remote, unknown waters, and its discovery would again offer the opportunity to use this genotype in modern fishery management.

We believe that an unusual cutthroat trout population discovered in 1977 in a small stream on Pilot Peak, Nevada–Utah, represents an introduced population of *S. c. henshawi* of Pyramid Lake origin.

Pilot Peak lies at the western edge of the Bonneville salt flats on the Utah–Nevada border, north of the city of Wendover. Its maximum elevation is 3513 m (10,716 ft). Two perennial streams drain its eastern slopes, Bettridge Creek and an unnamed stream in Morrison Canyon called Donner Creek by Hickman and Duff (1978). Donner Creek is the water supply for the city of Wendover and is diverted at an elevation of 1800 m (5900 ft). Above the diversion point, Donner Creek is perennial for about 3.2 km (2 mi); about half of this length is in Nevada and half in Utah.

The first report of an unusual type of cutthroat trout in Donner Creek was made by personnel of the Utah Division of Wildlife Resources during a survey of the Pilot Peak area in April 1977 in cooperation with the U. S. Bureau of Land Management (BLM). The senior author, assisted by Donald Duff (BLM Utah State fisheries biologist), collected 17 specimens from Donner Creek in June and August 1977 as part of a BLM-funded research project on the native trout of the Bonneville basin (Hickman 1978a).

Although Pilot Peak is in the Bonneville basin, the trout of Donner Creek are Lahontan cutthroat trout, *S. c. henshawi,* not *S. c. utah,* the native trout of the Bonneville basin, and thus they must have been introduced.

Fortunately, *S. c. henshawi* is the most conspicuously differentiated subspecies of *Salmo clarki*. Three characters, in particular, allow for positive identification of this subspecies: the more-or-less uniform distribution of moderately large, roundish spots over the sides of the body and onto the ventral surface; the large number of gillrakers (21-28; modal and mean values typically 23-25 vs. 17-21 in other subspecies); and the large number of pyloric caeca (typically 45-80 vs. 25-50 in other subspecies). We used multiple discriminant function analysis to compare 16 characters of the Donner Creek cutthroat trout with those of several other cutthroat trout subspecies. This analysis clearly classified the Donner Creek specimens as *S. c. henshawi* (Hickman 1978a).

The typical *S. c. henshawi* spotting pattern is apparent on the Donner Creek cutthroat trout specimens (Fig. 1). The gillraker counts on 17 specimens ranged from 24 to 29 (mean, 26.1). The number of pyloric caeca ranged from 57 to 77 (mean, 66.0). The average number of gillrakers was higher than that of any known sample of *S. c. henshawi*. Snyder (1917) reported gillraker counts of 22-27 (mean, 23.6) for 45 Pyramid Lake cutthroat trout from the Truckee River. Possibly there is a direct environmental (nongenetic) component that increases the gillraker number of the extant population in Donner Creek by about 10% above the assumed source stock, but we believe the largest part of the increased number of gillrakers is due to the "founder's principle," whereby a new population is started from a few individuals and these individuals carry values skewed toward one or the other extreme (rather than modal values) in some characters such as gillraker number. Evidently, this has occurred in a subgroup of the Bonneville cutthroat trout, native to the Snake Valley region. The parent population in Pine Creek, Nevada, averages 22 gillrakers, a population introduced into Hampton Creek averages 21, and a population in Goshute Creek averages 20 (Wernsman 1973) — or about a 10% change between the Pine Creek parent population and a population derived from a few individuals transplanted from Pine Creek into Goshute Creek. These three small streams exhibit similar environmental characteristics.

Although there is no possible method of taxonomic comparison to verify Pyramid Lake as the source of the Donner Creek population of *S. c. henshawi,* the circumstantial evidence is convincing that the original introduction was made from eggs collected from *S. c. henshawi* of Pyramid Lake.

The city of Wendover is partly in Nevada and partly in Utah. Evidently, many years ago a shipment of trout was sent to the Wendover area by the Nevada Fish commission and some were stocked into Donner Creek, which was barren of fish at that time. Many small streams, similar to Donner Creek, in the Lahontan and Bonneville basin were barren of fish in historical times because of the steep gradient of the watersheds, which made the small streams vulnerable to scouring and to elimination of fish life by catastrophic floods. Hampton Creek and Goshute Creek are examples where the introduced rainbow trout populations were eliminated by floods about 1950, thereby providing the opportunity to introduce the rare Bonneville cutthroat trout and establish new populations (Hickman 1978b).

If the trout originally introduced into Donner Creek had been obtained from the nearest natural source, the introduced trout would have been the Bonneville cut-

Fig. 1. Cutthroat trout from Donner Creek, exhibiting typical spotting pattern of Salmo clarki henshawi.

throat trout, *S. c. utah* (assuming the time period was sufficiently early, before nonnative trouts replaced the native cutthroat trout from virtually the entire Bonneville basin). The nearest geographical source of native trout in the Lahontan basin is the Humbolt River drainage, which has a native cutthroat trout differentiated from *S. c. henshawi* by fewer gillrakers, averaging 20 instead of 23-25 (Behnke and Zarn 1976).

About 1955 the Heenan Lake cutthroat trout began to be propagated in Nevada as *S. c. henshawi*. Before 1955 it appears that Pyramid Lake was the sole source of *S. c. henshawi* propagated in Nevada. More than a million eggs of Pyramid Lake trout were shipped to several eastern Nevada counties in 1910 (Miller and Alcorn 1946). Apparently the last egg-taking operation using Pyramid Lake trout was the 1929-1930 season, when 3 million eggs were taken (Anon. 1965).

The retired water master of Wendover, Howard Gibson, told the senior author that cutthroat trout were in Donner Creek when he began work there in 1952. Patrick Coffin (regional fisheries biologist, Nevada Department of Fish and Game, personal communication) reported that there are no records of fish stockings for the Pilot Peak area.

Kendall Kimber (Conservation Officer, Utah Division of Wildlife Resources at Snowville, personal communication) reported that Bettridge Creek (immediately to the north of Donner Creek) was stocked with rainbow trout in the early 1940's. In 1957 he was told by an elderly rancher and long-time resident of the Pilot Peak area, Pete McKeller, that Morrison Canyon (Donner Creek) "always had native trout."

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It is thus relatively certain that Donner Creek was stocked with *S. c. henshawi* long before 1950, during the time when the only source of *S. c. henshawi* used in propagation in Nevada was the cutthroat trout of Pyramid Lake.

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Livestock Grazing Impact on Stream Fisheries: Problems and Suggested Solutions

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Problem Identification

I believe most professional fisheries biologists would agree that domestic livestock grazing on public lands is a valid and desirable use of this forage resource if damage to streams could be minimized. The focal point of conflict concerns the fact that livestock tend to concentrate along stream bottom land leading to excessive use and eventual destruction of riparian vegetation, which in turn leads to destabilized stream banks and altered stream channels. The end result is a major change in stream morphology--either a down-cutting, trenching effect or a spreading, braided channel. Both types of alteration in the stream channel morphology converts slow, deep water with adequate cover (optimum trout habitat) into shallow, high velocity flows without adequate cover (loss of undercut banks). Data from three papers presented in this symposium documenting these effects on trout streams all agree that trout biomass is 3-4 times greater in protected areas than in overgrazed areas within the same stream (Duff, Marcuson, Clair and Storch). Lorz (1974) found a similar effect of livestock grazing impact on the Little Deshutes River, Oregon, where 175 lbs/acre of trout occurred in a section with good riparian vegetation and stable stream banks and only

48 lbs/acre in a section where livestock impact had destroyed the riparian vegetation and destabilized the banks. Further confirmation that shallow, high velocity flows without suitable cover holds considerably less biomass of trout (especially less of the older, larger fish) and that this difference is due to differences in the physical habitat not the food supply, was demonstrated by the experimental alteration of a section of Lawrence Creek, Wisconsin (Hunt 1969, 1976). The works of White (1973) and Wesche (1973, 1974) also documents the relationships of channel morphology, undercut banks and adequate cover to trout abundance.

Depending on several factors, the impact of livestock grazing on a trout stream and its trout population can vary from nil or even beneficial to devastating (stream completely barren of fish). At high elevations with a short grazing season and with a riparian vegetation of conifers or large woody plants providing a dense and deep root systems, and where forage and water is well dispersed throughout the allotment, reasonable livestock densities should have little, if any, negative impact. In meadow areas where dense stands of willows may completely encase small headwater streams, moderate grazing pressure may be beneficial by opening sections of the stream to sunlight and allowing angler access.

The most severe damage to streams from livestock grazing typically occurs in arid and semi arid foothill regions where the tendency for livestock to concentrate along stream bottom lands is greatly magnified because by mid summer such areas hold the only water and green vegetation of the allotment.

It might be asked: If livestock grazing is such a serious multiple-use conflict in relation to its degradation of stream fisheries--why then hasn't more serious research and management efforts been devoted to quantifying the cause and effect relationship and guidelines developed to minimize the damage?

The degradation of streams by livestock can be characterized as a gradual, cumulative impact rather than a sudden, catastrophic event. Grazing of western lands has been going on for over 100 years. In many areas the present degraded conditions date back a considerable period and all living residents of the area may never have seen the watersheds prior to livestock use and believe that the silted-in, trenched or braided streams are completely the result of natural forces. The relationships of overgrazing to vegetation removal and subsequent flooding and erosion were well known before the turn of the century (Chapman 1933).

Virtually all range research and management has been devoted to forage conditions of rangelands. Historically, the riparian ecosystem has been ignored or considered an unfortunate but unavoidable sacrifice area of an allotment. Thus, in many areas range management techniques have improved the forage conditions of the rangelands, while the streams in the watersheds may continue to decline in habitat quality.

The relatively few fisheries and wildlife biologists employed by the federal agencies in relation to the magnitude of the areas involved and their problems, in addition to their small budgets and small influence in the decision-making process, undoubtably have contributed to a general lack of awareness of the livestock-fisheries multiple-use conflict.

Meaningful progress towards a solution to the problem has been hindered by the fact that public natural resource advisory boards have been made up of, or dominated by, the dominant user groups of public lands.

There are no demonstrably effective guidelines to follow on BLM or USFS grazing allotments to allow for grazing while minimizing damage to streams, as there are for other multiple use activities.

Some Suggested Actions

In situtations such as livestock impact on fish, where much is yet to be learned, there is an innate response to call for more research to quantify cause and effect relationships under various conditions. I would agree that such research is necessary, but action to protect or restore stream habitat quality should not be delayed pending the outcome of years of research. We have sufficient data on hand to know that the quality and integrity of the riparian ecosystem is the basic key to the problem.

It would be foolish for a supposedly learned person to claim that a direct relationship between overgrazing and stream degradation is yet to be proved. The range science literature well documents the relationship of grazing densities on various types of land to vegetation change, run-off and erosion. The fisheries literature abundantly documents the effects of sediment, temperature and habitat change on trout populations.

Ultimately it makes no difference to the trout in the stream if the removal of shading vegetation raising the daily maximum water temperature from 68^{o}F to 82^{o}F, is caused suddenly by chain saws or more gradually by livestock. The end result is the same as far as the trout is concerned if a stream undergoes a radical alteration of its morphology from channelization by bulldozers and draglines or by streambank destabilization from livestock overuse; only the time frame differs.

In the general agreement that more research is necessary, I foresee a danger that much of this research will be virtually useless for quantifying the cause and effect relationship of livestock grazing and loss of desirable fishes. As pointed out above, the major negative impact is from direct physical alteration of the environment--the loss of adequate riparian vegetation to bind a stream bank and provide suitable habitat which, in turn, leads to a decline of a trout population. Water quality changes (except in rare instances of great cattle density and non-flowing streams) are not a contributing factor--the slight additional enrichment would most likely have a beneficial effect on the food supply in most streams.

Invertebrate abundance and diversity indices have little to contribute toward a better understanding and quantification of the cause and effect relationship between livestock and trout except as a corollary to what should be obvious--that the stream is "stressed". Insects are likely to sustain a higher biomass in degraded stream sections than in protected sections (see Duff's paper in this symposium), but the trout do not utilize them for want of adequate living space in streams characterized by shallow, high velocity flows.

In situations where the habitat has been "stressed" as discussed above, food supply is not expected to be the limiting factor of trout abundance. However, riparian vegetation may make a significant contribution to a trout's diet in the form of terrestrial insects (Hunt 1975) and this loss or gain would not be reflected in stream bottom sampling. Thus, to me, it seems fruitless to devote much attention to the invertebrate fauna or to water quality (except for sediment and temperature) in hopes of quantifying livestock-fisheries relationships.

The most direct and useful studies will concern the correlation of environmental change (riparian vegetation, bank stability, channel morphology, cover, etc.) with changes in fish abundance and biomass. The basic question is: How many more pounds and numbers of trout or other game fish (for which licenses are purchased and recreational days expended) could a certain number of miles or acres of water, exposed to livestock impact, support if the streams were protected from grazing and a quality environment restored?

Ideally, such data could be obtained by sampling and correlating environmental factors with fish abundance in protected sections and sections exposed to livestock grazing of the same stream as has been done in the three papers presented at this symposium. This may not be possible for some streams where the entire watershed is grazed. In such situations data must be extrapolated from other ungrazed streams with similar physical and chemical characteristics (elevation, gradient, average width, depth, flow regime, etc.)

within the same geographical region. A system of stream classification can be developed, given certain environmental parameters, predicting trout biomass expected to be sustained with habitat quality. Wyoming has been a leader in associating environmental parameters to trout abundance and biomass in a quantitative manner (Binns 1976; Wesche 1973, 1974).

If, for example, a stream is predicted to have the potential to support 100 lbs of trout per acre with environmental quality, or 100 lbs per acre is actually sampled from protected sections of the stream, but only 25 lbs per acre is found in this stream under impact from livestock grazing, then it can be assumed that grazing is causing a net loss of 75% or 75 lbs per acre in a particular allotment under a certain grazing system. Because annual production typically, equals or exceeds instantaneous biomass (standing crop), this loss can be considered an annual loss.

Given such data, more quantitative definitions can be assigned to nebulous multiple-use phraseology such as "maintenance of a quality environment" or "no intolerable loss of other resources will be allowed". A quality environment or levels of intolerability can be set, for example, at no less than 75% of the potential biomass which would be expected if the stream were to be completely protected from grazing.

Considering the geographic area involved in the 11 western states where livestock grazing occurs on public lands (probably more than half of all the miles of trout streams), the total estimates of annual fisheries loss due to livestock grazing, if it is ever gathered, I predict, will be enormous.

Because the riparian vegetation is also the most significant area for wildlife and recreation on most grazing allotments, the total values involved will make a most impressive case to confront the inevitable resistence to change which will result over a temporary loss of a relatively few AUM's during a period of riparian vegetation restoration and stream stabilization. The emphasis here is on the word temporary, for as two studies reported on in this symposium (Duff and Clair and Storch), the protected riparian zone produces significantly more livestock forage than the continually grazed portions of the allotment. By admitting livestock into the protected riparian zone later in the season this forage can be utilized without damage to the stream, if the grazing is closely controlled. Thus, even livestock interests can benefit from proper riparian management.

Quantitative figures on pounds of trout lost annually, which in turn can be converted to the potential number of angler days this amount would generate, can be used to derive a dollar value of this loss attributed to a multiple use conflict; however, influences on endangered, threatened or rare native species are a more difficult problem for assigning monetary values.

The first step recommended to initiate changes leading the rehabilitation of riparian communities and stream habitat on federal lands is to separate the riparian zone from other grazing allotments, and to manage the riparian zone with the highest priorities assigned to maintenance of vegetative integrity in relation to fish, wildlife and recreation. Perhaps in some situations, this can be accomplished by range management techniques designed to modify timing of grazing and better dispersal of animals. If not, then exclosure fencing will be necessary.

The BLM and USFS will need increased staffing and funding of fisheries biologists to conduct the needed work and to contract with state fish and game agencies and universities for assistance.

Natural resource advisory boards must be structured to reflect a broader cross section of society. The performance of administrators must be evaluated not only on the AUM's or board feet of timber their region produces, but on what impact these uses have on other resources.

Previously (Behnke and Zarn 1976), I identified livestock grazing as the greatest threat to the habitat integrity of trout streams in the western U.S. I would now prefer to modify my statement and phrase it on a more hopeful note: The rehabilitation of streams presently suffering from the negative impact of livestock grazing offers the single greatest potential to increase the abundance of wild, self-sustaining trout populations in the western U.S.

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[ca. Late 1970's]

Summary and Supplement to thesis:
Systematics of the Westslope Cutthroat Trout

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The intent of this report is to concisely synthesize the relevant points developed in the graduate thesis of Mr. James Roscoe and to make this information available to anyone interested in the systematics and biology of the cutthroat trout native to the upper Columbia, South Saskatchewan and upper Missouri river basins.

The basic problem which was treated concerned the taxonomic status of the cutthroat trout native to the Clark Fork and Coeur d'Alene river systems of Montana and Idaho. It has been long recognized by fishery biologists that the cutthroat trout of this area "looked different" from the Yellowstone Lake cutthroat trout so widely used in propagation. It had been assumed that the correct classification of the Yellowstone trout is *Salmo clarki lewisi*, and that the westslope trout then must represent a distinct species or subspecies. It was also recognized that the native cutthroat trout had been drastically depleted from westslope waters and the westslope cutthroat trout (called *Salmo* sp.) was declared an endangered species in earlier editions of the U.S.D.I. redbook. The 1973 edition placed this trout in an undetermined status because of its uncertain taxonomy.

To clarify the taxonomic status, 68 collections numbering about 700 specimens from a wide geographical area were examined. This data has since been supplemented with additional material by Dr. Richard Wallace, University of Idaho. Biological , taxonomic, zoogeographical and geological evidence were evaluated to arrive at the following conclusions.

The cutthroat trout of the upper Missouri basin (above Great Falls) and the upper Columbia system are virtually identical. This is explained by the origin of the cutthroat trout in the upper Missouri drainage via a postglacial transfer (Ca. 8000 years ago) from the Clark Fork system in the area around Waterton Park. The name S. c. lewisi is assigned to cutthroat trout collected at Great Falls Montana in 1856. Because of taxonomic similarities, the west-slope cutthroat trout is also correctly designated as S. c. lewisi. This same trout (S. c. lewisi) is also native to the South Saskatchewan River (Hudson Bay drainage) and the Kootenai River of the upper Columbia basin. It is also native to the Salmon and Clearwater drainages, tributary to the Snake River, although the cutthroat trout native to the remaining portion of the Snake River is more closely related to the Yellowstone cutthroat. Figure 3 plots the original range of S. c. lewisi.

Differences between the Yellowstone trout and S. c. lewisi are real. Figures one and two illustrate the most prominent diagnostic characters to separate S. c. lewisi from Yellowstone trout (small, irregualr, more profuse spotting vs. larger,rounder more pronounced spots). There are differentiating trends in other characters such as lower numbers of vertebrae, scales, gillrakers and pyloric caeca in S. c. lewisi compared with Yellowstone trout, but variability and overlap is such in these characters that clear-cut and all inclusive discrimination cannot consistantly separate S. c. lewisi from Yellowstone cutthroat trout or most other subspecies of Salmo clarki.

The differentiation of S. c. lewisi from Yellowstone trout is explained by their different origins. S. c. lewisi likely split off from a common cutthroat ancestor under isolation in a glacial refuge lake (Glacial Lake Missoula) from there it eventually spread to its historical range. The ancestral (large-spotted cutthroat) trout gained access to the headwaters of the Snake River prior to formation of Shoshone Falls. From here it radiated into the Bonneville basin and into the Yellowstone River via Two Ocean Pass (about 8,000 years ago). The two distinct lines of cutthroat trout, one in the upper Missouri and one in the Yellowstone drainages evidently never got together to hybridize due to unfavorable downstream habitat.

The correct subspecific name for the Yellowstone trout is in doubt. The Yellowstone trout is virtually identical to the large-spotted cutthroat trout of the Snake River and both are relatively similar to the Bonneville basin cutthroat trout, called S. c. utah. There is little doubt that the genetic affinities of the Yellowstone cutthroat are closer to S. c. utah than they are to S. c. lewisi.

For practical purposes it may not be prudent to apply the subspecies name utah to a trout of such wide geographical distribution. The next available name which applies to this large-spotted cutthroat trout is Salmo clarki bouvieri, for a trout (now extinct) once native to Waha Lake, Idaho.

The study revealed that S. c. lewisi is indeed a rare fish in its pure form. Extensive hybridization has occurred in many areas with rainbow trout, Yellowstone cutthroat trout and probably Henry's Lake cutthroat trout. S. c. lewisi has been displaced from much small stream habitat by brook trout, Salvelinus fontinalis, from large stream habitat by brown trout, Salmo trutta and lake populations have been depleted by degradation of spawning and nursury streams and competition with a variety of introduced fishes.

The fact is, however, that S. c. lewisi is more severely depleted on the east slope (upper Missouri and South Saskatchewan) rather than the westslope (Clark Fork, Coeur d'Alene,Salmon and Clearwater drainages) where relatively pure populations still persist in good numbers in some segments of these basins.

All available information on the ecology, life history and reproduction of S. c. lewisi was evaluated and synthesized. It is apparant that the success of this trout is intricately related to maintenance of environmental quality. Any habitat disruption resulting in increased siltation, warmer temperatures, etc., makes the native cutthroat trout vulnerable to replacement by non-native fishes. The cutthroat trout is vulnerable to overexploitation by angling, but this attribute also makes it an ideal fish for special regulations or a fish-for-fun type fishery, such as has been instituted in Idaho and in Yellowstone Park. The cutthroat trout is the ideal fish for a fishery management program offering the opportunity to fish for a rare and beautiful fish of good size under a restricted kill regulation.

Cutthroat trout populations have responded with a dramatic increase in size and numbers under special regulations in Kelly Creek and the upper St. Joe R., Idaho. Jack Dean, Fisheries Management Biologist at Yellowstone Park provided data on the Yellowstone River cutthroat fishery. In an area open to fishing (Fishing Bridge) the electro fishing survey sampled 378 trout from 10.6 - 16.7 in. ($\bar{X}$ 14.2 in.). In a closed area, downstream (Hayden Valley), 309 trout ranged from 13.2 - 22.0 in. (17.6).

This type of fisheries management, promoting the opportunity to fish for large wild trout, but severly limiting the kill, is quite a different concept from that of providing massive numbers of hatchery fish, but inherent is a greater quality of recreational experience. This type of management should be astutely pursued from a public information angle to gain angler acceptence for programs designed to perpetuate those populations of native cutthroat trout wherever they exist.

A fundamental problem facing any proposed management program designed for maintaining pure populations of native cutthroat trout is: How can such populations be recognized?

Mr. Roscoe's thesis provides the diagnostic characters for S. c. lewisi and an earlier thesis by Wernsman in 1973 gives this data for S. c. pleuriticus, S. c. virginalis and S. c. stomias. It must be emphasized, however, that the taxomic comparisions necessary for determination of relative purity cannot be accurately performed by an inexperienced person.

Once pure populations are determined, special recognition should be afforded for protection against habitat degradation and introductions of non-native trouts.

If a stream or lake with native cutthroat trout is not remote from public access and is exposed to moderate to heavy fishing pressure, then special regulations with artificial lures, and restrictive size and bag limits can provide a high quality fishery for large, wild trout, while maintaining a healthy, self-maintaining natural populations of a rare and beautiful fish.

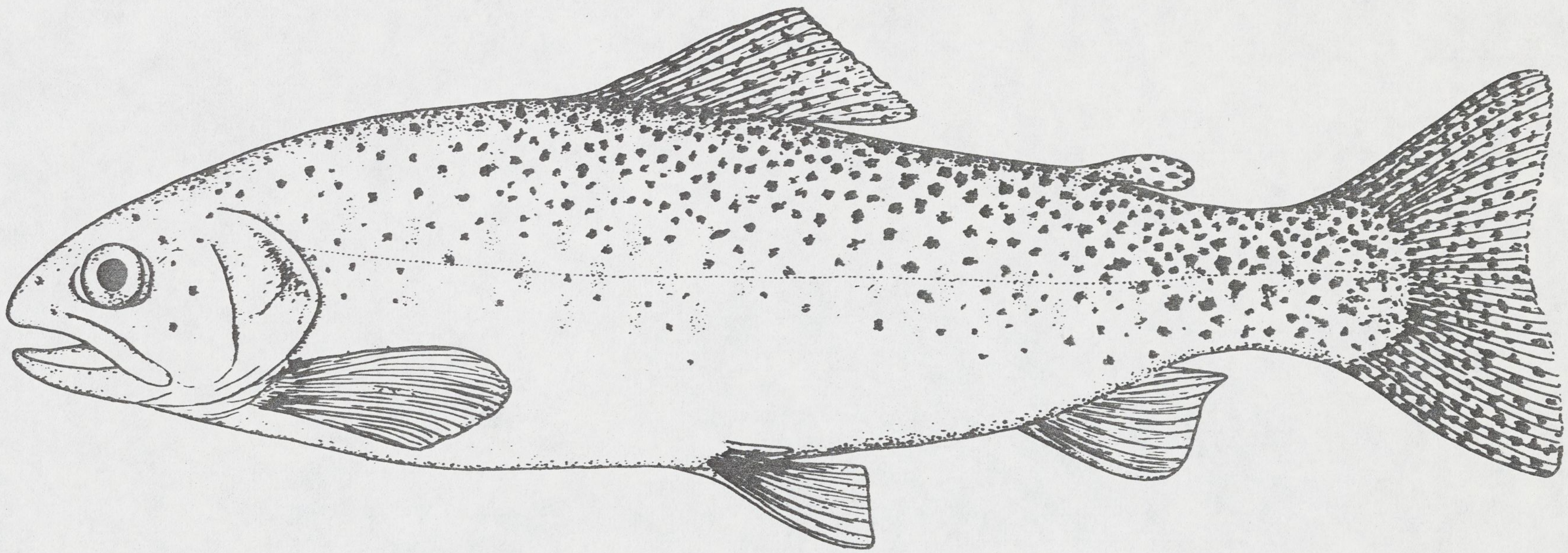

Figure 1. Spotting pattern of Salmo clarki lewisi.

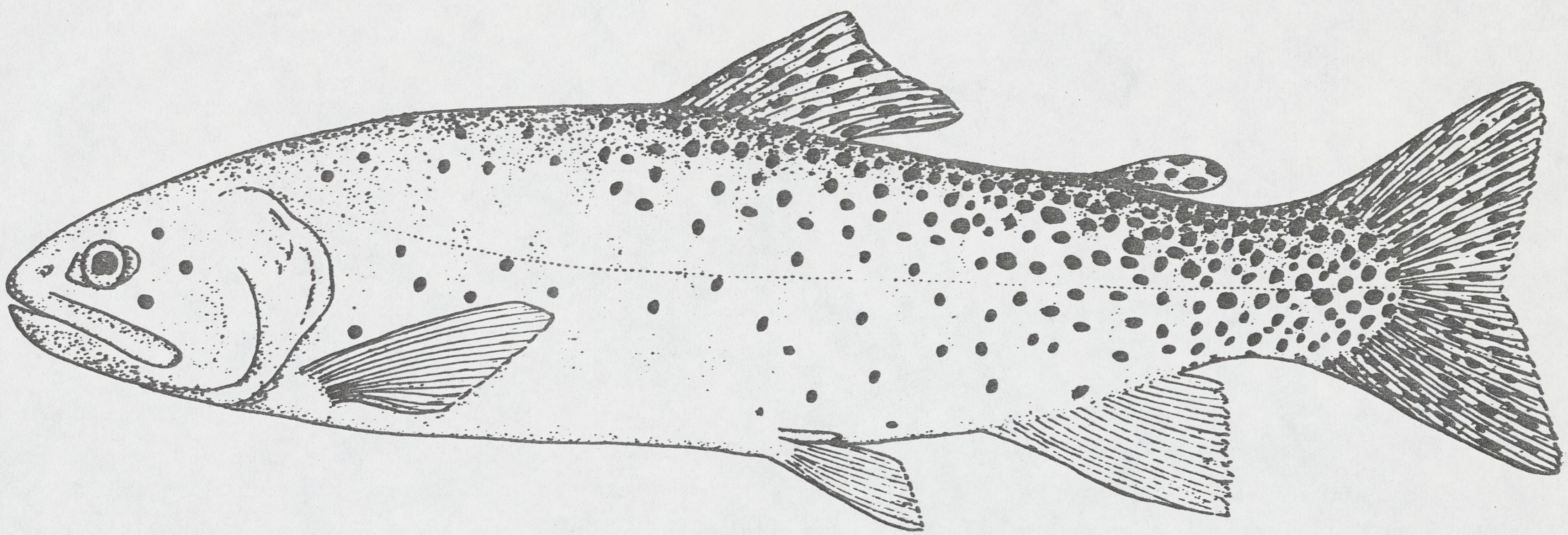

Figure 2. Spotting pattern of the Yellowstone cutthroat trout.

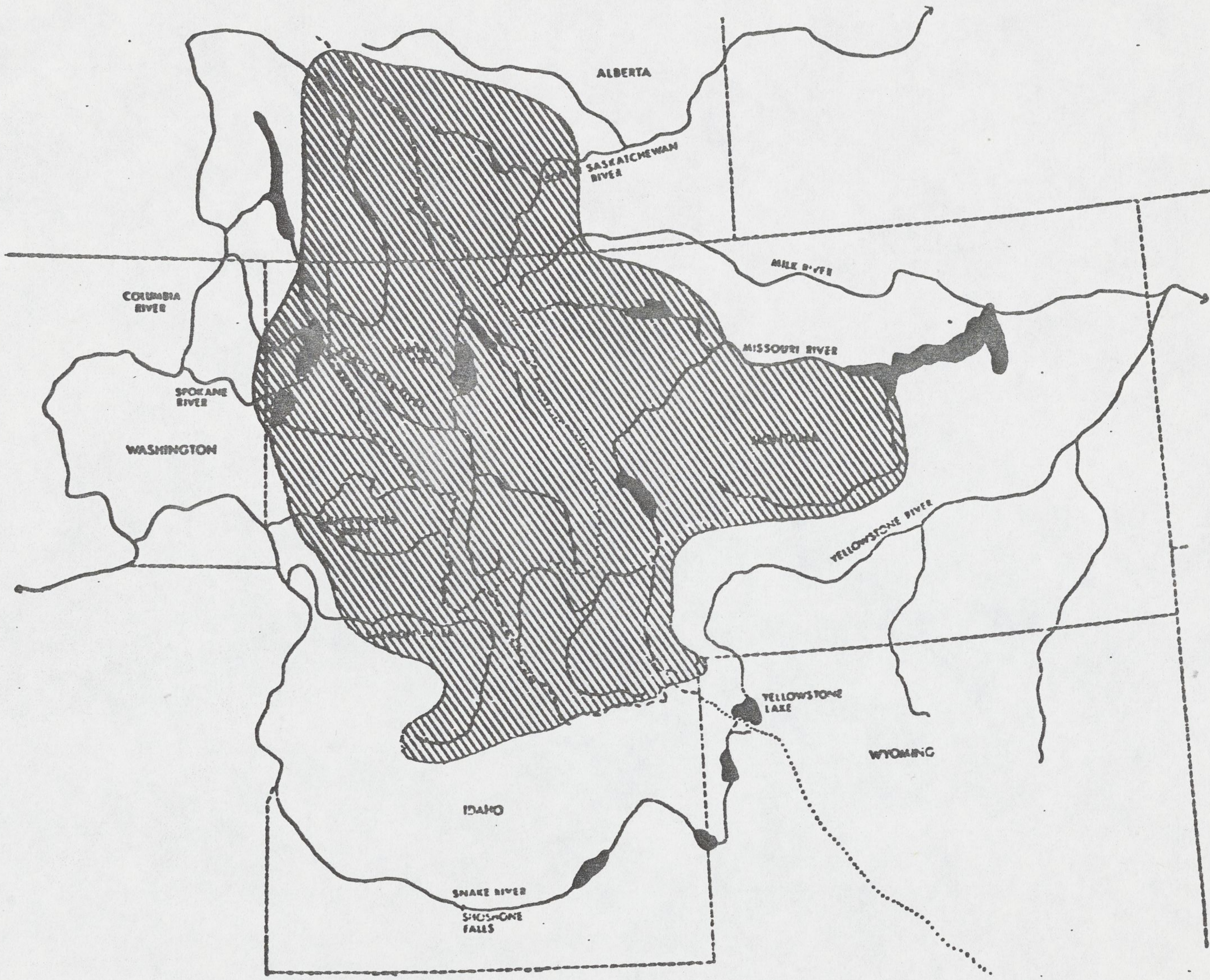

Figure 3. Distribution of S. c. lewisi

[ca. late 1970s]

Management Guidelines for Unique Rare or Endangered Species
Six Western North American Trouts:
Salmo gilae, *Salmo apache*, *Salmo clarki pleuriticus*,
Salmo clarki stomias, *Salmo clarki henshawi*, and *Salmo clarki seleniris*

Introduction

All of the six trouts included in this report are closely related, share many common attributes and all have suffered catostrophic declines in abundance due to essentially similar factors. Thus, general statements applicable to all of these trouts and relevant to any meaningful preservation, restoration or management efforts are summarized in this introductory section.

Taxonomy

The evolutionary history which resulted in the diverse array of western North American trouts of the genus *Salmo* is not fully known. Formerly, it was considered that all western trouts belonged to or were recently derived from two evolutionary lines or species; the rainbow trout, *Salmo gairdneri* and the cutthroat trout, *S. clarki*. Recent studies have demonstrated the true situation is much more complex with several distinct groups, such as the Gila trout, Arizona native trout, Mexican golden trout the California golden trout and red-band trout, which can not be authoratatively assigned to either the rainbow or cutthroat trout species and are assumed to represent distinct evolutionary lines of their own from a common ancestor of all western *Salmo*. (Behnke 1972b; Miller 1972; Schreck and Behnke 1971)

Despite this evolutionary diversity, all western trouts are closely related to the extent that they are fully capable of hybridizing with each other and the hybrids are fertile. The only natural situations where coexistence occurs without hybridization are in Pacific Coast rivers where rainbow trout and the coastal subspecies of cutthroat trout exist together and in the Salmon and Clearwater drainages (Columbia River basin) of Idaho where resident interior cutthroat trout occur with anadromous steelhead trout. All instances where rainbow trout have been introduced beyond their native range and stocked with Gila trout, Arizona native trout, golden trout or any of the interior subspecies of cutthroat trout, hybridization has invariably resulted.

The fact that untold millions of rainbow trout and several subspecies of cutthroat trout have been indiscriminantly mixed and stocked into virtually every habitable water throughout the west and hybridized with the indigenous trouts is the primary cause for the almost complete elimination of pure populations of most of the taxonomic categories of native trouts in the interior regions of the west.

Because of the presence of all degrees of hybridization, the problem of correct identification and evaluation of the purity of existing populations of the native trout of most regions is greatly confounded and the recognition of pure stocks of any of the six trouts considered in this report is not a simple matter.

Although it is possible to aquire sufficient familiarity with the subtle differences between the different species and subspecies of western trouts to adequately distinguish the various taxa, just as one might recognize friends or relatives in a crowd, the average biologist and field personnel cannot be expected to accurately differentiate the true native trout of his area from hybrid populations. Taxonomic criteria have been worked out for all the trouts in this report, but the sorting and evaluation of specimens collected during survey work to determine the status of a native trout and to find pure populations is an involved process of detailed examination and comparison of many characters. The fish collection at Colorado State University (formerly Cooperative Fishery Unit collection, now housed in the Zoology building) contains the best representative collection of all taxa of western trouts and can serve as a basis for such work.

Thus, unless an agency is dealing with "certified" pure populations in a rare trout management program, they will be confronted with the problem of identification. There are possibilities for additional refinement of information useful for taxonomic evaluation such as biochemical techniques (protein electrophoresis) and karyotype examination (chromosome number and morphology) and examples will be discussed in relation to individual taxa. Caution is suggested, however, in utilizing these modern techniques to determine the relative purity of trout populations because much time and money can be needlessly wasted unless the investigator is knowledgeable of basic principles of systematic zoology and particularly with the natural range of variability of the trout under study. In general, if the extent of hybridization has reached the level where it can be detected by electrophoresis or alternations in the chromosome complement, it will also be readily apparent in morphological characters such as spotting pattern, dentition, scale counts, etc.

Our western trouts are not good "biological species" due to the fact that they freely hybridize when they occur together (lack of reproductive isolation in sympatry). This fact plus the lack of clear-cut diagnostic features has raised questions on the validity of the recognized taxa of western trouts. The most pertinent advice relevant to management policies on the trout under discussion is to ignore or avoid questions concerning the validity of zoological nomenclature, but to recognize that each of these trouts are evolutionary realities. That is, they represent the native trout of a particular geographical area, which have been separated from each other for untold thousands of years and are an intregal part of the biological and evolutionary heritage of the area by being subjected to unique genetic programming under natural selection leading to their divergence.

The rationale and practical value of preserving the remaining genetic diversity of the western trouts has been discussed by Behnke (1972a) and Trojnar and Behnke (1974).

It should be mentioned that all of the six taxa of trout discussed in this report are within the province of the 1973 Endangered Species Act (P.L. 93-205) where a species is defined to include "subspecies, smaller taxa or any viable population segment thereof."

Reasons for Decline

As mentioned above, hybridization caused by massive introduction of rainbow trout and various subspecies of cutthroat trout into waters where they were not native is the primary factor leading to the virtual elimination of pure populations of the trouts under discussion. Habitat loss and degradation from irrigation projects, mining, logging, road building and overgrazing has been particularly severe in the arid regions of the west. These factors not only greatly reduced the amount of suitable habitat but also favor the displacement of native trout by more tolerant introduced species such as the brook trout, *Salvelinus fontinalis*, and the brown trout *Salmo trutta*.

Most pure populations of native trout in the interior regions of the west are restricted to small, isolated headwater stream situations in essentially undisturbed habitat.

Basic Life History Attributes and Ecology

The point to be stressed here is that all of the western trouts are highly adaptable to a live in a variety of environments such as small brooks, large rivers or lakes and feed on a broad sprectrum of organisms. This environmental adaptability makes it highly misleading to base the ecological characteristics of a whole taxon on data from a population in a specific environment such as the life history of the Gila trout in Diamond Creek, New Mexico, or the Lahontan cutthroat trout of Pyramid Lake, Nevada. All trouts are opportunistic and eclectic in their diet, essentially reflecting the availability of organisms in their particular environment. Growth is mainly dependent on food availability, size of prey, degree of intra and interspecific competition, water temperatures and length of growing season. Fecundity, in turn, is dependent on size. The life history and ecology of two neighboring populations of the same subspecies living in distinctly different environments will differ much more from each other than they do from other trout species living in similar environments. One must be aware of the fact that the different genotypes allow for a broad and labile range of ecological options and to assume that the specific food habits, growth rate, fecundity, etc. of any particular population under study represents genetically "fixed" attributes of the taxon as a whole, is a misconception. The significance of this point for restoration efforts to expand the range of a rare trout is that potential waters for introduction do not have to closely match the conditions of the waters of the potential donor population. For this purpose it can be assumed that almost any waters suitable for any trout species, will be suitable for all of the six trouts treated in this report (with the condition that no non-native trout are present). One notable exception in adaptability to environmental extremes is found in the Lahontan cutthroat trout, which can tolerate tremendous ranges in alkalinity and flourish in waters such as Walker Lake, Nevada under conditions lethal to all other trouts.

All of the non-domesticated western trouts of the genus Salmo are spring spawners. Reproduction is triggered by increasing water temperatures. Most spawning activity begins in water temperatures of about 42°-48°F. Influenced by elevation and latitude, spawning may occur as early as March or April in some areas and extend well into June in others. Due to the necessity of gravel for nest construction and high oxygen tensions for the developing embryos, all of the trouts under discussion can be considered as essentially obligatory stream spawners. Depending on time of spawning and length of the growing season, the fry emerge from the nests in early to mid summer and attain a size of 1-3 inches by fall. In small streams with restricted habitat and dense populations, growth is slow and maximum size may be no more than 10 inches in fish 6-8 years of age. In large rivers and lakes growth can be rapid with trout reaching several pounds in weight in 4-5 years. In Pyramid Lake, Nevada, the last spawning run of the native cutthroat trout in 1938 averaged 20 lbs. in weight (mainly 7-8 yr. old fish) (Sumner, 1940), whereas populations of this same sub-species living in small headwater streams may not exceed 9-10 inches.

Sexual maturity is attained typically at an age of 2-4 years. In small stream populations such trout may be only 6-8 inches in size and spawn only 100-200 eggs. A generalization on fecundity (with wide individual variation) is that females will spawn approximately 1000 eggs per pound of body weight.

It is doubtful that any present populations of the trouts under discussion live in waters where maximum temperatures consistantly exceed 70°-72°F. It is likely, however, that they do possess thermal tolerance to survive (although under stress) brief daily periods of higher temperatures (78°-80°F.), if the waters significantly cool at night. The interpretation of the pattern of replacement of native trouts by the introduced brook, brown and rainbow trouts throughout the interior west is that the native trouts (subspecies of cutthroat trout, Gila and Arizona native trout) prefer and function best at lower temperatures than do other trout species. Almost all examples where native cutthroat trout coexist with and dominate the introduced species are in cold, headwater situations. Thus, clear-cutting and overgrazing which remove vegetative cover and warm the waters will favor the replacement of native trout by other species.

In Oregon, after clear-cutting of a watershed, water temperatures increased (due to lack of cover) and dissolved oxygen in the spawning gravel decreased (due to siltation). The coho salmon population was not significantly affected but the cutthroat trout population suffered a decline by two thirds in number during six years of a follow-up study (Ringler and Hall, 1975).

Another significant facet of the biology of cutthroat trout and perhaps Gila and Arizona trout is their vulnerability to angling; they are readily caught by fishermen. In a small stream in Idaho, 32 man hours of fishing removed 50% of the cutthroat trout (and 25% of the brook trout) six inches and over in length (McPhee, 1966). In New Mexico, the native cutthroat trout in the Rio Chiquito dominated the introduced brown trout by 420-37 in sampling made in 1965-66 (Little and McKirdy, 1968) when the stream was on private land and closed to fishing. In 1969, two years after the land was aquired by the U.S. Forest Service and opened to fishing, sampling revealed the ratio of cutthroat trout to brown trout was drastically reversed (137 brown trout, 39 cutthroat) due to the differential vulnerability to angling. (Carson Nat. For. memo: "Rio Chiquito population survey." H.J. McKirdy, Aug. 22, 1969.) Their vulnerability to angling, however, can be a positive attribute for management programs for native trout under special regulations such as catch and-release or restrictive size and bag limits as discussed below.

Suggestions for Preservation, Restoration and Management Programs

The general pattern of organized efforts to save rare forms of trout is analagous to the weather--a popular topic of converstion, but one that seems difficult to do anything meaningful about. Although there are real problems and obstacles to be faced, they can be overcome if a set of priorities and goals are established with specific recommendations for action carried out. It is a relatively simple matter to transplant trout from a remnant population into new waters (either naturally barren or where all other fish have been eliminated) and establish a new population.

The first major problem to be faced in most restoration programs for a rare, native trout is one of identification, as mentioned above. How do you know the trout when it is found? This first step involves a survey and inventory of waters where there is a likelihood of encountering pure populations. Areas of the greatest potential for native trout populations are remote and isolated headwater situations, particularly above barrier falls and without any tributary lakes which are a popular target for introductions. When such waters are found and the trout appear to resemble the diagnosis of the native trout, samples of 10-20 specimens from each isolated site should be collected and preserved in 10% formalin. In the field, the specimens can be wrapped in formalin soaked cloth in plastic bags and formalin injected into the body cavity with a hypodermic syringe. When sufficient collections have been made, comparative examinations can begin to identify those populations most ideally conforming to the diagnosis of the taxon involved. In general, the most efficient and economical means of handling the survey and identification aspects of a program is through a university as a graduate student research thesis. Once the relative purity of the populations is established and the distribution and abundance of the native trout known, those populations judged to be pure (uncontaminated by hybridization) can be given special consideration in land-use decisions and environmental impact analysis and serve as a source for introductions to increase their abundance.

It is at this stage, after specific populations have been identified, that unnecessary delays and procrastination in restoration projects typically begin. A prevailing belief is that life history and habitat studies must be initiated before any management decisions or transplants can take place. The objectives are to obtain detailed data on the age, growth, food habits, fecundity, etc. of the trout population and on the biological, physical and chemical parameters of the waters where they live, with the idea that once this knowledge is available intelligent and scientifically based management programs can begin. Such a course of action seems logical and it would be if the life history characteristics studied were genetically fixed traits and the environmental parameters measured were a true reflection of the limitations for survival, but in fact they are not as discussed above. Such information is virtually meaningless in regards to predicting success of a transplant into new waters or for most other matters concerning the management of a particular trout, except where basic information is needed to design special regulations for a fishery to maintain abundance and a desirable age structure of a population exposed to exploitation.

If a survey finds that pure populations of a native trout are rare and restricted to a few small isolated stocks and their future appears precarious, then the top priority should be to effect transplants into new waters within their native range, and increase their dustribution and abundance before a forest fire or flash flood can further decimate the remnant stocks. After new populations are established in new waters, then any life history studies and environmental analysis can include both the donor and receipient populations and their environments. Such information would have greater predictive value because some insight into the range of adaptive responses would be gained.

Ideal sites for introductions to establish new populations would be naturally barren waters above barriers to prevent mixing with introduced trouts. The expense and efforts of effecting a transplant to such a site merely involves the collection and transportation of live fish. Although some naturally barren waters, fully suitable for trout yet exist, they are rare. Some barren headwater streams, particularly at high elevations, appear to be quite suitable trout habitat in the summer, but do not possess sufficient pools and cover to successfully carry trout through a hard winter. In such situations the trout will migrate out of the area and a permanent population can not be maintained (Bjornn, 1971). It is feasible to carry out habitat improvement work in headwater areas, creating pools and cover providing for the establishment of a permanent population (Gard, 1961, 1972).

The next choice of a site to establish a new population of a rare trout in regards to minimal effort and expense, would be a stream with a natural barrier to prevent upstream migration of non-native trouts, but possessing non-native trout or hybrids. There is no doubt that such waters can support the transplanted trout, after the complete elimination of all of the existing fish. A complete kill of all fish in small streams is feasible with contimycin or rotenone treatment if care is taken to be certain all possible refuge areas such as backwaters of beaver ponds and spring seeps are treated. This technique was used in Rocky Mountain National Park to eliminate the brook trout from Hidden Valley Creek and re-establish the native greenback cutthroat trout.

If no natural barriers exist on an otherwise suitable stream, an artificial barrier can be constructed or possibly blasted out of rock, and then chemically treat the stream, as was done to establish new populations of greenback cutthroat in Black Hollow Creek, Colorado, and of Gila trout in McKnight Creek, New Mexico.

Another viable possibility that should not be overlooked in a rare trout restoration program is their introduction into newly constructed lakes to establish a unique fishery under special regulations, such as the example of Christmas Tree Lake on the Apache Indian Reservation, Arizona, stocked with the Arizona native trout. Available lake populations would also offer an abundant and easily obtainable source of eggs for propagation which would greatly facillitate new introductions.

There may be some difficulties in establishing a new population from transplants of a few adult fish into a new environment, particularly in small headwater streams without deep pools above a barrier. The natural tendency of a displaced fish is to find its way home, and most may soon migrate downstream over the barrier. Trout movement is also more pronounced in low or decreasing temperatures (Bjornn, 1971). Once natural reproduction has occurred in the new environment, the success of the introduction should be assured, barring some catastrophe.

Particularly in arid regions where streams are characterized by intermittant summer flows and lack of suitable pools and cover, stream improvement devices can promote increased abundance of trout or create trout habitat where none previously existed. Construction of stream improvement devices can be costly and require considerable labor, but the existence of such devices in Diamond Creek, New Mexico, constructed by CCC personnel in the 1930's may have saved the Gila trout population in this stream during subsequent drought years when virtually the entire population was restricted to the pools created by the small dams.

Unless properly constructed and sited, improvement devices cannot be expected to produce desired results. It is important, therefore that before any ambitious scheme of artificial improvement is undertaken, personnel should be thoroughly familiar with the subject (see: Boreman, 1974; Packer, 1957; Jester and McKirdy, 1966; Gee, 1952; Hunt, 1969; White and Brynildson, 1967; Jackson, 1974).

Protection of natural habitat is certainly the best gaurantee of perpetuating native trout populations. The most ubiquitous and pernicious threat to the integrity of habitat quality is livestock overgrazing.

The most significant trout habitat in small to moderate sized streams is undercut banks, which in turn depend on an extensive vegetative cover of the exposed bank (Wesche, 1973). Livestock grazing typically destroys the vegetative cover and caves in the banks, eliminating the most important habitat of trout. Concomittant effects of overgrazing result in loss of stream bank vegetation and increased water temperatures, erosion and silting, eliminating spawning sites and reducing food supplies.

Although grazing allotments may seem reasonable on paper, in arid regions all the available summer vegetation is found along streams and the livestock concentrate there at high densities. The impact on a stream can be truly devastating in regards to the well-being of a trout population.

For background information on the actual or potential impact of various land-use practices on trout streams see: Burns (1970), Cordone (1956). Cordone and Kelley (1960), Elser (1968), Megahan and Kidd (1972), Mullan (1975), and Platts (1974).

Region VI (Portland, Oregon) of the U.S. Forest Service has developed a fish habitat management policy which includes guidelines on:

I. Fish Habitat Protection and Restoration

   A. Timber management and road construction
   B. Livestock grazing
   C. Mining

II. Fish Habitat Enhancement

The Oregon chapter of the American Fisheries Society passed a resolution endorsing this habitat management policy and urged its adoption on a nation-wide basis (A.F.S. newsletter, March-April, 1975).

Potential Role of Native Trout in Fisheries Management

Superficially, it may appear contradictory that angling may be allowed or even promoted for a rare trout while the goal of the program is to increase the abundance of this trout. The fact is, however, that the major hope for increasing the abundance of a rare trout is by re-establishing it in waters within its native range where it has been extirpated or hybridized, and in all liklihood, such sites are public fishing waters. State Fish and Game agencies funded by anglers licence fees will not be favorably inclined to close public fishing waters to re-establish a native population completely protected from anglers. Actually the status of no rare or endangered trout can be attributed to angling and the fear that fishermen might exterminate a population is without factual basis. With proper publicity, a native trout can be used to develop unique, quality fisheries at virtually no expense if based entirely on natural reproduction. Native trout fisheries have been popularly received by fishermen who place a higher recreational value on the opportunity to fish for native trout than on hatchery trout.

In Idaho special regulations for native cutthroat trout in test streams include a catch-and-release fishery (no kill) and a 13 inch minimum size limit. These regulations have dramatically increased the abundance (by 3-6 fold), average size and catch-per-hour (Ball, 1971; Bjornn and Thurow, 1974; Hogander, et. al., 1974). In Yellowstone Park a catch-and-release fishery was instituted in 1973 on the Yellowstone River after comparisons had shown that 309 cutthroat trout sampled in a closed section averaged 17.6 inches (13.2-22 in.) and 14.2 inches (10.6-16.7 in.) for 378 trout from the open fishing area. This no-kill regulation greatly increased the catch-per-hour (by 2-4 fold) over the previous four years and was enthusiastically received by most fishermen (Personal communication Jack Dean to Robert Behnke).

In general, special regulations designed for a trophy fishery require moderate to large rivers or lakes where food and space permit rapid growth and attainment of a large size. In small streams, virtually all fish may die of old age before exceeding 10 inches in size. Most of the streams containing pure populations of rare, native trout are too small and remote from civilization to attract more than neglible fishing pressure and special angling restrictions are not justified under such circumstances.

Summary

Steps in a native trout management program may logically consist of :
1. Survey of waters and collections of suspected pure populations plus location of potential sites for introductions. 2. Taxonomic study of collections to identify pure populations. 3. Habitat protection and possible improvements. 4. Introductions into barren or chemically treated waters isolated by some barriers against contamination by non-native trouts. 5. Special regulation fisheries.

Authorities

Robert Behnke, Dept. Fish. Wildlf. Biol., Colo. St. Univ., Ft. Collins. Trout taxonomy; evaluation of relative purity of populations; restoration projects.

Allen Binns, Habitat Mgt. Biol., Wyo. Game and Fish Dept., Lander, Wyo. State-federal cooperative restoration projects, including surveys, habitat improvements, construction of barriers.

Ted Bjornn, Leader, Idaho Coop. Fish. Unit, Univ. Idaho, Moscow, Id. Experience with special regulations to establish fisheries based on native trout.

Robert Borovicka, BLM, Portland, Ore. and Paul Jeppson, Idaho Fish and Game Dept., Boise, Id. State-federal cooperative projects to improve trout habitat by dams and other structures and protection from overgrazing. Results of this work was presented as a slide show at 1971 annual meeting of Amer. Fish. Soc.

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Henry McKirdy, U.S. Forest Ser., Missoula, Mont. Stream improvement devices; native trout management.

James Mullan, U.S. Fish and Wildlf. Ser., Vernal, Utah. Restoration projects; extermination of non-native fishes; land-use impacts.

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