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James Knude Andreasen for the degree of Doctor of Philosophy

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Title: SYSTEMATICS AND STATUS OF THE FAMILY CATOSTOMIDAE IN SOUTHERN OREGON

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Abstract approved: ______________________
Carl E. Bond

Suckers (Catostomidae) were formerly abundant in southern Oregon drainage basins. Three species, *Catostomus luxatus*, *C. snyderi* and *Chasmistes brevirostris*, occur in Upper Klamath Lake, but identification of these species has been difficult because of the presence of hybrid suckers. The once common sucker in the endorheic Warner Valley, *Catostomus warnerensis*, has been greatly reduced in numbers. *Catostomus occidentalis* lives in streams, lakes and reservoirs in the Goose Lake basin and is the only sucker in southern Oregon that has not declined in numbers.

This study was undertaken to clarify the systematic relationships and to determine characters useful in identifying the catostomids of southern Oregon. The nature and extent of hybridization between the species in Upper Klamath Lake was investigated and the population status of the species was determined.

The characteristics most useful in identifying the species are the number of gill rakers, head length, the number of lateral line scales, characteristics of the lips and head depth. Chasmistes have large numbers of long gill rakers, a terminal mouth with smooth reduced lips, a wide median notch separating the lobes of the lower lip and a series of osteological changes associated with movement of the mouth to a terminal position. Catostomus, except for C. luxatus, have inferior mouths with large fleshy lips; the lobes of the lower lip meet at the midline. In C. luxatus the lower lip is separated by a wide notch and the lips are covered with coarse papillae.

Some hybridization has occurred in Upper Klamath Lake between Catostomus snyderi and C. luxatus, and between C. snyderi and Chasmistes brevirostris, but introgression has not occurred and distinct species are still present. Extensive hybridization and introgression between C. snyderi and Chasmistes brevirostris has taken place in the Lost River, and brevirostris no longer exists there as a distinct species. Few C. luxatus were collected in the Lost River.

A unique species, Chasmistes stomias, was extirpated from Lake of the Woods, Oregon, by fish control operations in 1952.

Examination of historical data, field collections and creel census data all support the conclusion that Chasmistes brevirostris and Catostomus warnerensis should receive an endangered species status under the criteria of the Endangered Species Act of 1973.

Much of the decline in sucker numbers has been caused by the loss of spawning habitat due to the construction of irrigation diversion dams. To prevent further reduction in the abundance of these unique species, steps must be taken to restore access to adequate spawning habitat.

Systematics and Status of the Family Catostomidae in Southern Oregon

by

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INTRODUCTION

Fishes of the family Catostomidae, the suckers, occur commonly in Oregon. There are ten species recognized in the state but relatively little is known about their life histories or ecology. Prior studies of the sucker fauna of southern Oregon have been limited. Bond (1948) gave a brief report of suckers in consideration of management problems in Lake of the Woods, Klamath County, Oregon. Vincent (1968) captured a few suckers during his study of fish distribution in Upper Klamath Lake, but did not identify all specimens. One of the catostomids in Upper Klamath Lake and the Lost River, *Catostomus luxatus*, the Lost River sucker, is considered a game fish in Oregon and is subjected to a snag fishery during its spring spawning migration. Van Wormer (1955) wrote a popular article dealing with this fish, locally called "mullet." Coots (1965) reported the occurrence of *C. luxatus* and *Chasmistes brevirostris*, the shortnose sucker, in California. The distribution of these species in the Clear Lake drainage Siskiyou County, California was studied by Sonnevil (1972). In another unpublished report, Golden (1969) reviewed what was known of the life history of *C. luxatus* in Oregon.

The systematics of the family, especially the species in southern Oregon drainage basins, are not well understood. The identification of the species in the Klamath basin has been especially difficult, due, in part, to the presence of what appear to be hybrid suckers, and this has led to doubts about the applicability of the recorded information on C. luxatus. Generally, all the data collected from suckers in the Klamath drainage have been lumped together under the heading of "mullet" on the reports of the Oregon Wildlife Commission (Wendell Stout, pers. comm.). When I use the term "mullet" it will refer to this general usage, when the identification of the species is in doubt or is unspecified.

Three nominal genera have been reported from Upper Klamath Lake, Catostomus, Chasmistes and Deltistes. The latter has been placed into the synonymy of Catostomus (Miller, 1958), and is listed in that genus by Bailey et al. (1970), but Miller and Smith (1967) used Deltistes for both living and fossil suckers. Catostomus (depending on the status of Deltistes) is represented there by one or two species, luxatus and snyderi. The name Catostomus labiatus was used for a sucker from the area (Girard, 1857) but the name was later considered to be a synonym of C. occidentalis from the Sacramento drainage and the species from Upper Klamath Lake was described as Catostromus snyderi (Gilbert, 1898). Four species of Chasmistes have been described from Upper Klamath Lake. One of these, luxatus, was placed into Deltistes (Seale, 1896) and the others were considered to be representatives of one species, Chasmistes brevirostris (R. R. Miller, pers. comm. to C. E. Bond, 1952). There have been no life history studies of Chasmistes in Oregon.

The sucker in the Goose Lake basin was referred to Catostomus labiatus (Cope, 1884), but was later recognized as C. occidentalis, the common sucker of the Pit-Sacramento drainage system (Snyder, 1908).

In the three interconnected remnant lakes of the Warner Valley the once-common sucker was first referred to Catostomus tahoensis, the common sucker of the Lahontan drainage system (Cope, 1884). Later it was described as a separate species, C. warnerensis (Snyder, 1908). Collections in Warner Valley during 1953 yielded small numbers of suckers in each tributary stream, but no suckers were found at these same locations in the mid 1960's (Merton Bali, collection notes; Bond, pers. comm.).

Suckers were formerly abundant in Upper Klamath Lake and the Lost River and were a staple food item in the diets of local Indians and early settlers (Howe, 1968). Recent collections and conversations with local residents have led to the conclusion that the population levels of Chasmistes brevirostris and Catostomus luxatus are very low compared with early accounts of the species. Bond (1974) reviewed the current status of native Oregon fishes and concluded that Chasmistes brevirostris and Catostomus warnerensis were in danger of extinction.

The primary objectives of this study were: (1) to clarify the systematic relationships of the catostomids of southern Oregon, including the determination of those characteristics useful for identifying the various species and determination of the nature and extent of hybridization; (2) to determine the population status of the species for their consideration as rare or endangered species; (3) to determine the distribution of the species so that the future impact of man's activities can be estimated; (4) to utilize this information in developing management plans that might be applied to these species.

MATERIALS AND METHODS

Possible hybridization and the systematic relationships among the catostomids of southern Oregon were investigated by the examination of meristic and morphometric data, preparation and examination of skeletal material and electrophoretic analysis of tissue samples.

Fish examined for meristic counts and morphological measurements were from the fish collection of Oregon State University Department of Fisheries and Wildlife (OS), the California Academy of Sciences (CAS), the University of Michigan Museum of Zoology (UMMZ), the U. S. National Museum (USNM) and the Philadelphia Academy of Natural Sciences (ANSP).

Fishes collected at the locations indicated in Fig. 1 were examined during 1973 and 1974. Adults in the Sprague and Williamson rivers were collected primarily with snagging gear and by dip-netting fish out of the fish ladder at Chiloquin. An electroshocker mounted in a drift boat was used during one trip each year down the Sprague and Williamson rivers, a back pack shocker was used upstream on these rivers and on all the other creeks sampled (Fig. 1). An experimental gill net was set for 18 hours in Hart Lake and a New York style trap net was set for 18 hours in both Hart and Crump lakes. Suckers collected in the Lost River drainage in California-Oregon by

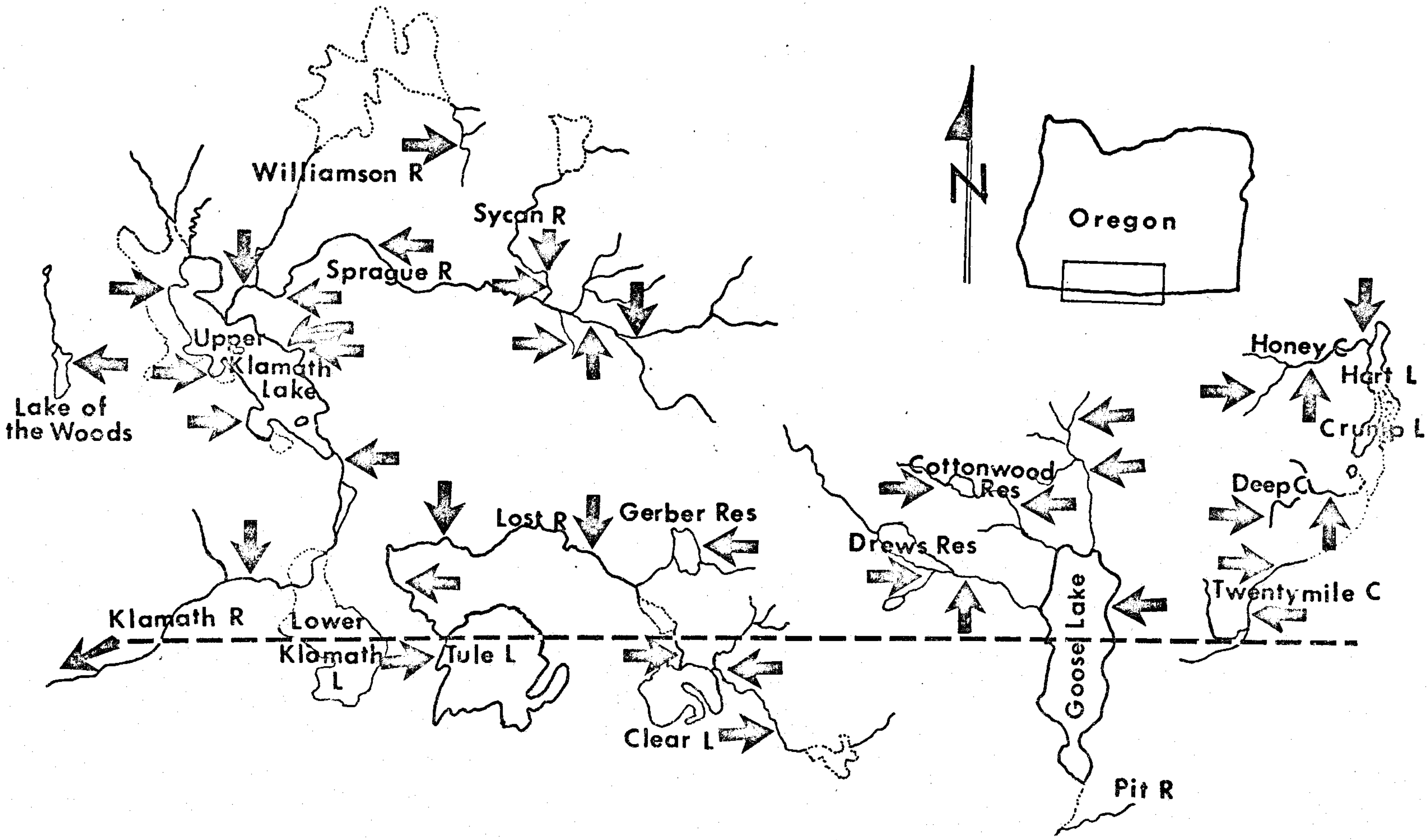


Fig. 1. Map of some southern Oregon drainage basins showing locations from which specimens were examined.

the (unofficial) Klamath Basin Threatened Fishes Recovery Team (Koch and Contreras, 1973a) were examined and compared with specimens from Upper Klamath Lake.

The methods of Hubbs and Lagler (1958) for making counts and measurements were utilized except as noted. The following 18 counts and measurements were recorded: standard length; head length; head depth; isthmus width - the width of the isthmus taken at the point of attachment of gill membranes; snout to occiput length - distance from most anterior point of head to start of squamation at occiput; snout length; caudal depth; occiput to dorsal length - distance from occiput, the start of squamation to origin of dorsal fin; pelvic fin origin to the caudal base - oblique distance from origin of pelvic fin to caudal fin base; dorsal fin base, anal fin base; number of dorsal rays; number of anal rays; lower lip papillae - number of rows of papillae between median notch separating lower lip and edge of lower lip; lateral line scale count; scale count above lateral line; scale count below lateral line; and gill raker count - total number of rakers (including rudiments) on anterior surface of first arch. Measurements were made using dial calipers or fine pointed dividers and a steel rule. A dissecting microscope was used in counting gill rakers and scales on small specimens.

The morphometric data were standardized for analysis by dividing each measurement by the standard length (SL) of the fish.

The resulting ratios and the meristic counts, were graphed against the standard length of the fish. The graphs showed essentially horizontal lines, indicating little allometric growth over the size range of fish used in this phase of the analysis, but allometry may have been a factor in treatment of *Catostomus warnerensis* and *C. snyderi.* Numerous small immature specimens from the Klamath drainage were examined for gillraker counts and lip characteristics.

The range, mean, standard deviation and standard error were computed for each character for each species. These were used to construct a graphical comparison of the data for each species following the method of Hubbs and Hubbs (1953). The graphs were drawn by a Cal-Comp plotter.

The standardized morphometric data and the meristic counts were evaluated using the UCLA BMD stepwise discriminant analysis program (Dixon, 1968). Discriminant analysis combines the mean and variance of several characters of a group into a linear combination (function) of variables that will distinguish that group from another group. The program compares the data for each object (fish specimen) to the data for each group and computes the probability of each fish belonging to each group. At each step in the program one variable is entered into the set of discriminating variables. The order in which the variables are selected is determined by the size of the F value, the multiple correlation coefficient and by which variable gives the greatest decrease in the ratio of within group to total variance (Dixon, 1968). The print-out lists each fish, the squared distance of that fish from the mean of each group, and the probability of that fish belonging to each species. The program also computes cannonical correlations, coefficients for canonical variables and plots the first and second canonical variable for each group to show graphically the dispersion of each group around its mean. After the objects are classified into groups, objects whose classification are unknown can be added to the analysis and the program will classify them and indicate their positions on the plot.

Skeletal material was prepared using dermestid beetles, laundry enzyme presoaker (Biz), KOH digestion and by dissection of preserved fish. Some small specimens were cleared and stained for examination using Taylor's enzyme (1967) technique. Some specimens were x-rayed using a Faxitrol radiographic inspection system and Polaroid Type 52 film. The nomenclature used for the discussion of osteology follows Weisel (1960).

Tissue samples (white muscle, liver, and the right eye lens) were removed in the field, placed together in a vial, and kept on ice. These were frozen within two to ten hours and stored at -15 C until analyzed by electrophoresis. The tissue samples were prepared in a standard manner and assayed on horizontal starch gels (Electro-starch) using standard techniques. Liver and white muscle were analyzed on a Ridgway buffer system (Ridgway et al., 1970). The liver samples were stained for tetrazolium oxidase (TO) lactate dehydrogenase (LDH) and esterases and the white muscle samples were stained for phosphohexoseisomerase (PHI) and phosphoglucomutase (PGM). The staining methods followed was that of Shaw and Presad (1970). White muscle samples were also analyzed on an amine-citrate buffer system and stained for malate dehydrogenase (MDH) (Clayton and Tretiak, 1972). The resulting stained gels were examined for species-specific banding patterns.

As an additional aid for evaluation of the extent of hybridization among the three species of catostomids in Upper Klamath Lake, cross breeding experiments were planned. An old hatchery trough and wire baskets were procured and set up in a spring near the Klamath hatchery of the Oregon Wildlife Commission. The trough was placed in the outflow of the spring in such a way that there was a steady flow of well oxygenated water through the baskets. A cheesecloth cover was arranged over the baskets to shade the eggs and to help control predation by birds. The first available ripe Catostomus luxatus were from the spring areas on the east side of Upper Klamath Lake. Eggs were stripped into a dry bucket and the milt from two males was expressed over the eggs and stirred gently by hand. The eggs were gently covered with lake water and after ten minutes, were gently rinsed with lake water. The water hardened eggs, which were adhesive and stuck together into one large mass, were transported to the hatchery site in a bucket filled with lake water and gracually acclimatized to the spring water. Some of the eggs from the large mass were gently separated and the individual eggs placed in one basket in a single layer. The other eggs were not separated but aggregations of about 300 to 1000 eggs were placed in another basket. The water temperature at the improvised hatchery was 6.6 C.

Observations on the natural history of the species were recorded in the field during 1973 and 1974. Data on the time of spawning, location of spawning sites, relative sex ratios, relative populations size and distribution of each species were gathered. During April, May and June, 1974, some specimens were examined for parasites following the method outlined by Millemann (1970).

The impact of the snag fishery for Catostomus luxatus ("mullet") on the other suckers was evaluated by means of a creel census conducted during the spring, 1974 spawning migration. Fishermen were interviewed each time fishing areas were visited and information concerning the number of anglers, total hours fished, the length, weight and sex of the fish, and the number of each species caught was recorded.

RESULTS

Meristics and Morphometrics

With only one exception, all of the suckers examined had seven anal rays. Because there was such minor variation in this character, it was omitted from the analysis.

The results of the graphical analysis of the meristic and morphological data are shown in Figs. 2 through 17. These graphs are based on data from 41 *Catostomus luxatus*, 84 *C. snyderi*, 31 *C. occidentalis*, 14 *C. warnerensis*, 59 *Chasmistes brevirostris* and 30 specimens of a now extinct *Chasmistes* species from Lake of the Woods regarded to be *C. stomias*.

These graphs show the mean (vertical bar), one standard deviation (open rectangle plus one half of the hatched rectangle), two standard errors of the mean (hatched rectangle on each side of the mean) and the range (the base line) for each character for each species. The standard deviation indicates the dispersion of the measurements and two standard errors indicates the reliability of the measurements. Non-overlap of the standard deviations indicates that the samples are separable based on that character. The separate plots show overlap between species for most characters, indicating that the species are similar morphologically. However, the following characters show significant differences among the species, head

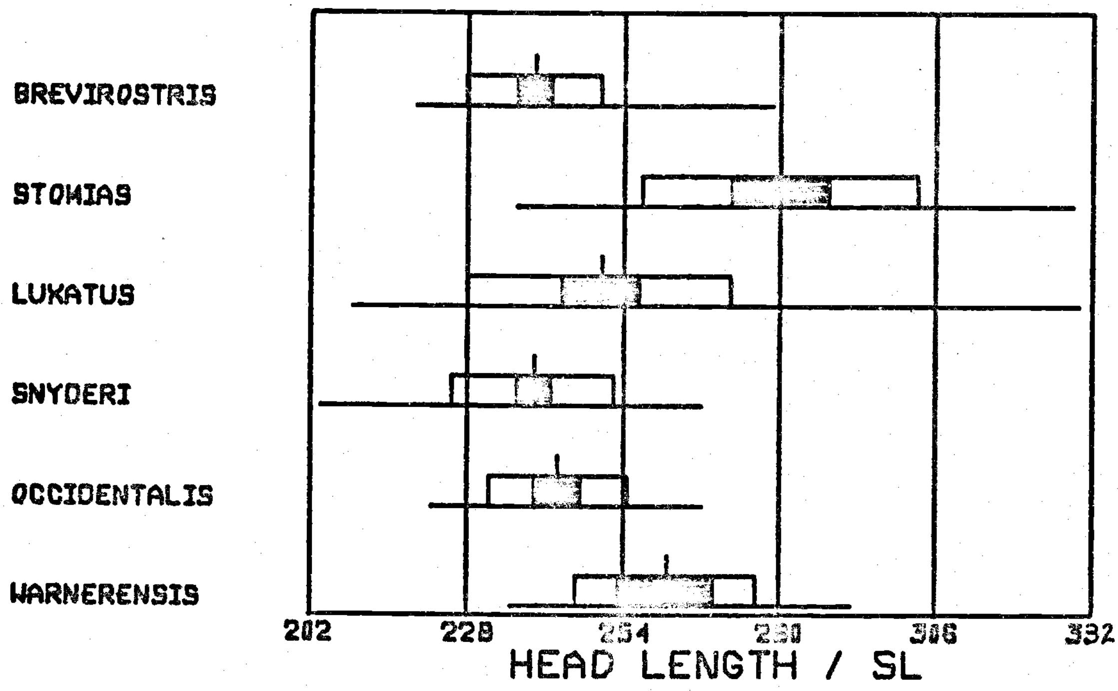


Fig. 2. Comparison of proportional head length measurements of southern Oregon catostomids. See page 12 for explanation of figures.

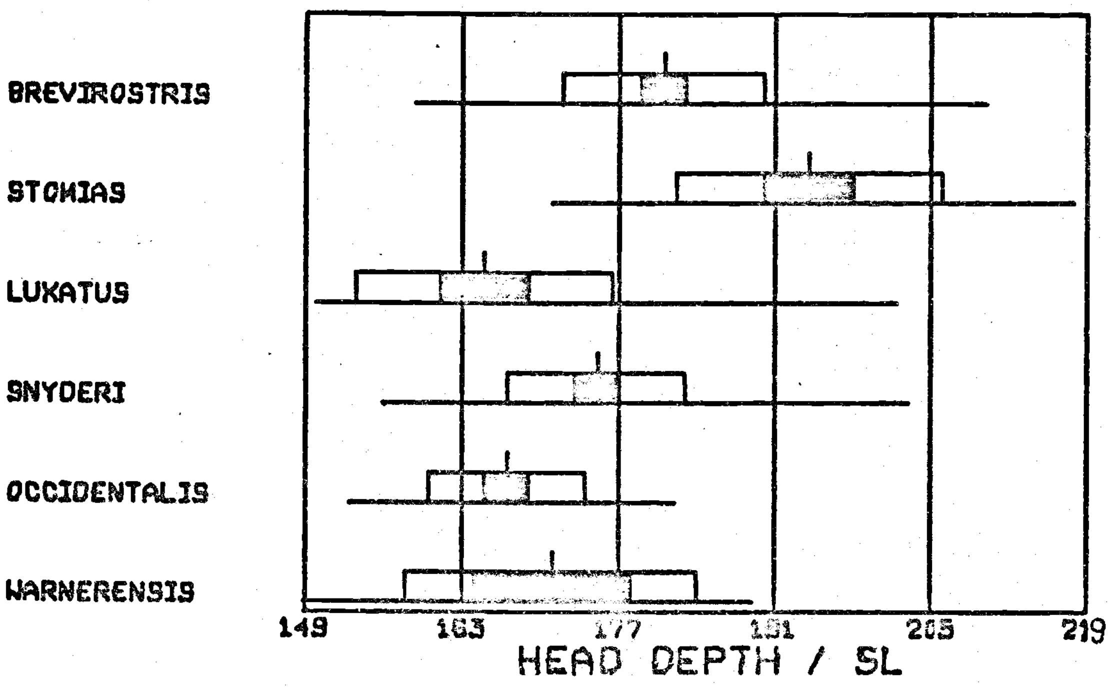


Fig. 3. Comparison of proportional head depth measurements of southern Oregon catostomids.

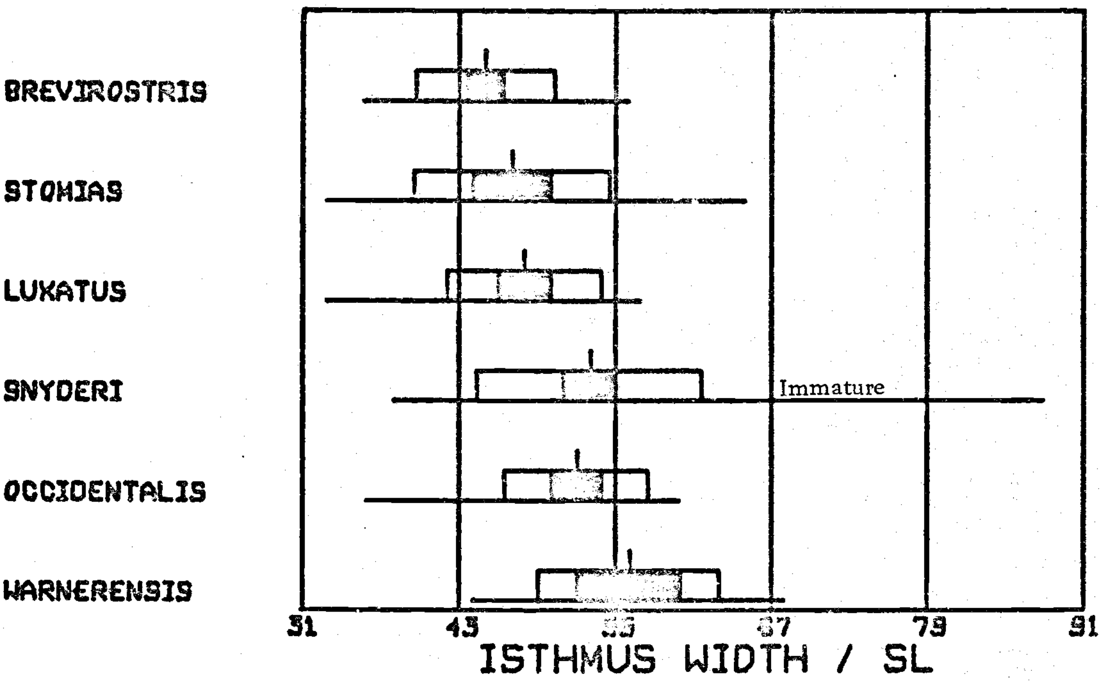


Fig. 4. Comparison of proportional isthmus width measurements of southern Oregon catostomids.

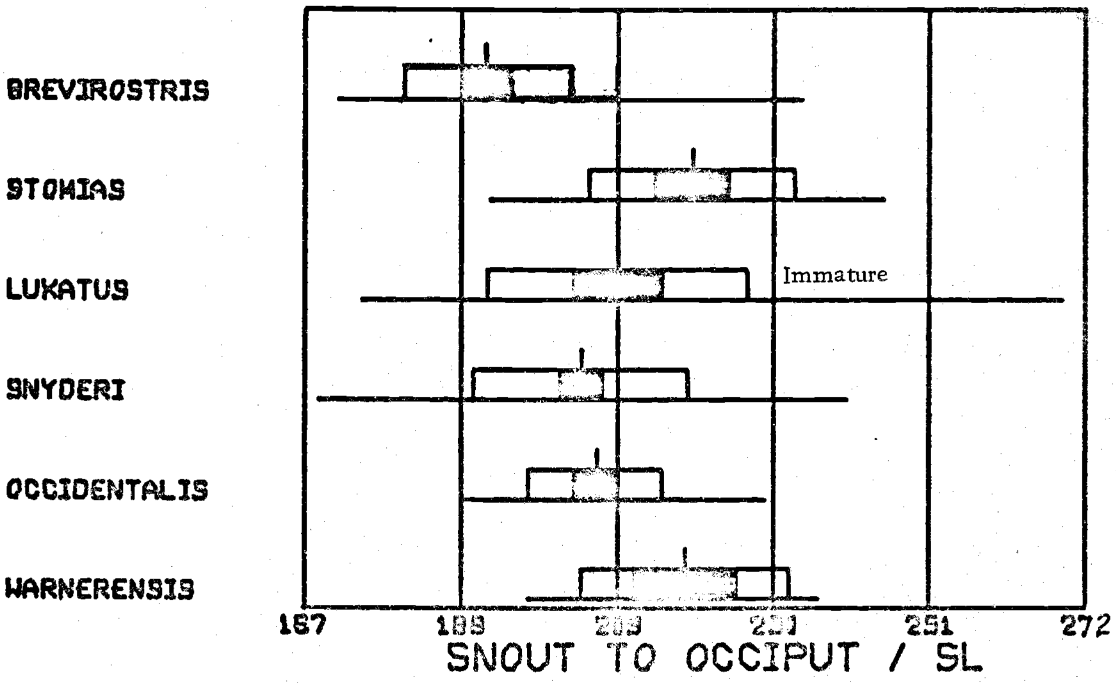


Fig. 5. Comparison of proportional snout to occiput measurements of sothern Oregon catostomids.

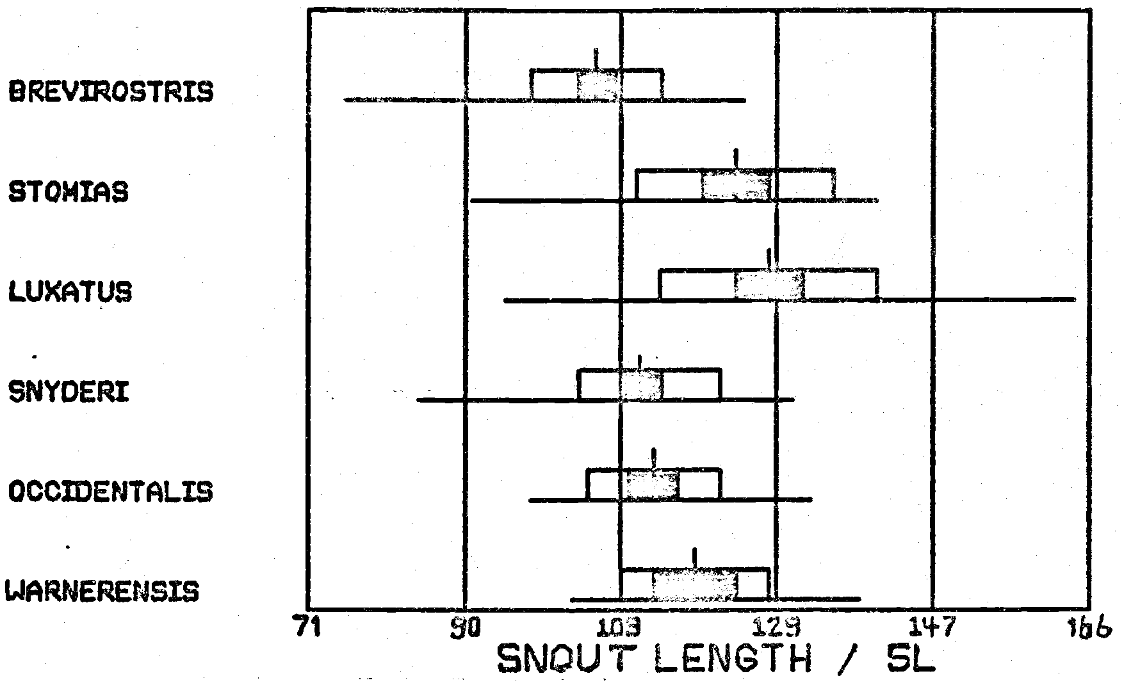


Fig. 6. Comparison of proportional snout length measurements of southern Oregon catostomids.

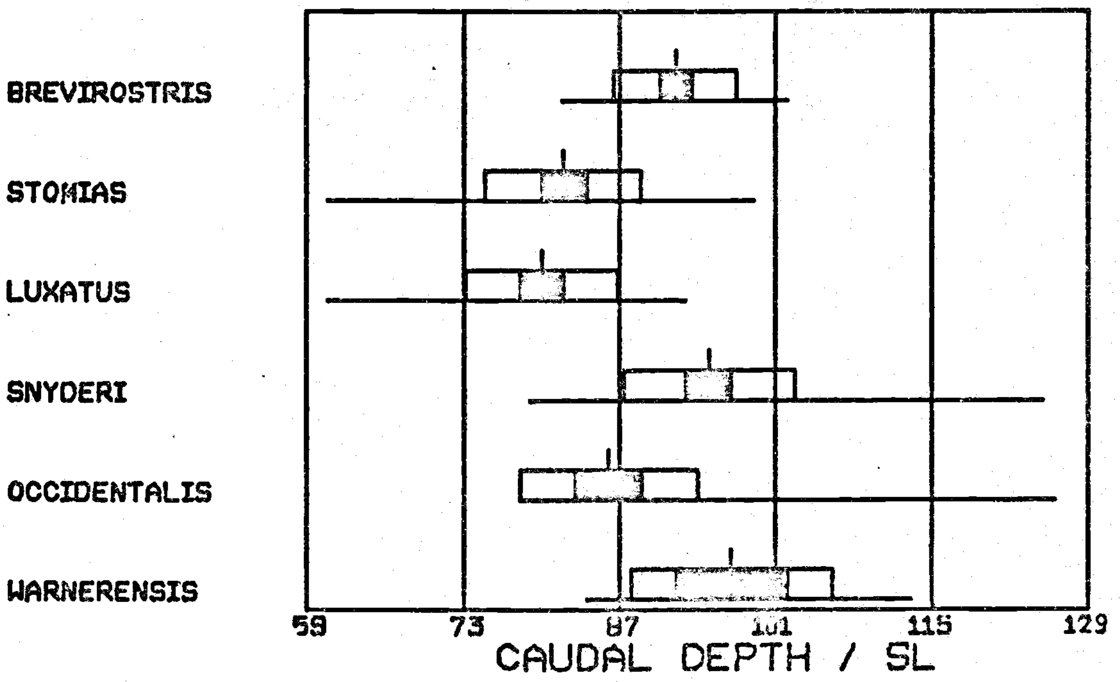


Fig. 7. Comparison of proportional caudal depth measurements of southern Oregon catostomids.

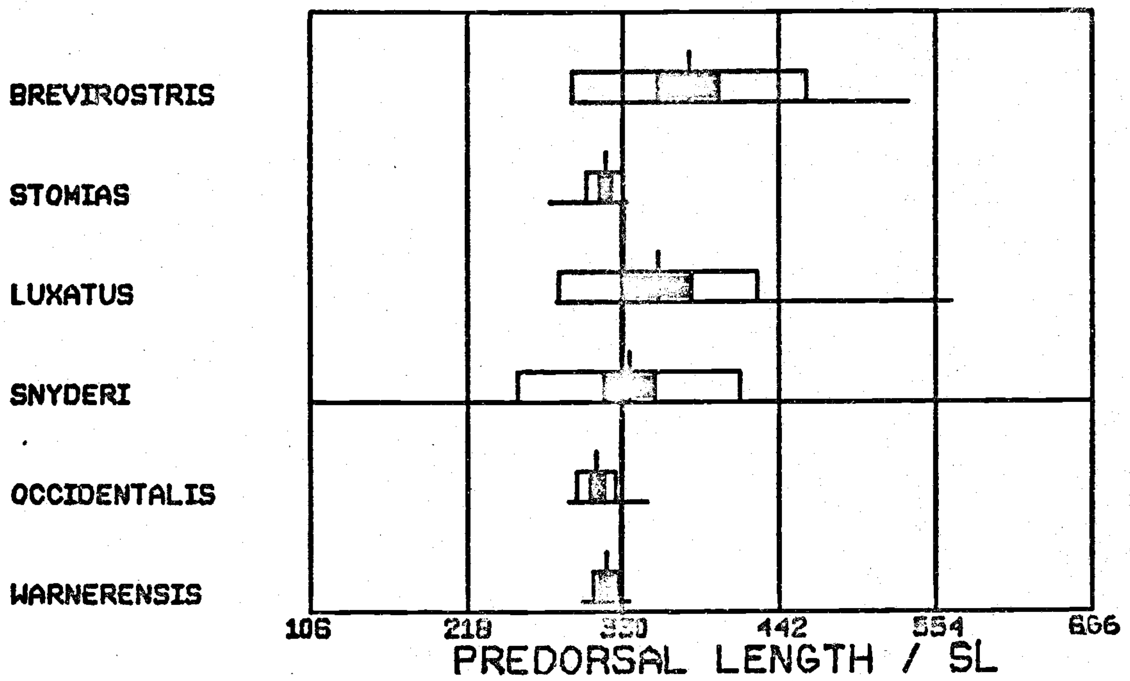


Fig. 8. Comparison of proportional predorsal length measurements of southern Oregon catostomids.

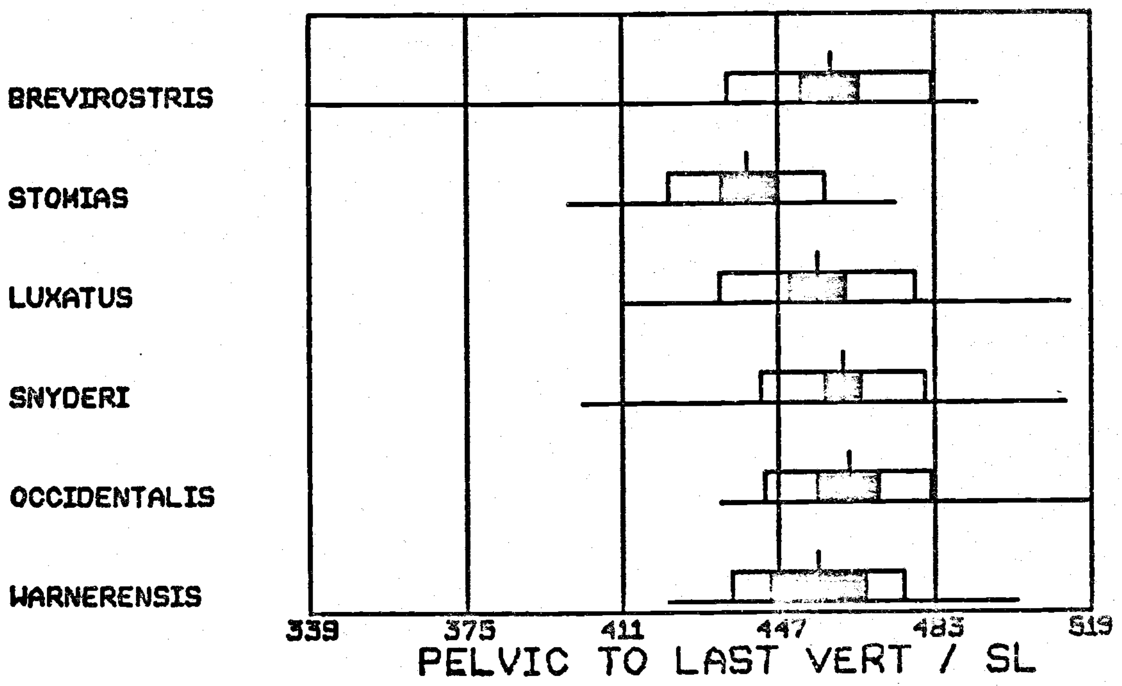


Fig. 9. Comparison of proportional pelvic to last vertebra measurements of southern Oregon catostomids.

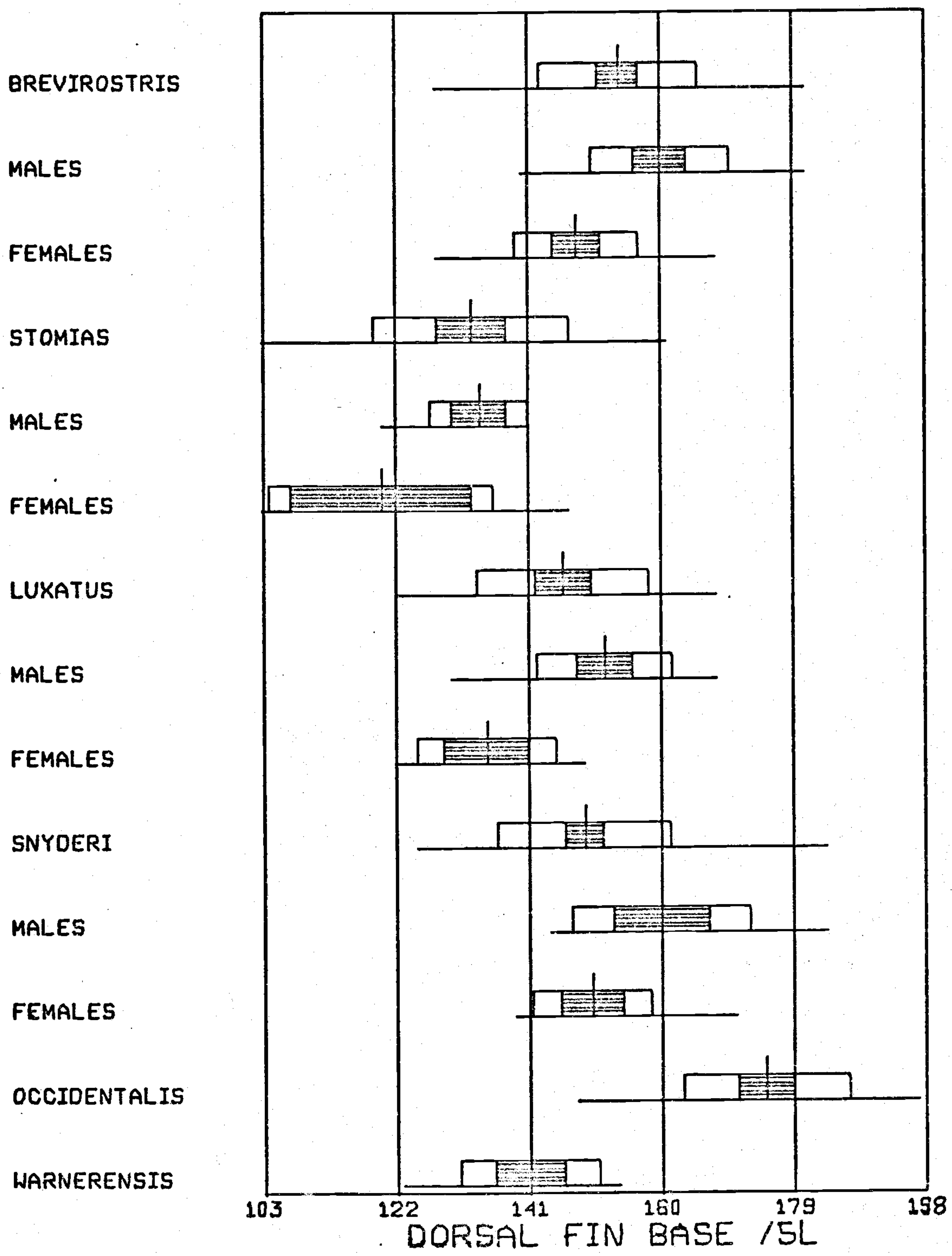


Fig. 10. Comparison of proportional dorsal fin base measurements for males and females of southern Oregon catostomids.

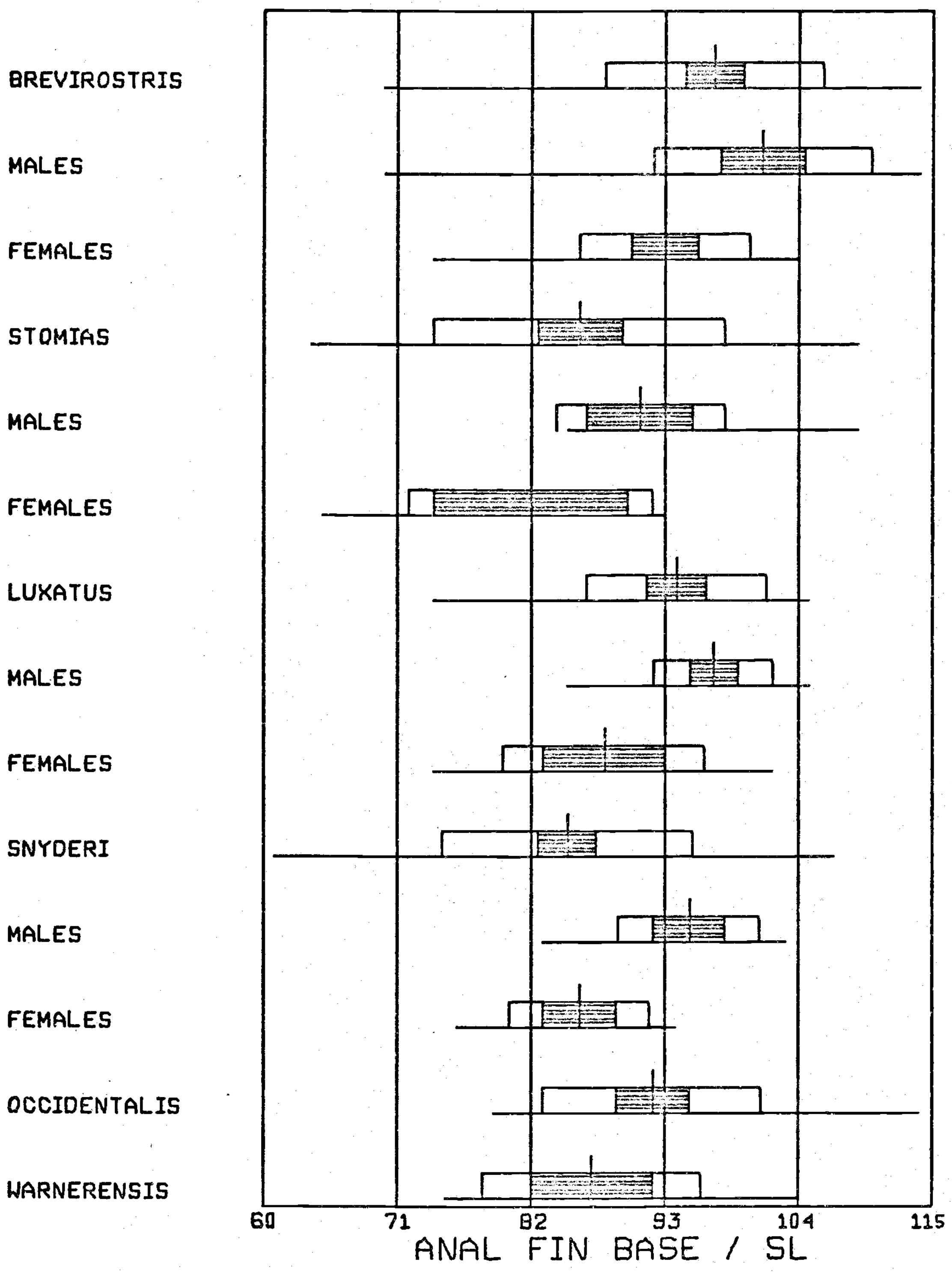


Fig. 11. Comparison of proportional anal fin base measurements for males and females of southern Oregon catostomids.

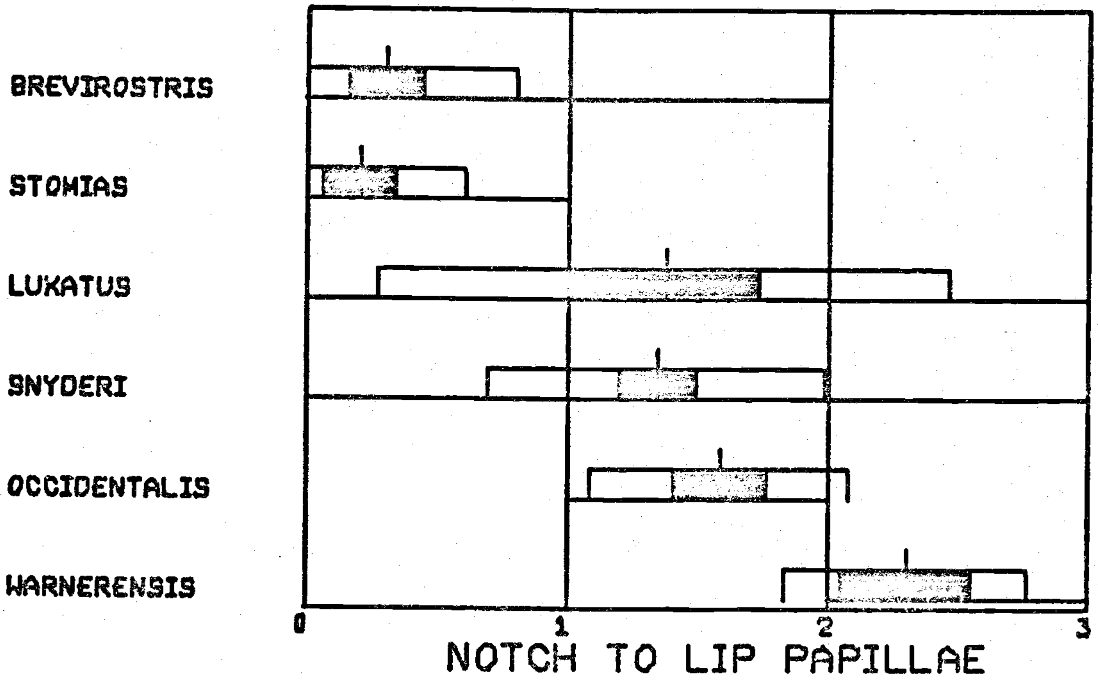


Fig. 12. Comparison of the number of papillae between the notch in the lower lip and the edge of the lower lip of southern Oregon catostomids.

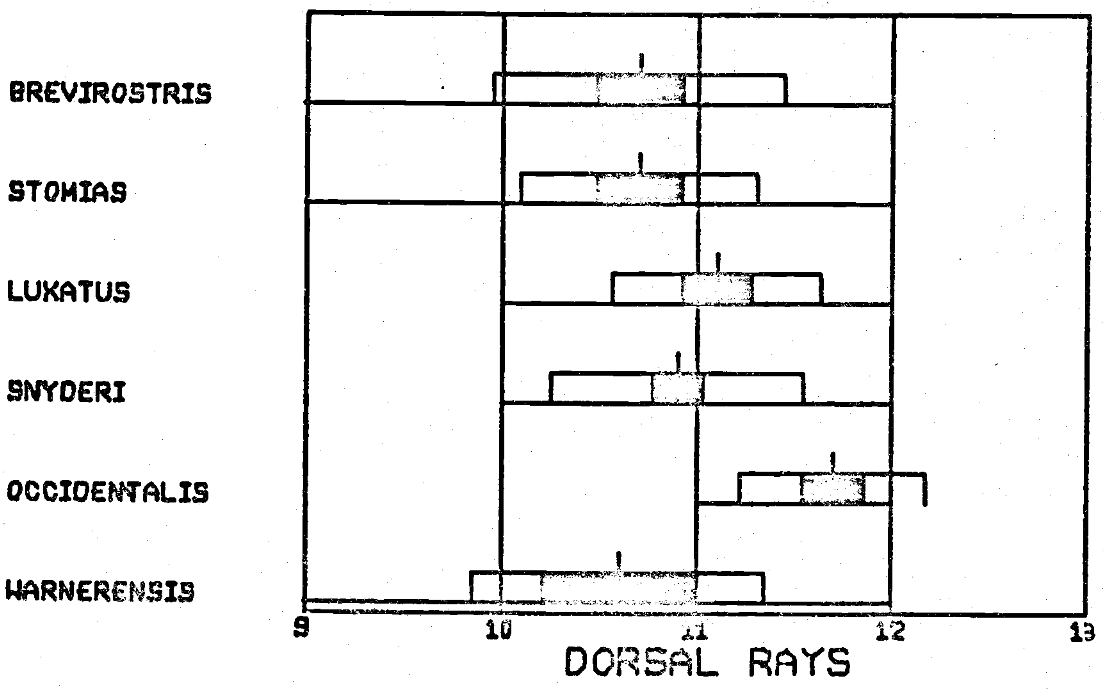


Fig. 13. Comparison of the number of dorsal fin rays of southern Oregon catostomids.

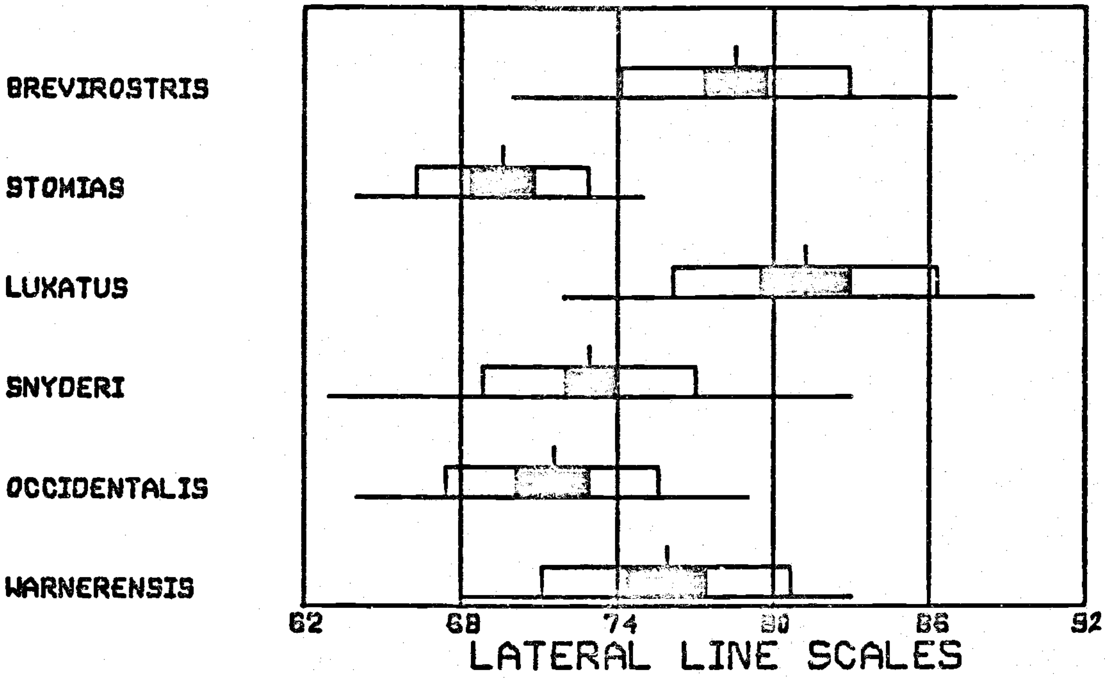


Fig. 14. Comparison of the number of scales in the lateral line of southern Oregon catostomids.

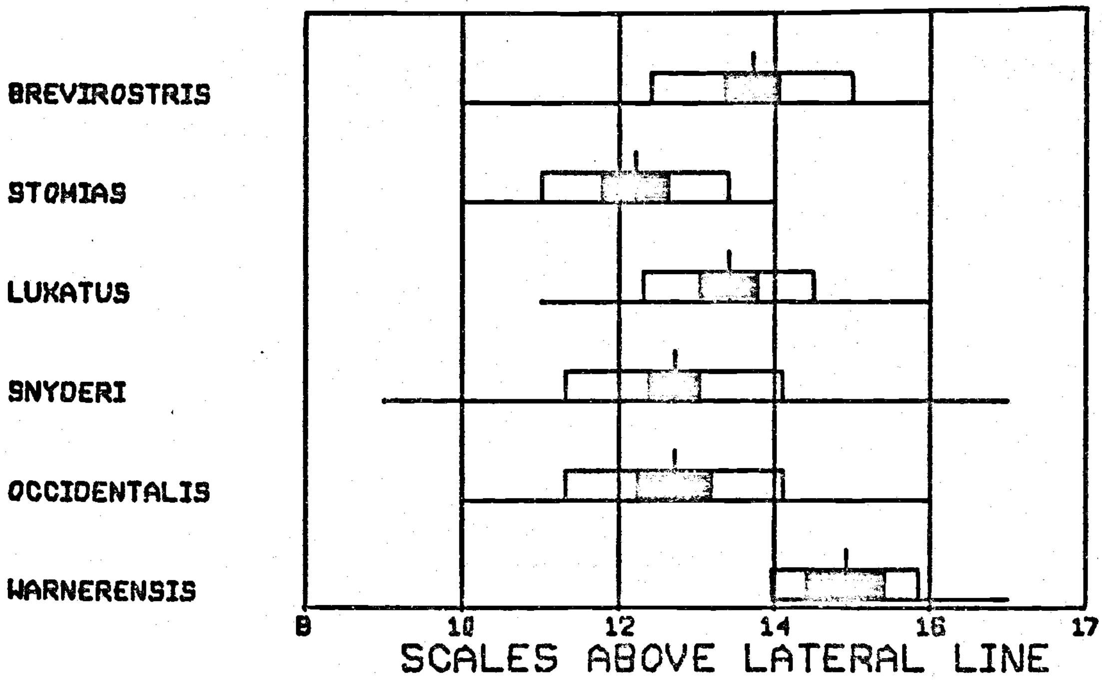


Fig. 15. Comparison of the number of scales above the lateral line of southern Oregon catostomids.

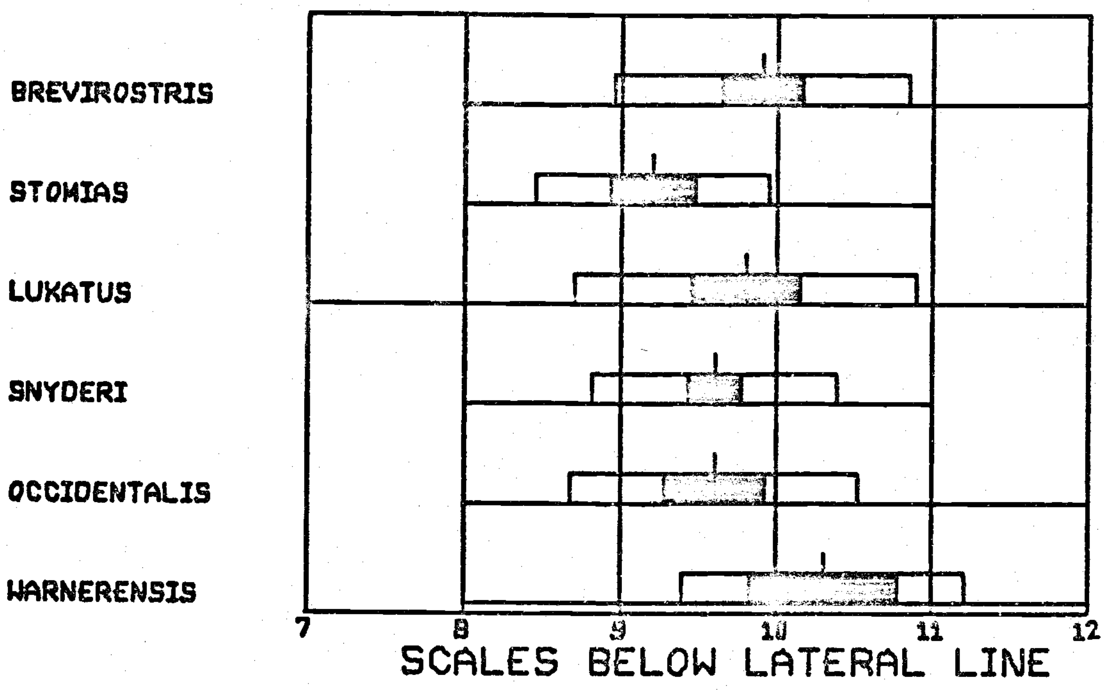


Fig. 16. Comparison of the number of scales below the lateral line of southern Oregon catostomids.

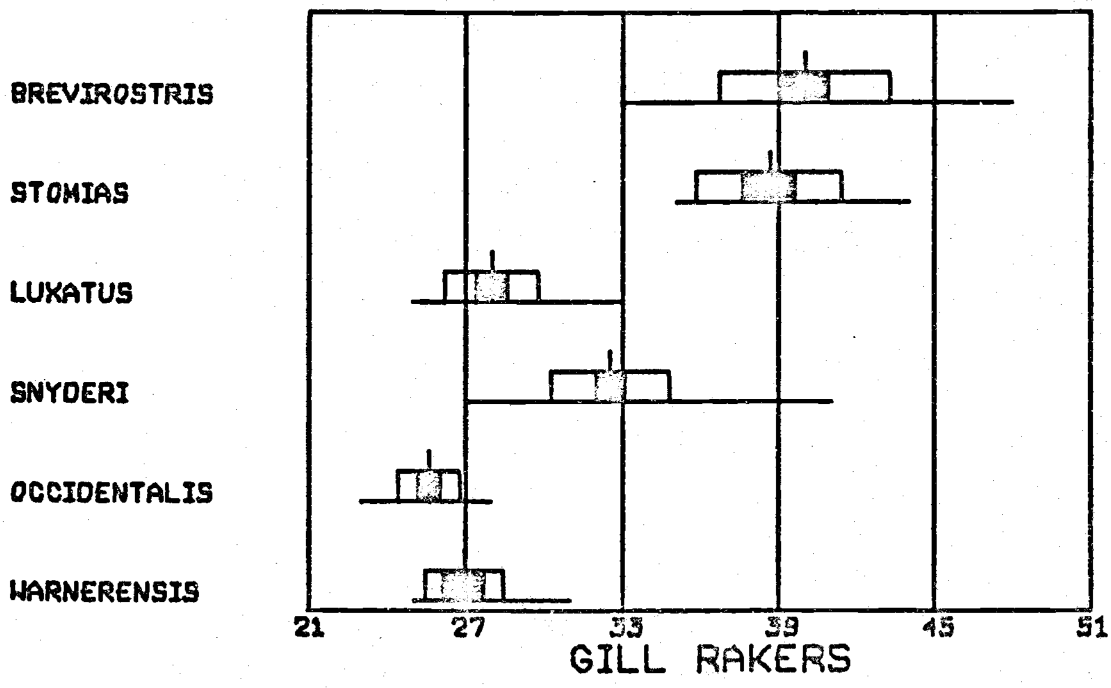


Fig. 17. Comparison of the number of gill rakers on the anterior surface of the first gill arch of southern Oregon catostomids.

length, head depth, snout to occiput length, lip papillae, lateral line scale count and the number of gill rakers.

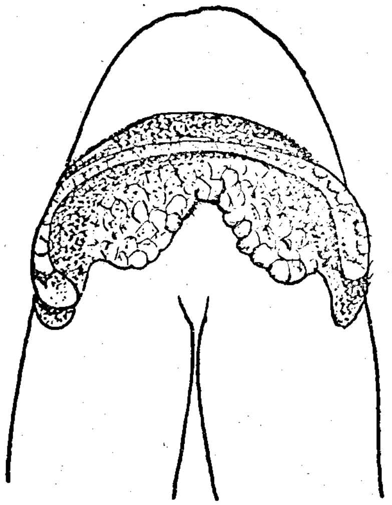
The head length (Fig. 2) of Chasmistes stomias is significantly longer than that of Chasmistes brevirostris but shows some overlap with Catostomus luxatus and Catostomus warnerensis. The Chasmistes species are not distinguishable by head depth, but they differ from Catostomus in this character (Fig. 3). There is some indication that Chasmistes have a smaller distance across the isthmus (Fig. 4) than do Catostomus but the difference between them is not great enough to be of use in distinguishing the species. There is considerable overlap in snout to occiput length (Fig. 5), but as shown with head length, stomias and warnerensis have longer heads than the other species. Snout length (Fig. 6) is greatest in luxatus and stomias and least in brevirostris while the other species are intermediate. There is little overlap between the Chasmistes species in caudal depth (Fig. 7) and luxatus has a narrower peduncle than both snyderi and warnerensis with occidentalis being intermediate. The number of dorsal rays shows a large degree of overlap, C. occidentalis has the smallest range and a higher average number (Fig. 13). C. warnerensis has the greatest average number of scales above (Fig. 15) and below (Fig. 16) the lateral line.

Sexual dimorphism is shown in the length of the anal and dorsal fin base. The ratio of these measurements to SL is larger in males of the four species in which this was examined (Figs. 10 and 11). Although not statistically analyzed, it is obvious that the anal fin is much longer and the pelvic fins are longer and broader in males of these species, similar to the dimorphism noted in Catostomus commersoni (Spoor, 1935).

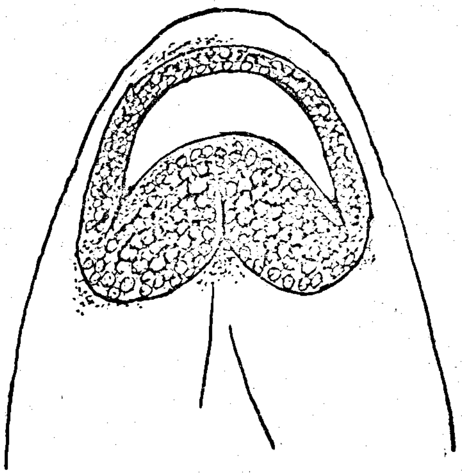
The two Chasmistes species are distinct from Catostomus snyderi, occidentalis and warnerensis in the number of papillae between the lower lip notch and edge of the lower lip, but overlap with some specimens of luxatus (Fig. 12). Chasmistes species have very smooth lips with no papillae while Catostomus species have the lips covered with coarse papillae. Features of the mouths of the Upper Klamath Lake species are illustrated in Fig. 18.

The six species can be divided into two groups based on lateral line scale counts. Chasmistes brevirostris, Catostomus luxatus and C. warnerensis have a mean greater than 74 while the mean counts of the other species are less than 74 (Fig. 14).

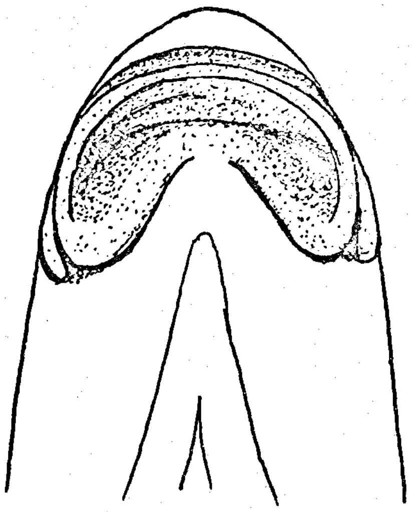
The difference in gill raker count is the most discriminating characteristic among the species (Fig. 17). Chasmistes species have large numbers of closely spaced gill rakers with dense processes on the free edges while Catostomus species have lower counts with C. occidentalis having the fewest number. The rakers of C. luxatus are usually triangular in shape, widely spaced and have very smooth edges.



Catostomus luxatus



Catostomus snyderi



Chastmistes brevirostris

Fig. 18. Differences in the morphology of the mouth and lips of catostomids from Upper Klamath Lake, Oregon. Drawn by Michael Barton.

The large range of measurements for some characters may be due to the method of preservation of the older specimens. Fleshy parts, especially the snout, were often shrunken, or the specimens had been crowded into bottles head down. Both of these conditions made accurate measurements difficult. C. snyderi is a highly variable species but the extremely wide range of some measurements may have been due to other factors. Large specimens of C. snyderi that were immature or that could not be sexed were excluded when species were analyzed for allometric growth and sexual dimorphism. When it was determined that there was no allometric growth or sexual dimorphism for most characters, these specimens were then included in the analysis. Later re-examination showed that these specimens were at the extremes of the ranges for some characters thus extending the range of measurements beyond that usually observed in mature specimens. This did not affect the discriminant analysis of C. snyderi.

Using all 16 of the meristic and morphometric variables the discriminant analysis program correctly classified the following percentage of the specimens of each species: luxatus 88, snyderi 91, occidentalis 93, warnerensis 64, brevirostris 93 and stomias 90. Misclassification of nearly 40% of the warnerensis specimens is probably due to the inclusion of immature fish in the analysis. The classification matrix is shown in Table 1. The order in which the variables entered the analysis and the percent of the dispersion accounted for at each step are shown in Table 2. The plot of the first canonical variable against the second shows good separation of the species (Fig. 19). Another examination of the data using only the first six variables to enter the analysis resulted in an eight percent decrease in the correct classification for each species, however, the plot of the canonical variables still showed good separation of the species.

Table 1. Classification matrix, showing number of specimens of each species that were classified correctly by the discriminant analysis program.

Species	Number of specimens classified into each species					
	luxatus	snyderi	occidentalis	warnerensis	brevirostris	stomias
luxatus	36	1	3	0	0	1
snyderi	3	77	2	0	2	0
occidentalis	1	1	29	0	0	0
warnerensis	4	1	0	9	0	0
brevirostris	0	3	0	0	55	1
stomias	0	0	0	0	3	27

Table 2. Morphometric or meristic variable added at each step in the discriminating function and the cumulative percentage of dispersion accounted for with the addition of that variable.

Step	Variable added	Cumulative percent of the total dispersion accounted for
1	Number of gill rakers	57.52
2	Lateral line scale count	73.11
3	Length of dorsal fin base as proportion of SL	85.70
4	Caudal peduncle depth as proportion of SL	94.59
5	Head length as proportion of SL	100
6	Width of isthmus as proportion of SL	100
7	Head depth as proportion of SL	100
8	Predorsal length as proportion of SL	100
9	Snout length as proportion of SL	100
10	Number of papillae between notch and lip	100
11	Number of scales above lateral line	100
12	Length of anal fin base as proportion of SL	100
13	Snout to occiput distance as proportion of SL	100
14	Number of dorsal fin rays	100
15	Number of scales below lateral line	100
16	Distance from pelvic fin origin to last vertebrae as proportion of SL	100

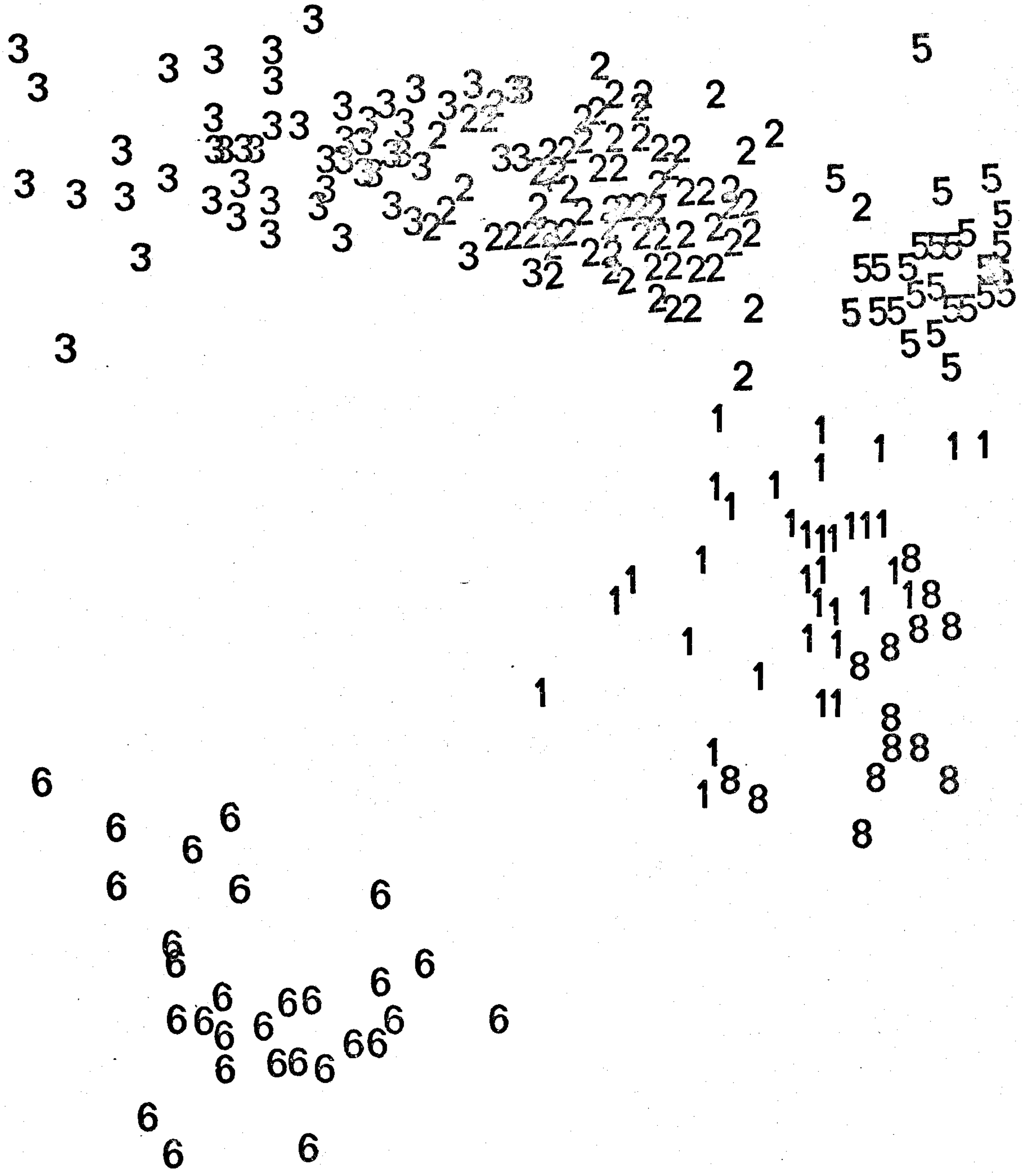


Fig. 19. Plot of first and second canonical variables showing distribution of the species in two dimensional space. 1 = Catostomus luxatus, 2 = C. snyderi, 3 = Chasmistes brevirostris, 5 = C. occidentalis, 6 = Chasmistes stomias, 8 = C. warnerensis.

One reason for using discriminant analysis was to determine the occurrence and extent of hybridization between the species in Upper Klamath Lake. Because Catostomus occidentalis and C. warnerensis are geographically separated from each other and from the other species, natural hybridization involving them is not possible. The inclusion of these species was probably burdening the analysis and masking some relationships (G. R. Smith, UMMZ, pers. comm.) so data from these species were excluded from all subsequent runs. It is assumed that if a specimen is not in a species cluster but is in an intermediate position between two clusters, then the conclusion that the specimen is a hybrid is justified. The program was executed again with data from Catostomus luxatus, C. snyderi, Chasmistes brevirostris and Chasmistes stomias. Specimens from Lake of the Woods that appeared to be intermediate between C. stomias and C. snyderi were entered as unknowns. The position of the unknown fish on the resulting plot (coded W on Fig. 20) confirms their identification as hybrids. The same data from Upper Klamath Lake were utilized for another run in which specimens from Fig. 19 that were intermediate between C. brevirostris and C. snyderi, and other fish from Clear Lake, the Lost River and the Klamath River, were entered as unknowns. The hybrid nature of some of the Clear Lake-Lost River fish is shown by their position between the snyderi and brevirostris clusters (coded B on Fig. 21). Most of the suspected

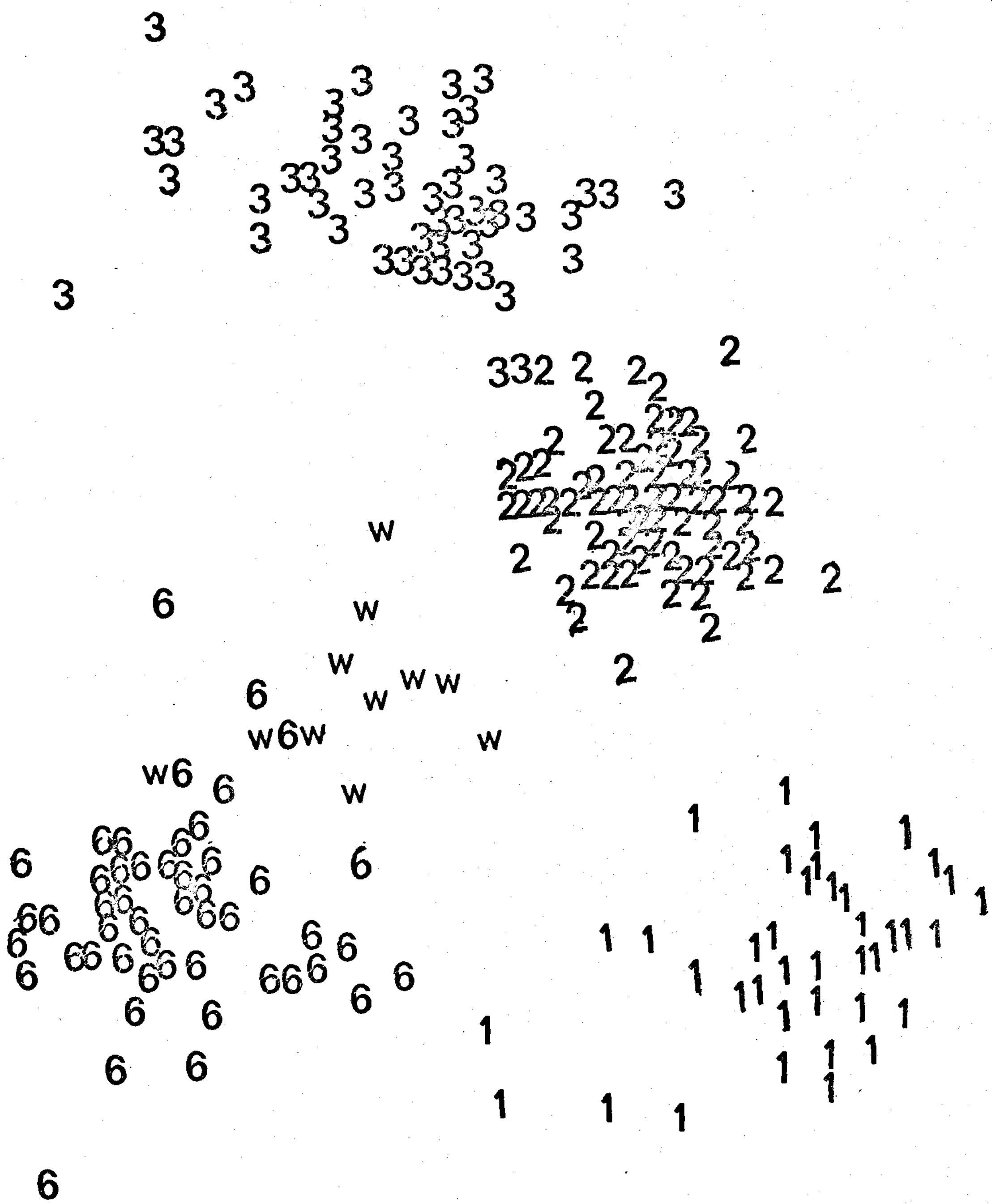


Fig. 20. Plot of first and second canonical variables, W's indicate the position of hybrids from Lake of the Woods.

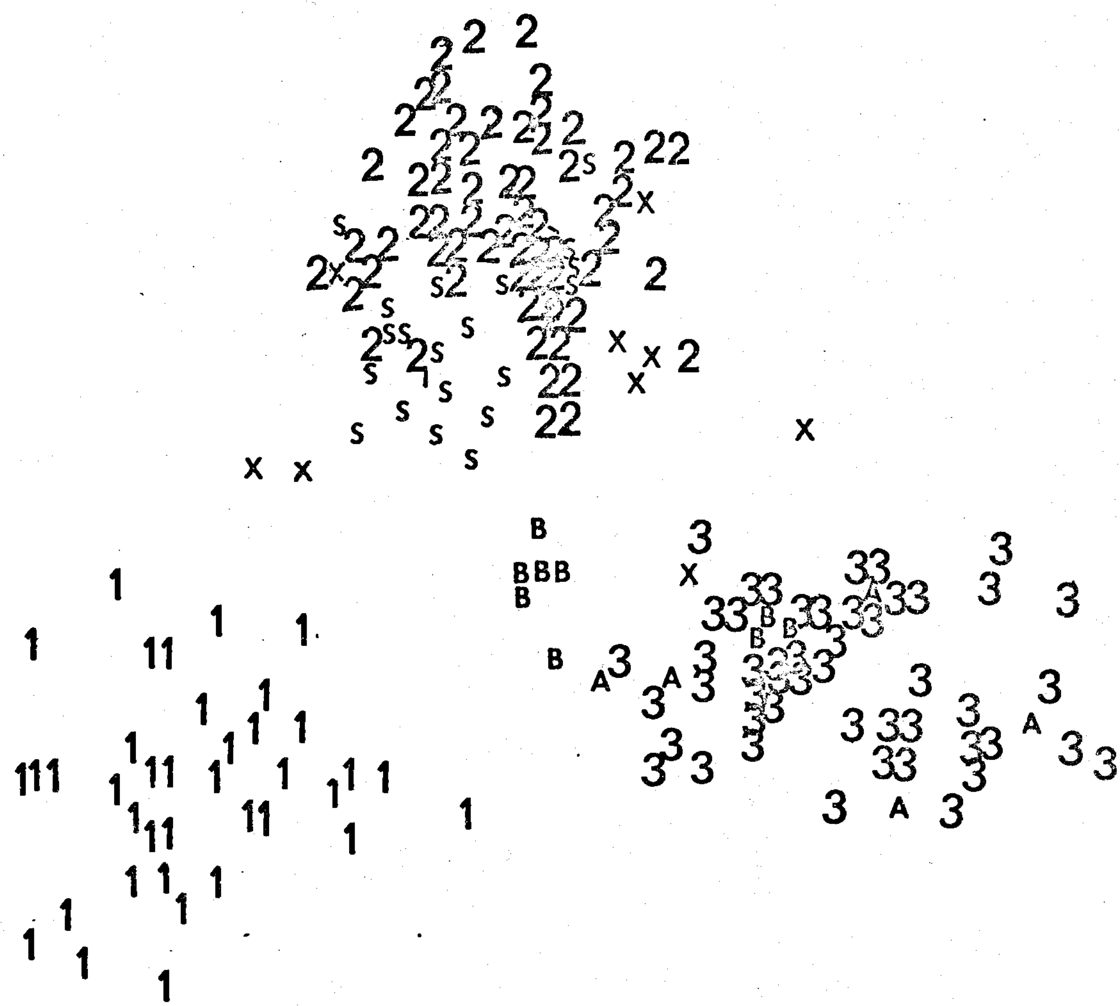


Fig. 21. Plot of first and second canonical variables showing position of fish entered into the discriminant program as unknowns 1 = luxatus, 2 = snyderi, 3 = brevirostris; 1, 2, 3, all from Upper Klamath Lake. A = brevirostris from Klamath River, S = snyderi from Lost River, B = "brevirostris-like" from Lost River, X = suspected hybrids from Upper Klamath Lake.

hybrids (coded X) from Upper Klamath Lake were grouped with the snyderi cluster, one with the brevirostris cluster and one was intermediate between snyderi and brevirostris. Two of the specimens appear to be intermediate between luxatus and snyderi. Both of these fish had 29 gill rakers, typical of C. luxatus, but were similar to C. snyderi in other measurements.

Osteology

The morphology of some cranial bones from the species in Upper Klamath Lake is illustrated in Figs. 22, 23 and 24. Catostomus snyderi represents a basic, generalized type of sucker, similar to C. macrocheilus (Weisel, 1960). In C. luxatus the bones are heavier and the snout elongated. Chasmistes brevirostris has a series of changes associated with the movement of the mouth to a terminal position. In snyderi the ratio of the width of the premaxillary to the height is 1.2, in luxatus 1.5, and in brevirostris it is 0.9 (Fig. 22). The maxillae of the three species are very different (Fig. 22), especially in the development of the ventral keel and anteromedian process (terminology of Miller and Smith, 1967). The prevomer is elongate in luxatus and short in brevirostris in comparison with snyderi. The ratio of the width to length of the supraethmoid is 1.9 for snyderi, 1.5 for luxatus and 2.3 for brevirostris (Fig. 23), again illustrating the changes in brevirostris associated

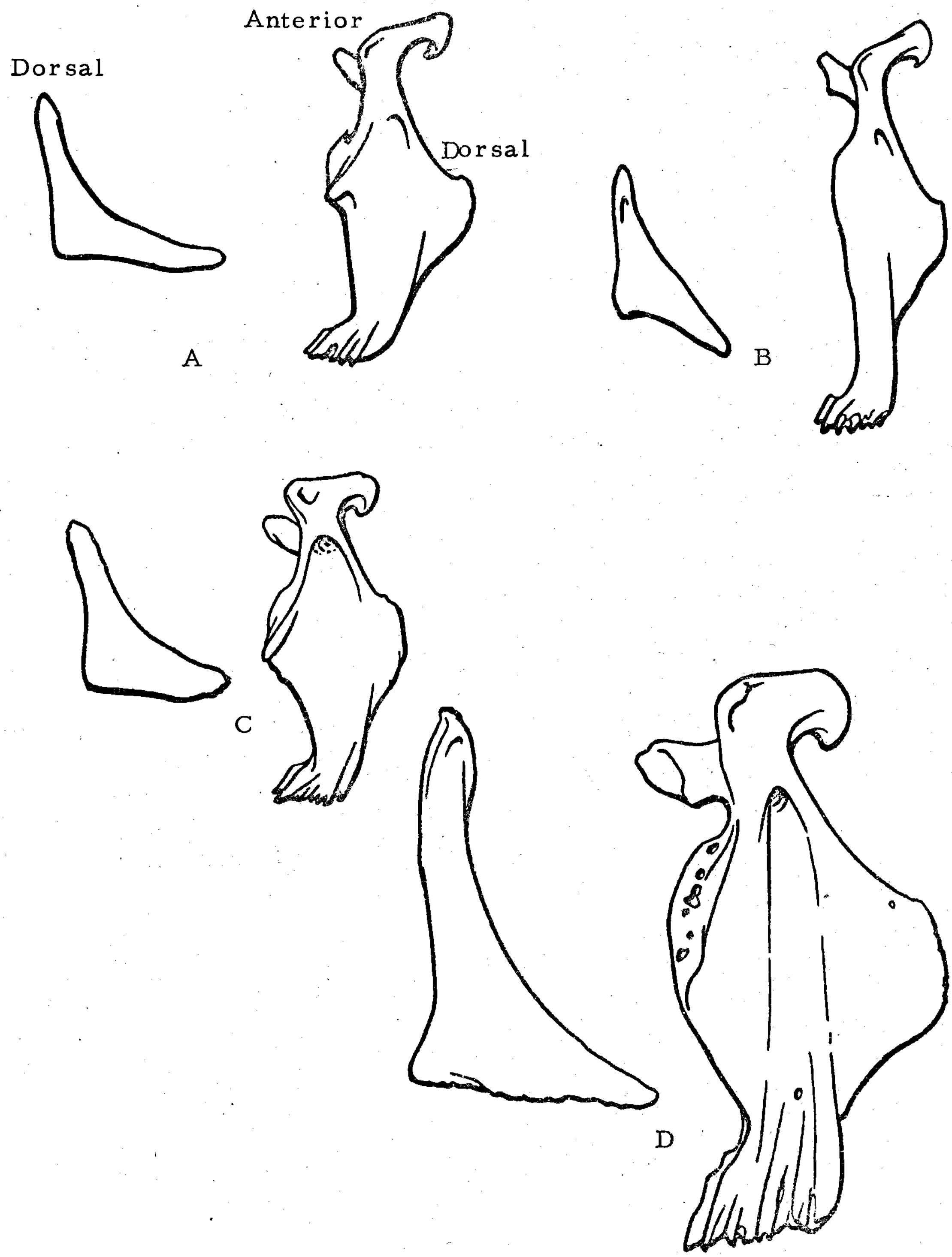


Fig. 22. Comparison of left premaxillary and maxillary bones. A. Chasmistes brevirostris, OS5097. B. C. stomias, OS5098. C. Catostomus snyderi, OS5096. D. C. luxatus, OS5095. Drawn by Bonnie Hall.

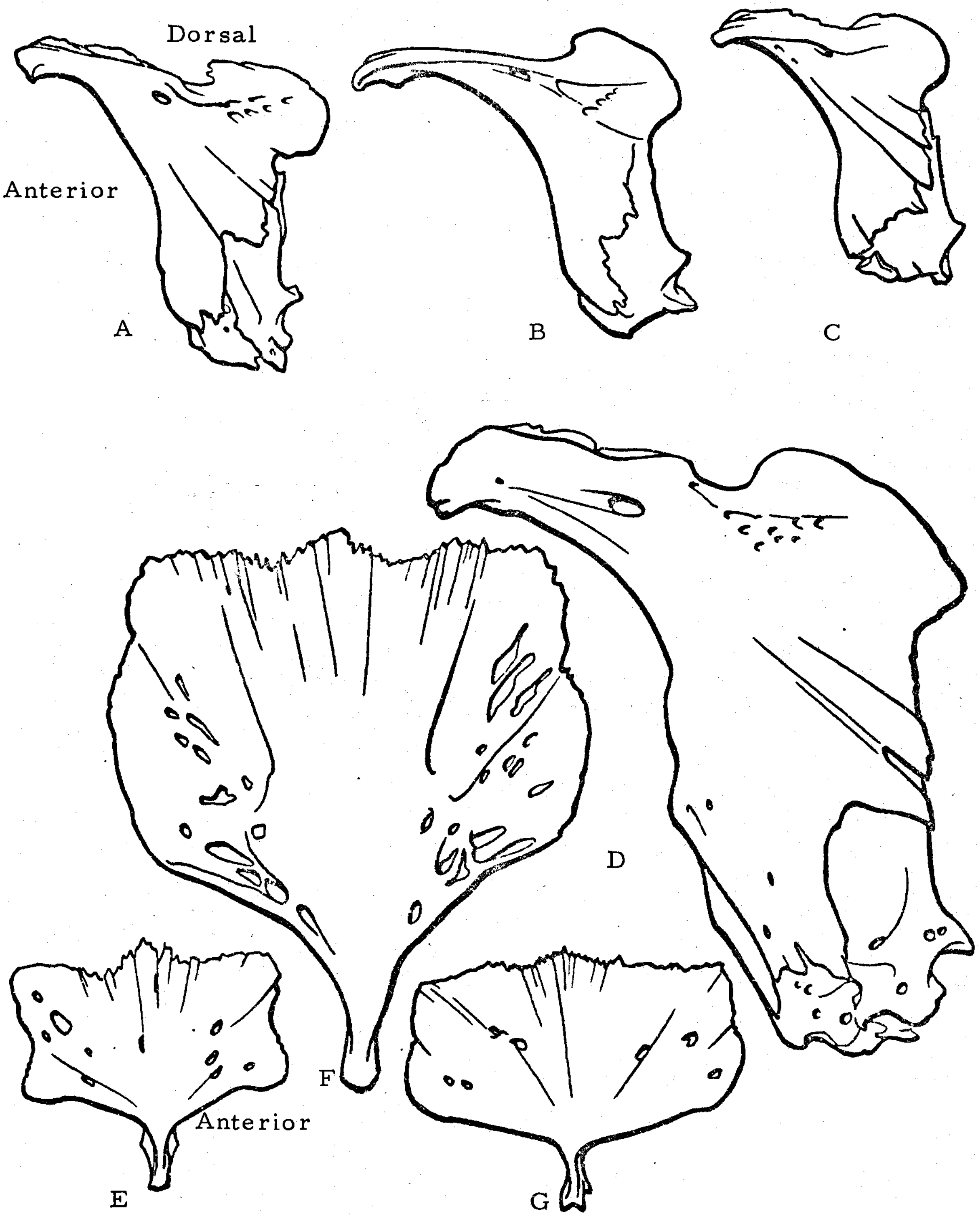


Fig. 23. Comparison of mandible (lateral view) (A to D) and supra-ethmoid (dorsal view) bones (E, F and G). A, G brevirostris; B, stomias; C, E snyderi; D, F luxatus. Same data as Fig. 22.

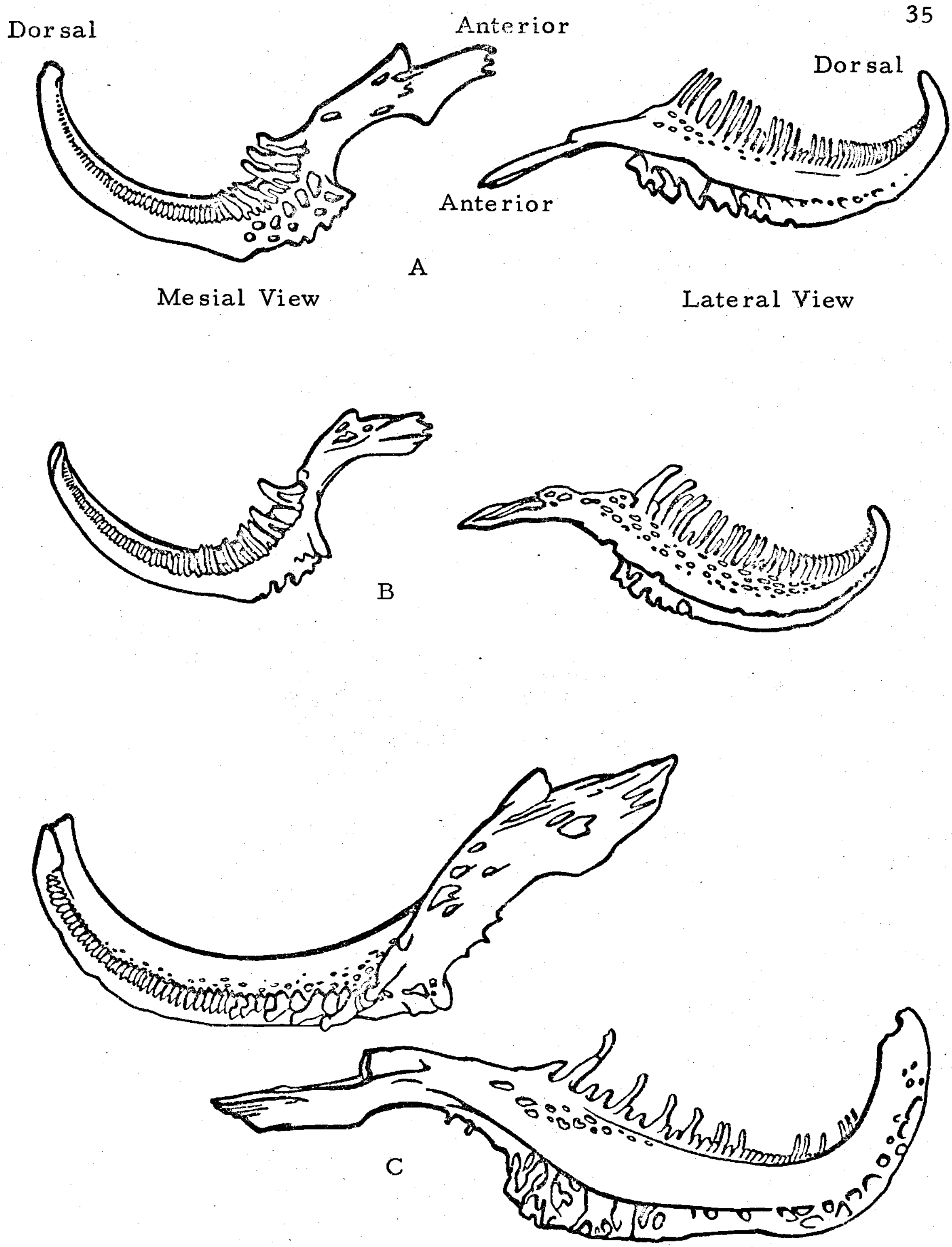


Fig. 24. Comparison of left fifth pharyngeal arch. A *Chasmistes brevirostris*, B *Catostomus snyderi*, C *C. luxatus*. Same data as Fig. 22.

with having a terminal mouth. The fifth pharyngeal arches of *brevirostris*, in addition to differences in shape compared with the other species (Fig. 24), are very different in that the bases have been lightened by the loss of bone.

Creel Census

Every fisherman was not interviewed because of the distance involved between fishing areas and the other phases of research that were taking place concurrently in the other drainage basins. Interviews were conducted with 396 fishermen and their catches examined. The catch consisted of 407 *Catostomus luxatus*, 213 *C. snyderi* and 28 *Chasmistes brevirostris*. The average sizes of the fish caught by fishermen are shown in Table 3. The average catch of all species was 1.64 fish per fisherman and the catch rate was 0.87 fish per hour.

Table 3. Average lengths and weights of fish caught by anglers during 1974.

Species		N	Av. fork length	Std. dev.	N	Av. weight	Std. dev.
Catostomus luxatus	- F	55	671 mm	56	62	3515 g	821
	- M	37	617	45	37	2672	612
Catostomus snyderi	- F	59	465	33	61	1438	331
	- M	38	434	38	38	1134	318
Chasmistes brevirostris	- F	8	452	14	8	1334	168
	- M	1	432	-	1	1134	-

Natural History Observations

The results in this section are mostly limited to observations made in the Upper Klamath area in 1974. Suckers were first observed in the Chiloquin fish ladder on 21 March but local fishermen reported that the spawning migration started in the river about the first week in March. The first suckers captured were mostly male Catostomus snyderi and a few C. luxatus males. Most of the males were ripe, but the few female snyderi that were examined at this time were not in spawning condition. The peak of the snyderi run occurred about the end of March when both sexes were present in large numbers and in a ripe condition. The first luxatus females were captured on 27 March, the peak of that run occurred about two weeks later and was generally over by 20 April, although an occasional fish was still caught in the fish ladder after this date. The first Chasmistes brevirostris were caught on the morning of 17 April at the Highway 97 bridge when the water temperature was 11 C. By late afternoon they were being caught below the dam at Chiloquin as well. The first brevirostris caught were males but females were caught one day later. Very few of this species were ever caught in the fish ladder or by fishermen and this run lasted only about two weeks with no definite peak. However, one brevirostris was captured in the fish ladder on 27 May.

Movement of suckers up the Williamson and Sprague rivers appears to be dependent on water temperature, with movement beginning at about 5.5 C. The weather turned very cold after a snowfall in late March; the water temperature dropped to 3 C and fish movement into the ladder stopped. After the river warmed to 8.4 C fish movement started again.

Additional spawning concentrations of *Catostomus luxatus* were discovered along the east shore of Upper Klamath Lake (Fig. 1). All of these are in areas where large amounts of fresh water from springs was entering the lake. Only *luxatus* were observed in these spawning areas or in the sport catch from Upper Klamath Lake. According to local fishermen, "mullet" were being caught at Sucker Springs the first of March, 1974, and in some years the fish enter these areas as early as the first of February. The earlier spawning in these areas is probably due to the warmer water temperature (15.2 C on 22 March). These spring areas are also popular with trout fishermen who stated that the trout come in to eat the "mullet" eggs. The stomach of a 360 mm SL rainbow trout which was examined was packed full of fish eggs the same color and size as *luxatus* eggs.

A historical spawning area for "mullet" is at Harriman Springs near Rocky Point on the west side of Upper Klamath Lake where a substantial flow of very clear water enters the lake. The bottom is clean of any silt or vegetation and the substrate consists of rocks about 35-50 mm in diameter. This location was checked about every other day for spawning fish and the first Catostomus luxatus, a single specimen, was observed on 21 March when the water temperature was 6. 7 C. On 24 March I observed one female and at least three male luxatus spawning in the springs. The female would circle slowly, close to the bottom, with two or three males following closely at her side. After making several circles the males would start to quiver, then the female would quiver, and a few eggs would be released after which the circling movements were started again. The same fish returned to the exact spot and repeated this performance three times in about 25 minutes. Between the spawning acts one or two of the males swam into the area and appeared to eat the eggs that had not fallen between the rocks. On 26 March two females and four males were observed at this same location. Despite continued visits, these were the only suckers observed spawning at Harriman Springs. The operator of the Harriman Resort said that he had not seen any suckers in the spring for several years.

Fecundity of some of the species was estimated by the gravimetric method (Lagler, 1956). There were not enough data to analyze statistically, but there appeared to be an increase in fecundity with an increase in standard length of the fish (Table 4). No estimate of fecundity was made for Catostomus warnerensis due to the scarcity of fish.

Table 4. Estimated fecundity of some southern Oregon catostomids. Each estimate based on four subsamples using the gravimetric method.

Species	Standard length	Estimated number of eggs
Catostomus luxatus	473	235, 667
	530	101, 886
	635	230, 970
	647	185, 593
Catostomus snyderi	353	39, 697
	405	64, 477
	421	63, 905
Chasmistes brevirostris	351	34, 114
	367	37, 790
	380	34, 994
	412	47, 470
	465	72, 467
Catostomus occidentalis	273	9, 851
	305	10, 642

During the examination of skeletal material the ages of some specimens from Upper Klamath Lake were estimated by counting the annuli in opercles and other bony structures. The annuli counted for individual Catostomus luxatus were 5, 7, 7, 10, 12, 16, 17, 18; for C. snyderi 5, 6, 7, 8; and for Chasmistes brevirostris 8, 10. All of these were mature fish from the spawning migration.

Specimens of each sucker species from Upper Klamath Lake were examined for parasites. External examination revealed that all of the species were parasitized by leeches (Piscicola salmositica) that were attached around the base of the fins and inside of the operculum. There were no fresh lamprey scars on any fish caught in the river until 26 March 1974. After that time, about one-half of the fish caught had at least one bleeding scar. None of the fish caught in the lake showed any evidence of recent attach by lampreys but fifty percent of all the fish examined showed at least one prior lamprey scar and one Chasmistes brevirostris had a total of nine old scars. The internal organs of several specimens of each sucker species were examined for parasites and the trematodes, cestodes and nematodes were removed and fixed in A. F. A. solution (Millemann, 1970). The classification and description of the parasites, which appear to be new species, is being completed by Mr. LeRoy Fisk of Oregon Institute of Technology (trematodes) and Dr. John Mackiewicz of the State University of New York at Albany (cestodes).

Observations were made on the Sprague and Williamson rivers to determine the extent of the upstream distribution of catostomids. Catostomus snyderi was found in the Williamson River above the marsh, in the Sprague River along its entire length and in the Sycan River (Fig. 1). One major spawning area of snyderi is at "Indian Springs" adjacent to the Sprague above Beatty, Oregon. All adults that were observed above the dam at Chiloquin appeared to be C. snyderi and only immature snyderi could be identified from any of the collections of juveniles taken upstream from the dam.

Sampling was carried out in most of the permanent streams in the Goose Lake drainage in Oregon during 1973-74. The spawning migration out of Cottonwood Reservoir into Cottonwood Creek was sampled on 23 May 1973 when the water temperature was 19 C. A collection was made at the same location on 28 May 1974, but there was considerably more runoff and a much lower water temperature (12.5 C). The few suckers collected were not in spawning condition, indicating that temperature is probably a controlling factor for reproduction in this species as well as in the species in Upper Klamath Lake. Catostomus occidentalis was the only sucker collected in the Goose Lake drainage in Oregon, but it has been collected in a variety of lentic and lotic habitats (Fig. 1).

Intensive collecting efforts were carried out in the Warner Valley to determine distribution patterns and to estimate population numbers of Catostomus warnerensis. Honey Creek was sampled along its entire length but only one warnerensis, an immature specimen 30 mm long, was collected. It came from a hole upstream from the bridge at Plush, Oregon. Deep Creek was sampled at several locations above the barrier falls and on the lower creek downstream from the bridge at Adel, Oregon. No suckers were collected in Deep Creek despite several sampling attempts at different times. Three different collections from Twentymile Creek during the two years of field work produced some immature specimens of warnerensis each year, but no adults were collected. Neither gill nets nor trap nets in Hart or Crump lakes captured any suckers but three adult warnerensis were caught by trout fishermen in Honey Creek on 27 April 1974. In May, 1975 Mr. Fred Bills, a graduate student in the Department of Fisheries and Wildlife, OSU, caught one female and four male warnerensis in a gill net set at the inlet-outlet of Pelican Lake. The female, 283 mm SL, was heavy with eggs and the males, 220, 155, 148, 146 mm SL, were in bright red spawning colors and had large nuptial tubercles on their anal fins. Mr. Bills reported that there was a large flow of water down Deep Creek, through a marsh and into Crump Lake. Pelican Lake receives water from Crump Lake during high water periods and releases water as Crump Lake recedes. A gill net set in Crump Lake the next day (17 May 1975) did not catch any suckers.

The extensive water diversions in Warner Valley were examined to determine their role in reducing the numbers of *Catostomus warnerensis.* Longtime residents of Warner Valley reported that in the late 1930's large numbers of suckers (locally called "redhorse") and "lake trout" ascended Honey Creek in the spring and would go far up into the canyon to spawn. By the time the adults were returning to Hart Lake the irrigation headgates were open and the returning adults and fry were washed out onto the fields. The irrigation diversions were screened in the 1950's but it became bothersome to clean them and the screens were removed (Raymond Morris, Watermaster, Plush, Oregon. pers. comm.). The irrigation dam on Deep Creek at Adel, Oregon, is impassable to fish and the stream bed below the dam has been extensively modified by livestock and farming practices. The lake-marsh into which Twentymile Creek formerly emptied has been diked off, drained and now supports large crops of wheat and hay. Twentymile Creek is totally diverted during the irrigation season. When water is allowed past the dam it flows far to the east side of the vally where it is held in a series of impoundments. Water from Twentymile Creek reaches Crump Lake only during the early spring. The fact that some sucker fry were collected in Twentymile Creek in 1973 and 1974 indicates that any adult suckers in the southern end of the valley must be dependent on the irrigation system for their existence. Pelican Lake should be intensively sampled to determine if it contains a population of suckers.

Electrophoresis Results

Sixteen samples of liver tissue and sixteen samples of white muscle from each of the species were examined for species specific banding patterns using electrophoresis. The resulting stained gels did not show any differences that could be used for species identification.

Hatching Experiment Results

Three different attempts at hatching *Catostomus luxatus* eggs were carried out in 1974, but none of these were successful. Art Gerlesch hatched "mullet" eggs in an aquarium using water at 16 C (pers. comm.). Evidently the water was too cold or the temperature fluctuated too much in the improvised hatchery.

DISCUSSION

The discussion includes a brief history of the nomenclature of Oregon catostomids and a description of each of the species under consideration. Following the descriptions, several hypotheses are proposed and examined in light of the data that were analyzed and the role of hybridization in these species is examined. Specimens from Clear Lake and the Lost River are compared to Upper Klamath Lake specimens and an explanation for the observed differences is offered. Historical data relating to size of the former sucker runs is presented and conclusions relating to the present status of the population are given. The concluding section contains recommendations for the protection and management of the species.

Catostomus - the Finescale Suckers

This genus contains two different morphological types. The subgenus Pantosteus, the mountain suckers, are inhabitants of cool mountain streams and their jaws are adapted for scraping attached material from the substrate (Smith, 1966). The species in the subgenus Catostomus do not show any trophic specializations and they are generally found in lower elevation streams and lakes. This genus is characterized by having inferior mouths with coarse papillae covering the lips. The body is not round in cross section like in

Chasmistes but is fusiform in shape and flattened on the ventral surface in keeping with their bottom living habits.

Catostomus luxatus - Lost River Sucker

Chasmistes luxatus Cope 1879 (original description, Upper Klamath Lake).

Catostomus rex Eigenmann 1891 (Lost River and Tule Lake, Oregon and California, description).

Deltistes luxatus Seale 1896 (creation of monotypic genus based on morphology of gill rakers).

Catostomus luxatus Miller 1959 (placement into *Catostomus* on basis that deltoid gill rakers are not always diagnostic).

Deltistes luxatus Miller and Smith 1967 (*Deltistes* recognized as including one living and two fossil species).

Catostomus luxatus Bailey et al. 1970 (no reasons given).

The Lost River sucker, the largest catostomid in Oregon, is found in Upper Klamath Lake and the Clear Lake-Lost River system in Oregon and California. This species can be recognized by its long snout (16.5% SL), a wide median notch in the lower lip with one or two large papillae between the notch and the edge of the lower lip (Fig. 18), 81 lateral line scales (usually 79 to 83), and 27 or 28 gill rakers. The gill rakers are widely spaced and are smooth (unarmed) on the free edges. The long snout tapers to a round point, the full lips are covered by coarse papillae and the entire snout as well as the mouth is protrusible. The mouth position is best described as subterminal. The "hump" on the snout which is caused by the pre-maxillary spines and referred to in many keys, is an artifact of preservation that is not seen in live specimens. Some diagnostic osteological features are illustrated in Figs. 22, 23 and 24. Fish as small as 65 mm SL can be identified as Catostomus luxatus by careful extraction of the first gill arch and examination of the gill rakers. C. luxatus feeds in lakes and enters rivers or spring areas only for spawning. The very protrusible mouth mechanism appears to be well suited for digging in the soft bottom of lakes and this species probably lives by straining benthic organisms out of the substrate.

Catostomus snyderi - Klamath Largescale Sucker

Catostomus lubiatus Girard 1857 (Klamath Lake, collected by Dr. John S. Newberry, not C. labiatus of Ayres 1855 from the San Francisco fish market).

Catostomus labiatus Cope 1879 (refers to description of Girard, but in 1884 Cope gives credit for name to Ayres and states that this species abounds in Klamath and Goose lakes).

Catostomus snyderi Gilbert 1898 (recognized that labiatus of Ayres was synonymous with occidentalis and that the Klamath large scale sucker was without a name).

This species is found in Upper Klamath Lake, the Clear Lake-Lost River system, the entire length of the Sprague River, at least the lower 20 kilometers of the Sycan River, the lower Williamson River and the Williamson River above Klamath Marsh. C. snyderi is a generalized sucker intermediate in most characters and has no special adaptations when compared to C. luxatus and species of Chasmistes. This species can be identified by its inferior mouth, large fleshy lips of large papillae and the lobes with the lower lip meeting at the midline (Fig. 18). There are 72 (usually 70 to 74) lateral line scales and 32 (usually 31 to 33) gill rakers. Osteological features are illustrated in Figs. 22, 23 and 24. This species shows a large degree of variability as would be expected since it lives in both lentic and lotic habitats. C. snyderi appears to be adapted primarily for a river existence and probably feeds on a variety of benthic organisms.

Catostomus occidentalis - Sacramento Sucker

Catostomus occidentalis Ayres 1855 (original description, common in fish markets, from Sacramento and San Joaquin).

Catostomus labiatus Cope 1879, 1884 ("This species abounds in Klamath and Goose Lakes . . . .").

Catostomus occidentalis Ayres (Snyder 1908, description based on 81 specimens from Goose Lake drainage).

Catostomus occidentalis lacus-anseriunus Fowler 1913 (re-description of specimens collected by Cope).

This common sucker is widespread throughout the Pit and Sacramento drainages of California. In Oregon it has been collected in small and large streams, reservoirs and Goose Lake, all in the Goose Lake drainage system. In general appearance this species is similar to C. snyderi. It has an average of 71 (69 to 72) lateral line scales and 26 (24 to 27) gill rakers. Nothing is known of the biology of this species in Oregon except that, in common with other catostomids, it makes an upstream spawning migration in the spring. Hopkirk (1974) discusses some phases of the biology of this species in California.

Catostomus warnerensis - Warner Sucker

Catostomus tahoensis Cope 1884 (misidentification, brief description).

Catostomus warnerensis Snyder 1908 (Description based on 12 specimens).

This species is confined to Warner Valley where it formerly was found in all the larger streams (Snyder, 1908) but its present distribution is much reduced. It has an average of 76 (usually 75 to 77) lateral line scales, 27 (26 to 28) gill rakers, two or three papillae between the median notch and edge of the lower lip and a long head. The males develop a brilliant red stripe on each side of the body during the spring spawning migration. Except for the migration out of the lakes for spawning purposes the biology and life history of this species is unknown.

Chasmistes - the Lakesuckers

The lakesuckers have a very interesting distributional pattern. There are only three extant species, *C. liorus* in Utah Lake, *C. cujus* in Pyramid Lake and *C. brevirostris* in Upper Klamath Lake. One species, *C. stomias*, of the Klamath basin is recently extinct. Large amounts of *Chasmistes* fossil material has been found in the Lake Idaho and Fossil Lake, Oregon deposits (Miller and Smith, 1967; Smith, pers. comm.). The fish of this genus are characterized by bodies that are round in cross section, large fins, large swim bladders, a large terminal mouth that forms a rounded shape when open, large heads and large numbers of long gill rakers that have dense processes on the free edges. The modifications of the head and mouth are adaptations to a planktivorous diet. This was confirmed by the results of the only food habits study of *Chasmistes* when Johnson (1958) found that 84% of the diet of *C. cujus* consisted of zooplankton.

Chasmistes brevirostris - Shortnose Lakesucker

Chasmistes brevirostris Cope 1879 (original description, Upper Klamath Lake, Oregon).

Lipomyzon brevirostris Cope 1881 (placement into new genus based on supposed differences in pharyngeal teeth).

Chasmistes brevirostris Cope 1884 (examination of more specimens showed that pharyngeal teeth were not different).

Lipomyzon brevirostris Fowler 1914 (Fowler evidently did not realize that Cope had replaced these fish into *Chasmistes*).

Chasmistes brevirostris Cope 1879 (Miller, 1952, pers. comm. to C. E. Bond).

The shortnose sucker was formerly confined to Upper Klamath Lake, but in recent years there have been some specimens captured in the Klamath River at the Keno Dam and at Copco Reservoir. However, the present status of *C. brevirostris* at these locations is unknown. This species has 78 (usually 77 to 79) lateral line scales, 40 (39 to 41) gill rakers, a short snout (10% of SL) and smooth lips with a wide median notch separating the lobes of the lower lip (Fig. 18). The osteological features were described in the Results section and are illustrated in Figs. 22, 23 and 24. There has been some confusion concerning which of the three *Chasmistes* described from Upper Klamath Lake is actually *C. brevirostris*. The descriptions by Cope (1879), Gilbert (1898) and Evermann and Meek (1898) do not include any discriminating characteristics and the type material (ANSP 20959 and 20522) is in very bad shape and no reliability can be placed on proportional measurements from these fish (R. R. Miller, UMMZ, pers. comm.). After examining the type material of these species Miller (pers. comm. to C. E. Bond, 1952) concluded that stomias and copei were conspecific. Evermann and Meek (1898) stated that the greatest difference between stomias and copei was in the size of the ventral fins. When I examined the type material I found that stomias (USNM 48223) was a male and copei (USNM 48224) was a female, which explains the differences in pelvic fins, and the counts and measurements I made are very similar for both species, therefore, I agree with Miller that stomias and copei are synonymous. Both stomias and copei have much longer heads and snouts and larger mouths than brevirostris and for this reason I believe that the name brevirostris is being applied to the correct species. Specimens are small as 46 mm SL can be identified as brevirostris by counting the gill rakers.

Nothing is known of the lake phase of the life cycle of C. brevirostris but data from the spring spawning migration were given in the Results section.

Chasmistes stomias - the Bigmouth Lakesucker

Chasmistes stomias Gilbert 1898 (original description, Upper Klamath Lake, Oregon).

Chasmistes copei Evermann and Meek 1898 (based on examination of a female).

Chasmistes brevirostris Miller 1952 (personal communication to C. E. Bond).

A series of a sucker species was obtained from Lake of the Woods, Oregon during 1949 to 1952 and deposited at UMMZ, (M166441, M166442 and 160950) and CAS (31499). These fish have large stout heads (28% of SL) with long snouts and large terminal mouths. The lips are smooth with a wide median notch and have reduced lobes on the lower lip. The average number of lateral line scales in 70 (usually 69 to 72) and the number of gill rakers averages 39 (37 to 40). They have a wide supraethmoid bone, reduced anterioventral keels on the maxillae (Fig. 22 and 23) and lightened fifth pharyngeal arches. This combination of characteristics supports the conclusion that they are a Chasmistes species. The larger heads, snouts and mouths of these fish, in comparison with C. brevirostris, indicates this species was C. stomias.

Ten specimens (UMMZ 166440 and 160948) from Lake of the Woods were intermediate between Catostomus snyderi and C. stomias in lip characteristics, gill raker number, and most morphological measurements. As shown in the Results section the discriminant analysis confirmed the identification of these specimens as hybrids.

Bond (1948) reported that all of the suckers in Lake of the Woods spawned together over a gravel area in the lake during the spring. This occurred after many exotic species had been introduced into the lake and after the lake environment had been modified by home construction and recreational activities.

Chasmistes stomias were extirpated during fish control operations in 1952 and no fish resembling this species were found in any recent collections from Upper Klamath Lake.

Although *Catostomus occidentalis* and *C. warnerensis* present no problems of identification and will not be discussed further in this section, there have been difficulties in the identification of suckers from Upper Klamath Lake. Several hypotheses might explain this confusion: (1) there is only one species present but it is highly variable; (2) there were four or more species present but they have crossbred into a hybrid swarm; and (3) there are distinct species present but keys have been based on limited numbers of specimens and therefore, the extent of variation and what constitutes a discriminating character was not known.

The discriminant analysis program, using the phenetic data supplied, grouped the fish from Upper Klamath Lake into three distinct clusters (Figs. 19, 20 and 21). The fish within each cluster are more similar to each other than they are to fish in the other clusters. If there were only one highly variable species present there would be no clustering of specimens, but there would be a cline on Figs. 19, 20 and 21. Therefore, based on the discriminant analyses, Hypothesis One is discounted.

Hybridization is rare in natural populations but occurs much more often in fish than in other animals (Stebbins, 1959). Schwartz (1972) gives 1,945 references, encompassing 56 families of fishes, in which hybridization has been reported. According to Hubbs (1955) some of the causes of hybridization in fish are overcrowding on spawning sites, scarcity of one species compared to another and recent mixing of long isolated species. Hybrids are much more common where man's activities have "hybridized" the environment. If fertile, or partially fertile, hybrids are produced they may cross back to either parental population, a process called introgression (Anderson, 1949). In spite of somewhat widespread hybridization in fish, only a few cases of introgression have been reported (Centrarchidae, Hubbs, 1955; Cyprinidae, Gilbert, 1961; Greenfield and Greenfield, 1972; Greenfield and Deckert, 1973; Hubbs and Miller, 1943; Smith, 1973; Poeciliidae, C. Hubbs, 1959). Hybridization is common in suckers (Hubbs et al., 1943) but introgression has not been reported. There is evidence indicating some hybridization has occurred in Upper Klamath Lake between Chasmistes brevirostris and Catostomus snyderi. Some of the fish examined had the lobes of the lower lips separated by a wide notch (like brevirostris) but the lips were covered with coarse papillae (like snyderi, and the gill raker counts were intermediate between snyderi and brevirostris. The discriminant analysis identified two fish from Upper Klamath Lake as possible hybrids between C. luxatus and C. snyderi, but these specimens may have been snyderi with abnormally few gill rakers. If mass hybridization had taken place there would be no clusters on Fig. 19, 20 and 21, but there would be a random scatter of points. Although some hybridization has occurred, there is no evidence for introgression and Hypothesis Two does not appear valid.

Hypothesis Three appears to be most nearly correct. The description of the species from Upper Klamath Lake has been based on only a few specimens because early workers did not have the equipment to collect or store more than one or two specimens of each species and often these were not examined in detail. This is the first study in which a large series of these species have been examined and the amount of variation within the species reported. As already noted, the species are highly variable and overlap considerably in some characteristics, but by careful examination they can be identified. A key to the species is given in Appendix I.

When this study was initiated it was hoped that electrophoresis would be useful in distinguishing the species in Upper Klamath Lake and in detecting hybridization. The fact that no species specific paterns were found could be due to one or more reasons. The tissue samples (white muscle, liver and eye lens) from one fish were placed together in one vial and kept on ice, but they were not frozen until from two to ten hours later and this may have been long enough for contamination to have occurred. The samples remained frozen for six to seven months and this may have altered the activity of the enzymes. However, the possibility exists that there are no discernible species specific patterns in these catostomids (G. R. Smith, pers. comm.). Huntsman (1970), using disc electrophoresis, reported such a wide range of intraspecific variability of serum proteins that he could not discern species patterns in catostomids. Koehn (1969) reported that in the subgenus Catostomus the hemoglobin electrophoretic patterns were very uniform. Research on catostomid genetics presently being conducted at the University of Illinois has found only one enzyme out of 22 that showed a difference in electrophoretic mobility between Catostomus luxatus and Chasmistes brevirostris (S. Ferris, pers. comm.).

Although numbers cannot be placed on the size of either the former or present sucker populations, available historical data indicate that present population levels are much reduced.

The Klamath and Modoc Indians relied heavily on the spring sucker runs as a food source. The sucker migration signaled winters-end, and occurred at a time when winter food stores were nearly exhausted (Howe, 1968). Enormous amounts (up to 50 tons, Stern, 1966) of suckers were caught and dried both on the Lost River and on the Sprague River at Chiloquin (Cope, 1879; Gilbert, 1898). That the sucker runs on the Lost River were enormous is shown by the expenditures put forth to establish commercial enterprises there. A Mr. Whitman established a fish cannery on the Lost River in 1892 (Howe, 1968). Earlier, a factory was built to process fish into oil (Sutton, 1876, cited in Helfrich, 1972). Fish were also packed into barrels (salted?) and shipped to market (Helfrich, 1972). There was a large "mullet" migration into Harriman Springs on the west side of Upper Klamath Lake. Residents there told me that early settlers backed wagons into the springs and loaded them with "mullet" using pitchforks.

The available creel census data also document the decline in sucker numbers. The snag fishery for suckers developed in the 1950's, but "mullet" were not reported in the creel census records for the Williamson and Sprague rivers until 1966 (Oregon Wildlife Comm. Annual Reports; Stout, pers. comm.). There are no creel census records for "mullet" or other suckers from the Lost River. Prior to 1974 all suckers were recorded under the heading of "mullet" and to make the 1974 data comparable, the length and weight data for all three species caught in 1974 were combined into an overall average length and weight. The data in Table 5 show that the average size, the catch per fisherman and the catch rate have all declined during the period for which data have been recorded. Bond et al., (MS 1968) set nets in Upper Klamath Lake for a total of 18,292 hours in 1964 and 1965. Less than one percent of the fish they caught were suckers. An extensive collection effort over the entire Clear Lake-Lost River system captured only 59 suckers and, as discussed previously, many of these appear to be hybrids. There is no longer a fishery for "mullet" on the Lost River (Stout, per. comm.).

The sport fishery for "mullet" has probably not been a significant factor in the decline of Catostomus luxatus or Chasmistes brevirostris for the following reasons. There are only two areas on the Williamson and Sprague rivers that are accessible to snag fishermen, just below the Highway 97 bridge and below the dam at Chiloquin, which limits the fishing pressure. Snagging gear is selective for larger fish and therefore, C. luxatus will be preferentially caught. In 1974 C. brevirostris spawned later than the other species and this was after the opening of the general fishing season when the fishing pressure for "mullet" was greatly reduced. If it does become necessary to further reduce the catch of C. brevirostris, a size limit of 470 mm fork length could be imposed which would restrict the catch to primarily C. luxatus.

Table 5. Comparison of creel census data from the Williamson and Sprague river snag fishery for the years 1966 to 1974.

Year	Average fork length	Average weight	Fish per angler	Fish per hour
1966	25. 7 inches	7. 54 pounds	5. 6	1. 19
1967	24. 7	6. 05	-	-
1968	26. 2	8. 17	3. 5	1. 57
	---------------- 10 fish bag limit ----------------			
1969	-	-	3. 0	4. 70
1970	25. 1	6. 80	2. 5	1. 50
1971	24. 5	6. 04	2. 8	1. 38
1972	24. 5	6. 38	2. 1	1. 00
1973	23. 7	-	2. 2	1. 28
1974	21. 3	4. 90	1. 6	0. 87

The decline of the sucker population in Upper Klamath Lake may have been caused by several factors. Increased agricultural development and the increase in population of the Klamath basin may have caused an increase in cultural eutrophication of Upper Klamath Lake. Bond et al., (MS 1968) reported that there has been a change in the dominant species of plankton in the lake since 1913. Nothing is known about food selection by Chasmistes brevirostris, but the now common plankton species may not be successfully utilized for food. There have been five species of non-native fishes introduced into Upper Klamath Lake (brown trout, brook trout, brown bullhead, pumpkinseed and yellow perch). The young of all of these species have a diet similar to the diet of young suckers and the adults can be expected to prey on young suckers. Indian legends (Spier, 1930) and archeological evidence (Cressman et al., 1956) show that suckers formerly migrated further up the Sprague River than they do at present. An irrigation dam was constructed on the Sprague River just above Chiloquin in 1928 but at this time suckers were considered "trash fish" and it is very doubtful that provisions were made for their passage over the dam. Stout (pers. comm.) reports that passage was poor for all species in the late 1940's. A new fish ladder was constructed in 1965, but it is not passable to fish at all river stages. The crowding of fish on the available spawning sites below the dam may be responsible for the hybridization that has been observed and the loss of spawning habitat may have been a significant factor in the decline of these species.

The relationship of Upper Klamath Lake suckers to suckers in Clear Lake and the Lost River was investigated in order to explain observed differences between these populations. Koch and Contreras (1973a) and Contreparas (1973) reported that no _C. snyderi_ were collected during their sampling in Lost River and Clear Lake. Koch and Contreras (1973a) mentioned that hybrid specimens were collected, but Contreras (1973) stated that no hybridization was detected. I examined the fish that had been collected and divided them into four groups - _luxatus_, _snyderi_ with small mouths, _snyderi_ with large mouths, and another group that were like _brevirostris_ except for coarse papillae on lips. Gill raker and lateral line scale counts from the _brevirostris_-like fish were almost exactly intermediate between _snyderi_ and _brevirostris_. These same counts for the _snyderi_-like fish were intermediate between the counts for the _brevirostris_-like fish and _snyderi_, giving a cline from _brevirostris_ to _snyderi_. This indicates that hybridization with repeated back-crossing - introgression - has occurred in this population. The lateral line was not well defined in any of the Clear Lake-Lost River fish, there were interruptions and extra branches in every fish examined. About one half of the specimens had an abnormal left nasal opening, as the septum between the incurrent and excurrent opening was lacking. Bond (pers. comm.) indicated both of these teratological features could indicate hybridization.

Water diversions can be implicated in the reduction and hybridization of suckers in the Lost River. The first irrigation projects in this area were undertaken in 1886, in 1910 the dam at Clear Lake was constructed and in 1914 a project was started to "reclaim" Tule and Lower Klamath Lakes. These lakes were drained by 1922 but farming the old lake beds was not successful and they were later reflooded (Hayden, 1941). The Lost River is now essentially an irrigation canal, and interconnecting canal systems allow for the exchange of water and fish between Upper Klamath Lake, the Lost River and the Klamath River (Bureau of Reclamation map no. 12-208-124). After the irrigation season the flow of water from Clear Lake into the Lost River is shut off, reducing the river to a series of pools (Koch and Contreras, 1973a). Habitat alteration has caused widespread hybridization between the species in this area and *Chasmistes brevirostris* no longer exists there in a pure form.

Three specimens from the Klamath River at Keno and two from Copco Reservoir appeared to be typical *Chasmistes brevirostris*. The discriminant analysis placed these fish close to the center of the *brevirostris* cluster (Fig. 20), however further sampling is necessary to determine if there are reproducing populations in these areas.

Consideration of the historical data and the results of two years of field work leads to the conclusion that Chasmistes brevirostris and Catostomus warnerensis are endangered species and Catostomus luxatus is a threatened species under the definitions of the Endangered Species Act of 1973. Unless steps are taken to reverse their downward population trend, Chasmistes brevirostris and Catostomus warnerensis will join the ranks of those species extirpated by man's activities.

Recommendations for Protection and Management

The overall reasons for the decline of these species has been a general increase in the human population and increased agricultural development. It would be impossible to reverse either of these. However, it is possible to change some fisheries management practices that may have contributed to the decline. Total poisoning of any body of water for control of native non-game fish should be halted and further introduction of exotic species should be stopped. Enhancement of the population of endangered or threatened species should be made a primary consideration of management agencies.

The following specific recommendations are made for the management of Catostomus warnerensis: (1) all irrigation canals should be screened to prevent the entrance of fish; (2) the existing diversion dams should be modified to allow the downstream escapement of adults and fry; (3) sufficient water should be released past the diversion dams to ensure the survival of adults and fry and to allow their return to the lakes; and (4) the lower portions of the creeks should be fenced to keep cattle out. Some data, relating principally to distribution, have been gathered, but it was not possible during this study to devote sufficient time to learn much about the basic biology of C. warnerensis. Funds should be made available to continue research into the life history of this unique fish.

Catostomus luxatus is not in immediate danger of extinction but because its population has been reduced, this species could easily become endangered and a continuing program to monitor this species should be established. However C. luxatus will benefit from the recommendations suggested for the protection of Chasmistes brevirostris. The most serious factor affecting these species has been the loss of spawning habitat. To make the upstream spawning areas available the diversion dam at Chiloquin could be removed with very little economic loss. An irrigation pumping station, constructed on the Williamson River just downstream from Highway 97, has not been put into operation but it could supply water to the existing canal system. At the very least the fish ladder and dam should be modified so that suckers are able to move upstream under all water conditions. In Upper Klamath Lake natural eutrophication occurs (Phinney and Peak, 1961) but, cultural eutrophication may also be a factor and any programs that would decrease agricultural run-off and influx of municipal and industrial wastes should be encouraged.

If these species do not recover when given access to suitable spawning areas an artificial propagation program could be started. Catostomus luxatus have been hatched successfully (Gerlach, pers. comm.) and Koch and Contreras (1973b) have worked out techniques for hatching Chasmistes. There are several spring areas on the east side of Upper Klamath Lake where eggs might be incubated successfully. A small hatchery for Catostomus warnerensis could be improvised on Honey Creek.

There has been increasing public concern over the plight of endangered species, however, the so called, "glamour" species (wolves, whooping cranes, eagles, etc.) have received most of the attention. Suckers were formerly considered to be "rough" or "trash" fish but recent research (Symposium on trout-nongame fish interactions in streams, California-Nevada Chapter of American Fisheries Society, 23 Jan 1975, P. B. Moyle, Chairman) has shown that they are a characteristic component of the fish fauna and are important in the biological economy of the aquatic ecosystem. The recovery of these species may restore a balance that will, in turn, enhance other parts of the ecosystem.

The knowledge and technology to help these species recover is available, the factors determining whether or not the species will be saved are economic. Under the Endangered Species Act of 1973 Federal Aid is available on a matching basis to allow states to implement plans for handling endangered and threatened species problems. It is hoped that Oregon will appropriate funds to further study these unique species and will begin a recovery program.

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APPENDIX

APPENDIX I

The use of the following key, based on the results of the discriminant analysis program and the graphical analysis, will identify the species under discussion.

1. a. Mouth inferior, lobes of lower lip together 2
   b. Mouth terminal or subterminal, wide notch separating lobes of lower lip 4
2. a. Number of gill rakers 30 to 35, *Catostomus snyderi*, Upper Klamath Lake, Clear Lake, Lost River.
   b. Fewer than 30 gill rakers 3
3. a. Lateral line scales 69 to 74, gill rakers 25 or 26, *Catostomus occidentalis*, Goose Lake drainage.
   b. Lateral line scales 74 to 78, gill rakers 26 to 28, *Catostomus warnerensis*, Warner Valley
4. a. Lips smooth, no papillae, upper lip reduced, lobes of lower lip reduced 5
   b. Lips covered with coarse papillae, upper lip pendulant, 27 to 29 unarmed widely spaced gill rakers, 79 to 83 lateral line scales, *Catostomus luxatus*, Upper Klamath Lake, Clear Lake, Lost River.
5. a. Lateral line scales 77 to 80, 39 to 40 long gill rakers with dendritic edges, head short (23% of SL) snout

short (10% of SL), Chasmistes brevirostris Upper Klamath Lake.

b. Lateral line scales 69 to 71, 38 to 40 long gill rakers with dendritic edges, head long (28% of SL), snout long (12% of SL), Chasmistes stomias, extinct, formerly in Upper Klamath Lake and Lake of the Woods, Oregon.