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REPORT ON COLLECTIONS OF

CUTTHROAT TROUT FROM

GLACIER NATIONAL PARK

Evaluation of purity of specimens collected in 1978.

Robert J. Behnke

May 1, 1979

INTRODUCTION

A single species and subspecies of trout (genus Salmo) is native to all drainage basins of Glacier National Park (Columbia River system, South Saskatchewan River system, and upper Missouri River system). This fact has not been clearly understood nor delineated in past fisheries activities in the Park and has resulted in considerable confusion.

Park waters have a long history of introductions of nonnative trout. The cutthroat trout of Yellowstone Lake, a subspecies distinctly different from the native trout, was the most widely and abundantly introduced trout, but other species such as rainbow, brook and brown trout, lake trout, kokanee salmon and lake whitefish were also introduced.

The replacement of the native trout by the introduced species is a major problem confronting the Park Service's goal of preserving and restoring native fauna. Basic to this goal is the documentation of the occurrence of the native trout, a correct taxonomic diagnosis of the native subspecies, and the identification of hybrid populations.

No previous study on this subject has been undertaken in the Park because the problem was believed to be insoluble. This mistaken notion essentially can be traced to the studies of Schultz (1941) and to the

general belief that the cutthroat trout species is so variable that the validity of subspecies determination could never be verified. Schultz believed that the coastal cutthroat trout, S. clarki clarki, is the native trout in the Columbia (Flathead) River basin in the Park and that the Missouri basin lakes and streams held S. c. lewisi. He also assumed that the Yellowstone Lake trout is S. c. lewisi, but mentioned that trout resembling the greenback cutthroat trout, S. c. stomias, inhabited Park waters (these are actually introduced Yellowstone Lake cutthroat trout).

A reading of Schultz' 1941 publication conveys an attitude of hopelessness that the taxonomy of the native trout would ever be satisfactorily worked out. Because of the massive introductions of nonnative species and subsequent hybridization, it appeared that the correct identification of native trout would be an impossible task.

The basic problem, however, was that no one had ever accumulated sufficient data on the cutthroat trout species from throughout its range to make accurate diagnoses of all of the subspecies. During more than 20 years of study on cutthroat trout taxonomy I believe I now have the necessary data on which to correctly define the many subspecies. In recent years, my taxonomic arrangement also has been supported by other evidence such as chromosome numbers and gene loci data (electrophoresis).

Several years ago it became apparent to me that the trout native to the upper Missouri basin (S. c. lewisi) also is the native trout of the South Saskatchewan River drainage and the upper Columbia River basin. The Yellowstone Lake trout is derived from a distinctly differentiated ancestor crossing the Continental Divide from the Snake River drainage into the Yellowstone River drainage. The subspecific designation of the

Yellowstone trous is Salmo clarki bouvieri. S. c. lewisi and S. c. bouvieri never came into contact in the Missouri River basin (although they occur within a few miles of each other in headwater tributaries in their respective drainages in Yellowstone National Park) and thus have remained distinct. The spotting pattern and (potential) coloration between the two subspecies is entirely different and field separation to one subspecies or the other can be readily made (but a slight hybrid influence cannot be determined from external examination). The Yellowstone cutthroat trout has large, roundish spots more or less evenly distributed on the body. S. c. lewisi has a profusion of small, irregularly shaped spots concentrated posteriorly with few or no spots occurring in an area of an arc from the anal fin to the pectoral fin. S. c. lewisi has the genetic potential to develop brilliant red, yellow, or orange coloration, but the pigments must be derived from the diet and are also dependent for expression on age and sex. S. c. bouvieri lacks the genetic basis for brilliant coloration. They typically exhibit brownish-yellow base colors with some tints of pink or orange occasionally appearing on old specimens (particularly males).

The details of the taxonomy and distribution of S. c. lewisi and S. c. bouvieri was the subject of a graduate thesis by Roscoe (1974).

In the specimens examined in the present study I found several characters correlated with the spotting differences between the two subspecies. There is a clear-cut distinction between the two subspecies in the number of gillrakers on the posterior side of the first gill arch. There are significant differences in the number of anterior gillrakers and in the number of basibranchial teeth. A total of 12 characters were recorded

from all specimens and the data were run in two multi variate analysis computer programs, one for principal component analysis and one for discriminant function analysis. The computer printout assisted in the evaluation of possible hybrid influence in the S. c. lewisi samples.

This present study is unique in that the specimens used in the morphological analysis were also used for electrophoretic analysis to detect gene loci differences between the two subspecies and evaluate hybridization. This is the first attempt to correlate electrophoretic data with morphological data on the same samples of fish. The report on the results of the electrophoretic analysis is being prepared at the University of Montana.

This present study is based on samples from five lakes in the North Fork of the Flathead River drainage, totalling 142 specimens.

DISCUSSION OF RESULTS

Evangeline Lake

The trout in Evangeline Lake are judged to represent a pure population of the introduced Yellowstone cutthroat trout. Evangeline Lake is at the headwaters of Camas Creek. A high barrier falls occurs between Evangeline Lake and Arrow Lake, further downstream. Evidently, Evangeline Lake was barren of fish before it was stocked with 90,000 eggs and fry of Yellowstone Lake trout in 1925 and 1935.

The 30 specimens from Evangeline Lake are identical to Yellowstone Lake trout, with large, pronounced, roundish spots. Undoubtedly, it was the introduced Yellowstone Lake trout that Schultz (1941) referred to as "S. c. stomias-like" trout in Park waters. The Evangeline Lake specimens

differ from the native trout samples in their more numerous gillrakers, 19-22 (20.7) and basibranchial teeth (8-44). There is a clear-cut (non-overlap) difference in the number of gillrakers on the posterior side of the first gill arch: 3-16 in Evangeline Lake specimens; 0, 1, or 2 in native trout.

Arrow Lake

Examination of 30 specimens from Arrow Lake revealed 28 specimens identified as the native trout, S. c. lewisi, and two specimens of the nonnative S. c. bouvieri, based on spotting pattern. The two specimens, numbers 16 and 17 are 180 mm and 185 mm total length and evidently moved downstream from Evangeline (or Camas) Lake over the barrier falls. The number of gillrakers and basibranchial teeth also identify these specimens as Yellowstone trout. If specimens 16 and 17 resulted from hybridization, a gradual transition in characters in the sample would be expected. This did not occur, these two specimens are sharply differentiated from the other 28 specimens and the computer identified them with the Evangeline Lake sample.

Almost certainly some hybridization between S. c. bouvieri moving down from above the barrier falls and S. c. lewisi in Arrow Lake must have occurred over the last 50 years. There is some evidence for this assumption in the data analysis. Two specimens with high numbers of basibranchial teeth are specimens 4 and 19 from Arrow Lake with 15 and 13 teeth, respectively. I found no basibranchial teeth in specimens 3, 8, 13, 22, and 29. The lack of basibranchial teeth indicates hybridization with rainbow trout.

Although the Arrow Lake sample may be considered the "most hybridized" of any of the samples, the hybrid influence is small. The Arrow Lake population is overwhelmingly S. c. lewisi genotype and is identified as S. c. lewisi (but not pure). A hybrid influence is not apparent from external appearances. Obviously, the Arrow Lake population has been exposed to hybridization (not only from migration from above but also from the introduction of 122,000 eggs and fingerlings of Yellowstone Lake trout into Arrow Lake in the 1920's and 30's), and has resisted genetic swamping. Natural selection must strongly favor the native genotype and negative selection must occur against S. c. bouvieri and hybrids. This would be expected in any population living and adapting to the same environment for perhaps several thousand years. They should have a definite selective advantage over nonnative groups of the same species as long as the environment does not change. In this regard, a cestode parasite may play a role in favoring the native subspecies. I found the most severe infestation of parasites in Arrow Lake specimens, but they showed no indication of ill effects -- they are fine, robust fish. The evolution of the native population with a parasite should promote adaptations to lessen negative impacts of parasite infection. The Yellowstone Lake cutthroat trout evolved with different parasite species and may lack the particular physiological adaptations of the native trout for tolerating the parasite burden.

Quartz Lake and Cerulean Lake

Quartz Lake is in the Quartz Creek drainage. It contains a population of native trout but was stocked with 8,500 cutthroat trout fry (probably of Yellowstone Lake origin) in 1940. Quartz Lake specimens are very

similar to specimens from Cerulean Lake which lies above it in the drainage. The only significant difference noted in any character is the mean value of pyloric caeca (Table 1). The most sensitive indicator of a hybrid influence from Yellowstone Lake trout is the number of posterior gillrakers. Typically, S. c. lewisi has 0, 1, or 2 posterior gillrakers. Cerulean Lake sample averages 0.6 posterior rakers, the Quartz Lake sample 0.9, Logging Lake 1.1, and Arrow Lake 1.2; in the order from "purest" to "most hybridized". The Evangeline Lake sample averages 11.0 posterior gillrakers, typical of Yellowstone Lake trout.

Fish from Quartz Lake can migrate into Cerulean Lake and free mixing is theoretically possible. However, resident lake populations generally exhibit little movement out of lakes except for spawning. I would assume that the dominant movement would be of young fish (surplus reproduction) from Cerulean Lake into Quartz Lake.

The computer analyses (Figures 1 and 2) of the data treating all characters in various combinations places the Cerulean and Quartz Lake specimens most distant from Yellowstone trout as represented by Evangeline Lake specimens. Analyses of data and the remoteness of Cerulean Lake (no stocking records) indicates that this population is the purest of the groups examined. The Quartz Lake population is ranked a close second.

Logging Lake

Logging Lake is formed on Logging Creek and is the largest body of water sampled in the 1978 collections (about 6 miles long by .5 miles across). Phenotypically, the specimens appear to be wholly typical of

S. c. lewisi. The lake was stocked with 202,000 fingerling Yellowstone trout from 1934 to 1944. There is also possible movement of fish down from Grace Lake (believed to hold hybrids) and perhaps up from the North Fork of the Flathead River. The computer analyses of all characters did place some Logging Lake specimens toward Evangeline Lake specimens. The surprising aspect is that the Logging Lake population appears as pure as it is despite exposure to massive hybridization. As with Arrow Lake, the native genotype possesses superior adaptive and survival qualities in its undisturbed native environment and has resisted the influence of hybridization.

Discussion and Recommendations

The most significant result of this study of the taxonomy of samples from five populations is that native cutthroat trout can be identified from introduced cutthroat trout with certainty. None of the populations are obviously hybridized. Considering all of the information, the ranking from "most pure" to least pure" is in the order, Cerulean, Quartz, Logging, and Arrow. In this case I would consider the "least pure" to still be on the order of 90-95% pure S. c. lewisi. Thus, for classification purposes, and all practical purposes (except for reintroductions) all the samples, except Evangeline Lake (S. c. bouvieri), should be classified as S. c. lewisi. The massive numbers of Yellowstone cutthroat trout stocked into these drainages have not significantly altered the native genotypes. The Yellowstone trout is established only in the originally barren Evangeline Lake. The presence of two Evangeline Lake fish among the sample of 30 specimens from Arrow Lake (and no obviously intermediate specimens) suggests

that Yellowstone Lake trout from above are continually mixing into the Arrow Lake population, but are not contributing, to any extent, to reproduction. Obviously, they are at a severe competitive disadvantage with the native fish. As mentioned, the heavy level of parasite infestation in Arrow Lake may be one of the selective factors favoring the native trout.

The cestode parasite was most commonly found in the pyloric caecae. Specific identification of the parasite was not made but the scolex is without hooks as in Proteocephalus. I assume that the parasite has a completely aquatic life cycle, entering the fish via infected crustaceans in the diet. Thus this cestode should be absent from lakes barren of fish (none were observed in Evangeline Lake specimens). Antipa (1974) and Becker and Brunson (1968) discussed tapeworms identified (possibly incorrectly) as Proteocephalus amboplites, infecting trout in the Northwest.

Although, there was no observable ill effects of the parasite on the specimens examined (the largest, most robust specimens were often the most heavily infected), it would be adviseable not to spread the parasite. Thus, for introductions of native trout into barren waters, eggs or newly hatched fry could be used. If a lake is treated to eliminate non-native fish. A period of time (perhaps one year) without fish should eliminate the parasite.

It is not known if the relatively clear-cut results of this study will extend to other Park waters. Where the native trout were exposed to hybridization with rainbow trout, S. gairdneri, may be quite different situations in regards to hybrid resistance. There is a suggestion of a rainbow trout hybrid influence in Arrow Lake with 5 of 28 specimens (18%) lacking basi-

branchial teeth. However, no other character suggests a rainbow influence. Typically, I expect pure populations of cutthroat trout to have basibranchial teeth in 90% or more of the population.

It is now clear that the native trout of Glacier National Park can be positively identified and this is not such a complex problem as formerly believed. Field identification as *S. c. lewisi* can be based on observation of the consistency of the diagnostic spotting pattern. Populations of suspected hybrids or populations considered as a source for introductions will require a more detailed study of specimens.

Literature Cited

Antipa, R. 1974. Food habits of lacustrine salmonids in Washington State in relation to infections with larvae of the bass tapeworm (*Proteocephalus ambloplites*). *Trans. Am. Fish. Soc.* 103(4):811-814.

Becker, C. D. and W. D. Brunson. 1968. The bass tapeworm: a problem in northwest trout management. Prog. Fish Cult. 30(2):76-83.

Roscoe, J. W. 1974. Systematics of the westslope cutthroat trout. M.S. Thesis, Colo. St. Univ., Fort Collins: 74pp.

Schultz, L. P. 1941. Fishes of Glacier National Park, Montana. USDI, Nat. Park Ser., Conserv. Bull. 22:42pp.

TABLE 1. Character Variation

Sample	Gillrakers	Scales	Basibranchial	Pyloric caeca
Evangeline N=30 (+2 from Arrow L.)	19-23 (20.7) ant. 3-16 (11.0) post.	35- 49 (43.6) 158-206 (177.8)	8-44 (18.0)	31-49 (38.5)
Arrow N=28	16-20 (18.4) 0- 2 (1.2)	37- 46 (40.9) 163-211(182.8)	0-15 (4.4) 5 w/o teeth (18%)	30-43 (35.0)
Logging N=35	17-21 (19.0) 0- 2 (1.1)	33- 45 (38.6) 141-186(166.5)	0-16 (7.2) 1 w/o teeth (3%)	29-45 (36.1)
Quartz N=30	16-20 (18.2) 0- 1 (0.9)	34- 42 (37.8) 156-195(170.7)	0-12 (6.2) 1 w/o teeth (3%)	33-57 (42.4)
Cerulean N=17)	16-21 (18.6) 0- 2 (0.6)	34- 42 (37.8) 157-185(169.1)	0-13 (5.1) 1 w/o teeth (6%)	26-41 (34.2)

FIGURES

Figures one and two are graphic representation of the specimens arranged according to the morphological data. Figure 1 is the results of a principal component analysis and figure two represents a discriminant function analysis. The major difference between these two types of multivariate analyses is that with principal components, the data from the specimens are not identified with any group, whereas in discriminant function the specimens are assigned to known groups (Arrow Lake, Cerulean Lake, etc.). Principal component analysis stresses variance between groups and discriminant function emphasizes the variance between individuals. Principal components is an identification statistic (identification of unknown specimens) and discriminant function is more of a classification statistic (testing the "goodness of fit" between groups of predetermined classification).

Both techniques clearly show the separation of the native *S. c. lewisi* specimens from the nonnative Yellowstone Lake cutthroat trout and also classified the two specimens of Yellowstone trout found in Arrow Lake with the Evangeline Lake specimens. The "centroids" depicted on Figure 2 are the "mean of means" for a particular sample. Note the horizontal distance between the four centroids representing *S. c. lewisi* and the Evangeline Lake centroid. Some specimens from Logging Lake and Arrow Lake are oriented toward Evangeline Lake specimens, but the tightness of the clusters and lack of transitional specimens indicates any hybrid influence is slight.

Figure 3 illustrates the spotting pattern of S. c. bouvieri and Figure 4 the spotting of S. c. lewisi. S. c. bouvieri may be highly variable in spotting pattern in different geographical areas. Spots may vary from sparse to abundant and may be generally distributed on the body or concentrated posteriorly. S. c. lewisi (pure populations) are less variable in spotting pattern, but the two subspecies are always distinct in the size and shape of the spots. The spots are large, rounded and more-or-less smooth in outline in S. c. bouvieri. In S. c. lewisi the spots are small, irregularly shaped and concentrated on the caudal peduncle area.

Figure 5 depicts the known distribution of S. c. lewisi. This subspecies is the only trout of the genus Salmo indigenous to Glacier National Park.

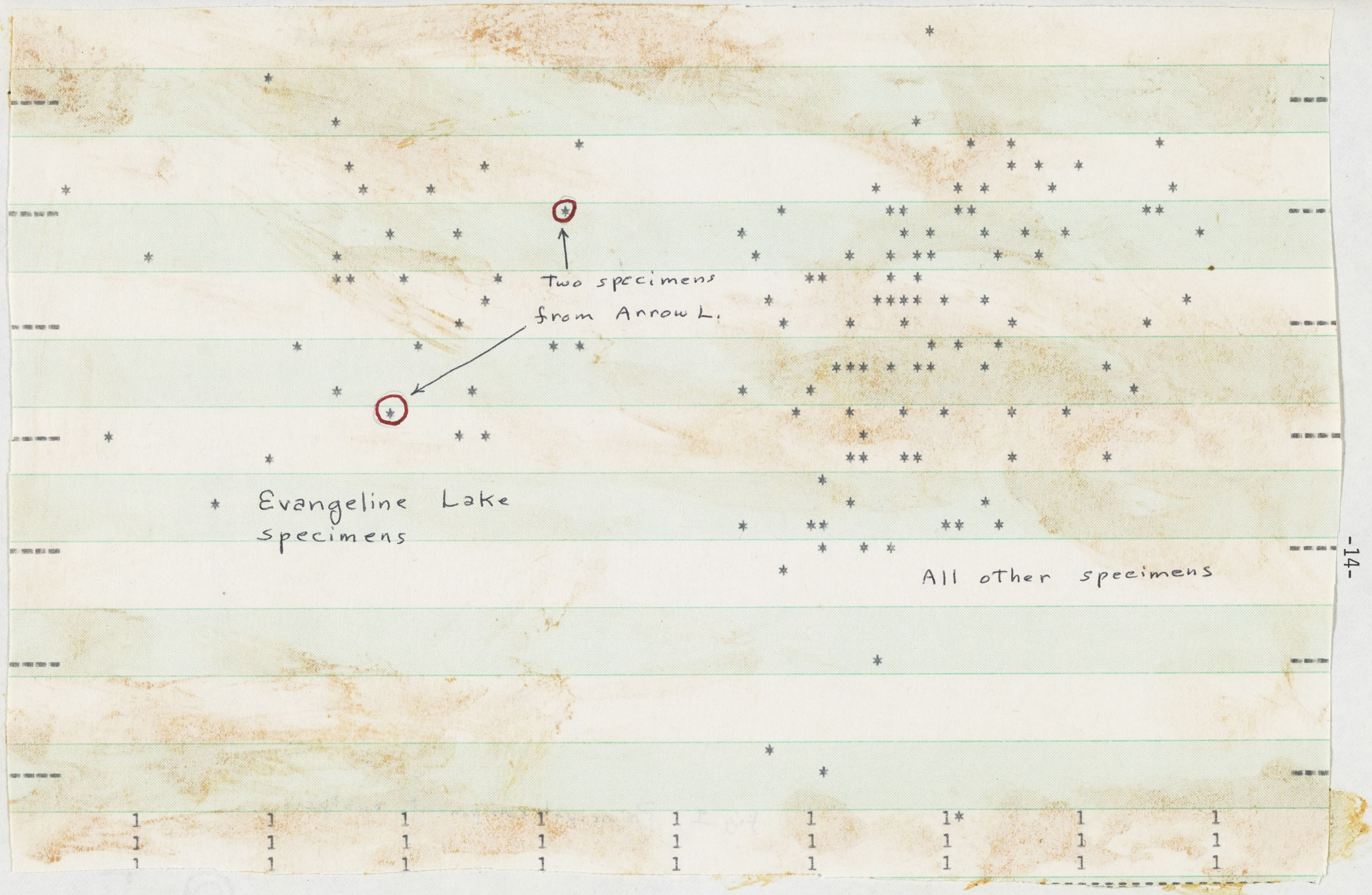

FIGURE 1. Principal component analysis.

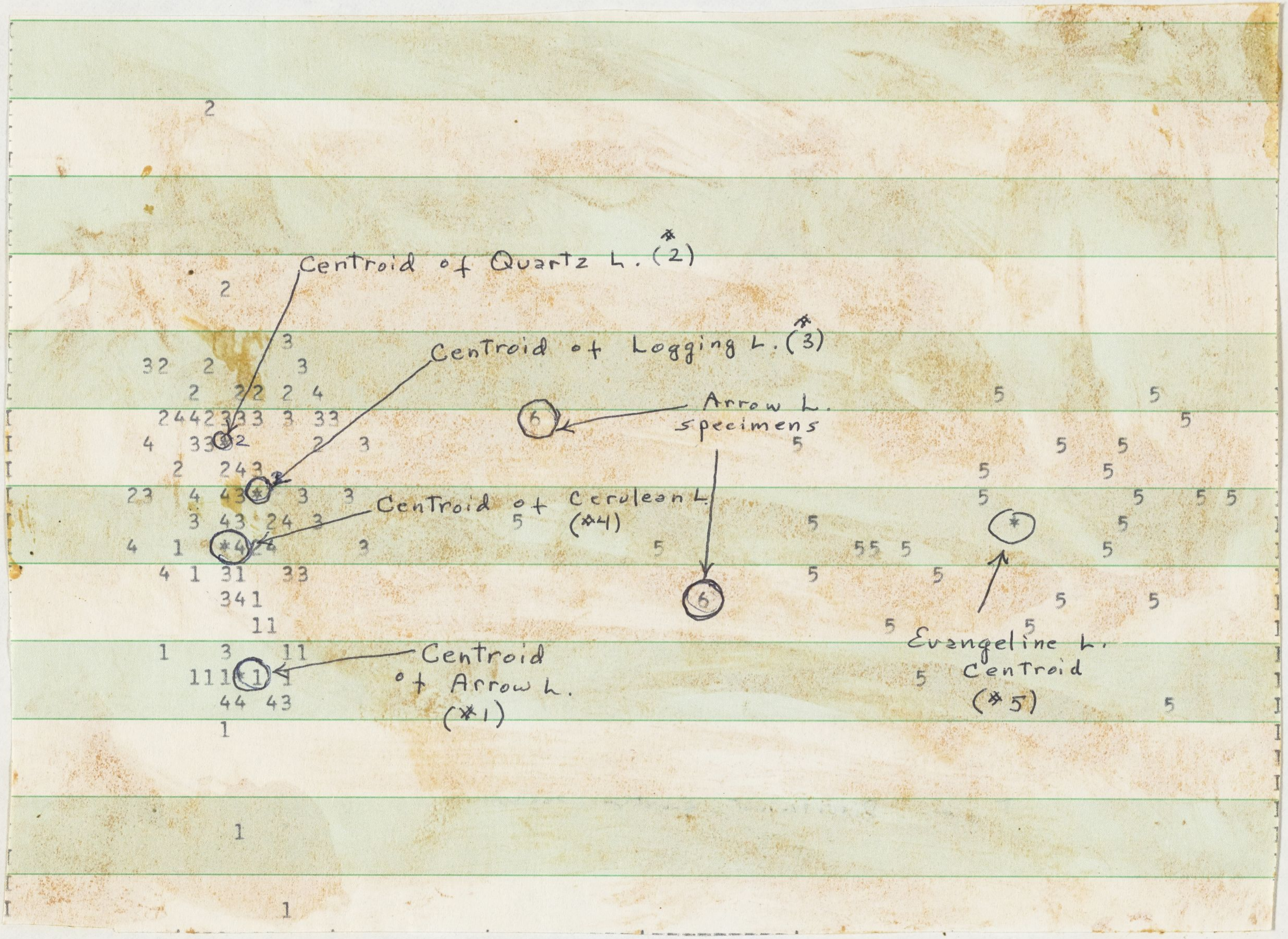

FIGURE 2. Discriminant function analysis.

THE NATURE CONSERVANCY

WYOMING NATURAL HERITAGE PROGRAM

with Wyoming State Dept. Environmental Quality - Land Quality Division

1603 Capitol Avenue, No. 325 • Cheyenne, WY 82001 • 307-634-9629

May 22, 1979

Dr. R. J. Behnke
Dept. of Fisheries and Wildlife Biology
Colorado State University
Fort Collins
Colorado 80523

Dear Dr. Behnke,

Thanks for the enclosed reprints. I've made copies of them for our filing system. I read them and it really helped clear up a confusing situation for us. We will be mapping occurrences of native Wyoming sub-species in their native habitat unless all natives have been destroyed, leaving only relict "pure" populations (introduced) in non-native habitats. As this sort of information becomes available for Wyoming fishes, we would appreciate reprints, etc. from your research groups. Thanks.

Sincerely

Mark R. Stromberg

Mark R. Stromberg, P.h.D.

Zoology/Program Coordinator

MRS/lw

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branchial teeth. However, no other character suggests a rainbow influence. Typically, I expect pure populations of cutthroat trout to have basibranchial teeth in 90% or more of the population.

It is now clear that the native trout of Glacier National Park can be positively identified and this is not such a complex problem as formerly believed. Field identification as *S. c. lewisi* can be based on observation of the consistency of the diagnostic spotting pattern. Populations of suspected hybrids or populations considered as a source for introductions will require a more detailed study of specimens.

Literature Cited

Antipa, R. 1974. Food habits of lacustrine salmonids in Washington State in relation to infections with larvae of the bass tapeworm (*Proteocephalus ambloplites*). *Trans. Am. Fish. Soc.* 103(4):811-814.

Becker, C. D. and W. D. Brunson. 1968. The bass tapeworm: a problem in northwest trout management. Prog. Fish Cult. 30(2):76-83.

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Schultz, L. P. 1941. Fishes of Glacier National Park, Montana. USDI, Nat. Park Ser., Conserv. Bull. 22:42pp.

TABLE 1. Character Variation

Sample	Gillrakers	Scales	Basibranchial	Pyloric caeca
Evangeline N=30 (+2 from Arrow L.)	19-23 (20.7) ant. 3-16 (11.0) post.	35- 49 (43.6) 158-206 (177.8)	8-44 (18.0)	31-49 (38.5)
Arrow N=28	16-20 (18.4) 0- 2 (1.2)	37- 46 (40.9) 163-211(182.8)	0-15 (4.4) 5 w/o teeth (18%)	30-43 (35.0)
Logging N=35	17-21 (19.0) 0- 2 (1.1)	33- 45 (38.6) 141-186(166.5)	0-16 (7.2) 1 w/o teeth (3%)	29-45 (36.1)
Quartz N=30	16-20 (18.2) 0- 1 (0.9)	34- 42 (37.8) 156-195(170.7)	0-12 (6.2) 1 w/o teeth (3%)	33-57 (42.4)
Cerulean N=17)	16-21 (18.6) 0- 2 (0.6)	34- 42 (37.8) 157-185(169.1)	0-13 (5.1) 1 w/o teeth (6%)	26-41 (34.2)

FIGURES

Figures one and two are graphic representation of the specimens arranged according to the morphological data. Figure 1 is the results of a principal component analysis and figure two represents a discriminant function analysis. The major difference between these two types of multivariate analyses is that with principal components, the data from the specimens are not identified with any group, whereas in discriminant function the specimens are assigned to known groups (Arrow Lake, Cerulean Lake, etc.). Principal component analysis stresses variance between groups and discriminant function emphasizes the variance between individuals. Principal components is an identification statistic (identification of unknown specimens) and discriminant function is more of a classification statistic (testing the "goodness of fit" between groups of predetermined classification).

Both techniques clearly show the separation of the native S. c. lewisi specimens from the nonnative Yellowstone Lake cutthroat trout and also classified the two specimens of Yellowstone trout found in Arrow Lake with the Evangeline Lake specimens. The "centroids" depicted on Figure 2 are the "mean of means" for a particular sample. Note the horizontal distance between the four centroids representing S. c. lewisi and the Evangeline Lake centroid. Some specimens from Logging Lake and Arrow Lake are oriented toward Evangeline Lake specimens, but the tightness of the clusters and lack of transitional specimens indicates any hybrid influence is slight.

Figure 3 illustrates the spotting pattern of *S. c. bouvieri* and Figure 4 the spotting of *S. c. lewisi*. *S. c. bouvieri* may be highly variable in spotting pattern in different geographical areas. Spots may vary from sparse to abundant and may be generally distributed on the body or concentrated posteriorly. *S. c. lewisi* (pure populations) are less variable in spotting pattern, but the two subspecies are always distinct in the size and shape of the spots. The spots are large, rounded and more-or-less smooth in outline in *S. c. bouvieri*. In *S. c. lewisi* the spots are small, irregularly shaped and concentrated on the caudal peduncle area.

Figure 5 depicts the known distribution of *S. c. lewisi*. This subspecies is the only trout of the genus *Salmo* indigenous to Glacier National Park.

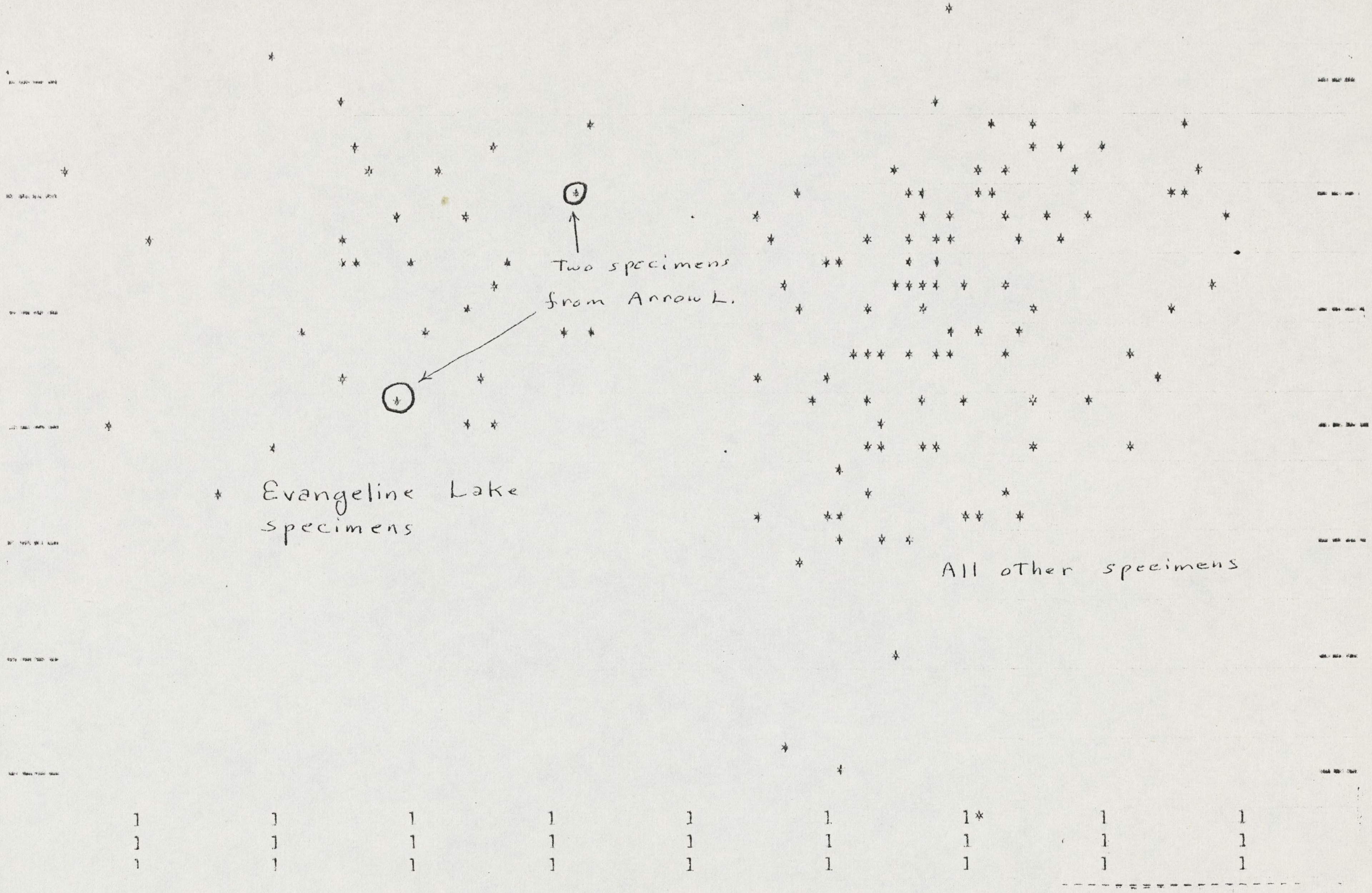

FIGURE 1. Principal component analysis.

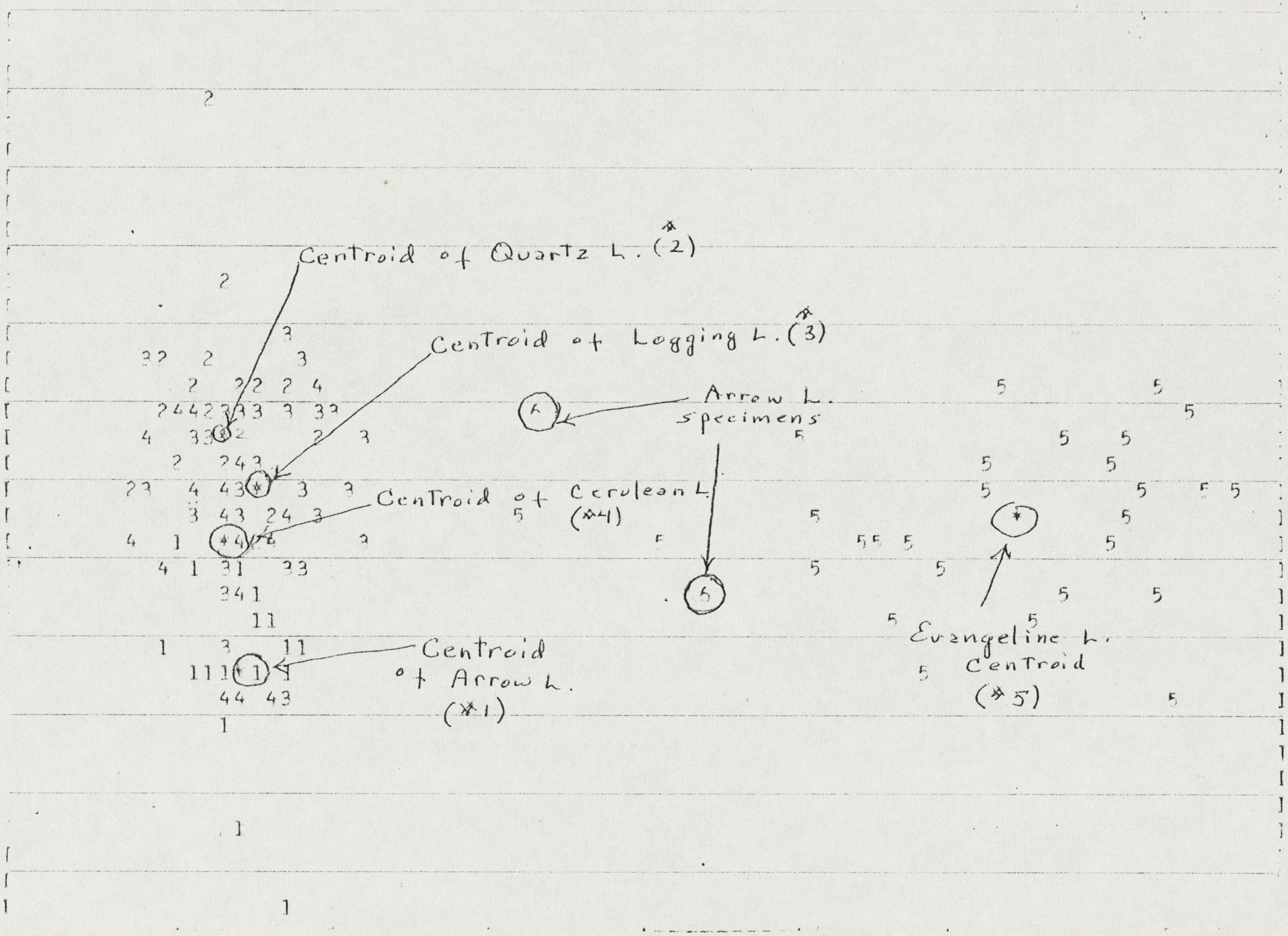

FIGURE 2. Discriminant function analysis.

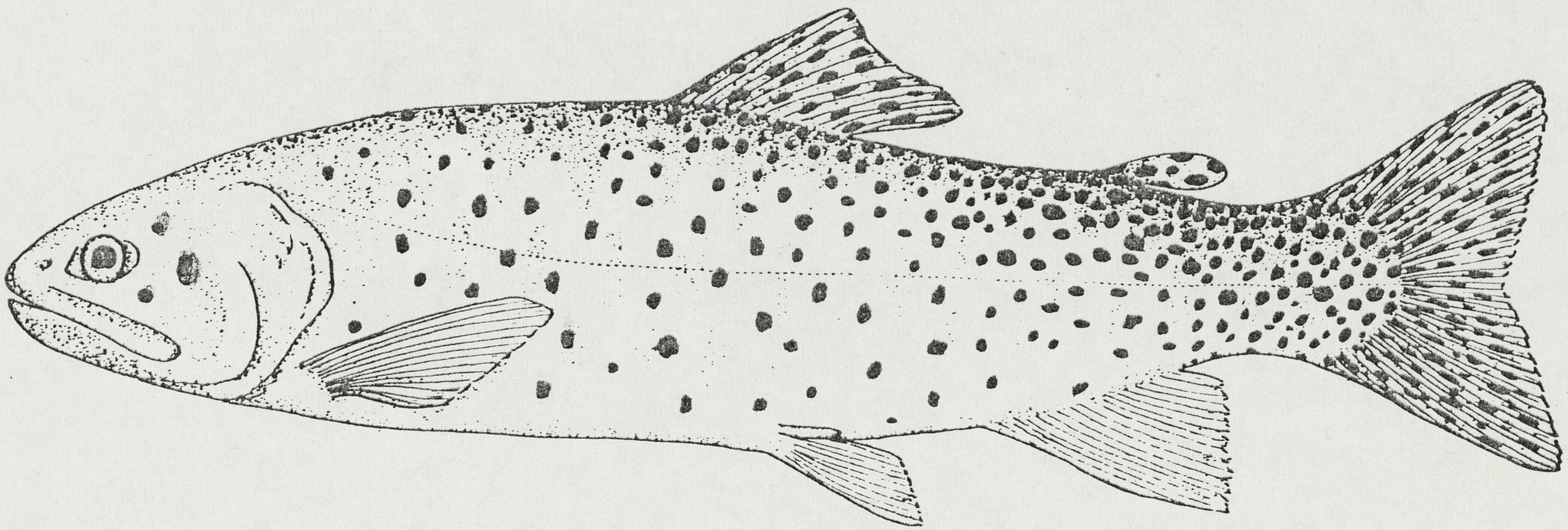

Figure 3. Spotting pattern of the Yellowstone cutthroat trout.

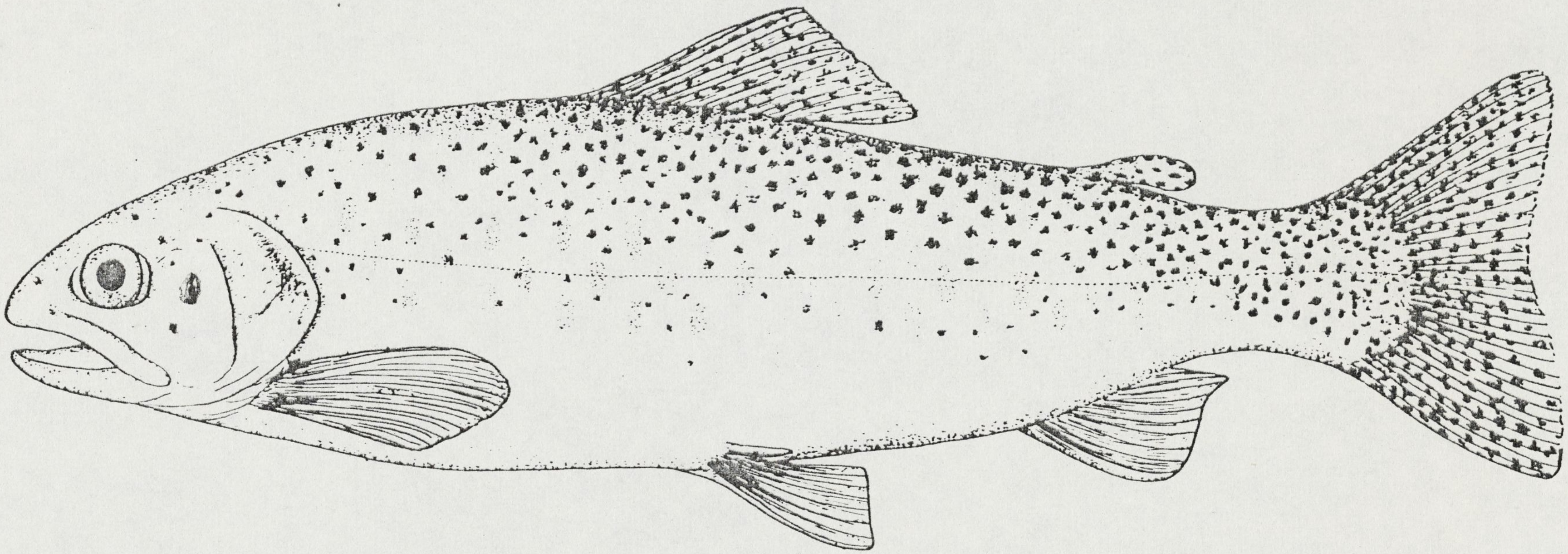

Figure 4. Spotting pattern of Salmo clarki lewisi.

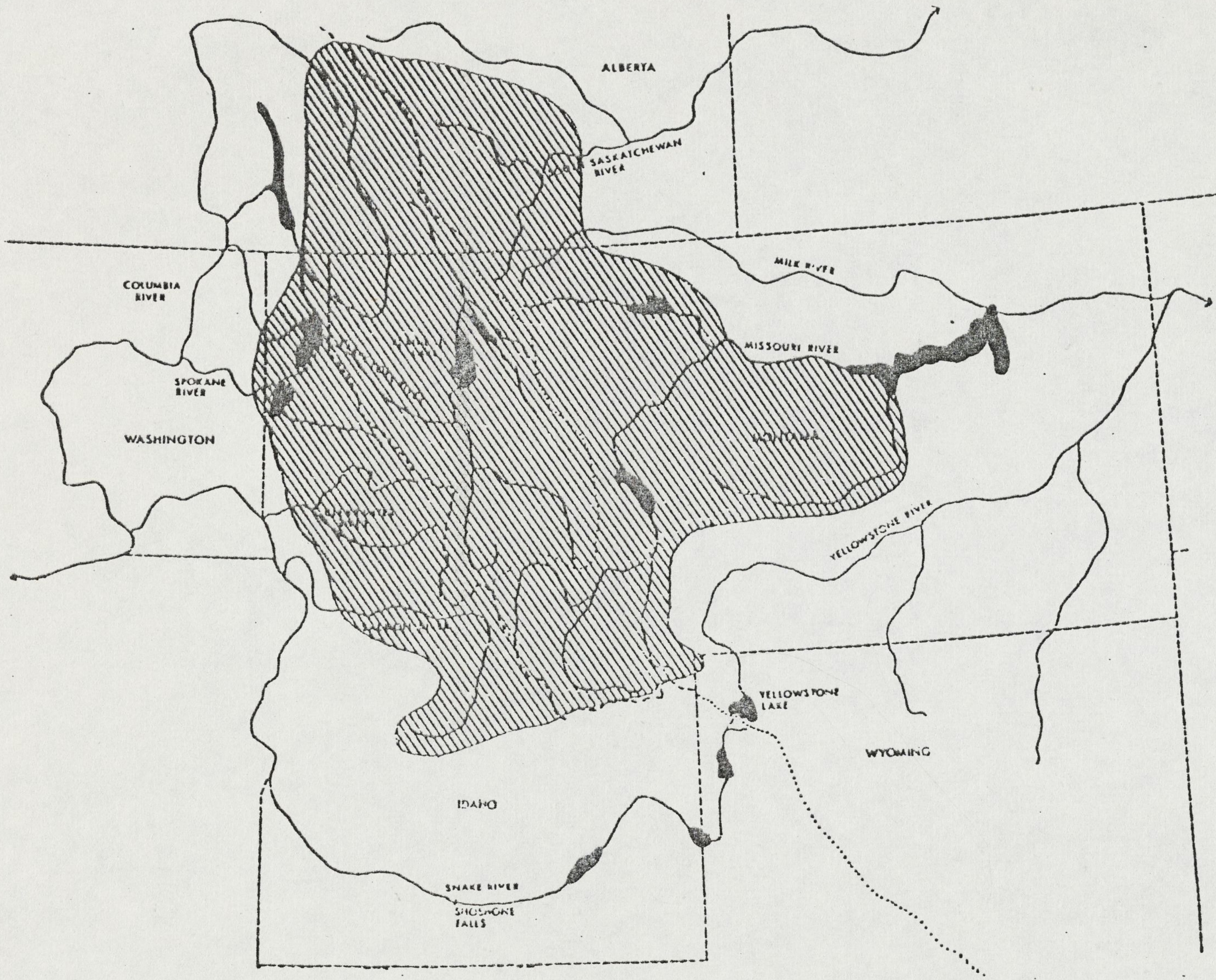

FIGURE 5. Distribution of *Salmo clarki lewisi*.

REPORT ON COLLECTIONS OF

CUTTHROAT TROUT FROM

GLACIER NATIONAL PARK

Evaluation of purity of specimens collected in 1978.

Robert J. Behnke

May 1, 1979

INTRODUCTION

A single species and subspecies of trout (genus Salmo) is native to all drainage basins of Glacier National Park (Columbia River system, South Saskatchewan River system, and upper Missouri River system). This fact has not been clearly understood nor delineated in past fisheries activities in the Park and has resulted in considerable confusion.

Park waters have a long history of introductions of nonnative trout. The cutthroat trout of Yellowstone Lake, a subspecies distinctly different from the native trout, was the most widely and abundantly introduced trout, but other species such as rainbow, brook and brown trout, lake trout, kokanee salmon and lake whitefish were also introduced.

The replacement of the native trout by the introduced species is a major problem confronting the Park Service's goal of preserving and restoring native fauna. Basic to this goal is the documentation of the occurrence of the native trout, a correct taxonomic diagnosis of the native subspecies, and the identification of hybrid populations.

No previous study on this subject has been undertaken in the Park because the problem was believed to be insoluble. This mistaken notion essentially can be traced to the studies of Schultz (1941) and to the

general belief that the cutthroat trout species is so variable that the validity of subspecies determination could never be verified. Schultz believed that the coastal cutthroat trout, S. clarki clarki, is the native trout in the Columbia (Flathead) River basin in the Park and that the Missouri basin lakes and streams held S. c. lewisi. He also assumed that the Yellowstone Lake trout is S. c. lewisi, but mentioned that trout resembling the greenback cutthroat trout, S. c. stomias, inhabited Park waters (these are actually introduced Yellowstone Lake cutthroat trout).

A reading of Schultz' 1941 publication conveys an attitude of hopelessness that the taxonomy of the native trout would ever be satisfactorily worked out. Because of the massive introductions of nonnative species and subsequent hybridization, it appeared that the correct identification of native trout would be an impossible task.

The basic problem, however, was that no one had ever accumulated sufficient data on the cutthroat trout species from throughout its range to make accurate diagnoses of all of the subspecies. During more than 20 years of study on cutthroat trout taxonomy I believe I now have the necessary data on which to correctly define the many subspecies. In recent years, my taxonomic arrangement also has been supported by other evidence such as chromosome numbers and gene loci data (electrophoresis).

Several years ago it became apparent to me that the trout native to the upper Missouri basin (S. c. lewisi) also is the native trout of the South Saskatchewan River drainage and the upper Columbia River basin. The Yellowstone Lake trout is derived from a distinctly differentiated ancestor crossing the Continental Divide from the Snake River drainage into the Yellowstone River drainage. The subspecific designation of the

Yellowstone trous is Salmo clarki bouvieri. S. c. lewisi and S. c. bouvieri never came into contact in the Missouri River basin (although they occur within a few miles of each other in headwater tributaries in their respective drainages in Yellowstone National Park) and thus have remained distinct. The spotting pattern and (potential) coloration between the two subspecies is entirely different and field separation to one subspecies or the other can be readily made (but a slight hybrid influence cannot be determined from external examination). The Yellowstone cutthroat trout has large, roundish spots more or less evenly distributed on the body. S. c. lewisi has a profusion of small, irregularly shaped spots concentrated posteriorly with few or no spots occurring in an area of an arc from the anal fin to the pectoral fin. S. c. lewisi has the genetic potential to develop brilliant red, yellow, or orange coloration, but the pigments must be derived from the diet and are also dependent for expression on age and sex. S. c. bouvieri lacks the genetic basis for brilliant coloration. They typically exhibit brownish-yellow base colors with some tints of pink or orange occasionally appearing on old specimens (particularly males).

The details of the taxonomy and distribution of S. c. lewisi and S. c. bouvieri was the subject of a graduate thesis by Roscoe (1974).

In the specimens examined in the present study I found several characters correlated with the spotting differences between the two subspecies. There is a clear-cut distinction between the two subspecies in the number of gillrakers on the posterior side of the first gill arch. There are significant differences in the number of anterior gillrakers and in the number of basibranchial teeth. A total of 12 characters were recorded

from all specimens and the data were run in two multi variate analysis computer programs, one for principal component analysis and one for discriminant function analysis. The computer printout assisted in the evaluation of possible hybrid influence in the S. c. lewisi samples.

This present study is unique in that the specimens used in the morphological analysis were also used for electrophoretic analysis to detect gene loci differences between the two subspecies and evaluate hybridization. This is the first attempt to correlate electrophoretic data with morphological data on the same samples of fish. The report on the results of the electrophoretic analysis is being prepared at the University of Montana.

This present study is based on samples from five lakes in the North Fork of the Flathead River drainage, totalling 142 specimens.

DISCUSSION OF RESULTS

Evangeline Lake

The trout in Evangeline Lake are judged to represent a pure population of the introduced Yellowstone cutthroat trout. Evangeline Lake is at the headwaters of Camas Creek. A high barrier falls occurs between Evangeline Lake and Arrow Lake, further downstream. Evidently, Evangeline Lake was barren of fish before it was stocked with 90,000 eggs and fry of Yellowstone Lake trout in 1925 and 1935.

The 30 specimens from Evangeline Lake are identical to Yellowstone Lake trout, with large, pronounced, roundish spots. Undoubtedly, it was the introduced Yellowstone Lake trout that Schultz (1941) referred to as "S. c. stomias-like" trout in Park waters. The Evangeline Lake specimens

differ from the native trout samples in their more numerous gillrakers, 19-22 (20.7) and basibranchial teeth (8-44). There is a clear-cut (non-overlap) difference in the number of gillrakers on the posterior side of the first gill arch: 3-16 in Evangeline Lake specimens; 0, 1, or 2 in native trout.

Arrow Lake

Examination of 30 specimens from Arrow Lake revealed 28 specimens identified as the native trout, *S. c. lewisi*, and two specimens of the nonnative *S. c. bouvieri*, based on spotting pattern. The two specimens, numbers 16 and 17 are 180 mm and 185 mm total length and evidently moved downstream from Evangeline (or Camas) Lake over the barrier falls. The number of gillrakers and basibranchial teeth also identify these specimens as Yellowstone trout. If specimens 16 and 17 resulted from hybridization, a gradual transition in characters in the sample would be expected. This did not occur, these two specimens are sharply differentiated from the other 28 specimens and the computer identified them with the Evangeline Lake sample.

Almost certainly some hybridization between *S. c. bouvieri* moving down from above the barrier falls and *S. c. lewisi* in Arrow Lake must have occurred over the last 50 years. There is some evidence for this assumption in the data analysis. Two specimens with high numbers of basibranchial teeth are specimens 4 and 19 from Arrow Lake with 15 and 13 teeth, respectively. I found no basibranchial teeth in specimens 3, 8, 13, 22, and 29. The lack of basibranchial teeth indicates hybridization with rainbow trout.

Although the Arrow Lake sample may be considered the "most hybridized" of any of the samples, the hybrid influence is small. The Arrow Lake population is overwhelmingly S. c. lewisi genotype and is identified as S. c. lewisi (but not pure). A hybrid influence is not apparent from external appearances. Obviously, the Arrow Lake population has been exposed to hybridization (not only from migration from above but also from the introduction of 122,000 eggs and fingerlings of Yellowstone Lake trout into Arrow Lake in the 1920's and 30's), and has resisted genetic swamping. Natural selection must strongly favor the native genotype and negative selection must occur against S. c. bouvieri and hybrids. This would be expected in any population living and adapting to the same environment for perhaps several thousand years. They should have a definite selective advantage over nonnative groups of the same species as long as the environment does not change. In this regard, a cestode parasite may play a role in favoring the native subspecies. I found the most severe infestation of parasites in Arrow Lake specimens, but they showed no indication of ill effects -- they are fine, robust fish. The evolution of the native population with a parasite should promote adaptations to lessen negative impacts of parasite infection. The Yellowstone Lake cutthroat trout evolved with different parasite species and may lack the particular physiological adaptations of the native trout for tolerating the parasite burden.

Quartz Lake and Cerulean Lake

Quartz Lake is in the Quartz Creek drainage. It contains a population of native trout but was stocked with 8,500 cutthroat trout fry (probably of Yellowstone Lake origin) in 1940. Quartz Lake specimens are very

similar to specimens from Cerulean Lake which lies above it in the drainage. The only significant difference noted in any character is the mean value of pyloric caeca (Table 1). The most sensitive indicator of a hybrid influence from Yellowstone Lake trout is the number of posterior gillrakers. Typically, S. c. lewisi has 0, 1, or 2 posterior gillrakers. Cerulean Lake sample averages 0.6 posterior rakers, the Quartz Lake sample 0.9, Logging Lake 1.1, and Arrow Lake 1.2; in the order from "purest" to "most hybridized". The Evangeline Lake sample averages 11.0 posterior gillrakers, typical of Yellowstone Lake trout.

Fish from Quartz Lake can migrate into Cerulean Lake and free mixing is theoretically possible. However, resident lake populations generally exhibit little movement out of lakes except for spawning. I would assume that the dominant movement would be of young fish (surplus reproduction) from Cerulean Lake into Quartz Lake.

The computer analyses (Figures 1 and 2) of the data treating all characters in various combinations places the Cerulean and Quartz Lake specimens most distant from Yellowstone trout as represented by Evangeline Lake specimens. Analyses of data and the remoteness of Cerulean Lake (no stocking records) indicates that this population is the purest of the groups examined. The Quartz Lake population is ranked a close second.

Logging Lake

Logging Lake is formed on Logging Creek and is the largest body of water sampled in the 1978 collections (about 6 miles long by .5 miles across). Phenotypically, the specimens appear to be wholly typical of

S. c. lewisi. The lake was stocked with 202,000 fingerling Yellowstone trout from 1934 to 1944. There is also possible movement of fish down from Grace Lake (believed to hold hybrids) and perhaps up from the North Fork of the Flathead River. The computer analyses of all characters did place some Logging Lake specimens toward Evangeline Lake specimens. The surprising aspect is that the Logging Lake population appears as pure as it is despite exposure to massive hybridization. As with Arrow Lake, the native genotype possesses superior adaptive and survival qualities in its undisturbed native environment and has resisted the influence of hybridization.

Discussion and Recommendations

The most significant result of this study of the taxonomy of samples from five populations is that native cutthroat trout can be identified from introduced cutthroat trout with certainty. None of the populations are obviously hybridized. Considering all of the information, the ranking from "most pure" to least pure" is in the order, Cerulean, Quartz, Logging, and Arrow. In this case I would consider the "least pure" to still be on the order of 90-95% pure *S. c. lewisi*. Thus, for classification purposes, and all practical purposes (except for reintroductions) all the samples, except Evangeline Lake (*S. c. bouvieri*), should be classified as *S. c. lewisi*. The massive numbers of Yellowstone cutthroat trout stocked into these drainages have not significantly altered the native genotypes. The Yellowstone trout is established only in the originally barren Evangeline Lake. The presence of two Evangeline Lake fish among the sample of 30 specimens from Arrow Lake (and no obviously intermediate specimens) suggests

that Yellowstone Lake trout from above are continually mixing into the Arrow Lake population, but are not contributing, to any extent, to reproduction. Obviously, they are at a severe competitive disadvantage with the native fish. As mentioned, the heavy level of parasite infestation in Arrow Lake may be one of the selective factors favoring the native trout.

The cestode parasite was most commonly found in the pyloric caecae. Specific identification of the parasite was not made but the scolex is without hooks as in Proteocephalus. I assume that the parasite has a completely aquatic life cycle, entering the fish via infected crustaceans in the diet. Thus this cestode should be absent from lakes barren of fish (none were observed in Evangeline Lake specimens). Antipa (1974) and Becker and Brunson (1968) discussed tapeworms identified (possibly incorrectly) as Proteocephalus amblopliites, infecting trout in the Northwest.

Although, there was no observable ill effects of the parasite on the specimens examined (the largest, most robust specimens were often the most heavily infected), it would be adviseable not to spread the parasite. Thus, for introductions of native trout into barren waters, eggs or newly hatched fry could be used. If a lake is treated to eliminate non-native fish. A period of time (perhaps one year) without fish should eliminate the parasite.

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Literature Cited

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FIGURES

Figures one and two are graphic representation of the specimens arranged according to the morphological data. Figure 1 is the results of a principal component analysis and figure two represents a discriminant function analysis. The major difference between these two types of multivariate analyses is that with principal components, the data from the specimens are not identified with any group, whereas in discriminant function the specimens are assigned to known groups (Arrow Lake, Cerulean Lake, etc.). Principal component analysis stresses variance between groups and discriminant function emphasizes the variance between individuals. Principal components is an identification statistic (identification of unknown specimens) and discriminant function is more of a classification statistic (testing the "goodness of fit" between groups of predetermined classification).

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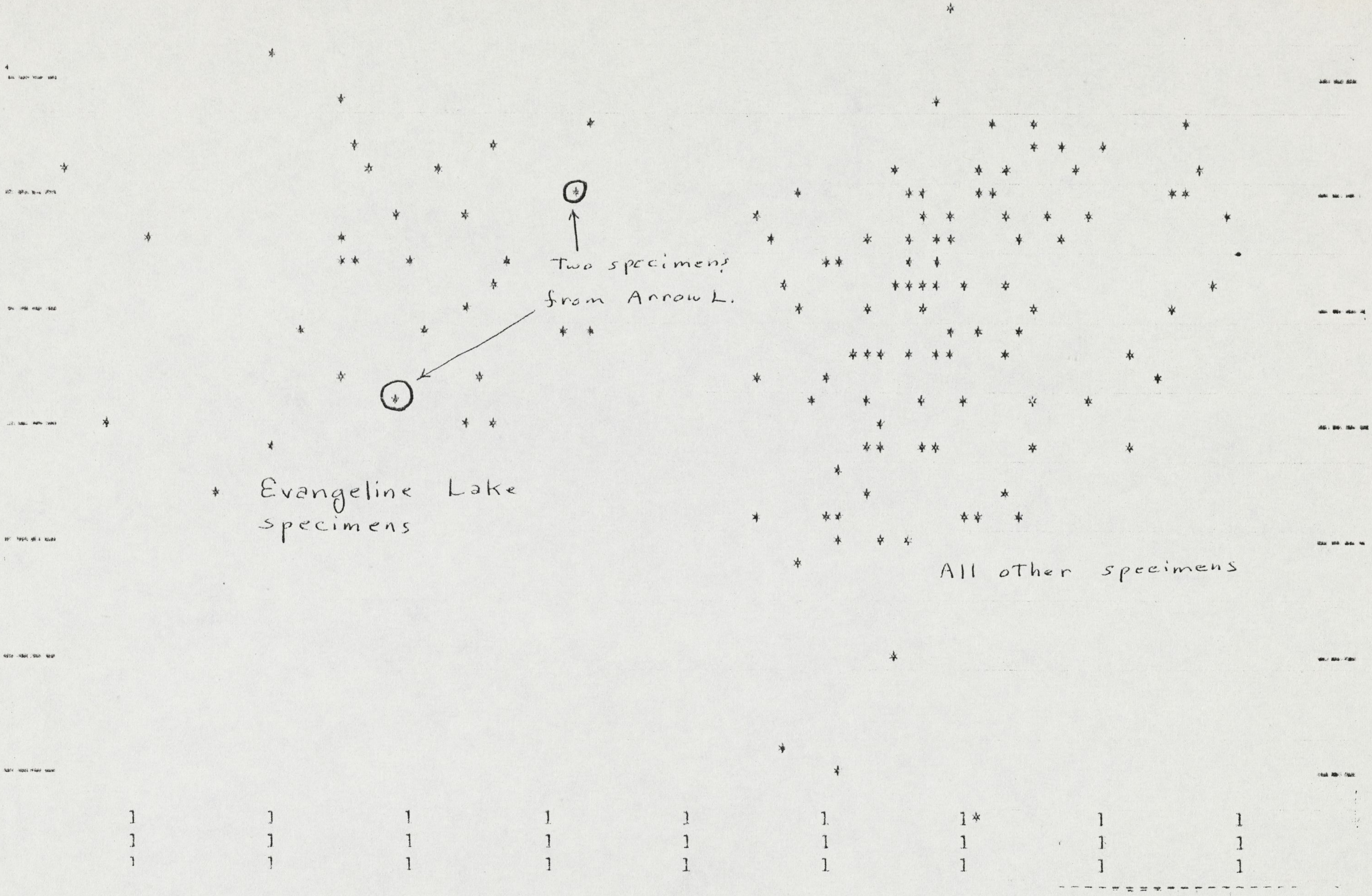

FIGURE 1. Principal component analysis.

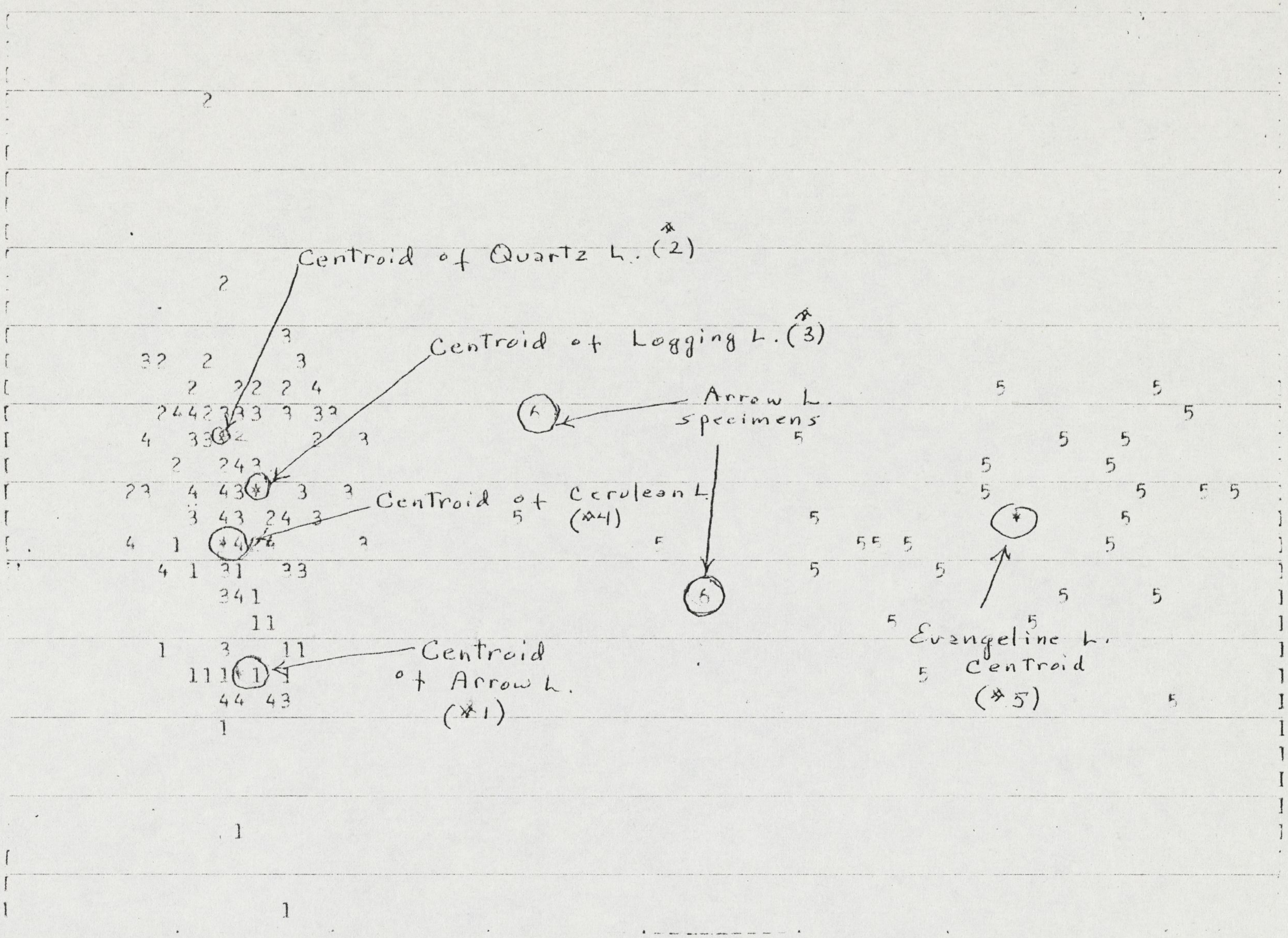

FIGURE 2. Discriminant function analysis.

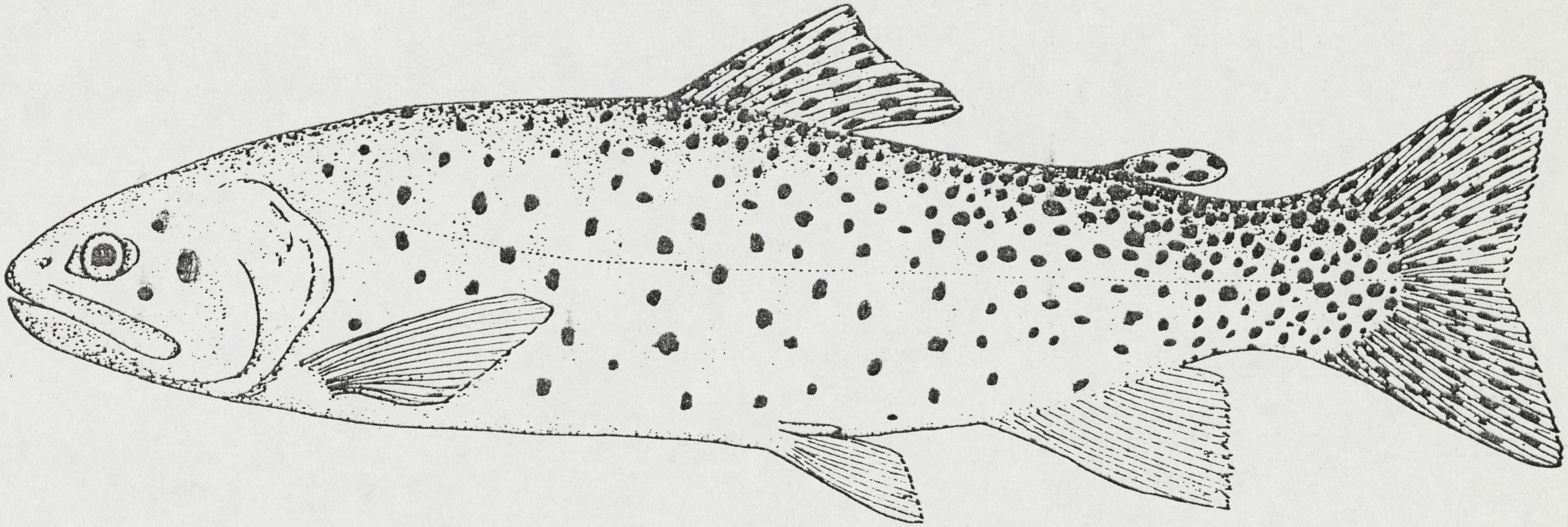

Figure 3. Spotting pattern of the Yellowstone cutthroat trout.

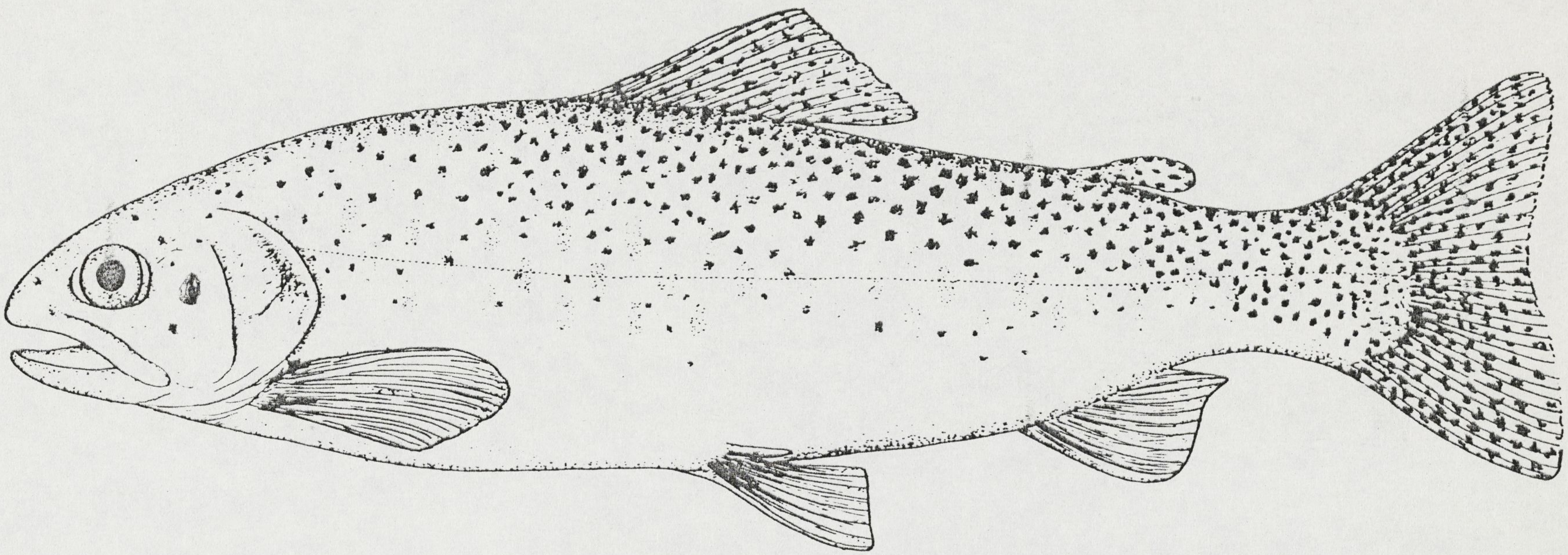

Figure 4. Spotting pattern of *Salmo clarki lewisi*.

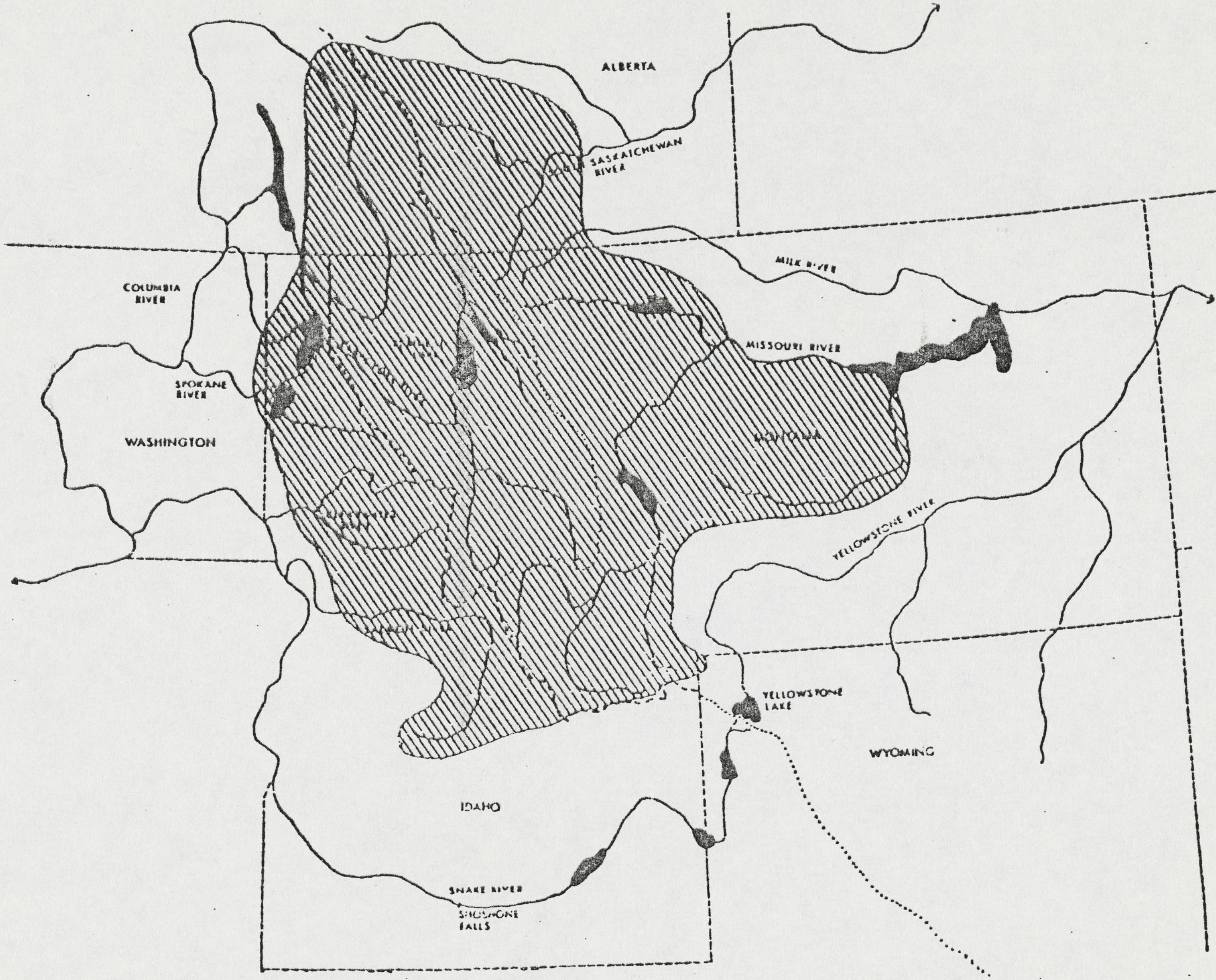

FIGURE 5. Distribution of Salmo clarki lewisi.

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*

REPORT ON 1980 TROUT COLLECTIONS FROM GLACIER NATIONAL PARK

Robert J. Behnke

April 1981

INTRODUCTION

The results of the 1980 collections on the east side on the Continental Divide show no evidence of native trout. Two small samples from Bowman and Kintla lakes on the west side of the Divide do appear to represent the native trout, Salmo clarki lewisi.

Nine samples with a total of 133 specimens were examined. Two samples (Old Man Lake, Katoya Lake) are from the Missouri River basin and five samples (Red Eagle Lake, Otokomi Lake, Upper, Lower, and Middle Slide lakes) are from the South Sakatchewan basin. The complete absence of any indication of S. c. lewisi influence in the east side collections, which is in complete contrast to the 1978 and 1979 west side collections, indicates that the east side lakes sampled in 1980 were originally barren of fish prior to the stocking of non-native trouts. The trout of Red Eagle Lake are predominantly rainbow trout with a slight cutthroat trout influence. The other six east side lakes contain a trout that is predominantly of Yellowstone Lake origin.

In consideration of questions raised in last year's report regarding fish stocking in Park waters and in view of the non-native trout found by the 1980 collections, an inquiry was made concerning the origins of trout stocked during the early years of introductions.

RESULTS

Flathead River Basin

Bowman Lake. Four specimens from 196 to 303 mm total length were examined. These specimens appear to be typical of the native *S. c. lewisi* in appearance and in meristic characters except for a high number of gillrakers (19, 21, 21, 22) and three of four specimens have from 1 to 3 posterior gillrakers on the first arch. This could denote a Yellowstone cutthroat influence but, if so, then a modification of the spotting pattern would be expected. The sample size is small, but the Bowman Lake cutthroat trout may be the first example of lacustrine specialization in gillraker development in Glacier Park lakes (comparable to the Yellowstone Lake cutthroat trout).

Kintla Lake. Four large specimens (324, 357, 395, 425 mm TL) that were gutted prior to preservation. Only scale counts could be obtained from these specimens. The scale counts are typical of the native trout and the spotting pattern is wholly typical of *S. c. lewisi*. The size of the specimens is among the largest for native trout yet collected. A food habit analysis of the Kintla Lake cutthroat trout would be of interest. Perhaps heavy predation pressure from bull trout (and lake trout?) greatly thins the cutthroat population resulting in rapid growth of the survivors.

Missouri River Basin

Old Man Lake. A sample of 30 specimens is predominantly of Yellowstone Lake origin. A hybrid influence from rainbow trout is noted in the reduced numbers of basibranchial teeth, scales, and posterior gillrakers in comparison with pure Yellowstone specimens. The specimens are moderate to relatively large size (200 to 384 mm TL).

Table 1. Character analyses of samples.

Sample	Gillrakers	Scales above l.l. and lat. ser.	Basibranchial teeth	pyloric caeca	Comments
Flathead R. basin					
Bowman L. N=4	19-22(20.8)	34-41 (37) 149-181(165.3)	1 no teeth 3 w/4-9(5.6)	28-41(36)	Probably pure native population but may have lacustrine specializations.
Kintla L. N=4	Gutted	40-49 (43.5) 151-189(174.3)			Gutted specimens but spotting typical of pure S. c. lewisi. Large, 324-425 mm.
Missouri R. basin					
Old Man L. N=30	18-23(20.5)	35-47 (40.9) 149-200(169.4)	2-24 (9.3)	33-48(38.9)	Predominantly Yellowstone cutthroat.
Katoya L. N=30	19-22(20.5)	35-47 (39.9) 159-194(174.9)	3-27(16.4)	31-57(44.1)	Virtually pure Yellowstone cutthroat.
So. Saskatchewan basin					
Red Eagle L. N=6	19-21(19.5)	27-37 (31.5) 125-149(136)	5 no teeth 1 w/one tooth	37-52(44.8)	Predominantly rainbow trout.
Otokomi L. N=26	18-21(19.9)	42-53(45.1) 160-210(181.4)	3-25(13.2)	29-47(38.9)	Predominantly Yellowstone cutthroat.
Upper Slide L. N-5	20-21(20.4)	41-51 (44) 163-200(177.6)	11-19(15)	37-58(42.8)	Yellowstone cutthroat.
Lower Slide L. N=17	18-21(19.7)	41-51 (44) 160-185(171.6)	1-33(12.2)	33-58(42.8)	Predominantly Yellowstone
Middle Slide L. N=11	19-22(20)	38-46 (42) 164-202(182.7)	3-23(10.2)	36-43(37.5)	Predominantly Yellowstone cutthroat.

Red Eagle Lake. These 6 specimens are predominantly rainbow trout. Variability in spotting, meristic characters, and particularly the presence of a basibranchial tooth in one specimen denotes a slight hybrid influence from cutthroat trout. Specimens of moderate to relatively large size (211-382 mm TL).

Otokomi Lake. These 26 specimens are quite typical of Yellowstone Lake cutthroat trout with a slight trace of rainbow trout influence. Most specimens small (170-230 mm) but a few are relatively large (350-410 mm).

Slide Lakes. Samples from upper (N=5), lower (N=17), and middle (N=11) Slide lakes are all predominantly of Yellowstone Lake origin with varying, but slight, influence from rainbow trout. Specimens from Upper Slide Lake are largest (389-485 mm TL), Middle Slide Lake sample has the smallest specimens (175-270 mm TL), and Lower Slide Lake specimens are intermediate (some relatively small, 168-268 and some large, 324-485 mm TL).

Strictly from a fisheries management point of view, the Yellowstone cutthroat, particularly hybridized stocks, typically attain a larger size than the native trout and the average angler is likely to place a higher value on non-native populations in Park waters. The results of the 1980 east slope collections indicates that the Yellowstone cutthroat was the first trout widely stocked into barren lakes. Rainbow trout were stocked later, or in fewer waters. Only the trout of Red Eagle Lake are predominantly rainbow trout. The other six east slope collections have been exposed to rainbow hybridization but retain a predominance (80 to 95% of the Yellowstone cutthroat trout genotype.

PROPAGATION AND STOCKING NOTES

It was mentioned in last year's report that the stocking of Park waters was not as straightforward as formerly believed, nor were all introductions officially recorded. Some items of interest were uncovered in a search of U.S. Fish Commission Reports and other sources.

In 1916, "blackspotted" trout eggs were stocked in Avalanche, Bowman, Logan, and McDonald lakes. Although trout were almost certainly not native to Avalanche Lake, they were established at an early but unknown time. Thus, all of the lakes stocked in 1916 would be expected to be at their carrying capacity with native trout. Why, then, were the early official introductions made in lakes that already had trout rather than in barren waters? I believe it was due to the belief at the time that waters that were subjected to angling exploitation, should be "replenished" by the introduction of eggs and fry in order to maintain the fishery. Thus, the earliest stocking by government agencies concentrated on the lakes that were most heavily fished--those believed in need of "replenishment."

The earliest record I found for official federal stocking of rainbow trout in the Park was a 1917 plant of 30,000 into Gunsight Lake. In 1918, rainbow trout were stocked into Boulder Creek, St. Mary's River, Swift Current River, and more into Gunsight Lake. Red Eagle Lake was stocked with 7,500 blackspotted trout in 1918 (the six specimens from Red Eagle Lake collected in 1980 are about 80% or more rainbow trout). In 1920, the U.S. Fish Commission Report proudly announced that brook, brown, Loch Leven, lake, and rainbow trout had been successfully established in Yellowstone Park and this was a "noteworthy success;" furthermore, "similar

services" were now in progress in Glacier Park." The establishment of an auxiliary station of the Bozeman hatchery at Glacier Park in 1920 would greatly speed up the "services" of non-native trout stocking.

In 1922 the Glacier Park substation received eggs from Yellowstone Lake, rainbow trout eggs from Meadow Creek (tributary Madison R.) Montana, and steelhead eggs from Oregon.

In 1923, besides 1,332,000 eggs from Yellowstone Lake, 1,389,700 eggs were taken in Glacier Park from an unspecified source (perhaps McDonald Lake?). A great effort was made to stock barren waters along the Continental Divide in 1923. I suspect that the eggs and fry derived from Park waters were not maintained separately from the Yellowstone Lake eggs and fry (they were all considered as "blackspotted" trout). Such mixing as likely occurred in the 1923 stocking, might explain the hybrid combinations found in some of the 1979 collections. The 1923 report expressed interest in Logging Lake as a source of "blackspotted" eggs because it was believed the trout spawned there in February. The 1925 report has two photos (Fig. 5,6) illustrating the use of pack horses to stock remote waters in the Park.

In 1926, 1,486,000 "blackspotted eggs were received from Montana Fish and Game; 350,000 of which were stocked in "more inaccessible headwaters of the Park." Golden trout were stocked in 1929 and 1930, evidently all were stocked into Lake Wurdeman. In 1929, a shipment of 89,500 "blackspotted" eggs were received from Nevada. The Nevada eggs were undoubtedly from Lahontan cutthroat trout of Pyramid Lake. Could there be a remote possibility that the Pyramid Lake cutthroat still persists in the Park?

I found no mention in the U.S. Fish Commission Reports of the effects

of the earlier (1912-1917) stocking, particularly in east slope waters, of non-native trouts by the Great Northern Railroad. The six predominantly rainbow trout specimens from Red Eagle Lake suggest that rainbow trout were already in Red Eagle Lake prior to its 1918 stocking with "blackspotted trout."

A further note of confusion concerning the origins of trout stocked in the Park is the fact that in some years most of the eggs were not received from federal hatcheries but from the Montana Fish and Game Department. Montana used many sources for both cutthroat and rainbow propagation. A letter from Mr. Emmett L. Colley, Hatchery Bureau Chief, Montana Department of Fish and Game, kindly provided some information on sources used in the propagation of cutthroat and rainbow trout from 1912 to 1930. Besides Yellowstone Lake, cutthroat eggs came from Georgetown Lake (stocked with cutthroat in 1913 and rainbows in 1912--thus a source of hybrids), Bitterroot and Ashley lakes, Flathead Co. (*S. c. lewisi*), and eggs were received in trade from Nevada (*S. c. henshawi* from Pyramid Lake) and Idaho (*S. c. bouvieri* from Henry's Lake). Mr. Colley's records indicate a stocking of 20,000 cutthroat from Bozeman hatchery into Red Eagle L. in 1916.

Also the Madison River and its tributary Meadow Creek were a major source of eggs for both Montana Fish and Game and federal hatchery at Bozeman. "Rainbow" trout eggs are recorded as taken from the Madison R. as early as 1913. The native trout of the Madison, *S. c. lewisi*, evidently hybridized and was largely replaced by rainbows quite early, but the U.S. Fish Commission Reports state "blackspotted" eggs were obtained from Meadow Creek in 1918, but in 1919 and 1920 Meadow Creek yielded more than 4,000,000 rainbow trout eggs. Obviously the species composition did not

change from cutthroat to rainbow in one generation. I assume that eggs taken from the Madison R. and Meadow Creek were hybrids, although they were listed as either cutthroat or rainbows. A large amount of eggs of Madison R. origin were stocked into waters of Glacier Park.

Thus, the known sources of trout stocked into Park water that could have contributed to the various hybrid combinations found today include, S. c. bouvieri (Yellowstone L., Henry's Lake), S. c. bouvieri x S. gairdneri (Georgetown Lake), S. c. lewisi x S. gairdneri (Madison R.), S. c. lewisi (from Park waters plus Bitterroot and Ashley lakes), and S. c. henshawi (Pyramid L., Nevada).

In the American Angler magazine, two issues of 1888 (13[2], 13[5]) contain articles by Tarlton Bean, Curator of Fishes at the U.S. National Museum. Bean reported receiving specimens of "Dolly Varden" from a stream between upper and lower St. Mary's Lake, pointing out that this was the easternmost limit of the range of the species then known. He also received specimens of lake trout from St. Mary's Lake and fish which "seem to be Clark's trout" (cutthroat). W. W. Crosby (1926), a former Park Service employee, wrote a book on western fishing. He recounted some angling experiences in the Park (no dates given, but obviously prior to 1926). He found Arrow Lake was "full of cutthroats" reported to reach 5 pounds, but he caught none over 2. On the east side of the Park, it is interesting to note that he caught few cutthroat trout, even at such an early period. He mentioned that Red Eagle Lake had "excellent cutthroat fishing" (perhaps the present hybrid population had more cutthroat influence 60 years ago). He mentioned that the rainbow trout was the most numerous fish he caught--catching them in Josephine Lake, McDermott

Lake, St. Mary's Lake, and Two Medicine Lake. Brook trout were caught in McDermott and Two Medicine Lake and probable rainbow x cutthroat hybrids from McDermott. Crosby also saw a "silver trout" (kokanee?) that he couldn't identify in Lake McDermott. Crosby's observations would indicate that the native cutthroat trout was largely gone from east slope waters and the present situation probably differs little from what was there 60 years ago.

LITERATURE CITED

Crosby, W. W. 1926. Some western fishing. Waverly Press, Baltimore:128pp.

REPORT ON 1979 COLLECTIONS OF CUTTHROAT TROUT FROM GLACIER NATIONAL PARK

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INTRODUCTION

Last year's report on 1978 collections from 5 lakes, tributary to the North Fork of Flathead River drainage revealed that one originally barren lake (Evangeline) has a pure population of Yellowstone cutthroat trout, *Salmo clarki bouvieri*, and 4 lakes, although exposed to hybridization, have the native westslope cutthroat trout, *S. c. lewisi*. The 1979 collections are much more extensive. A total of 394 specimens representing 17 samples were examined from the Flathead drainage. In lakes that have had native populations for thousands of years, the results verify last year's conclusions that introductions of nonnative cutthroat trout have had virtually no detectable impact on the native populations. It is obvious that the native environments are strongly selecting for the native cutthroat trout genotype. Two environmental factors, the native cestode parasite and the native predatory bull trout, *Salvelinus confluentis*, suggest an advantage to the native cutthroat trout in relation to the introduced Yellowstone cutthroat. Predominantly Yellowstone cutthroat hybrids occur in 4 originally barren lakes. Several formerly barren lakes have pure native trout. This indicates widespread stocking of the native trout occurred and this is not apparent from the historical records of trout stocking in the Park. Akokala Lake specimens indicate a predominantly native trout but with some influence of Yellowstone cutthroat. Ole Lake trout have an unusual spotting pattern which suggests introgression from rainbow trout. A correlation of the spotting pattern of the specimens with other taxonomic characters verifies last year's conclusions that an accurate evaluation of purity of the native trout is possible from the spotting pattern alone.

RESULTS

Lakes With Native Populations

Samples judged to be pure or virtually pure (ca. 95% or more) *S. c. lewisi* are Upper and Lower Howes, Avalanche, Trout, Lincoln, Harrison, Middle and Lower Quartz, Upper and Lower Isabel, and Lower Snyder lakes. I assume that Trout, Lincoln, Harrison, Middle and Lower Quartz lakes have had native populations since the retreat of the glaciers. The populations in the other lakes were probably introduced by man (based on topography and gradient of outlet streams). All of the samples judged to be pure *S. c. lewisi* have the typical spotting pattern of the native trout (Fig. 4 of last year's report). The most diagnostic meristic characters separating the native cutthroat trout from the Yellowstone cutthroat are the numbers of anterior and posterior gillrakers and basibranchial teeth. To demonstrate the correlation of these characters with spotting pattern, I summed the mean values of the two gillraker counts and the basibranchial teeth counts for each sample (from Table 1). The 10 samples judged to be *S. c. lewisi* on spotting pattern (Upper Howes Lake sample with only 3 specimens omitted) have total scores of 23.7 (Harrison L.) to 28.2 (Avalanche L.) with an overall mean of means of about 25 to 26. The 4 samples identified as *S. c. lewisi* in last year's report (Arrow, Logging, Upper Quartz, and Cerulean lakes) have values of 24.0 to 27.3. The Evangeline Lake sample identified as pure

Yellowstone trout in last year's report has a score of 49.7 when the mean values of gillrakers and basibranchial teeth are summed.

The 4 samples identified as predominantly Yellowstone cutthroat trout (Grace, Fish, Camas, and Hidden lakes) have meristic scores of 35.9 to 39.4. The Akokala L. sample has a score of 29.0 and the spotting pattern indicates some Yellowstone cutthroat influence. The Ole Lake sample suggests a slight rainbow trout influence and it has a score of 25.7.

More than 10% of the specimens from Upper and Lower Isabel lakes and Lower Snyder Lake lack basibranchial teeth. However, no other character indicates any hybrid influence, except perhaps the higher number of pyloric caeca in the Upper Isabel Lake sample.

The size range of the specimens in each sample is given in Table 1. Although it is probable that the Yellowstone cutthroat trout has the genetic potential to reach a larger size than the native trout (based on my observations of *S. c. bouvieri* and *S. c. lewisi* throughout their ranges), I would attribute most of the differences in size to direct environmental effects (abundance and size of food organisms and success of reproduction and recruitment) rather than heredity. This is apparent in comparing the 3 large specimens from Upper Howes Lake (394 to 437 mm total length) with the sample from Lower Howes Lake (120 to 221 mm TL). It is assumed that no genetic differences exist between the two populations, only that the density is very sparse in Upper Howes Lake. In general, the largest specimens are from the Yellowstone hybrid populations. Three of the 4 Yellowstone hybrid samples have specimens over 400 mm. Five of the 10 *S. c. lewisi* samples have no specimens over 300 mm. In those lakes with *S. c. lewisi* and with good reproduction, it is likely that predation pressure from bull trout acts to stimulate growth (Trout, Lower Isabel, the Quartz lakes, and perhaps Harrison L.). The size distribution in these lakes suggests that an abundance of young, small cutthroat of age groups 0 to III are more-or-less restricted to inshore areas where intense intraspecific completion retards growth. Once a size of about 250 to 300 mm is attained, the cutthroat in these lakes are probably no longer vulnerable to bull trout predation and they utilize the whole lake for feeding. With much reduced intraspecific competition their growth rate is increased.

During my visit to Trout Lake, I observed only small cutthroat trout along the shoreline (about 150 to 200 mm). There were large schools of these small trout and I caught about 100 of them on flies in a few hours, but none much larger than 200 mm. Just before leaving the lake I cast my fly as far as I could out into the open, deep zone of the lake and caught a specimen of about 350 mm. This specimen was unusually plump. I examined the stomach contents and found it had consumed two small trout and a sculpin. In a monograph on the native trout of western North America, written in 1979, I mentioned that *S. c. lewisi* is not typically predaceous -- it seldom eats fish. Besides proving the exception to the rule, the Trout Lake situation suggests that in lakes with bull trout, the growth rates and food utilization of *S. c. lewisi* might be quite different than found in lakes without bull trout.

Lakes with Hybrid Populations

Grace, Camas, Fish, and Hidden lakes have populations made up of a predominance of the Yellowstone cutthroat trout genotype but with some *S. c. lewisi* influence. The Yellowstone cutthroat influence is readily observed in the spotting pattern and in the counts of gillrakers and basibranchial teeth. None of these populations represent pure Yellowstone trout. The *S. c. lewisi* influence can be detected in the shape of the spots. Although the spots are large, as in Yellowstone trout, many specimens have irregular shaped spots with rough, asymetrical borders, much like *lewisi* spots in outline.

In last year's report by Allendorf and Phelps on electrophoretic comparisons of Glacier Park specimens, it was concluded that the 14 Grace Lake specimens on which they obtained data were pure Yellowstone cutthroat.

It is evident to me that the 1979 Grace Lake sample contains some *S. c. lewisi* influence. This hybrid influence is probably of many years duration. Schultz (1941) specifically cited the trout in Grace Lake as an example of the intermediate type of spotting pattern characteristic of hybridization between native and introduced cutthroat trout.

Several specimens in the Fish lake sample are quite typical of *lewisi* in their spotting pattern. The appearance of the Fish Lake specimens would suggest that both native trout and Yellowstone trout coexist in the lake with reproductive isolation. However, I found no correlation between meristic characters and spotting pattern in the Fish Lake specimens. This demonstrates that the distinctly different spotting pattern is not due to genetic isolation between the two subspecies, but is the result of random recombinations of genes from both parental forms which have fused into a hybrid swarm.

As discussed previously, the meristic scores of the Grace, Fish, Camas, and Hidden lake samples are considerably lower than the score of the pure Yellowstone cutthroat trout of Evangeline Lake (35.9 to 39.4 vs. 49.7). It is not known which of the two subspecies was introduced into these originally barren lakes or if they were stocked together. The predominance of the Yellowstone genotype would indicate that it was first introduced and *lewisi* stocked later. However, it is likely that in barren lakes without bull trout and without the native cestode parasite, the native cutthroat loses much of the selective advantage favoring it in its native waters.

I observed the predator avoidance response in the native cutthroat in Trout Lake, which appeared to be an evolutionary trait evolved in the presence of bull trout. When large (500 to 700 mm) bull trout approached a school of small cutthroat trout, the school would become compact and maintain an open water position over depths of 6 to 10 feet. The bull trout would attempt to herd the school into shallow water. When the predator approached too close, the school would 'explode' with its members going in all directions radiating out from a center point. When this occurred the bull trout did not try an attack. I doubt that the Yellowstone cutthroat trout has this innate predator avoidance response to bull trout.

Several years ago I arranged with George Holton to stock 5 Montana lakes with both Yellowstone cutthroat and *S. c. lewisi* to observe ecological differences between the two subspecies. Although these lakes were not studied in great detail, a paper given at the Colorado-Wyoming Academy of Science meetings in 1979, by Dingman and Clark, presented some data. *S. c. lewisi* seemed to be more of a specialist feeding on littoral benthic organisms; particularly chronomid larvae. The Yellowstone cutthroat was more of a generalist, feeding on a wider variety of organisms. The Yellowstone cutthroat grew faster. *S. c. lewisi* had a higher survival to age III, but a high mortality from age III to IV. It was speculated that this high mortality in catchable size *lewisi* was due to differential vulnerability to being caught by anglers because of their preference for littoral areas.

Thus, in predicting what genotype might be favored in a particular environment, the proportion of littoral zone and the benthic vs. pelagic and terrestrial food organisms are factors to be considered. The more highly developed gillrakers in Yellowstone cutthroat trout should give them an edge over *S. c. lewisi* in competition for zooplankton.

Gold, et al. (1978) demonstrated that the introductions of massive numbers of Yellowstone cutthroat trout into Trappers Lake, Colorado, for many years did not change the native *S. c. pleuriticus* genotype. Similar to the lakes in Glacier Park with native populations of cutthroat trout, the Trappers Lake cutthroat evolved for thousands of years in Trappers Lake and are more finely tuned to their native environment than is the nonnative Yellowstone trout. However, in a new environment with different sets of selective factors, it is most probable that the two subspecies would hybridize and the parental genotype best preadapted to the new environment would predominate.

Two samples, Akokala and Ole lakes, are judged to be predominantly native *S. c. lewisi*, but with some nonnative hybrid influence. The Akokala population has a slight Yellowstone trout influence (18-22 [19.6] gillrakers, meristic score of 29, and larger, rounder spots than in pure *lewisi*). Examination of a map of Glacier Park does not suggest that Akokala Lake is isolated by falls. That is, I would assume that *S. c. lewisi* is native. If this is true, then Akokala Lake is the first instance of detectable hybrid influence of Yellowstone cutthroat trout on a native population. How does Akokala Lake differ from the other lakes where Yellowstone trout introductions have had virtually no effect on the native populations? Perhaps bull trout are absent and/or the morphometry and food chain in the lake are more favorable to the Yellowstone genotype.

The Ole Lake specimens have an unusual spotting pattern with relatively large spots anteriorly and on top of the head. This type of spotting pattern is indicative of a rainbow trout influence. The meristic characters are typical of *S. c. lewisi* (meristic score = 25.7). If the unusual spotting pattern is due to hybridization with rainbow trout, the hybrid influence is slight. It is possible that the Ole Lake population is a pure native population that has evolved some unique genes governing its spotting pattern, but I doubt that this is the case. Ole Lake is about one mile from Ole Creek and about 500 feet in elevation above the creek. Such a gradient indicates the lake was originally barren of fish. Also, *S. c. lewisi*, throughout its great original range, consistently exhibits the most uniform spotting pattern of any subspecies of cutthroat trout.

IMPLICATIONS OF INTRODUCTIONS

It has been generally believed that all or virtually all of the cutthroat trout stocked in Glacier Park originated from Yellowstone Lake. It is apparent from the 1979 collections that large scale introductions of the native trout, *S. c. lewisi*, also were made. Howes and Isabel lakes, Avalanche and Lower Snyder Lake were probably barren of fish and all have *S. c. lewisi* populations. Grace, Fish, Camas, and Hidden lakes, also originally barren, were stocked with both Yellowstone cutthroats and with native trout. I would surmise that a considerable amount of "unofficial" stocking occurred by carrying native trout from a local source into barren or assumed barren lakes. A clue to what may have happened to speed up to early efforts to stock all of the barren waters of the Park is found in a 1931 letter from W. F. Thompson, U.S. Bur. Fisheries, to E. Dissmore, Chief Ranger at Glacier Park. Thompson mentioned that several of the original introductions were believed to be failures and were not known to be successful until many years later (Hidden Lake is cited as an example). If a relatively small population resulted from the original plant of eyed eggs or fry, fish in the lake would not likely attain a density to be detected by the casual observer until the original stock had spawned and produced a successful year-class.

Sexual maturity would be expected to be attained in 3 to 5 years and the subsequent year-class would need an additional 2 to 3 years to reach a size obvious to a visitor to the lake. Thus, it is probable that many lakes were believed barren 5 to 8 years after the first stocking. Such a situation would have stimulated Park employees and local people to attempt to rectify the situation by carrying in native trout from local stocks. This would have been particularly true during the early years when the supply of eggs from Yellowstone Lake could not meet the demand to stock all of the barren waters of the Park.

The *S. c. lewisi* populations in the Howes and Isabel lakes, in Lower Snyder and Avalanche lakes, indicate that these lakes were never stocked with Yellowstone trout, and their present populations are derived from local sources.

FISHERY MANAGEMENT IMPLICATIONS

Glacier National Park is fortunate, in contrast to many other National Parks and Monuments, to have such a high proportion of native species still occurring in their natural environments. At least in the Flathead River drainage, the status of the native cutthroat trout is good -- much better than expected at the beginning of the present study. The situation may be very different on the eastern side of the Continental Divide where introductions of rainbow trout and brook trout were much more prevalent. Where the native trout coexists with nonnative species, special management techniques and regulations may be necessary to take advantage of life history and ecological differences to favor the native species over the nonnative.

With this thought in mind, I must express concern in regards to a news release issued by the National Park Service on Feb. 27, 1980. This news release invites public comment on a proposed Park Service Fisheries Policy. Item 3 of the news release states: "Following appropriate environmental analysis and after consideration of other relevant factors, non-native species appropriate to the well-being of the ecosystem may be declared by the Director, NPS, as "naturalized" and managed as native species". The cause for concern is the implication of the meaning of "naturalized." A naturalized citizen has the rights and privileges of a native born citizen. Applying this concept to Park waters could prohibit the restoration of native species. In Rocky Mountain National Park, I have been involved in restoration projects to restore the greenback cutthroat trout and the Colorado River cutthroat trout to Park waters after these two native trout were eliminated by nonnative trouts. Nonnative brook trout and rainbow-cutthroat hybrid populations have been eradicated from some isolated waters and pure stocks of both subspecies of the native cutthroat trout introduced. A strict interpretation of "naturalized" and "managed as native species" would block future restoration efforts.

In Glacier Park, the native cutthroat trout was probably once the dominant fish in Lake McDonald, the largest body of water in the Park. Three nonnative salmonid fishes now dominate the fish fauna of Lake McDonald and have virtually eliminated the native trout. In fish sampling carried out in Lake McDonald in September, 1977, the kokanee salmon, *Oncorhynchus nerka*, made up about 50% of all fish biomass, the Great Lakes whitefish, *Coregonus clupeaformis*, about 22%, and the lake trout, *Salvelinus namaycush* about 3%. The native cutthroat trout was represented by about 1% of the biomass. The kokanee salmon monopolizes the pelagic food resources (zooplankton). The Great Lakes whitefish is a highly specialized benthic feeder. The lake trout is an effective deepwater predator. The synergistic forces of these 3 nonnative salmonids must negatively impact every life history stage of the native trout. There is no doubt in my mind that the combined impact of these 3 introduced species is the cause of the virtual disappearance of the native trout.

If a meaningful native trout restoration program is to be initiated in Lake McDonald, angling regulations should be designed for maximum exploitation of the nonnative species. This would have to be combined with further control measures such as removal of large numbers during spawning aggregations if a restoration program is to have any chance of success. If these nonnative fishes are declared "naturalized citizens" of Lake McDonald, and managed as native species, no attempt could be made to restore the native trout to a semblance of its former abundance.

I would hope that in those National Parks, such as Glacier Park, which have active fishery research projects underway, the new Park Service Fisheries Policy would provide for management decisions concerning native and nonnative fishes to be made at the local level. Two years ago, when the present trout research project was started, so little was known of the native cutthroat trout that no one was certain if they still occurred in Park waters. Future fisheries management options must be allowed to discriminate in favor of the native trout if the Park Service is to effectively carry out its mandate to preserve native species.

LITERATURE CITED

Gold, J. R., G. A. E. Gall, and S. J. Nicola. 1978. Taxonomy of the Colorado cutthroat trout (*Salmo clarki pleuriticus*) of the Williamson lakes, California. Calif. Fish and Game 64(2):98-103.

Schultz, L. P. 1941. Fishes of Glacier National Park, Montana. U.S. Fish and Wildl. Ser. Conserv. Bull. 22:42p.

Table 1. Character analysis of samples.

Sample	Gillrakers	Scales above l.l. and lat. series	Basibranchial teeth	Pyloric caeca	Spotting pattern, size of specimens
S. c. lewisi					
Upper Howes N = 3	17-18(17.7) ant. 1-2 (1.7) post.	42-45 (43.3) 156-169(163.7)	0-4 (1.7) 1 w/o teeth	36-37 (36.3)	typical *lewisi* large specimens:394-437mm TL
Lower Howes N = 21	16-20(18.4) 0-6 (1.7)	35-46 (41.3) 162-184(172.5)	0-11 (5.2) 2 w/o teeth	22-44 (35.5)	typical *lewisi* small: 120-221 mm TL
Avalanche N = 29	17-22(19.0) 0-3 (1.3)	38-50 (42.6) 155-215(178.0)	2-24 (7.9)	29-42 (37.1)	typical *lewisi* small: 169-241 mm TL
Trout N = 30	16-19(17.8) 0-5 (2.6)	32-41 (38.0) 154-182(170.1)	0-14 (6.1) 1 w/o teeth	28-44 (36.6)	typical *lewisi* med. size: 149-358 mm TL
Lincoln N = 16	15-20(17.4) 2-7 (3.8)	35-41 (41.1) 157-192(175.8)	0-11 (4.1) 1 w/o teeth	31-43 (38.1)	typical , very uniform spotting. small: 187-256 mm TL
Harrison N = 30	17-20(17.3) 0-30 (0.8)	33-40 (37.8) 151-176(162.2)	1-13 (5.6)	30-48 (36.2)	typical *lewisi*, very uniform spotting small-med.: 175-304 mm TL
Middle Quartz N = 30	17-20(18.8) 0-2 (0.7)	33-47 (37.7) 148-176(163.4)	0-11 (5.1) 1 w/o teeth	34-48 (41.8)	typical *lewisi* small-med.large: 149-370 mm TL
Lower Quarts N = 31	15-21(18.1) 0-8 (2.2)	37-42 (38.6) 149-186(163.0)	1-16 (6.0)	34-43 (39.5)	typical *lewisi* small-med.: 157-316 mm TL
Upper Isabel N = 8	18-20(19.0) 0-3 (2.3)	35-46 (39.8) 167-184(173.8)	0-12 (5.1) 2 w/o teeth	39-57 (44.1)	typical *lewisi*, very uniform spots med.: 243-291 mm TL
Lower Isabel N = 30	17-20(18.5) 0-5 (1.4)	35-46 (40.2) 151-185(160.8)	0-21 (3.9) 4 w/o teeth	32-49 (41.2)	typical *lewisi* med.: 258-322 mm TL
Lower Snyder N = 33	16-21(18.3) 0-4 (2.2)	36-46 (41.7) 180-206(194.0)	0-8 (4.3) 4 w/o teeth	32-41 (36.0)	typical *lewisi*, very uniform spotting. very small: 158-229 mm TL
Hybrids: predominantly native					
Akokala N = 30	18-22(19.6) 0-7 (1.9)	38-48 (42.3) 164-204(180.1)	1-13 (7.5)	29-40 (36.0)	Irregular, predominantly *lewisi* but definite Yellowstone influence. small: 180-259 mm TL
Ole N = 30	16-21(18.9) 0-5 (1.9)	35-45 (40.0) 150-186(174.0)	0-14 (4.9) 2 w/o teeth	37-46 (41.3)	larger, rounder spots anterior and on head. small: 168-221 mm TL
Hybrids: predominantly Yellowstone					
Grace N = 23	19-24(21.2) 0-11 (5.3)	37-48 (42.3) 157-216(174.4)	2-26 (11.9)	32-56 (45.4)	Predominantly Yellowstone with *lewisi* influence large: 296-418 mm TL
Fish N = 28	18-24(20.3) 0-10 (3.9)	36-47 (42.1) 160-202(179.5)	4-37 (11.7)	34-54 (41.0)	Predominantly Yellowstone but some specimens typical of *lewisi* med.-large: 164-418 mm TL
Camas N = 14	19-23(20.3) 3-14 (7.1)	39-46 (42.6) 163-201(182.1)	4-29 (10.6)	34-42 (37.7)	Predominantly Yellowstone small: 176-247 mm TL
Hidden N = 18	17-23(19.9) 2-13 (7.6)	37-48 (42.9) 158-191(173.3)	6-21 (11.9)	29-41 (34.8)	Predominantly Yellowstone large:171-481

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Nine samples with a total of 133 specimens were examined. Two samples (Old Man Lake, Katoya Lake) are from the Missouri River basin and five samples (Red Eagle Lake, Otokomi Lake, Upper, Lower, and Middle Slide lakes) are from the South Sakatchewan basin. The complete absence of any indication of _S. c. lewisi_ influence in the east side collections, which is in complete contrast to the 1978 and 1979 west side collections, indicates that the east side lakes sampled in 1980 were originally barren of fish prior to the stocking of non-native trouts. The trout of Red Eagle Lake are predominantly rainbow trout with a slight cutthroat trout influence. The other six east side lakes contain a trout that is predominantly of Yellowstone Lake origin.

In consideration of questions raised in last year's report regarding fish stocking in Park waters and in view of the non-native trout found by the 1980 collections, an inquiry was made concerning the origins of trout stocked during the early years of introductions.

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Flathead River Basin

Bowman Lake. Four specimens from 196 to 303 mm total length were examined. These specimens appear to be typical of the native *S. c. lewisi* in appearance and in meristic characters except for a high number of gillrakers (19, 21, 21, 22) and three of four specimens have from 1 to 3 posterior gillrakers on the first arch. This could denote a Yellowstone cutthroat influence but, if so, then a modification of the spotting pattern would be expected. The sample size is small, but the Bowman Lake cutthroat trout may be the first example of lacustrine specialization in gillraker development in Glacier Park lakes (comparable to the Yellowstone Lake cutthroat trout).

Kintla Lake. Four large specimens (324, 357, 395, 425 mm TL) that were gutted prior to preservation. Only scale counts could be obtained from these specimens. The scale counts are typical of the native trout and the spotting pattern is wholly typical of *S. c. lewisi*. The size of the specimens is among the largest for native trout yet collected. A food habit analysis of the Kintla Lake cutthroat trout would be of interest. Perhaps heavy predation pressure from bull trout (and lake trout?) greatly thins the cutthroat population resulting in rapid growth of the survivors.

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Old Man Lake. A sample of 30 specimens is predominantly of Yellowstone Lake origin. A hybrid influence from rainbow trout is noted in the reduced numbers of basibranchial teeth, scales, and posterior gillrakers in comparison with pure Yellowstone specimens. The specimens are moderate to relatively large size (200 to 384 mm TL).

Table 1. Character analyses of samples.

Sample	Gillrakers	Scales above l.l. and lat. ser.	Basibranchial teeth	pyloric caeca	Comments
<u>Flathead R. basin</u>					
Bowman L. N=4	19-22(20.8)	34-41 (37) 149-181(165.3)	1 no teeth 3 w/4-9(5.6)	28-41(36)	Probably pure native population but may have lacustrine specializations.
Kintla L. N=4	Gutted	40-49 (43.5) 151-189(174.3)			Gutted specimens but spotting typical of pure <u>S. c. lewisi</u>. Large, 324-425 mm.
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Old Man L. N=30	18-23(20.5)	35-47 (40.9) 149-200(169.4)	2-24 (9.3)	33-48(38.9)	Predominantly Yellowstone cutthroat.
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Red Eagle L. N=6	19-21(19.5)	27-37 (31.5) 125-149(136)	5 no teeth 1 w/one tooth	37-52(44.8)	Predominantly rainbow trout.
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Red Eagle Lake. These 6 specimens are predominantly rainbow trout. Variability in spotting, meristic characters, and particularly the presence of a basibranchial tooth in one specimen denotes a slight hybrid influence from cutthroat trout. Specimens of moderate to relatively large size (211-382 mm TL).

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Strictly from a fisheries management point of view, the Yellowstone cutthroat, particularly hybridized stocks, typically attain a larger size than the native trout and the average angler is likely to place a higher value on non-native populations in Park waters. The results of the 1980 east slope collections indicates that the Yellowstone cutthroat was the first trout widely stocked into barren lakes. Rainbow trout were stocked later, or in fewer waters. Only the trout of Red Eagle Lake are predominantly rainbow trout. The other six east slope collections have been exposed to rainbow hybridization but retain a predominance (80 to 95% of the Yellowstone cutthroat trout genotype.

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Old Man Lake. A sample of 30 specimens is predominantly of Yellowstone Lake origin. A hybrid influence from rainbow trout is noted in the reduced numbers of basibranchial teeth, scales, and posterior gillrakers in comparison with pure Yellowstone specimens. The specimens are moderate to relatively large size (200 to 384 mm TL).

Table 1. Character analyses of samples.

Sample	Gillrakers	Scales above l.l. and lat. ser.	Basibranchial teeth	pyloric caeca	Comments
Flathead R. basin					
Bowman L. N=4	19-22(20.8)	34-41 (37) 149-181(165.3)	1 no teeth 3 w/4-9(5.6)	28-41(36)	Probably pure native population but may have lacustrine specializations.
Kintla L. N=4	Gutted	40-49 (43.5) 151-189(174.3)			Gutted specimens but spotting typical of pure S. c. lewisi. Large, 324-425 mm.
Missouri R. basin					
Old Man L. N=30	18-23(20.5)	35-47 (40.9) 149-200(169.4)	2-24 (9.3)	33-48(38.9)	Predominantly Yellowstone cutthroat.
Katoya L. N=30	19-22(20.5)	35-47 (39.9) 159-194(174.9)	3-27(16.4)	31-57(44.1)	Virtually pure Yellowstone cutthroat.
So. Saskatchewan basin					
Red Eagle L. N=6	19-21(19.5)	27-37 (31.5) 125-149(136)	5 no teeth 1 w/one tooth	37-52(44.8)	Predominantly rainbow trout.
Otokomi L. N=26	18-21(19.9)	42-53(45.1) 160-210(181.4)	3-25(13.2)	29-47(38.9)	Predominantly Yellowstone cutthroat.
Upper Slide L. N-5	20-21(20.4)	41-51 (44) 163-200(177.6)	11-19(15)	37-58(42.8)	Yellowstone cutthroat.
Lower Slide L. N=17	18-21(19.7)	41-51 (44) 160-185(171.6)	1-33(12.2)	33-58(42.8)	Predominantly Yellowstone
Middle Slide L. N=11	19-22(20)	38-46 (42) 164-202(182.7)	3-23(10.2)	36-43(37.5)	Predominantly Yellowstone cutthroat.

<u>Red Eagle Lake</u>. These 6 specimens are predominantly rainbow trout. Variability in spotting, meristic characters, and particularly the presence of a basibranchial tooth in one specimen denotes a slight hybrid influence from cutthroat trout. Specimens of moderate to relatively large size (211-382 mm TL).

<u>Otokomi Lake</u>. These 26 specimens are quite typical of Yellowstone Lake cutthroat trout with a slight trace of rainbow trout influence. Most specimens small (170-230 mm) but a few are relatively large (350-410 mm).

<u>Slide Lakes</u>. Samples from upper (N=5), lower (N=17), and middle (N=11) Slide lakes are all predominantly of Yellowstone Lake origin with varying, but slight, influence from rainbow trout. Specimens from Upper Slide Lake are largest (389-485 mm TL), Middle Slide Lake sample has the smallest specimens (175-270 mm TL), and Lower Slide Lake specimens are intermediate (some relatively small, 168-268 and some large, 324-485 mm TL).

Strictly from a fisheries management point of view, the Yellowstone cutthroat, particularly hybridized stocks, typically attain a larger size than the native trout and the average angler is likely to place a higher value on non-native populations in Park waters. The results of the 1980 east slope collections indicates that the Yellowstone cutthroat was the first trout widely stocked into barren lakes. Rainbow trout were stocked later, or in fewer waters. Only the trout of Red Eagle Lake are predominantly rainbow trout. The other six east slope collections have been exposed to rainbow hybridization but retain a predominance (80 to 95% of the Yellowstone cutthroat trout genotype.

PROPAGATION AND STOCKING NOTES

It was mentioned in last year's report that the stocking of Park waters was not as straightforward as formerly believed, nor were all introductions officially recorded. Some items of interest were uncovered in a search of U.S. Fish Commission Reports and other sources.

In 1916, "blackspotted" trout eggs were stocked in Avalanche, Bowman, Logan, and McDonald lakes. Although trout were almost certainly not native to Avalanche Lake, they were established at an early but unknown time. Thus, all of the lakes stocked in 1916 would be expected to be at their carrying capacity with native trout. Why, then, were the early official introductions made in lakes that already had trout rather than in barren waters? I believe it was due to the belief at the time that waters that were subjected to angling exploitation, should be "replenished" by the introduction of eggs and fry in order to maintain the fishery. Thus, the earliest stocking by government agencies concentrated on the lakes that were most heavily fished--those believed in need of "replenishment."

The earliest record I found for official federal stocking of rainbow trout in the Park was a 1917 plant of 30,000 into Gunsight Lake. In 1918, rainbow trout were stocked into Boulder Creek, St. Mary's River, Swift Current River, and more into Gunsight Lake. Red Eagle Lake was stocked with 7,500 blackspotted trout in 1918 (the six specimens from Red Eagle Lake collected in 1980 are about 80% or more rainbow trout). In 1920, the U.S. Fish Commission Report proudly announced that brook, brown, Loch Leven, lake, and rainbow trout had been successfully established in Yellowstone Park and this was a "noteworthy success;" furthermore, "similar

services" were now in progress in Glacier Park." The establishment of an auxiliary station of the Bozeman hatchery at Glacier Park in 1920 would greatly speed up the "services" of non-native trout stocking.

In 1922 the Glacier Park substation received eggs from Yellowstone Lake, rainbow trout eggs from Meadow Creek (tributary Madison R.) Montana, and steelhead eggs from Oregon.

In 1923, besides 1,332,000 eggs from Yellowstone Lake, 1,389,700 eggs were taken in Glacier Park from an unspecified source (perhaps McDonald Lake?). A great effort was made to stock barren waters along the Continental Divide in 1923. I suspect that the eggs and fry derived from Park waters were not maintained separately from the Yellowstone Lake eggs and fry (they were all considered as "blackspotted" trout). Such mixing as likely occurred in the 1923 stocking, might explain the hybrid combinations found in some of the 1979 collections. The 1923 report expressed interest in Logging Lake as a source of "blackspotted" eggs because it was believed the trout spawned there in February. The 1925 report has two photos (Fig. 5,6) illustrating the use of pack horses to stock remote waters in the Park.

In 1926, 1,486,000 "blackspotted eggs were received from Montana Fish and Game; 350,000 of which were stocked in "more inaccessible headwaters of the Park." Golden trout were stocked in 1929 and 1930, evidently all were stocked into Lake Wurdeman. In 1929, a shipment of 89,500 "blackspotted" eggs were received from Nevada. The Nevada eggs were undoubtedly from Lahontan cutthroat trout of Pyramid Lake. Could there be a remote possibility that the Pyramid Lake cutthroat still persists in the Park?

I found no mention in the U.S. Fish Commission Reports of the effects

of the earlier (1912-1917) stocking, particularly in east slope waters, of non-native trouts by the Great Northern Railroad. The six predominantly rainbow trout specimens from Red Eagle Lake suggest that rainbow trout were already in Red Eagle Lake prior to its 1918 stocking with "blackspotted trout."

A further note of confusion concerning the origins of trout stocked in the Park is the fact that in some years most of the eggs were not received from federal hatcheries but from the Montana Fish and Game Department. Montana used many sources for both cutthroat and rainbow propagation. A letter from Mr. Emmett L. Colley, Hatchery Bureau Chief, Montana Department of Fish and Game, kindly provided some information on sources used in the propagation of cutthroat and rainbow trout from 1912 to 1930. Besides Yellowstone Lake, cutthroat eggs came from Georgetown Lake (stocked with cutthroat in 1913 and rainbows in 1912--thus a source of hybrids), Bitterroot and Ashley lakes, Flathead Co. (*S. c. lewisi*), and eggs were received in trade from Nevada (*S. c. henshawi* from Pyramid Lake) and Idaho (*S. c. bouvieri* from Henry's Lake). Mr. Colley's records indicate a stocking of 20,000 cutthroat from Bozeman hatchery into Red Eagle L. in 1916.

Also the Madison River and its tributary Meadow Creek were a major source of eggs for both Montana Fish and Game and federal hatchery at Bozeman. "Rainbow" trout eggs are recorded as taken from the Madison R. as early as 1913. The native trout of the Madison, *S. c. lewisi*, evidently hybridized and was largely replaced by rainbows quite early, but the U.S. Fish Commission Reports state "blackspotted" eggs were obtained from Meadow Creek in 1918, but in 1919 and 1920 Meadow Creek yielded more than 4,000,000 rainbow trout eggs. Obviously the species composition did not

change from cutthroat to rainbow in one generation. I assume that eggs taken from the Madison R. and Meadow Creek were hybrids, although they were listed as either cutthroat or rainbows. A large amount of eggs of Madison R. origin were stocked into waters of Glacier Park.

Thus, the known sources of trout stocked into Park water that could have contributed to the various hybrid combinations found today include, *S. c. bouvieri* (Yellowstone L., Henry's Lake), *S. c. bouvieri* x *S. gairdneri* (Georgetown Lake), *S. c. lewisi* x *S. gairdneri* (Madison R.), *S. c. lewisi* (from Park waters plus Bitterroot and Ashley lakes), and *S. c. henshawi* (Pyramid L., Nevada).

In the American Angler magazine, two issues of 1888 (13[2], 13[5]) contain articles by Tarlton Bean, Curator of Fishes at the U.S. National Museum. Bean reported receiving specimens of "Dolly Varden" from a stream between upper and lower St. Mary's Lake, pointing out that this was the easternmost limit of the range of the species then known. He also received specimens of lake trout from St. Mary's Lake and fish which "seem to be Clark's trout" (cutthroat). W. W. Crosby (1926), a former Park Service employee, wrote a book on western fishing. He recounted some angling experiences in the Park (no dates given, but obviously prior to 1926). He found Arrow Lake was "full of cutthroats" reported to reach 5 pounds, but he caught none over 2. On the east side of the Park, it is interesting to note that he caught few cutthroat trout, even at such an early period. He mentioned that Red Eagle Lake had "excellent cutthroat fishing" (perhaps the present hybrid population had more cutthroat influence 60 years ago). He mentioned that the rainbow trout was the most numerous fish he caught--catching them in Josephine Lake, McDermott

Lake, St. Mary's Lake, and Two Medicine Lake. Brook trout were caught in McDermott and Two Medicine Lake and probable rainbow x cutthroat hybrids from McDermott. Crosby also saw a "silver trout" (kokanee?) that he couldn't identify in Lake McDermott. Crosby's observations would indicate that the native cutthroat trout was largely gone from east slope waters and the present situation probably differs little from what was there 60 years ago.

LITERATURE CITED

Crosby, W. W. 1926. Some western fishing. Waverly Press, Baltimore:128pp.

2:30 PM

Dr Behnke,

Here's your Glacier N.P. paper - thanks alot for it & all the info. as well. I'll be in touch w/you as the summer of this project progresses.

Sincerely,

Tom Bohanan

ABSENCE OF BROOK TROUT HYBRIDIZATION IN BULL TROUT SAMPLES FROM GLACIER NATIONAL PARK

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INTRODUCTION

Hybridization between fish species in nature is common (Hubbs 1955; Schwartz 1972). The identification of naturally occurring hybrid fishes has usually relied upon the assumption that the hybrids are morphologically intermediate to the parental species. Although this asumption is widely accepted, it remains largely untested. The morphology of hybrid fishes has seldom been described when their hybrid status was known independent of their morphology.

Natural hybrids can be unambiguously identified without knowledge of their morphology when the hybridizing populations do not have the same alleles at electrophoretically detectable protein loci (Reinitz 1977; Solomon and Child 1978; Beland et al. 1981). First generation hybrids will possess alleles characteristic of both species for all loci at which the species are electrophoretically distinct.

We have reported naturally occurring hybrids between bull trout, *Salvelinus confluentus* (Cavender 1978), and brook trout, *Salvelinus fontinalis* throughout western Montana (Leary and Allendorf, MS). All of the hybrids that we have detected are male, first-generation hybrids. The absence of any back-cross individuals or second-generation hybrids indicates that the hybrids are almost certainly sterile.

The natural ranges of the bull trout and the brook trout do not overlap (MacCrimmon and Campbell 1969; Cavender 1978). These fishes have come into secondary contact, however, due to the human introduction of the brook trout into the natural range of the bull trout. Hybridization between these fishes has only ocasionally been suspected or described (Paetz and Nelson 1970; Cavender 1978). Our results, however, indicate that these fishes hybridize much more commonly than has been recognized.

The purpose of this report is an electrophoretic examination of bull trout collected from Glacier National Park to see if there is any evidence of hybridization with brook trout in these populations.

METHODS

Samples

A sample of brook trout (N=14) from a private hatchery and a sample of bull trout (N=21) from Whale Creek, Montana were collected as control samples. Whale Creek is a tributary to the North Fork of the Flathead River in the Upper Columbia River drainage. Brook trout are not known to occur in Whale Creek. Experimental samples were collected from Cracker Lake (N=29) and Isabel Lake (N=30) in Glacier National Park.

Electrophoresis

The products of 39 protein loci were analyzed in all the samples using horizontal starch gel electrophoresis (Utter et al. 1974). Electrophoretic buffers and staining methods were after Allendorf et al. (1977). The designation of loci and alleles followed the procedures outlined by Allendorf and Utter (1979). The designation of all alleles is relative to the common allele at the homologous locus in rainbow trout, Salmo gairdneri. We have adopted this convention to facilitate the electrophoretic comparison of the numerous salmonid species we have analyzed.

The following enzymes (EC number and loci in parantheses) were examined in muscle, liver, and eye homogenates: adenylate kinase (2.7.4.8; Adk), alcohol dehydrogenase (1.1.1.1.; Adh), aspartate aminotransferase (2.6.1.1; Aat-1,2,3,4,), creatine kinase (2.7.3.2; Ck-1,2,3), glucose phosphate isomerase (5.3.1.9; Gpi-1,2,3,), glyceraldehyde-3-phosphate dehydrogenase (1.2.1.12; Gap-3,4), glycerol-3-phosphate dehydrogenase (1.1.1.8; G3p-1,2), isocitrate dehydrogenase (1.1.1.42; Idh-1,2,3,4), lactate dehydrogenase (1.1.1.27; Ldh-1,2,3,4,5,), malate dehydrogenase (1.1.1.37: Mdh-1,2,3,4), malic enzyme (1.1.1.40; Me-1,2,3,4), phosphoglucomutase (2.7.5.1; Pgm-1,2); 6-phosphogluconate dehydrogenase (1.1.1.44; 6Pg), sorbital dehydrogenase (1.1.1.14; Sdh), superoxide dismutase (1.15.1.1; Sod), and xanthine dehydrogenase (1.2.3.2; Xdh).

RESULTS

Ten of the loci that we examined can be used to distinguish bull trout, brook trout, and their hybrids (Table 1). The bull trout and brook trout that we sampled do not share alleles at seven of these loci (Table 1). The common allele of one species occurs in only a low frequency (less than 0.10) in the other species for the other three loci.

All of the samples from Cracker and Isabel Lakes in Glacier National Park contained electrophoretic alleles known to be characteristic of bull trout.

Thus, there is no evidence of any hybridization with brook trout in any of these samples.

REFERENCES

Allendorf,F.W., N. Mitchell, M. Ryman, and G. Stahl. 1977. Isozyme loci in brown trout (Salmo trutta L.). Detection and interpretation from population data. Hereditas, 86:179-190.

Allendorf, F.W., and F.M. Utter. 1979. Population genetics. Pp. 407-454, in Fish Physiology Volume 8 (W.S. Hoar, D. J. Randall, and J. R. Brett, eds.). Academic Press, New York. 786pp.

Cavender, T.M. 1978, Taxonomy and distribution of bull trout, Salvelinus confluentus (Suckley), from the American Northwest. California Fish and Game, 64:139-174.

Hubbs, Carl L. 1955. Hybridization between fish species in nature. Systematic Zoology, 4:1-20.

MacCrimmon, H.R., and J. S. Campbell. 1969. World distribution of brook trout, Salvelinus fontinalis. Journal of the Fisheries Research Board of Canada, 26:1699-1725.

Paetz, M. J., and J. S. Nelson. 1970. The fishes of Alberta. Province of Alberta, Edmonton, 281 pp.

Ross, M. R., and T. M. Cavender. 1981. Morphological analyses of four experimental intergeneric cyprinid hybrid crosses. Copeia, 1981:377-387.

Schwartz, F. J. 1972. World literature of fish hybrids witrh an analysis by family, species, and hybrid. Publication of the Gulf Coast Research Laboratory Museum, 3:328 pp.

TABLE 1. LOCI THAT DIFFERENTIATE BULL TROUT, _SALVELINUS CONFLUENTUS_, AND BROOK TROUT, _SALVELINUS FONTINALIS_. ALLELIC MOBILITIES ARE RELATIVE TO THE COMMON ALLELE AT THE HOMOLOGOUS LOCUS IN RAINBOW TROUT, _SALMO GAIRDNERI_. WHEN INTRASPECIFIC VARIATION IS PRESENT AT A LOCUS THE MOST COMMON ALLELE IS LISTED FIRST. LOCI MARKED WITH AN ASTERISK (*) ARE DIAGNOSTIC LOCI.

Locus	Allelic mobilities	
	Bull trout	Brook trout
_Aat-1_*	100	54,191
_Ck-1_*	85	100
Idh-4	106,135	135,82
_Ldh-1_*	54	0
_Ldh-4_*	76	28
_Mdh-1_*	144	110
_Me-1_	110	56,110
_Me-4_	95,97	97
_Sdh_*	120,125	190
_Sod_*	177	97