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MATERIALS FOR THE REVISION OF CICHLIDS
FROM NORTHERN MÉXICO AND SOUTHERN TEXAS, U.S.A.

(PERCIFORMES: CICHLIDAE)

by

James Francis LaBounty

A Dissertation Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

ARIZONA STATE UNIVERSITY

May 1974

MATERIALS FOR THE REVISION OF CICHLIDS
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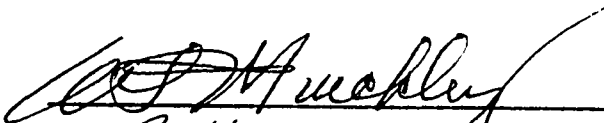
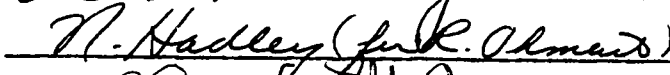
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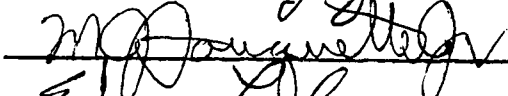
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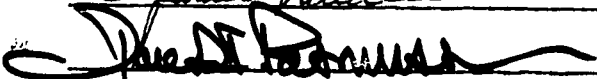
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ABSTRACT

Structural adaptations of North American cichlid fishes parallel those of many cichlid groups of the Eastern Hemisphere. Adaptive radiation in two groups in southern Texas, U.S.A. and northern and eastern México has involved modifications of nutritional features, principally of the pharyngeal mill. Dentition of the jaws was deemed too highly variable to be taxonomically useful by early workers. However, it was found quite conservative when ontogenetic changes, wear, and breakage were identified and excluded. Jaw dentition is a useful criterion at the generic level of taxonomy based on the specimens studied.

Structure and dentition of the pharyngeal mill were also highly conservative at the specific or populational level. Again, ontogenetic change, wear, and breakage were evident, and were easily discernible. In most instances, morphology of the pharyngeal mill and teeth was the most useful tool in separation of species, and in identification of hybrids or other questionable populations.

External morphology, with a few notable exceptions, was far less reliable than dentitional or pharyngeal morphology in diagnoses of taxa. Combinations of external morphological features could be used to separate some species or populations, but variation was high as a result of allometric changes with growth (size) in some characteristics, highly variable about the mean in others, and remarkably similar among different species in many instances.

Length of the alimentary canal, coupled with structural adaptations of the predorsal area (length of head, length of jaws, and related structures, plus body depth), served to emphasize the parallelism among North American cichlids and those of Africa. In a small species flock in the Cuatro Ciénegas basin, Coahuila, México, this was especially evident. Two kinds, known to be piscivorous, had elongated heads, strong jaws, slim, shallow bodies, and raptorial teeth on the jaws and pharyngeal bones. One kind that feeds almost exclusively upon mollusks, had a deeper, thicker body, short head, relatively small dentition on the jaws, but strong, molariform teeth on its greatly enlarged pharyngeal mill. The fourth, a detritivore, was similar in external morphology to the last, but had oral and pharyngeal dentition and bone structure which was delicate and unspecialized. Gut length in these fishes ranged from shortest in the piscivores, scarcely more than body length, though almost twice body length in the molluskivore, to many times body length in the detritus feeder. Omnivorous cichlids exhibited intermediate modifications of pharyngeal dentition, were uniform in oral dentition, and had highly variable lengths of the alimentary canal.

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INTRODUCTION

American percoid fishes of the family Cichlidae have received little taxonomic attention at the generic level since the times of Regan (1905) and Meek (1904, 1908). On the basis of literature available and specimens examined, few if more than 4 to 6 of at least 30 nominal American cichlid genera are definable. Many distinctive forms have been placed with little quantitative support into the genus Cichlasoma Swainson (1839). Many workers have pointed out taxonomic difficulties with these fishes (Hubbs, 1936; Bailey, 1957; Miller and Nelson, 1961; Miller, 1966). Recently some "species groups" or other subcategories within "Cichlasoma" are again being sorted out (Miller, 1966).

Early classifications of cichlid fishes of the Americas were based largely upon dentition of the jaws (Regan, 1905). The highly modified pharyngeal mill has been little used in taxonomic study of American cichlids, but has proven invaluable in work on those of the Eastern Hemisphere (Fryer and Iles, 1972, and citations therein). Proportional measurements of external body parts have been used far less in the diagnosing of taxonomic differences of cichlid fishes than in many other groups. This reflects at least in part the fact that some external features are highly conservative among species or genera and others are exceedingly variable. Fryer (1959a) found one African

species so variable as a result of allometric changes that different sized individuals had been described as three distinct species. Counts of spines and fin rays seem far more conservative in the family, and when consistent differences are found they usually are taxonomically meaningful (Fryer and Iles, 1972). Osteological and soft anatomical features of American forms in general have been ignored.

Descriptions of American cichlids have been based upon characters that are either too general in nature to separate taxa, or which show high individual variations. It was therefore deemed appropriate to examine in detail a broad spectrum of characteristics in a number of North American forms available from southern Texas, U.S.A., and northern and eastern México to obtain some sort of insight into variations that might be expected. One population was selected for intensive analyses. Similar analytical work was done on a number of other kinds when sample sizes and ranges of ages (sizes) and of both sexes were available. What resulted was basically a revision of the nominal genus Herichthys Baird and Girard (1854) throughout the northern part of its range. Another taxon, Parapetenia Regan (1905), originally described as a subgenus of Cichlasoma is elevated to generic rank. The present paper deals with variation specifically, with nomenclatorial considerations kept at a minimum in text and detailed in Appendix I.

MATERIALS AND METHODS

Following is a listing of Taxa present within the area of study (Figure 1), listed from north to south in each of the two genera proposed as valid. Those marked with an asterisk (*) were studied intensively and represented by large samples. All others were allocated on the basis of examination of specimens, and on the bases of literature and consultation with R.R. Miller, University of Michigan, S. Contreras-Balderas, Universidad Autónoma de Nuevo León, and W. L. Minckley, Arizona State University. Appendix II provides a listing of specimens studied. Specimens examined are in the following museums: Arizona State University Collection of Fishes (ASU); University of Texas Natural History Museum (TNHM); University of Michigan Museum of Zoology (UMMZ); University of Kansas Museum of Natural History (KU); and Universidad Autónoma de Nuevo León Colección de Peces (UANL). One upstream record from the Pecos River was examined at the University of New México (UNM).

Genus Herichthys Baird and Girard (1854)

Herichthys, n. sp., Texas cichlid*

H. c. cyanoguttatus Baird and Girard (1854), Río Grande cichlid*

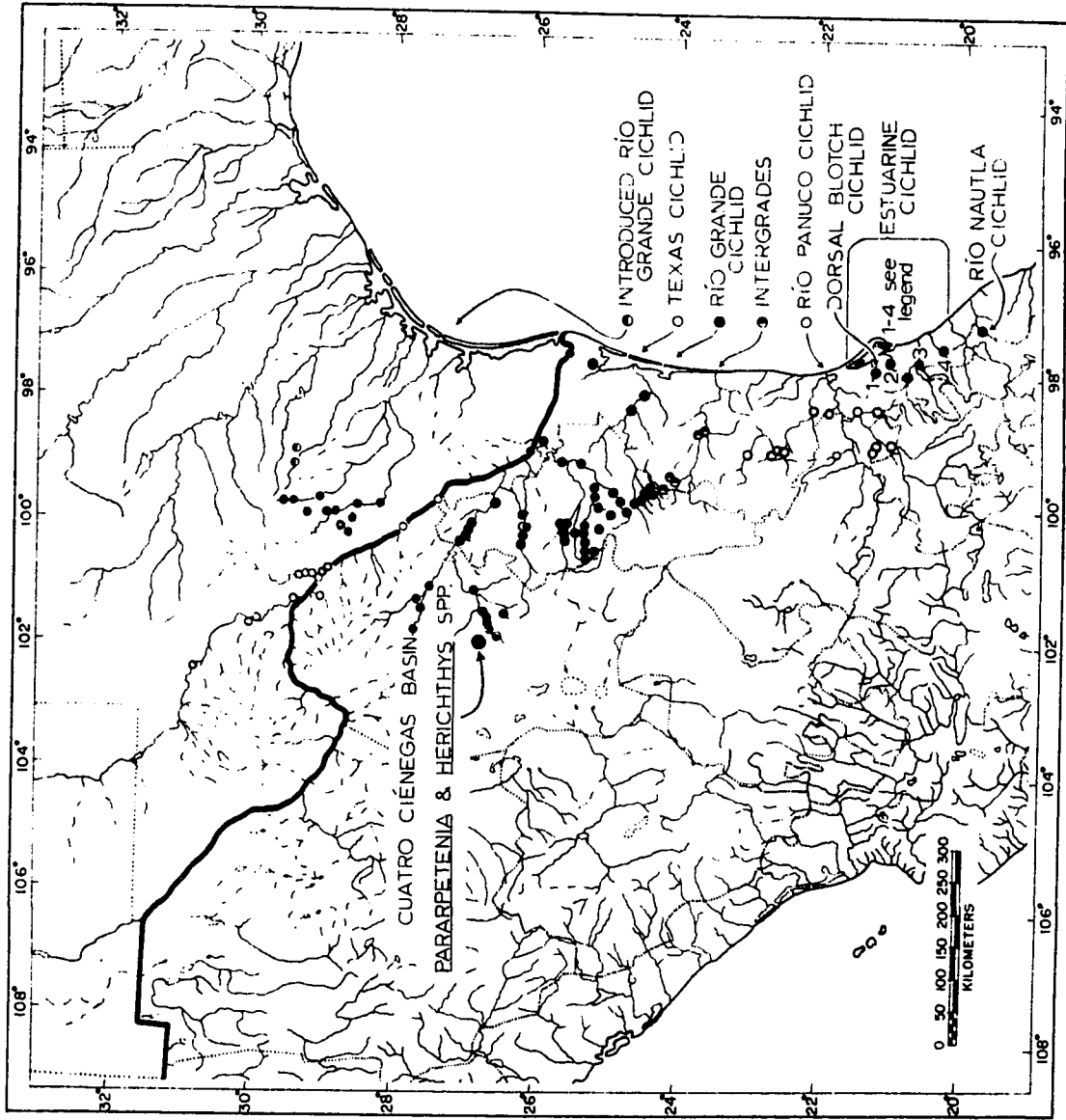
H. c. carpintis (Regan, 1905), Río Pánuco cichlid*

Herichthys, n. sp., n. subspp., estuarine cichlid*

Herichthys, n. sp., dorsal-blotch cichlid

Herichthys, n. sp., Río Nautla cichlid*

FIGURE 1. Distribution of collections of North American cichlids here referred to the genera Herichthys and Parapetentia studied for this report. Numbers for the estuarine cichlid identify the following drainage basins: 1 - Río Tancochin; 2 - Río Cucharas; 3 - Río Pantepec; and 4 - Río Cazonas. Distributions and discussions of the complex within the Cuatro Ciénegas basin, central Coahuila, México (indicated by the large, darkened circle and specifically labeled on the map), may be found later in text (pp. 55-66), and Appendix I should be consulted for ranges of species listed above in text, but not included here, and for more detail on the distributions and taxonomic considerations of the generic and specific identity of kinds of cichlid fishes covered here. See text for more information on Herichthys of the Frio-Nueces Rivers systems of southern Texas.



Genus Parapetenia Regan (1905)

Parapetenia, n. sp., Lugo's cichlid*

Parapetenia, n. sp., caracole cichlid*

Parapetenia, n. sp., long-head cichlid*

Parapetenia, n. sp., unexpected cichlid*

Parapetenia, n. sp., speckled cichlid (?)

P. bartoni (Bean, 1892), Barton's cichlid

P. labridens (Pellegrin, 1903), Río Verde cichlid

P. steindachneri (Jordan and Snyder, 1900), Steindachner's cichlid

Counts and Measurements

A total of 14 counts and 28 measurements of internal and external morphological features was made. Methods of counting and measuring were modified from Miller (1948) and Hubbs and Lagler (1970), insofar as was possible. Terminology for osteological features follow those of Gregory (1933) and Fryer and Iles (1972). To enable others to use and evaluate my techniques of counting and measuring, each is detailed in Appendix III, and some are depicted in Figures 2 and 3 in text.

All measurements were made on a straight line between points with vernier calipers accurate to 0.05 mm (Figures 2-3), with the exception of one measurement of pharyngeal teeth made with an ocular micrometer accurate to 0.001 mm. Fish were individually tagged to facilitate re-examination at a later date to check for possible errors and for consistency of techniques. Measurements were made

FIGURE 2. Generalized sketch of a cichlid fish showing some counts and measurements which were made; Appendix III details descriptions of each measurement and count.

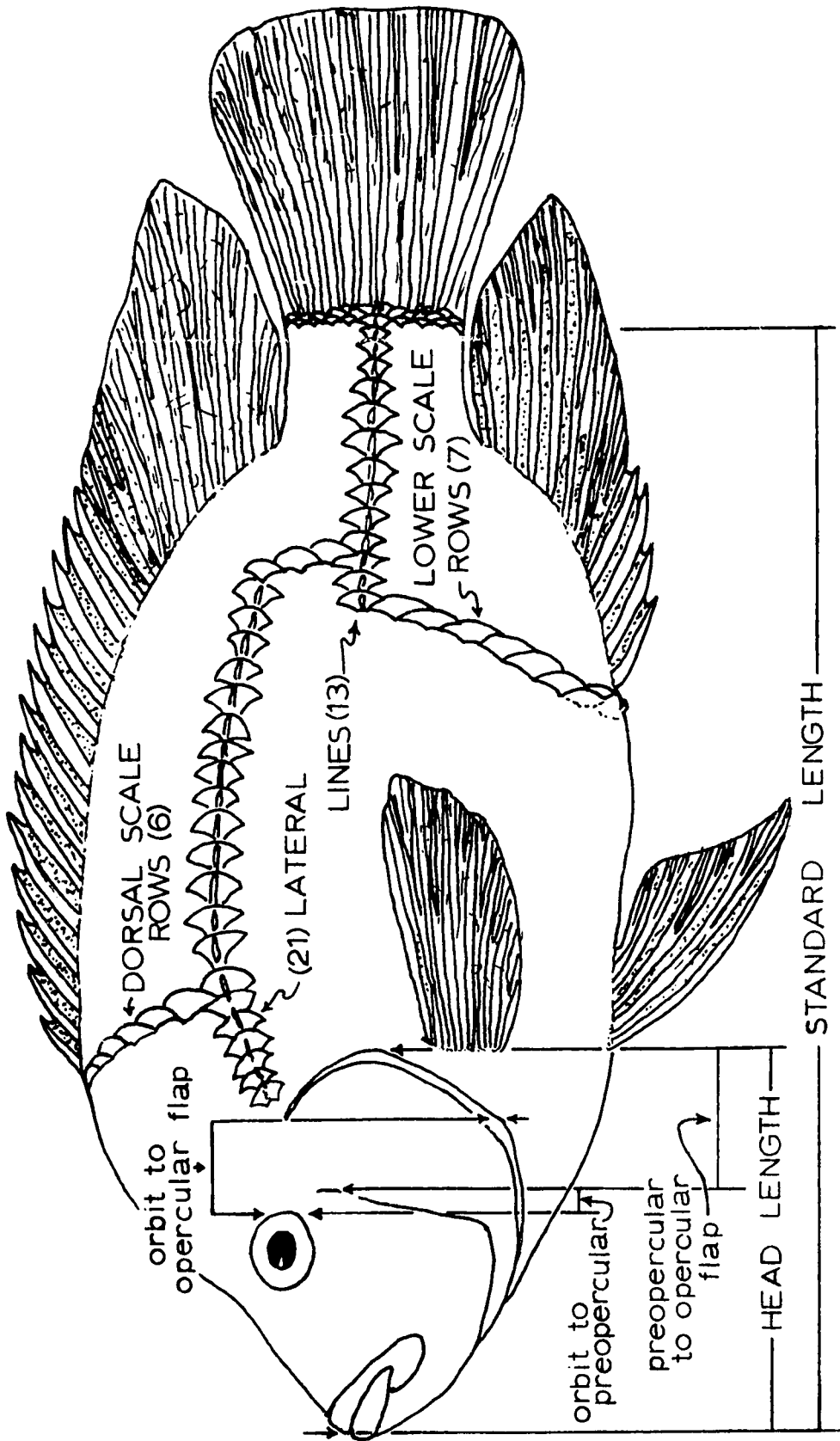
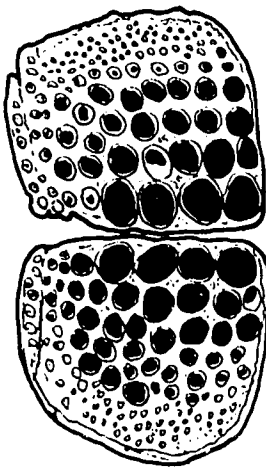
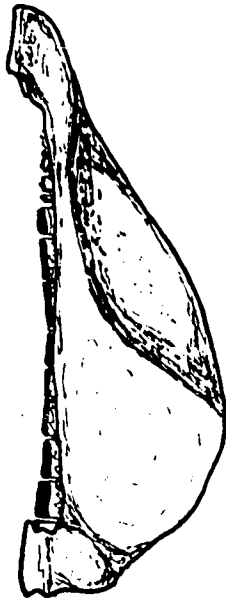


FIGURE 3. Generalized sketches of bones of the pharyngeal mill of a form of cichlid fish, genus Parapetenia, showing various measurements which were made; Appendix III details description of each measurement--A = occlusial (ventral) surfaces of longitudinally fused, upper three epipharyngobranchial bones; B = lateral view of fused, posteriormost basipharyngobranchial bone; C = occlusial (dorsal) surface of bone illustrated in "B"; and D = posterior view of bone illustrated in "B".

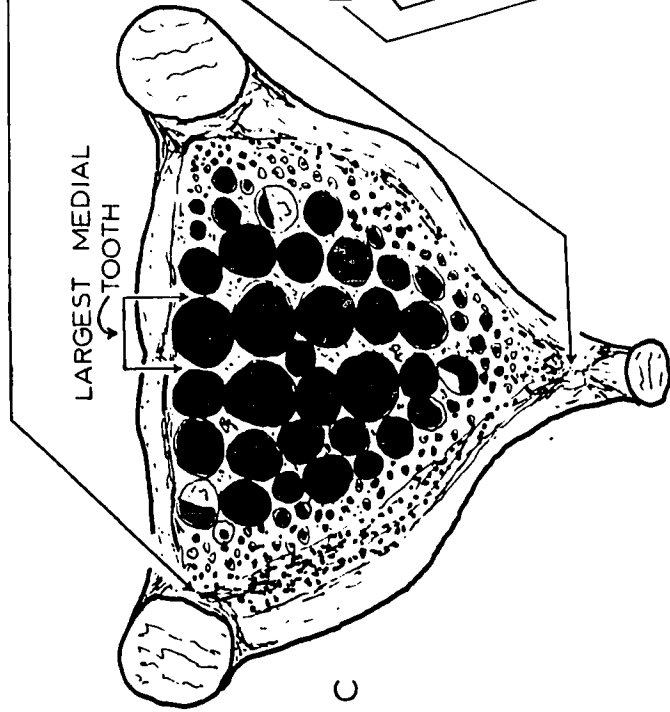


A



B

OCCLUSAL SURFACE

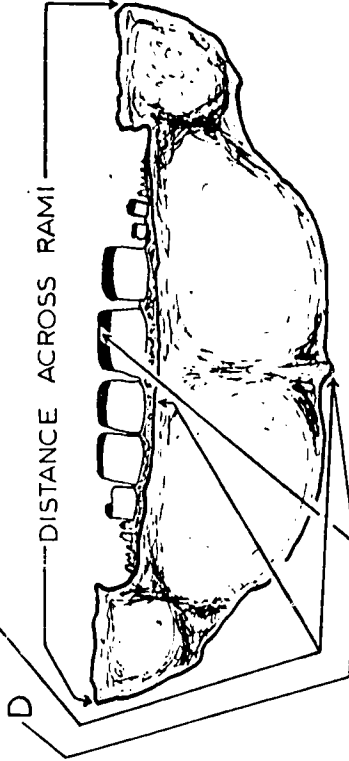


C

PHARYNGEAL BONE

PHARYNGEAL BONE AND TEETH

DISTANCE ACROSS RAMI



D

on the left side of the fish, with two exceptions: standard length (SL) was taken on the right; and the longer of either paired fin was measured. On occasion it was necessary to measure or count a feature on the right if it was obviously injured or deformed on the left side. All specimens were kept moist, which is particularly important for accuracy in measurements of fins. All numerical data were analysed statistically on an IBM 1130 computer. Measurements were divided by SL to produce a simple proportion of thousandths of SL expressed for analytical purposes as a whole number by multiplication $\times 10^3$.

Osteology

Osteological studies were made on materials prepared by dermestid beetles, X-rayed, or dissected. Qualitative examination of jaw teeth was done by careful manipulation of the lips and surrounding tissues with needle-point forceps. Removal of teeth for detailed studies was performed by use of hooked microscalpels constructed from standard dissecting needles. The fused basipharyngo-branchial bones (hereafter referred to as a single bone) were removed by deflecting the opercle anteriorly, and dissecting the musculature anterior to the cleithrum and mesial to it until the bone was found. The bone was dissected from musculature on each posterior ramus, and sometimes along the posterior surface, then disarticulated from the anterior and dorsal connections to the branchial basket. It was then lifted gently from the oropharynx.

Removal of epipharyngobranchial bones required dissection of musculature originating along the base of the neurocranium and from the occipital region. They are not fused mesially, and typically are symmetrical (Figure 3). After examination, the entire mill was placed back into position and secured by manipulation of dissected tissues and replacement of the opercle into a natural state. If tooth bearing skeletal parts are to be maintained in a dried condition, they should be soaked for a brief period in glycerin or some form of light oil to prevent loss of teeth after a long period of time.

Soft Anatomy

Study of soft anatomy was almost exclusively restricted to determination of length of the alimentary tract. This was performed by dissection or by qualitative examination under appropriate magnification and illumination.

VARIATION IN CHARACTERS OF SOME NORTH AMERICAN CICHLIDS

Taxonomic studies of American cichlid fishes have dealt almost entirely with descriptions of new taxa. No in-depth analyses of variation of their structural features have yet been published. In African forms, Trewetas (1935) carefully defined counts and measurements used in her studies, Fryer (1956a) discussed allometric changes in body proportions, and Greenwood (1965) dealt with the validity of using morphology of the pharyngeal mill in separation of two forms of Astatoreochromis alluandi Pellegrin. Fryer and Iles (1972) summarized and expanded upon these and other studies of variation within the group in the Eastern Hemisphere. My most intensive studies were of 491 specimens comprising the nominal form Herichthys cyanoguttatus (sensu stricto). Specimens ranged from 24 to ca. 150 mm SL and were from a number of river basins associated with the lowermost Río Grande system of southern Texas, U.S.A., and northern México. The form has been introduced elsewhere, but all such populations were excluded from analyses. In all, more than 2,500 specimens of cichlids were examined qualitatively or quantitatively. Each character was compared and contrasted to data collected for the "baseline" form--the Río Grande cichlid.

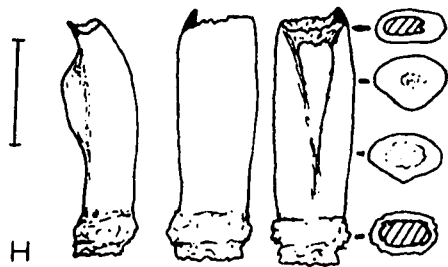
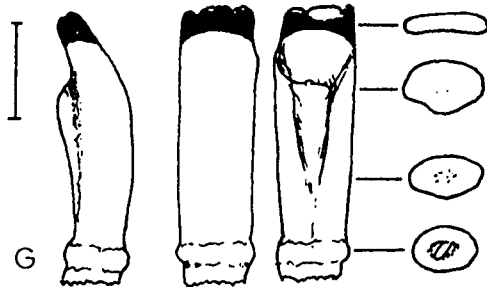
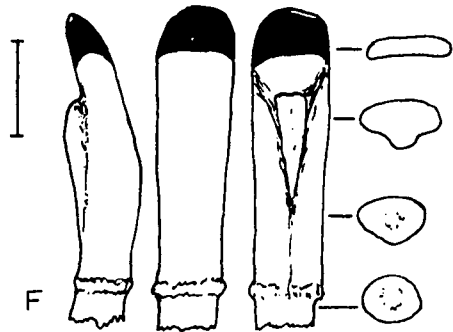
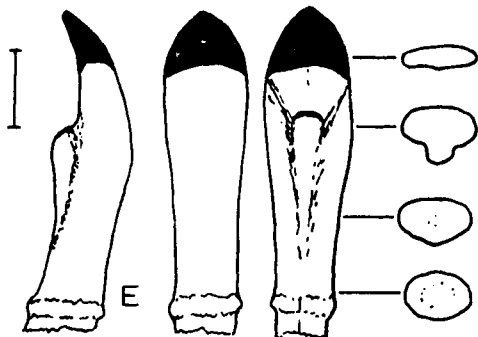
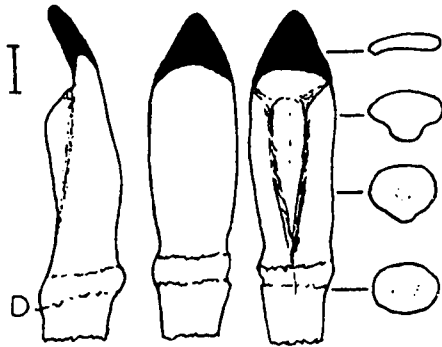
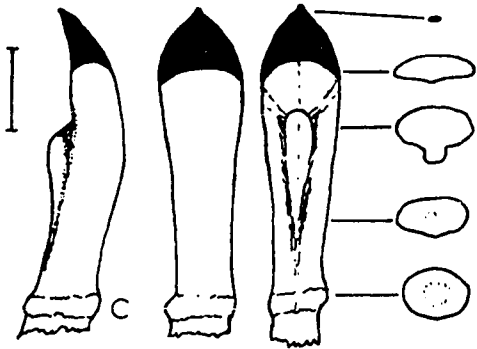
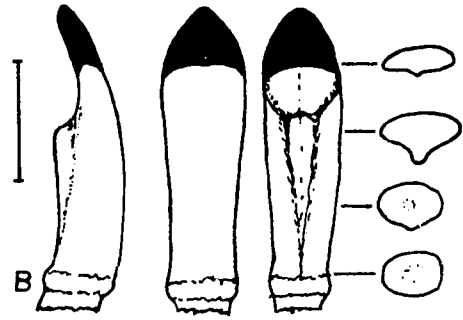
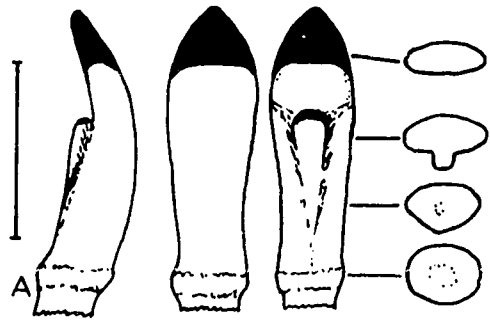
Dentition of the Jaws

Dentition of the jaws seemed remarkably conservative in the fishes studied so long as newly emerged or emerging teeth were examined. Wear, breakage, and replacement, all of which were evident in some specimens, easily explained the rejection of the character by Meek (1904, 1908), its misinterpretation (in part by Regan, 1905), and the mass synonymization of genera by some (in part, Regan, 1905; Eigenmann and Bray, 1894), or resurrection of obscure generic names (Jordan, et al., 1930).

Within and among populations of Herichthys, ontogenetic variation seemed minimal. Teeth on the dentary bones were similar in overall morphology to those on the premaxillae. However, occlusion of the jaw teeth was quite variable, and an overbite may produce variation in tooth shape quite different than that produced by an underbite or equivalence of the jaws. There seems a tendency with age (size) for these fishes to begin with a distinct overbite, trending through equivalence, to an underbite in very large individuals. This, however, may be modified by state of preservation or other possible factors.

Ontogenetic variation at the intrapopulation level was examined in a series of 63 Río Grande cichlids and 49 Texas cichlids; examples from the latter are illustrated in Figure 4a-d. Changes with size (age) related principally to development of a posterior "cusp", ranging from relatively well developed and

FIGURE 4. Newly emerged or emerging, anteriormost premaxillary teeth of fishes of the genus Herichthys; lateral, anterior, posterior, and cross-sectional views, left to right, respectively--A - D = morphological changes with growth (size) in a series of Texas cichlids; and E - F = morphological changes with wear in two individuals of Texas cichlids (all specimens from the Devil's River, Val Verde County, Texas; vertical scale is one mm).



heavily pigmented at its tip in young (small) fish, to generally rounded and non-pigmented in large adults. Cross-sections of tips of the teeth range from elongate-oval in smaller fish, through those having a minor posterior ridge in intermediate sized fish, to awl-like in larger (old) adults. The last may reflect wear of the posterior surface as only a few extremely large individuals were studied, and newly emerging teeth were not found in the specimens examined. Absolute sizes of the teeth increased with an increase in SL, but no studies were made of relative lengths of jaw teeth of any species.

Wear has an obvious influence on basic tooth morphology in these fishes, effecting changes in the proximal, occlusal surface, and also in the shape and massiveness of the posterior cusp (Figure 4e-h). Tooth replacement in Herichthys occurs from deep within the premaxillary bone. The tip of the emerging tooth appears first as a small, pigmented bud, which then grows forward and downward to penetrate the necrotic lumen of a severely worn tooth (Figure 4h), forcing it out. It then grows downward and anteriorly into its final position (Figure 5a-b).

Proceeding from north to south within the range of the forms of Herichthys studied, there is a distinct cline (with variations from river to river). Herichthys in the north have a sharp pointed, spade like tooth, with a broad, stout posterior cusp. This changes toward a broadly spatulate premaxillary incisor, with a delicate and discretely developed (although tiny) posterior cusp in southern

FIGURE 5. Sketches of the jaws of a specimen of Río Grande cichlid from the Río Salado, northern Coahuila, México--A = mesial view of premaxilla showing emerging tooth entering necrotic lumen of a worn and broken tooth; B - C = lateral views of premaxilla and dentary complex, respectively, showing progressive nature of incisor morphology in former, and the sharply demarked, anterior development of incisors on the latter; and D = dorso-anterior view of partially articulated premaxillae and dentary complexes (vertical scale is one cm).

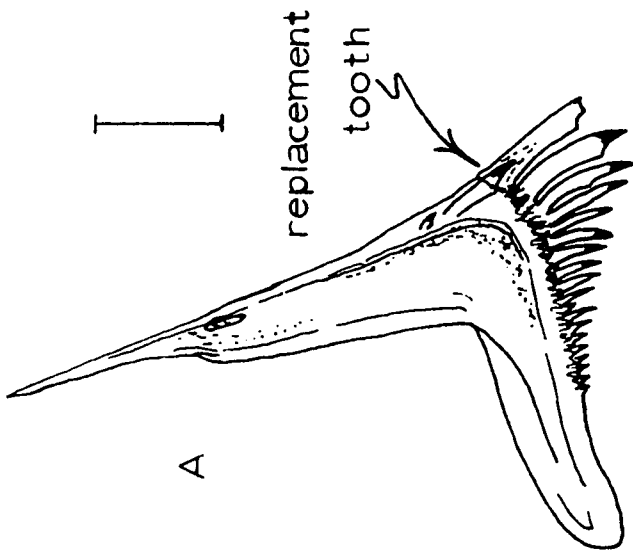
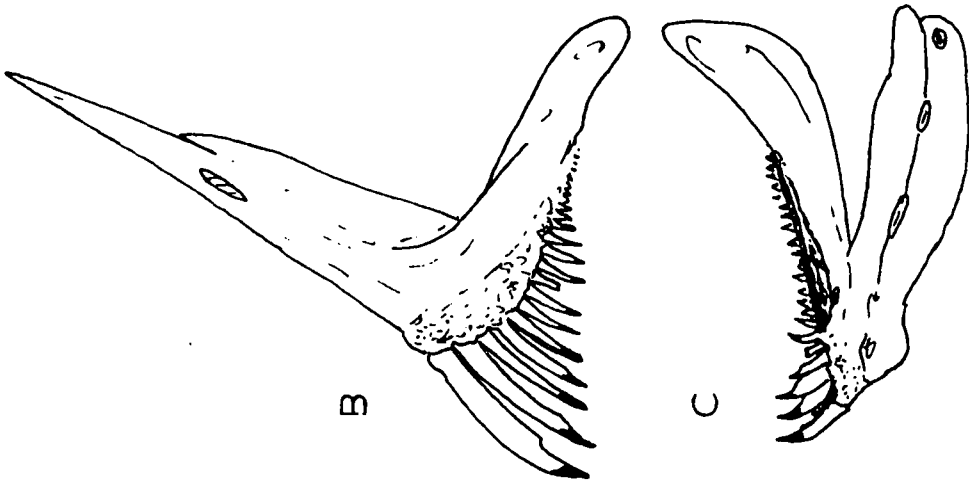
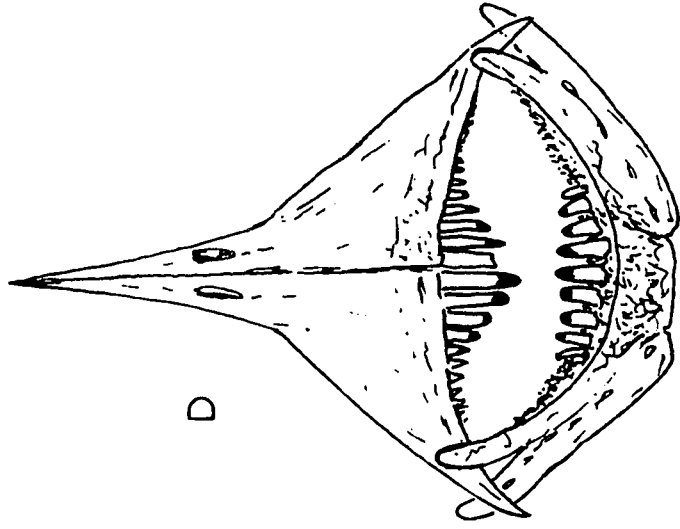
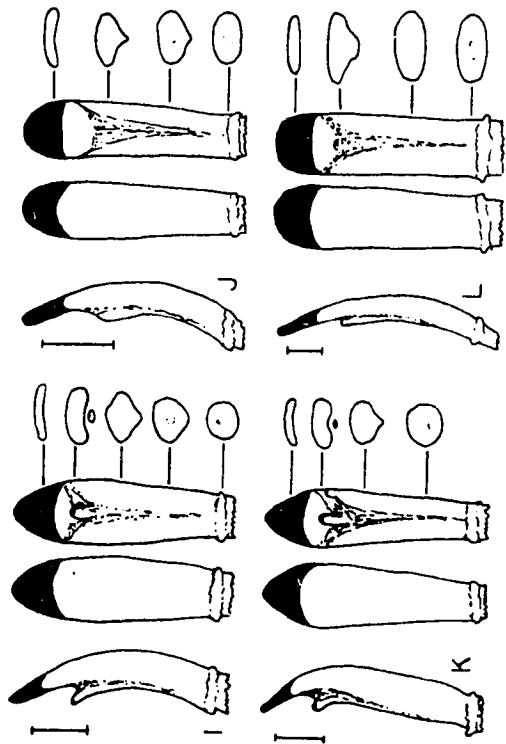
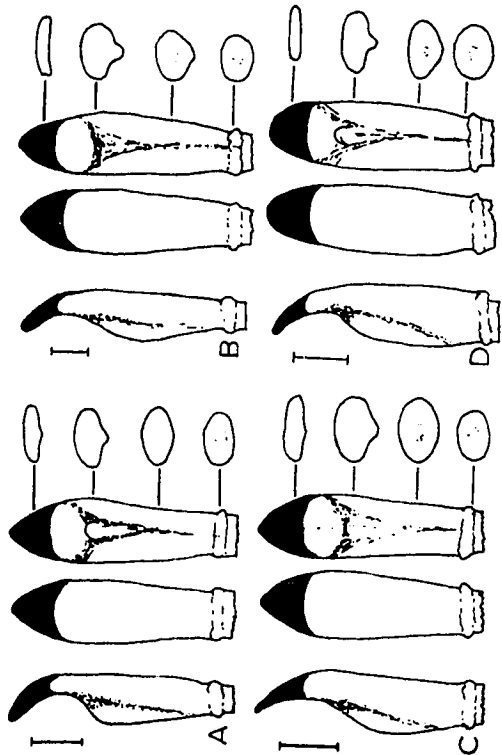
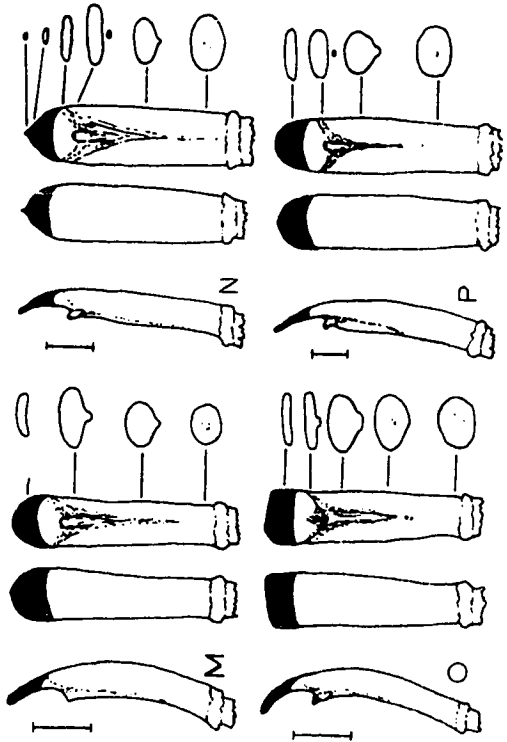
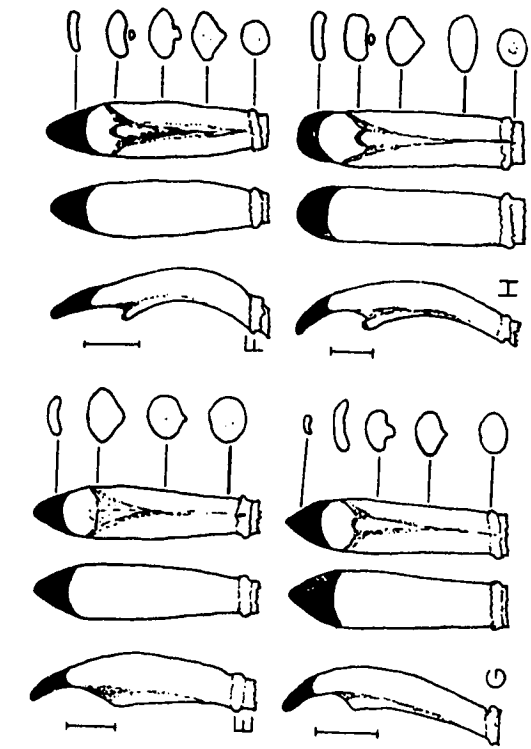


FIGURE 6. Newly emerged or emerging, anteriormost premaxillary teeth of fishes of the genus Herichthys from various localities; A = Río Salado, Coahuila, México; B = Río Sabinas de Nuevo León, Nuevo León, México; C = Río San Juan, Nuevo León, México; D = Río San Fernando, Tamaulipas, México; E - H = specimens, arranged from north to south, Río Soto la Marina system, Tamaulipas, México; I - L = specimens, arranged from north to south, Río Pañuco system, Tamaulipas, San Luis Potosi, and Vera Cruz, México; M = Río Tancochin, Vera Cruz, México; N = Río Cucharas, Vera Cruz, México; O = Río Pantepec, Vera Cruz, México; and P = Río Nautla, Vera Cruz, México (vertical scale is one mm).



forms (Figure 6). Care must be exercised in dissection and examination of the posterior face of the teeth in more southern forms. In many instances the posterior cusp is so fragile it is easily broken away to produce an essentially smooth surface.

Study of 145 individuals of various species of Parapetenia from within the region also inhabited by Herichthys indicated similar variations in ontogeny, wear, and interspecific differences. However, dentition of the jaws of the two genera differ radically. The sharp, canine teeth of Parapetenia (Figure 7) are quite distinct from the incisors of Herichthys, and become obtuse and peg like with wear. Worn teeth were easily discernible by the loss or reduction of pigmentation of their tips. All Parapetenia studied had an overbite, at least of the uppermost canines (Figures 7a-b, 8). Very old (large) individuals of that genus often had the anterior portions of both premaxillary and dentary bones toothless. This suggests that the number of germinal buds for the canines (at least) is finite, a feature which merits further study. In no instance was a "toothless" Herichthys found. Both genera are characterized by having only the anteriormost teeth on the dentary developed into canines or incisors, and by having those teeth sharply set off from the lateral, villiform to miniaturized cardiform, dentary teeth (Figures 5c, 7b).

Pharyngeal Bones and Teeth

The pharyngeal mill comprises a lower component consisting of the last two basipharyngobranchial bones, greatly fused and often

FIGURE 7. Sketches of the jaws of Lugo's cichlid (A-B), genus Parapetenia, from the Cuatro Ciénegas basin, Coahuila, México, and of newly emerged or emerging, anteriormost premaxillary teeth of fishes of the genus Parapetenia; lateral, anterior, posterior, and cross-sectional views, left to right, respectively--C = Lugo's cichlid; D = caracole cichlid; E = unexpected cichlid; and F = long-head cichlid--all from the Posos de la Becerra, Cuatro Ciénegas basin, Coahuila, México (vertical scale for A and B is one cm, for C through F one mm).

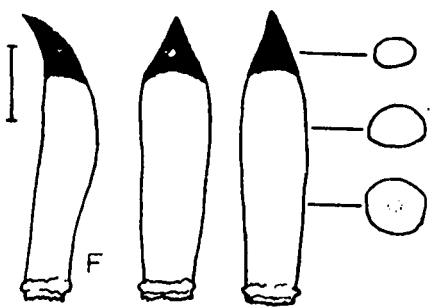
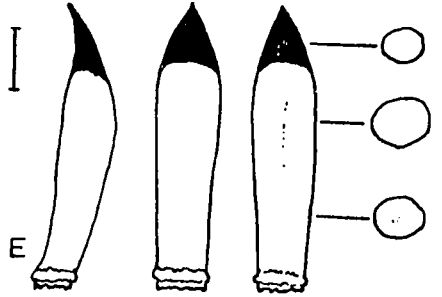
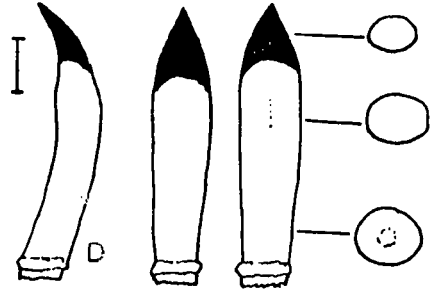
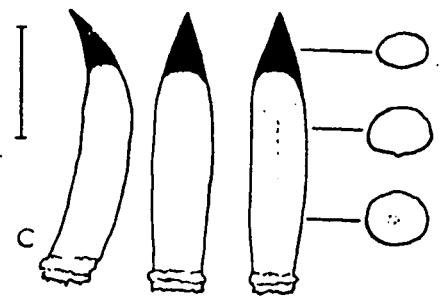
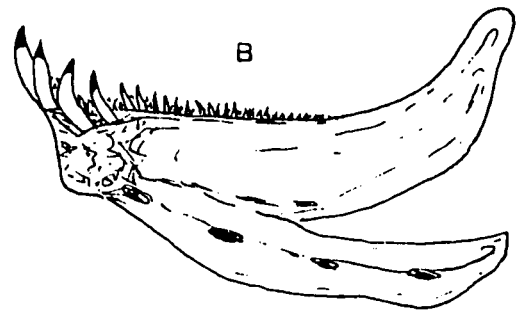
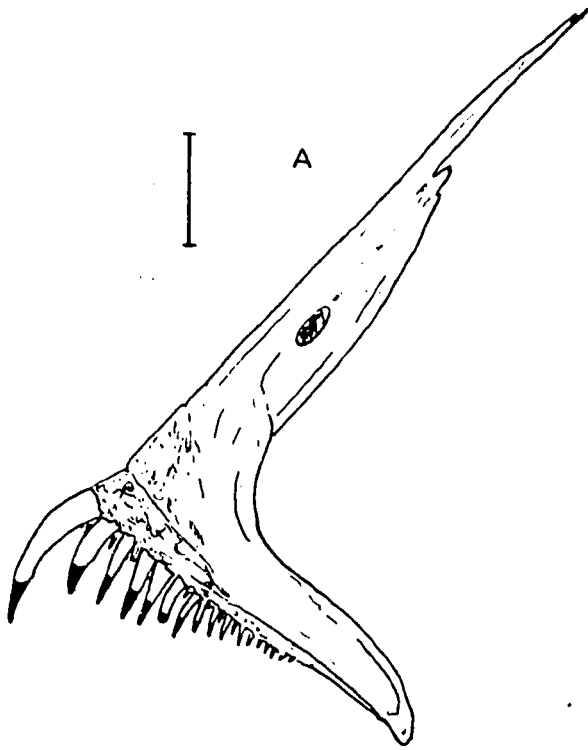
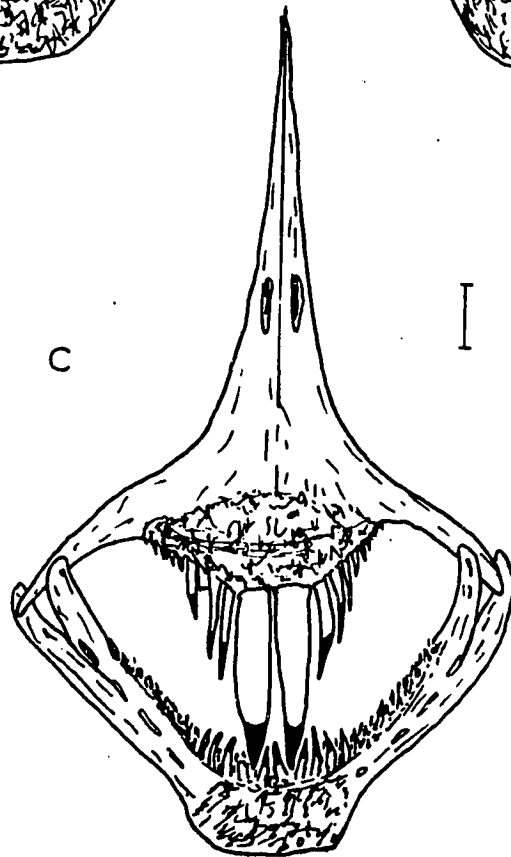
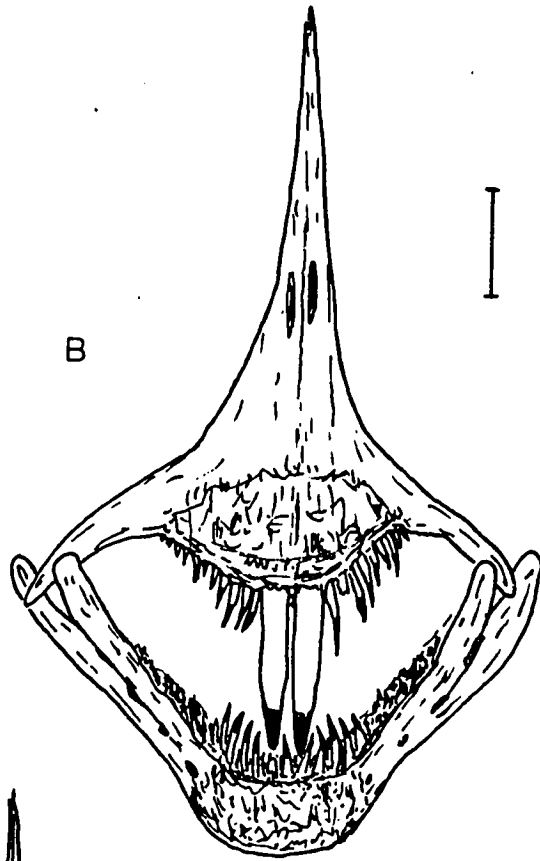
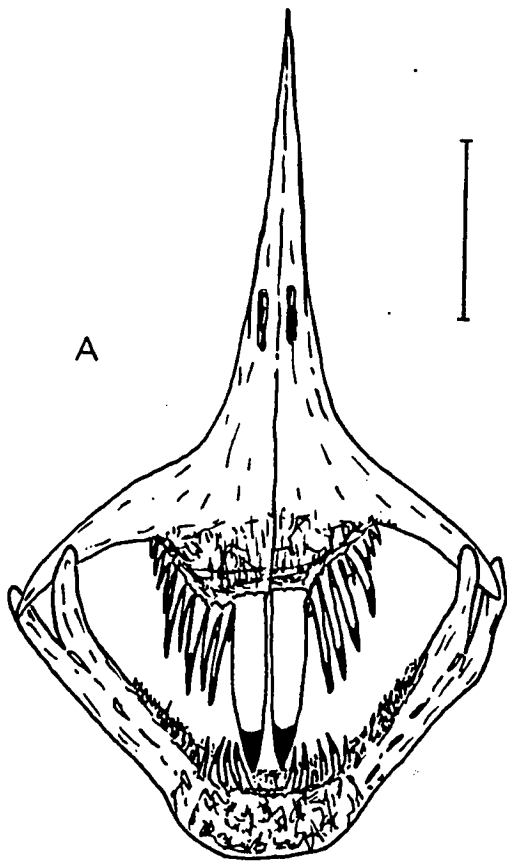


FIGURE 8. Dorso-anterior views of partially articulated premaxillary and dentary complexes of different sized Lugo's cichlids, genus Parapetenia; note variable, but consistent, pronounced enlargement of premaxillary canines, and sharp demarcation of dentary canines from lateral teeth (all specimens from Posos de la Becerra, Cuatro Ciénegas basin, Coahuila, México; vertical scale is one cm).



thickened, two separate, thickened structures dorsally, comprised of the posterior three (rarely two) epipharyngobranchial bones, variably fused longitudinally, but not fused along their mesial borders (Figure 3). Modifications of the base of the neurocranium for muscle attachments and for surfaces of articulation between the mill and the skull and anteriormost vertebrae also are evident. The modified pharyngeal bones bear teeth. Various kinds and orientation of these teeth, the sizes and shapes of the bones themselves, and numbers of teeth differ from taxon to taxon. Many differences found in proportional measurements of cichlids that are associated with the head and predorsal region may be attributed directly or indirectly to morphology of the pharyngeal mill. In more general terms, Fryer and Iles (1972) described the workings and anatomy of this apparatus as follows:

The position of the upper and lower pharyngeal bones at the back of the throat is such that all food must pass between them as between a pair of millstones... On what are the equivalents of the grinding surfaces of the millstones teeth are implanted, whose number, size and structure differ according to the kind of food with which they have to deal.

Both the upper and lower pharyngeal bones are moveable but whereas the upper bones slide mostly forwards and backwards and to a lesser extent from side to side, the movement of the lower bone is upward and downward, that is towards and away from its upper partners... Movement of the upper pharyngeal bones is effected to a large extent by muscles which in many species originate on a pair of processes (apophyses) which project downwards from the vertebral column and, in most species, meet and fuse as a median peg (apophysis)...

To facilitate movement of the upper pharyngeal bones special facets or bosses are developed on the base of the skull. These constitute what is somewhat confusingly called an apophysis (not to be confused with the vertebral apophysis just

described) which, besides being of great functional importance, has been used as a basis for classification, for it is not always made up from the same skull bones...the apophysis is a surface on which the upper pharyngeal bones can slide.

Dentition and morphology of the pharyngeal mill vary somewhat with age (size) within most species. This is due largely to an absolute increase in the number of teeth on the occlusal surface (Figure 9), as has also been demonstrated for African cichlids by Greenwood (1964). However, the qualitative aspect of the lower basipharyngo-branchial bone and teeth, emphasized in my research, and the five quantitative features measured, showed little allometric change (Figure 10). The most reliable of the five characters were width of the bone, depth of the bone and teeth, and width of the middle, posterior pharyngeal tooth (Table 1). No ecotypy was detected in development of the mill, teeth, or associated structures. Emerging teeth were the same as those already emerged and presumably in use at the time of death (Figure 9). Alterations of the distal portions of pharyngeal teeth were easily interpreted as to wear, breakage, or aberrancy, when such were encountered. In addition, a number of species with distinctive pharyngeal dentition have been reared in the laboratory or under semi-natural conditions, and individuals of these species have retained their pharyngeal morphology despite common artificial diets (Minckley, pers. comm.; Figure 11). Greenwood (1965) obtained different results in rearing one specimen of an African cichlid. His results were inconclusive on the basis of a number of factors, including the unplanned nature of the

FIGURE 9. Occlusial surfaces of the fused, posteriormost basi-pharyngobranchial bones in various sized Río Grande cichlids, genus Herichthys, from the Río San Juan system, Nuevo León, México (A - D); and similarly for various sized caracole cichlids, genus Parapetenia, from the Cuatro Ciénegas basin, Coahuila, México (E - H), showing the relatively small amount of variation with age (size) (vertical scale is one cm).

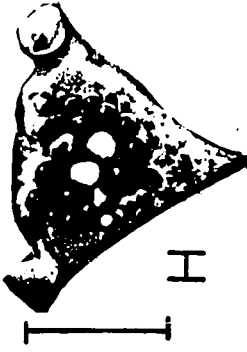
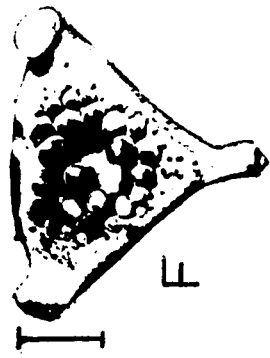
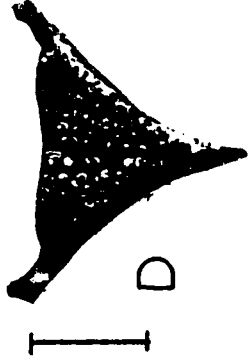
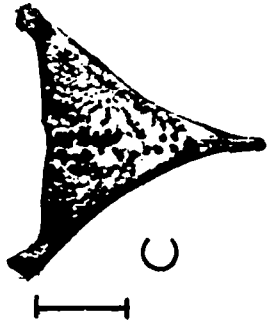
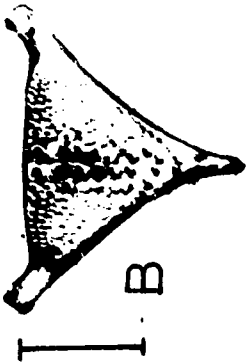
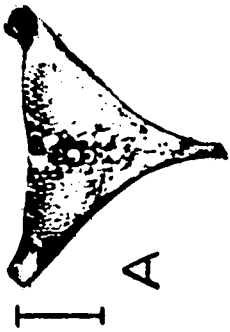


FIGURE 10. Proportional relationships, in thousandths of SL X 10³, of measurements of the basipharyngobranchial bone to SL in Río Grande cichlids, genus Herichthys; Appendix III and Figure 2 detail description of each measurement.

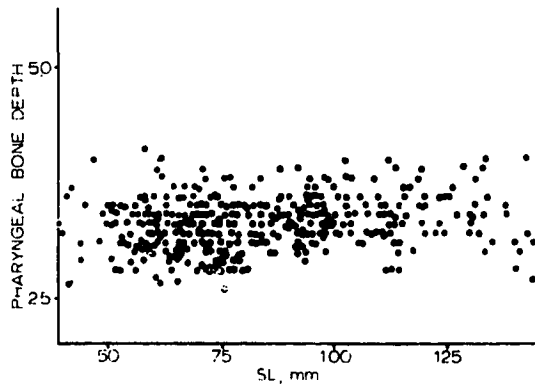
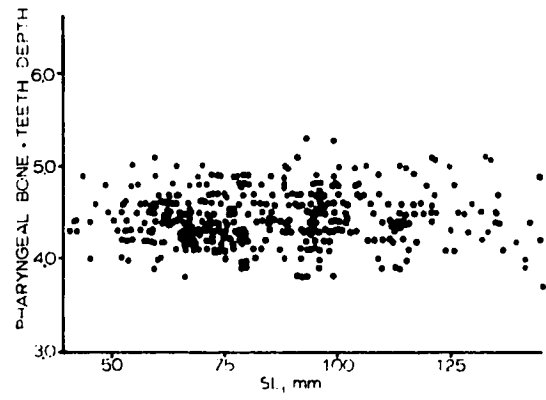
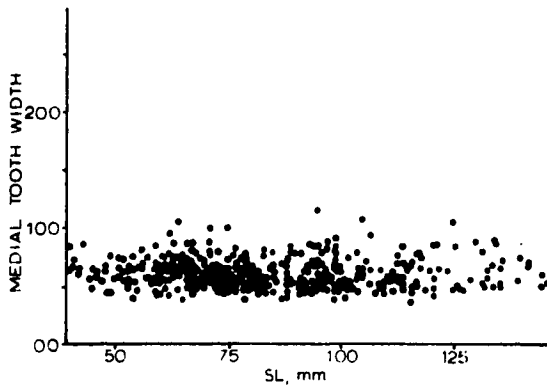
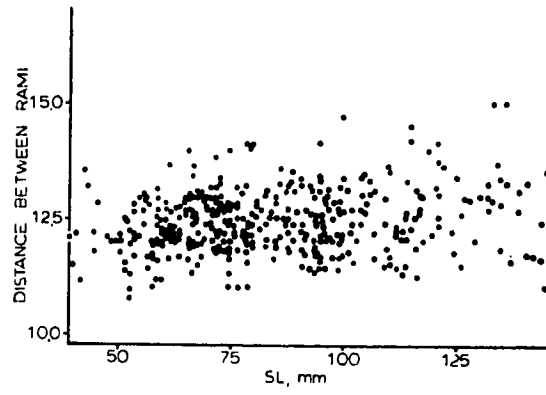
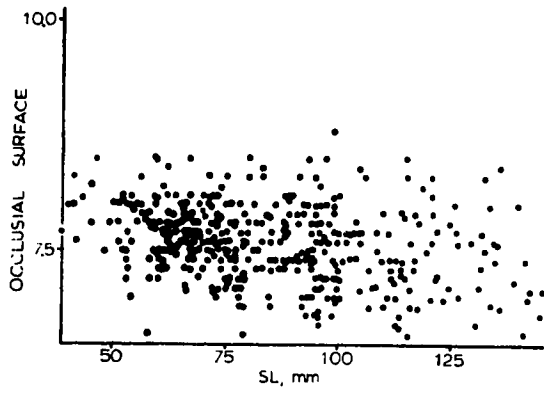


TABLE 1. Measurements of the lower basipharyngobranchial bone and teeth of various North American cichlid fishes; thousandths of standard length $\times 10^3$ --means are below ranges.

Fishes and localities	Maximum width	Width occlusial surface	Maximum depth	Maximum depth bone teeth	Width middle tooth
Texas cichlid, Río Grande system, N = 66	109-160 130	70- 93 77	28- 48 34	40- 56 45	6.2-21.0 12.5
Río Grande cichlid, Río Grande system, N = 391	109-160 124	63- 93 75	23- 48 32	37- 56 44	3.2-9.4 5.1
Río Grande cichlid, Río Salado basin, N = 226	110-160 123	63- 88 75	23- 41 32	38- 55 44	3.7-5.6 4.4
<u>Herichthys</u> , from Cuatro Ciénegas basin, N = 94	106-184 128	63-113 80	29- 93 35	40- 66 46	3.6-19.8 6.8
Río Grande cichlid, Río San Juan basin, N = 100	110-149 125	66- 85 75	27- 39 32	37- 51 43	3.2-9.4 5.4
Río Grande cichlid, Río San Fernando basin, N = 24	121-141 129	72- 85 76	28- 39 34	42- 49 45	4.3-6.4 5.0
intergrades, Río Soto la Marina system, N = 24	111-146 127	71- 89 77	25- 41 33	33- 50 43	3.8-6.8 4.9
Río Pánuco cichlid, Río Pánuco system, N = 56	109-147 125	65- 91 77	26- 36 31	37- 48 42	3.5-7.1 4.7
Río Pánuco cichlid, Río Tamesí basin, N = 16	115-137 124	67- 87 77	26- 34 30	39- 47 41	3.7-6.6 4.9

TABLE 1. Continued

Río Pañuco cichlid, Río Pañuco basin, N = 40	109-147 125	65- 91 77	26- 36 31	37- 48 42	3.5-7.1 4.7
estuarine cichlid, Vera Cruz state, México N = 28	101-149 121	63- 90 75	28- 37 31	38- 48 41	3.6-6.6 5.1
estuarine cichlid, Río Tancochin system, N = 5	127-149 133	82- 90 84	31- 36 33	42- 48 44	3.5-6.3 4.7
estuarine cichlid, Río Cucharas system, N = 5	116-129 120	72- 78 75	28- 34 30	41- 48 42	4.5-6.6 5.6
estuarine cichlid, Río Pantepec system, N = 14	101-123 117	63- 78 71	29- 37 32	38- 45 40	3.4-6.3 4.9
estuarine cichlid, Río Cazones system, N = 4	120-126 122	75- 83 77	30- 32 31	40- 42 41	5.0-6.1 5.6
dorsal-blotch cichlid, Río Tancochin system, N = 1	--- 143	--- 93	--- 37	--- 46	--- 3.2
Río Nautla cichlid, Río Nautla system, N = 5	111-115 113	69- 73 71	27- 30 28	36- 39 37	4.0-5.5 4.7
Lugo's cichlid, Cuatro Ciénegas basin, N = 139	102-134 116	61-101 72	23- 43 30	34- 52 42	2.2-6.0 3.9
caracole cichlid, Cuatro Ciénegas basin, N = 88	111-182 167	69-111 87	31- 63 45	46- 71 68	9.7-22.0 15.7

TABLE 1. Concluded

unexpected cich- lid, Cuatro Ciénegas basin, N = 26	109-127 113	69- 85 75	24- 35 29	37- 44 41	2.8-5.3 3.5
long-head cich- lid, Cuatro Ciénegas basin, N = 14	114-134 115	70- 86 77	26- 37 28	38- 49 38	7.2-13.8 10.1

experiment, lack of absolute filial data, and a possibility that lack of calcium could have been involved in hypotrophy of a pharyngeal mill that presumably should have been large, stout, and invested with molariform teeth.

Pharyngeal dentition provides a broad spectrum of variability within both Herichthys and Parapetenia. These variations, however, seem quite consistent as usable taxonomic features at the specific level. A number of taxa of each genus are best identified by examination of the pharyngeal mill.

Within Herichthys, the Texas cichlid may be characterized by two mesial rows of enlarged, semi-molariform teeth on either side of the median suture of the basipharyngobranchial bone (Figure 12a-c). One population, isolated and perhaps differentiated or subject to some hybridization with a form of Parapetenia within the Cuatro Ciénegas basin, Coahuila, México, will be discussed later in detail. The species is sympatric with H. c. cyanoguttatus (s.s.) as far east as the Río San Juan system of northeastern México (Figure 1). It is sympatric with Río Grande cichlids in the Frio-Nueces Rivers system of southern Texas, where one or both may have been introduced (Clark Hubbs, pers. comm.). It likely was sympatric with the Río Grande cichlid, at least in limited numbers in the past and perhaps now, in the mainstream Río Grande (Robinson, 1959). The Texas and Río Grande cichlids hybridize locally (Figure 13), in a pattern suggesting secondary contact that may have occurred in relatively recent times.

FIGURE 11. Comparisons of basipharyngobranchial bones of cichlids reared in captivity (A - C), with specimens collected in nature (D - F): A = Texas cichlid, genus Herichthys, aquarium stock reared on alfalfa pellets and commercial foods, and D = Texas cichlid collected in nature (both from the Devil's River, Val Verde County, Texas); B = Lugo's cichlid, genus Parapetenia, reared in presence of diverse foods, including gastropod mollusks, insects, and smaller fishes, in a seminatural pool at ASU and E = Lugo's cichlid collected in nature from the Cuatro Ciénegas basin, Coahuila, México; and C = caracole cichlid, genus Parapetenia, aquarium stock reared as "A" above, and F = caracole cichlid collected in nature from the Cuatro Ciénegas basin, Coahuila, México (vertical scale is one cm).

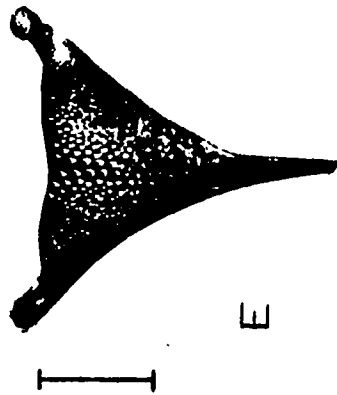
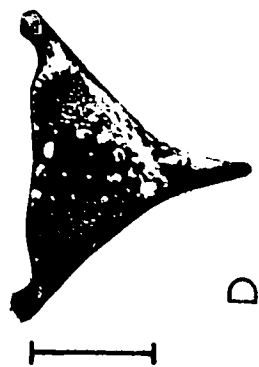
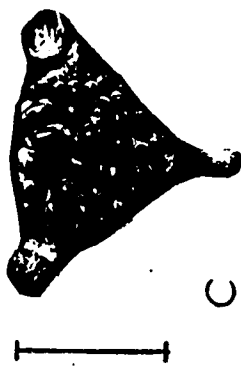
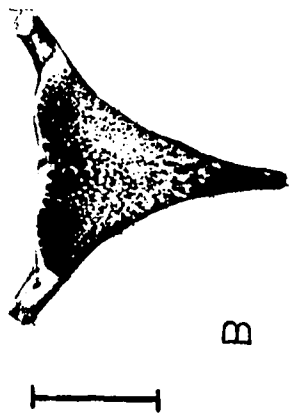
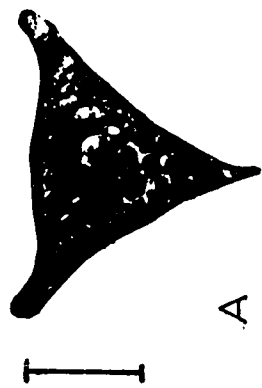
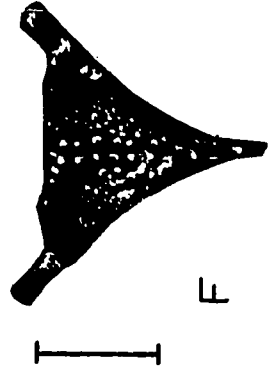
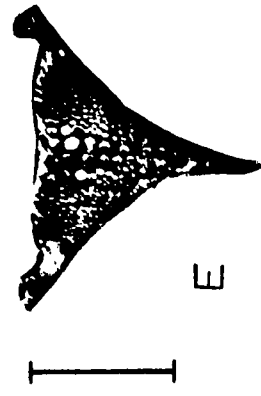
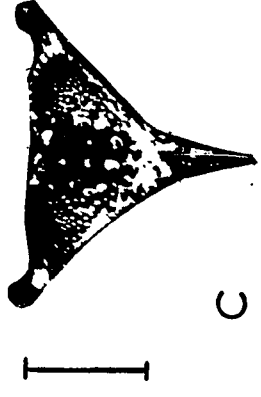
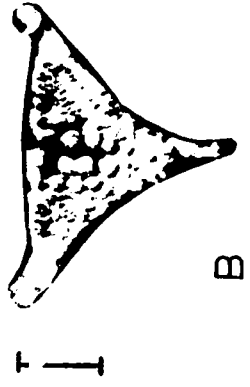
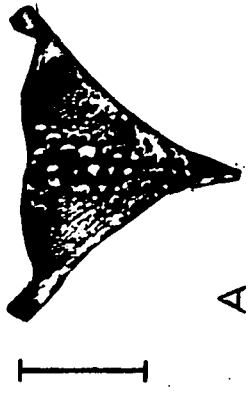


FIGURE 12. Basipharyngobranchial bones of Texas (A - C) and Río Grande cichlids (D - F), genus Herichthys; see text for discussion (vertical scale is one cm).

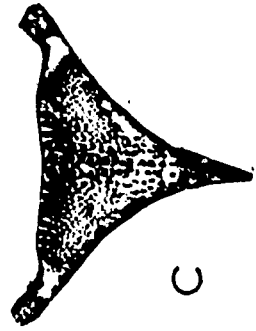


Herichthys c. cyanoguttatus occurs from the northern limits just noted, eastward and southward through the Río San Juan and Río San Fernando (Figure 1), and may be characterized as having a pharyngeal dentition consisting of a single, mesial enlarged row of semi-molariform teeth on each side of the fused suture (Figures 9a-d, 12d-f). The posteriormost tooth of each of these rows tends to be sharp, conical, and antrorse in orientation. This same pattern of pharyngeal dentition persists in other forms of Herichthys ranging southward to the Río Nautla, Vera Cruz, México (Figure 14), the southernmost limit of the present study, an exception being the dorsal-blotch cichlid. This last form differs radically from others in having the basipharyngobranchial bone invested with tiny, almost villiform teeth, flanking a single row of mesial, sharp pointed, and slightly enlarged teeth along the medial suture (Figure 14j). Only one adult was available in collections studied.

Intergradation is indicated between the Río Grande and Río Pánuco cichlids in the Río Soto la Marina system by measurements of the basipharyngobranchial bone (Table 1). The general conservatism of the pharyngeal teeth prevails, however, in the overall morphological aspect of the structure among all Herichthys studied.

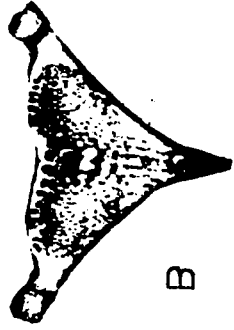
Interspecific differences also occur in Parapetenia, in sizes, shapes, and dentition of the pharyngeal mill (Table 1; Figures 9e-h, 15). Teeth of the lower pharyngeal bone provide a valuable tool in sorting out various species and populations. As noted earlier, some

FIGURE 13. Basipharyngobranchial bones of Texas cichlids, (A and D), Río Grande cichlids (C and E), and a putative F_1 hybrid, all genus Herichthys (B): A - C from the Río Sabinas de Nuevo León, TNHM 5,757; D from Río San Juan at Cienguilla, Nuevo León, UANL 52; and E from Río San Juan basin, UANL 444 (the last, D and E, implying sympatry of the two forms; vertical scale is one cm).



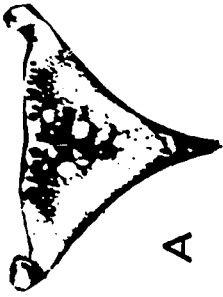
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A



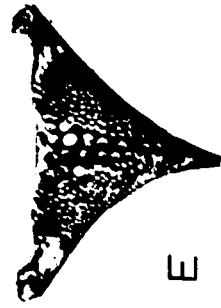
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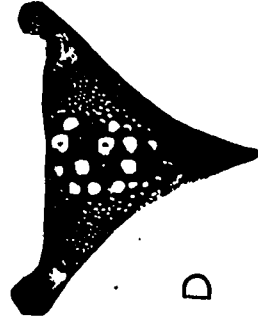
I

C



I

D



I

E

FIGURE 14. Basipharyngobranchial bones of fishes of the genus Herichthys from eastern México: A - C = Río Soto la Marina, Tamaulipas, México, arranged from north to south (proposed as intergrades between Río Grande cichlid and Río Pánuco cichlid, see text); D - F = Río Pánuco system, Nuevo León, San Luis Potosi, and Vera Cruz, México, arranged from north to south (Río Pánuco cichlid); G - I = Estuarine cichlid--G, Río Tancochin, Vera Cruz, México - H, Río Cucharas, Vera Cruz, México - I, Río Pantepec, Vera Cruz, México; J = dorsal blotch cichlid, Río Tancochin, Vera Cruz, México; and K = Río Nautla cichlid, Río Nautla, Vera Cruz, México.

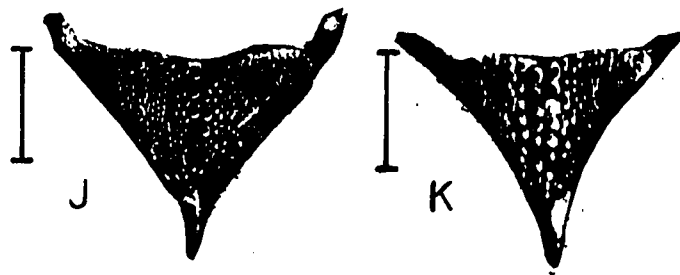
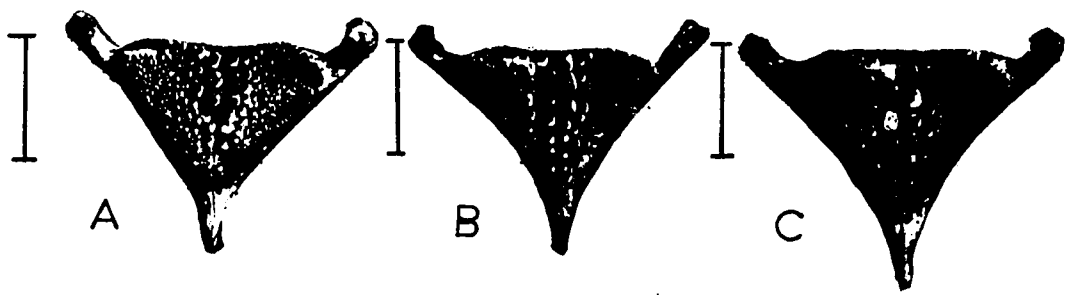
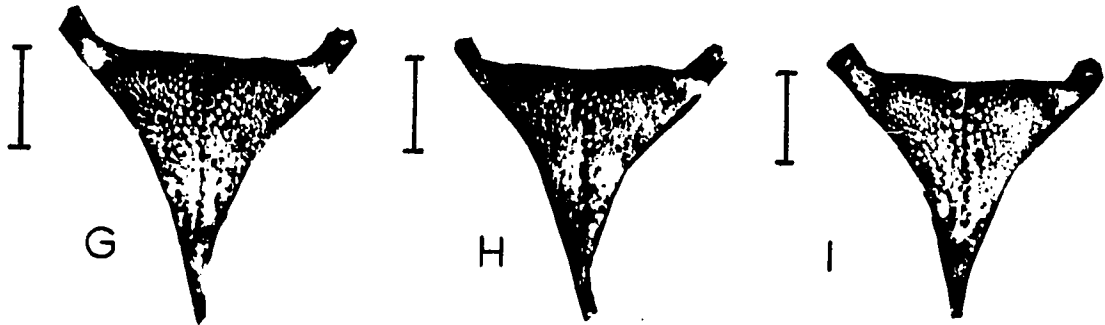
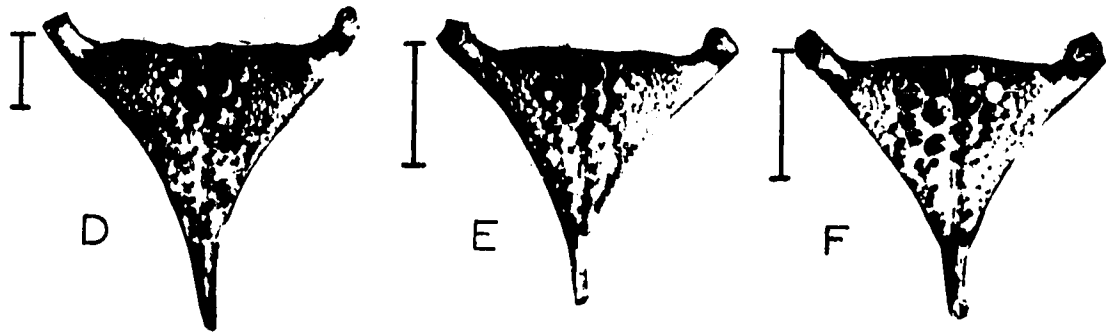
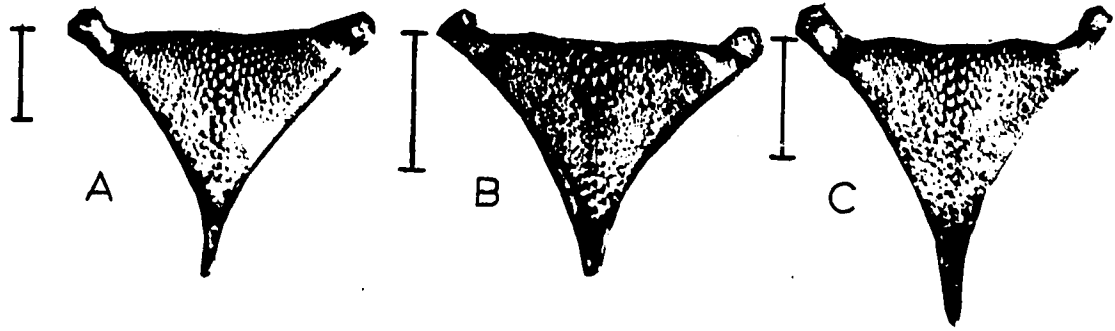


FIGURE 15. Basipharyngobranchial bones of fishes of the genus Parapetenia from northern and eastern México: A - C = Lugo's cichlid, Cuatro Ciénegas basin, Coahuila, México; D - F = long-head cichlid, Cuatro Ciénegas basin, Coahuila, México; G - I = unexpected cichlid, Cuatro Ciénegas basin, Coahuila, México; J = caracole cichlid, Cuatro Ciénegas basin, Coahuila, México (see also Figure 9e-h); K = Bean's cichlid, Sinaloa, México; and L = Steindachner's cichlid, la Media Luna, San Luis Potosi, México.



ontogenetic variations were present, especially in those species with greatly enlarged, molariform teeth as a result of the change in absolute numbers of molars (Figure 9). Wear or aberrancy were easily discernible.

External Morphology--Continuous Variation

Some general statements regarding growth in cichlids are important in interpretation of relative proportions of their various body parts. First, growth rates continuously decrease with age (size) in these fishes, but appear to be indeterminate as in most other fish families (Lagler, et al., 1962). Second, sexual maturity is attained far before full growth potential is realized, which may inject vagaries of sexual dimorphism into any measurement of external morphology (Fryer and Iles, 1972). Third, there is a male "growth superiority" in the group (Fryer and Iles, 1972), similar to that known for North American sunfishes, family Centrarchidae (Hubbs and Cooper, 1925), which presents a major problem when there is an attempt to equate size and age. Fourth, based mostly on aquarium and semi-natural laboratory studies, marked variability in growth occurs as a result of dominance hierarchies that develop, especially in Parapetenia (Minckley, pers. comm.). Whether the last comes into play under natural conditions is yet unknown.

This section deals with 22 measurements, all reduced to thousandths of $SL \times 10^3$, thus expressed as whole numbers. No significant differences were discovered among series of fish referable to

Herichthys c. cyanoguttatus (s.s.) in any of the measurements analysed. However, straight line measurements do not take into account enlargement of the predorsal and head regions in older (larger) males, which is quite evident in some examples as a distinctive sexual dimorphism.

The relative magnitude of allometry, or absence of it, was determined by calculation of the slope of a line of best fit relating the character to SL (Table 2). All relationships were assumed linear, and most appear to be so (Figures 16-20). Within computer generation of slopes for various characters relative to SL, an abrupt break appeared (Table 2), and those features having a slope of less than ca. $\pm .130$ were considered isometric or essentially isometric.

Variation resulted from negative or positive allometry, normal or near normal variation in certain characters that were basically isometric, and a combination of these factors. In the relative lengths of the pelvic, pectoral, and caudal fins, breakage, aberrancy, and wear eliminated them as useful characters (Figures 20-21). In some features, for example body depth, despite a high degree of allometry (Figure 16) and considerable variation about the mean ($\bar{X} = 461 \pm 28.2$), a coefficient of variation ($v = s \div \bar{X} \times 10^3$) was relatively low (6.1). In other measurements, such as those of bony structures that exhibited relatively low standard deviations and essential isometry, v was high (e.g., length of bony orbit, Table 2). As with means, the coefficient of variation should not

TABLE 2. Measurements of various body parts of the Río Grande cichlid, *Herichthys c. cyanoguttatus* (mean values), calculated as thousandths of SL $\times 10^3$, standard deviations of those means, coefficients of variation, and relative changes with growth (size) expressed as slope of a line of best fit relating the proportional data to SL; based on 491 specimens ranging from ca. 24 to 150 mm SL.

Character	Mean	Standard deviation	Coefficient of variation	Slope of line of best fit
Length of snout	162	9.9	8.0	+ .236
Greatest depth of body	461	28.2	6.1	+ .589
Interorbital width	105	10.6	10.1	+ .348
Distance from posterior margin preopercle to ventro-posterior margin opercular membrane	83	13.2	15.9	+ .489
Basilar length of dorsal fin	581	20.3	3.5	+ .566
Length of head	360	13.9	3.9	- .303
Dorsal origin posterior margin bony orbit	125	16.7	13.4	- .386
Length of bony orbit	104	13.7	13.2	- .474
Predorsal length	329	18.5	5.6	- .356
Depth of caudal peduncle	162	9.3	5.7	+ .120
Prepelvic length	387	13.8	3.6	- .073
Width of body	195	13.4	6.9	+ .129
Anal origin to caudal base	347	16.0	4.6	+ .072
Length of caudal peduncle	105	6.1	5.8	+ .028
Width of head	202	8.6	4.3	+ .093

TABLE 2. Concluded.

Length of upper jaw	106	25.6	24.1	+.028
Distance from bony orbit to ventro-posterior margin of opercular membrane	120	30.4	25.5	-.086
Distance from preoper- cular margin to bony orbit	38	17.3	43.9	-.084
Basilar length of anal fin	252	13.8	5.5	-.078
Length of middle caudal fin-ray	300	16.7	5.5	.000 ^{1/}
Length of pectoral fin	276	16.7	5.4	.000
Length of pelvic fin	301	28.0	9.3	.000

^{1/} Not presented because of exceedingly high variation; see text for further explanation.

FIGURE 16. Relative change in proportions of various body parts (absolute value/ $SL \times 10^3$) in a sample of 491 Río Grande cichlids, Herichthys c. cyanoguttatus, with increase in SL; variations occur in the number of dots plotted figure to figure since on many occasions a datum for one specimen was identical or almost identical to that for another, and some specimens were malformed due to preservation and could not be reliably used.

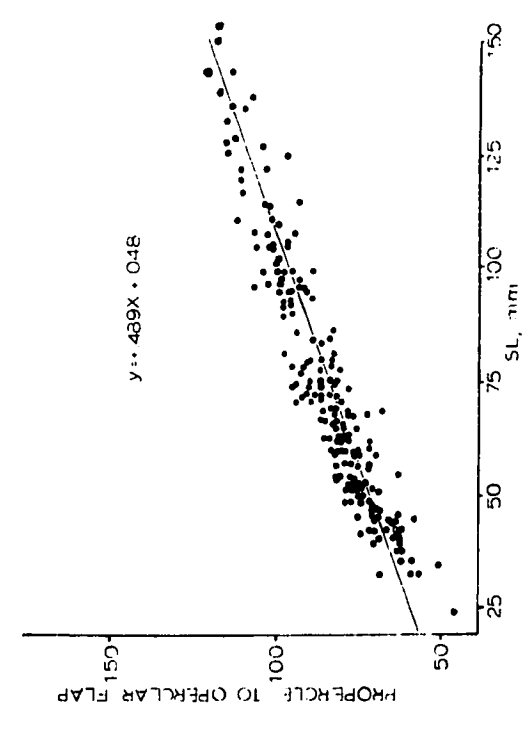
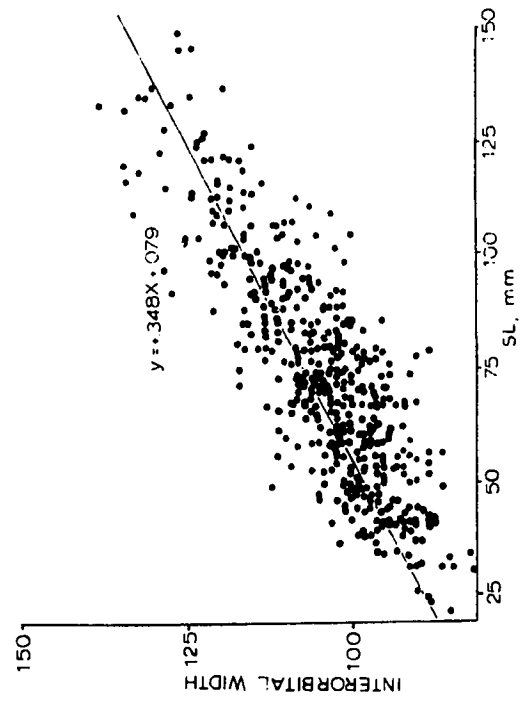
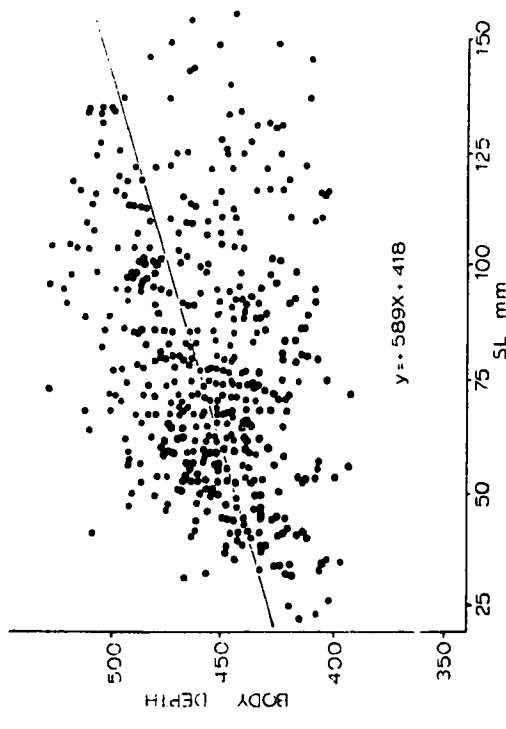
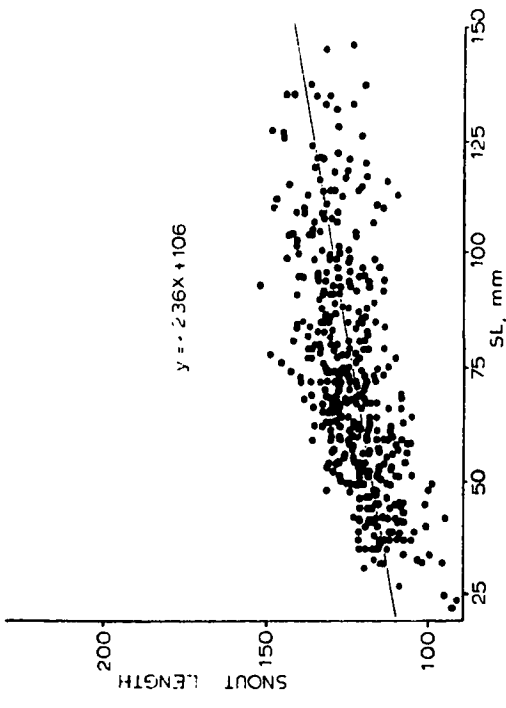


FIGURE 17. Relative change in proportions of various body parts in a sample of 491 Río Grande cichlids, Herichthys c. cyanoguttatus; see legend for Figure 16.

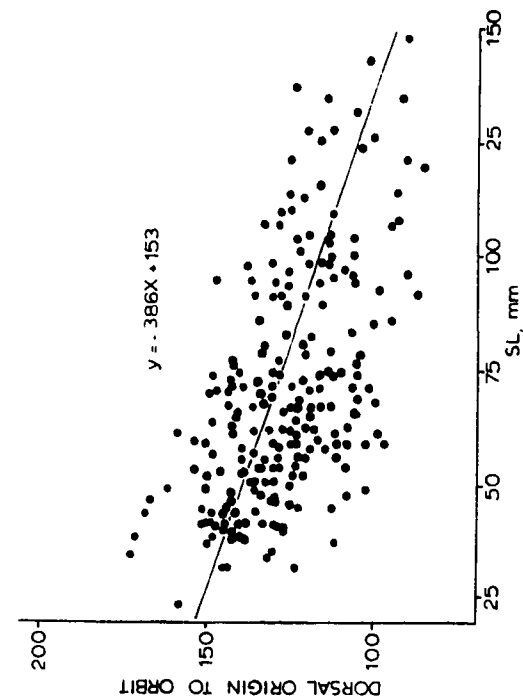
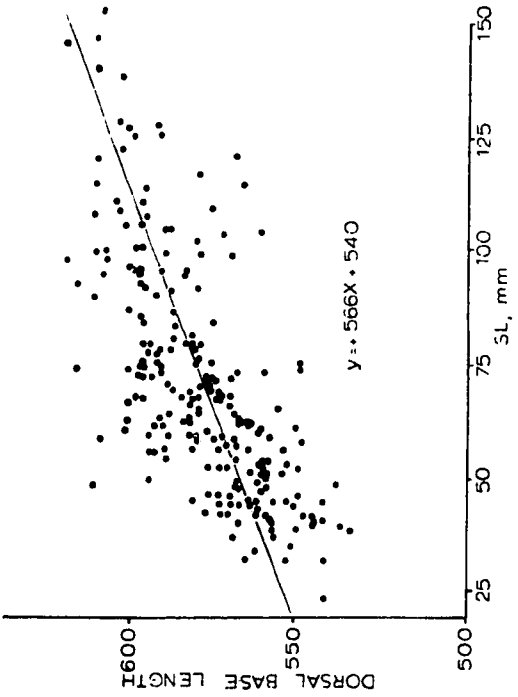
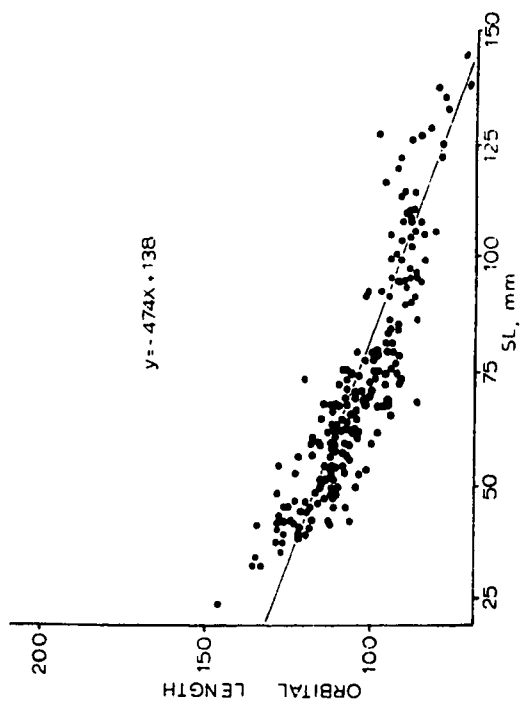
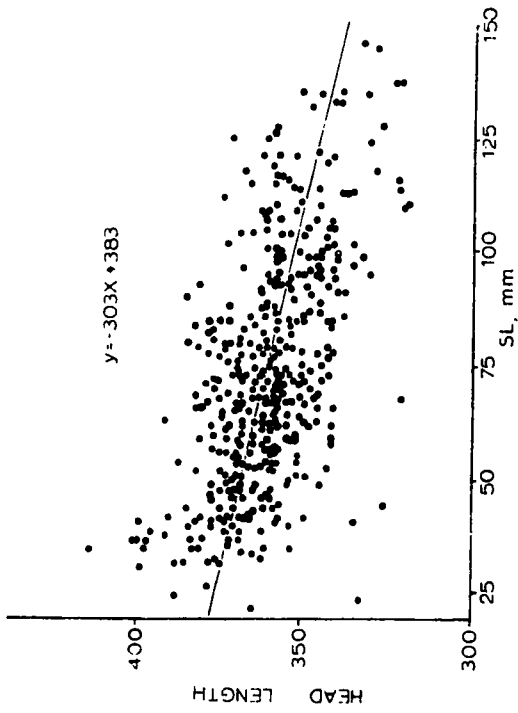


FIGURE 18. Relative change in proportions of various body parts
in a sample of 491 Río Grande cichlids, Herichthys c. cyanoguttatus;
see legend for Figure 16.

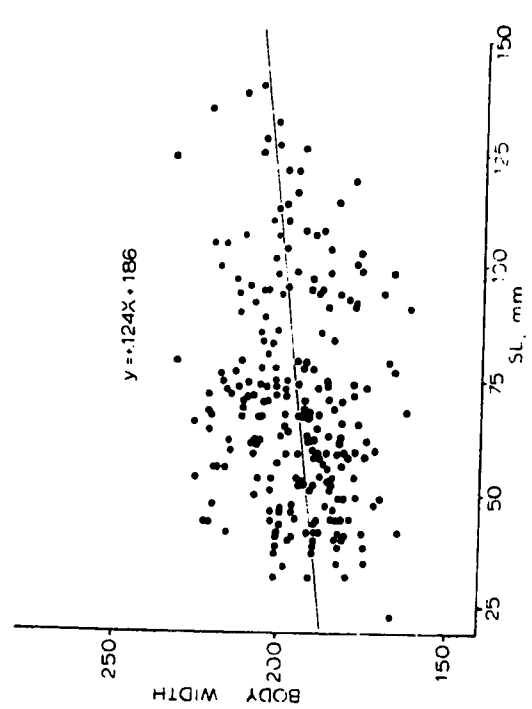
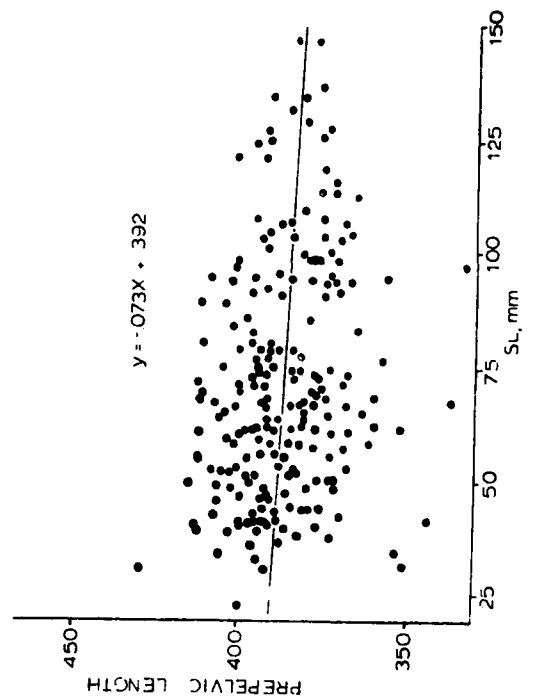
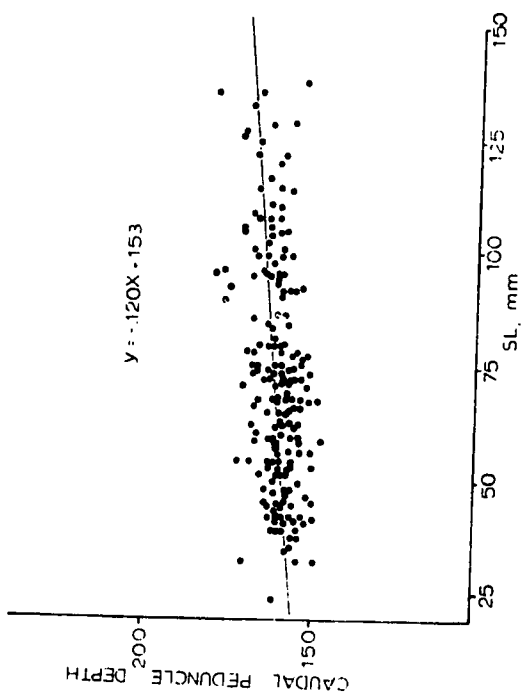
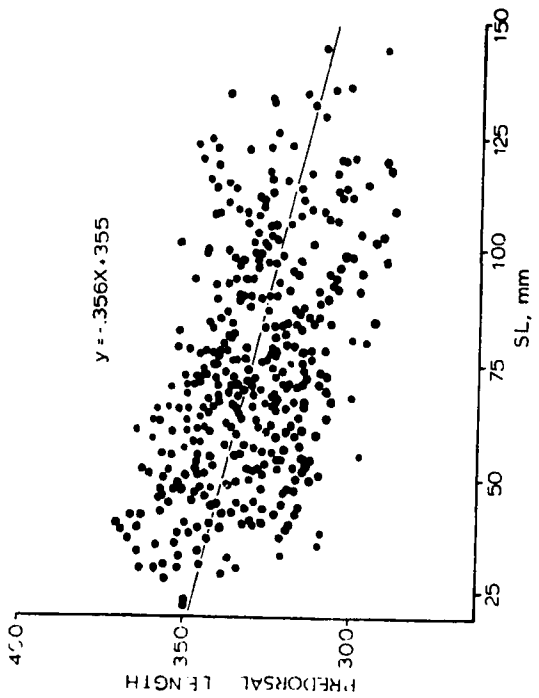


FIGURE 19. Relative change in proportions of various body parts in a sample of 491 Río Grande cichlids, Herichthys c. cyanoguttatus; see legend for Figure 16.

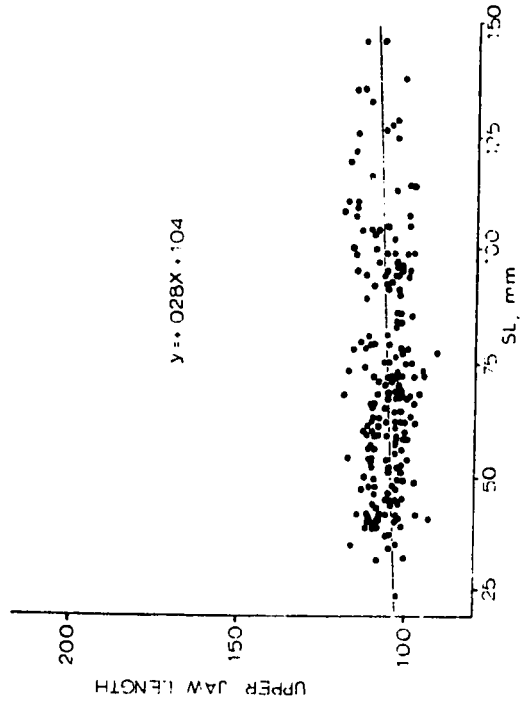
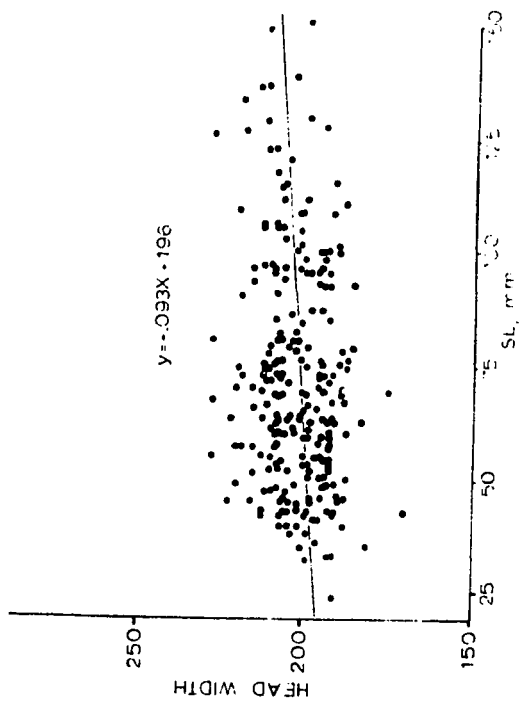
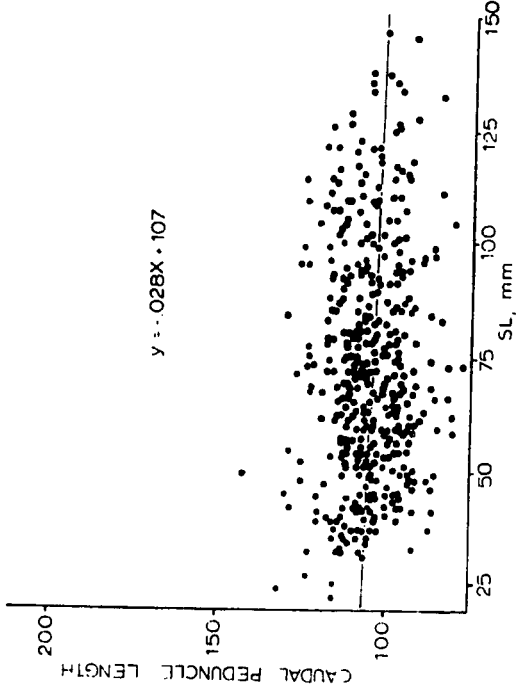
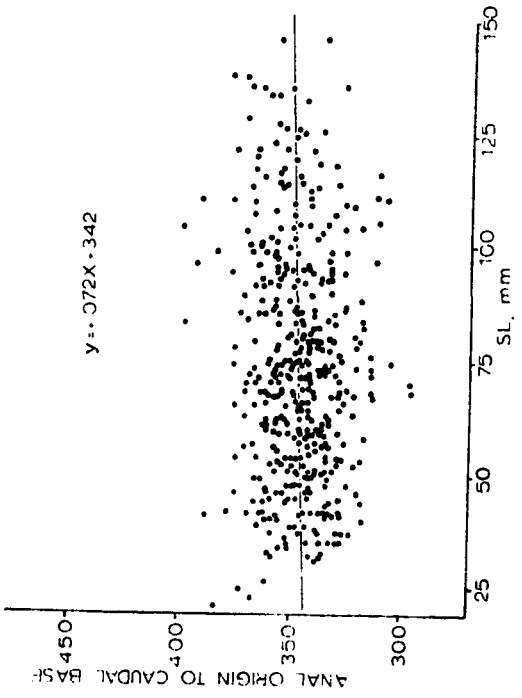


FIGURE 20. Relative change in proportions of various body parts
in a sample of 491 Río Grande cichlids, Herichthys c. cyanoguttatus;
see legend for Figure 16.

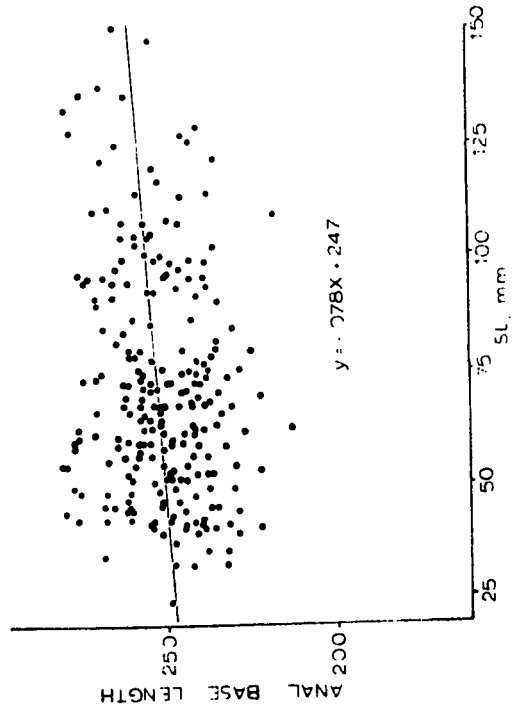
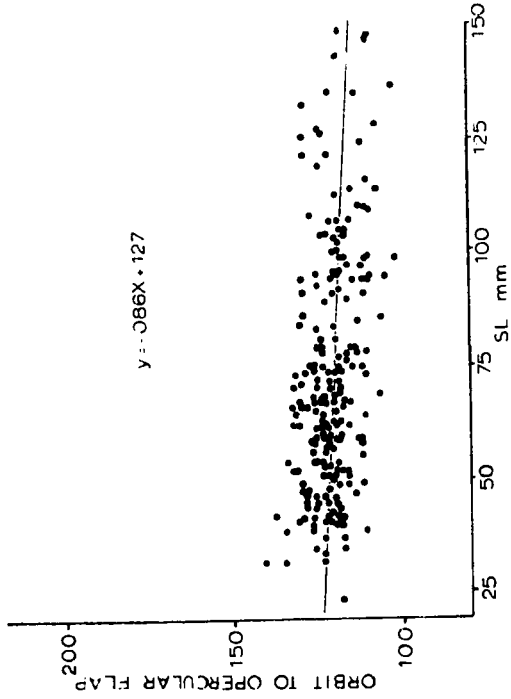
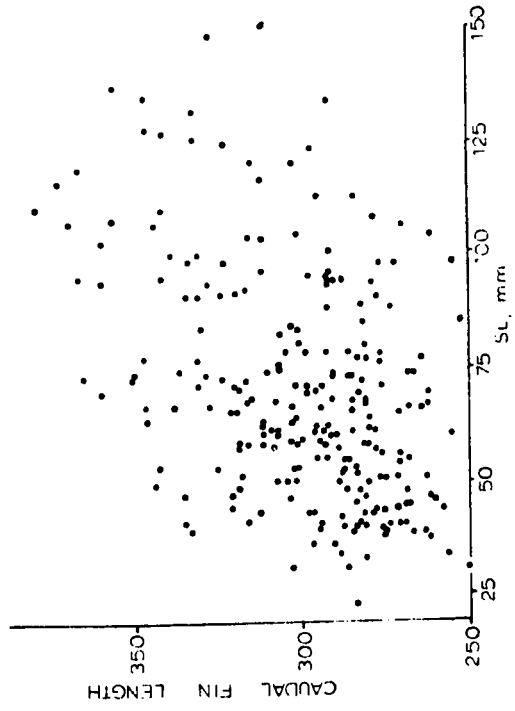
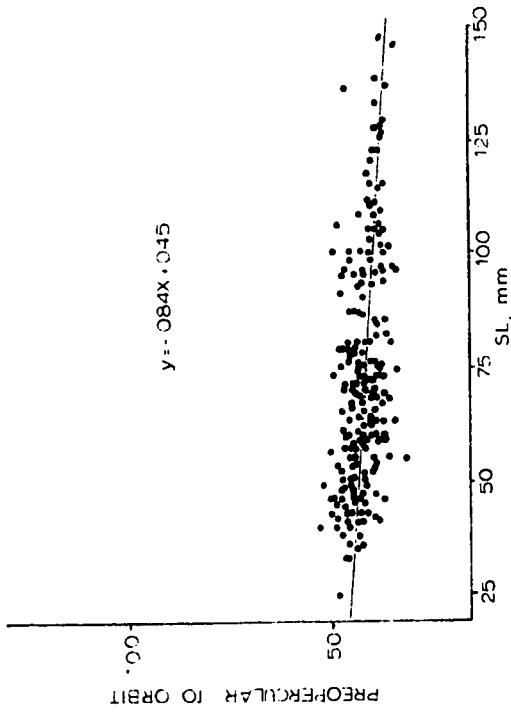
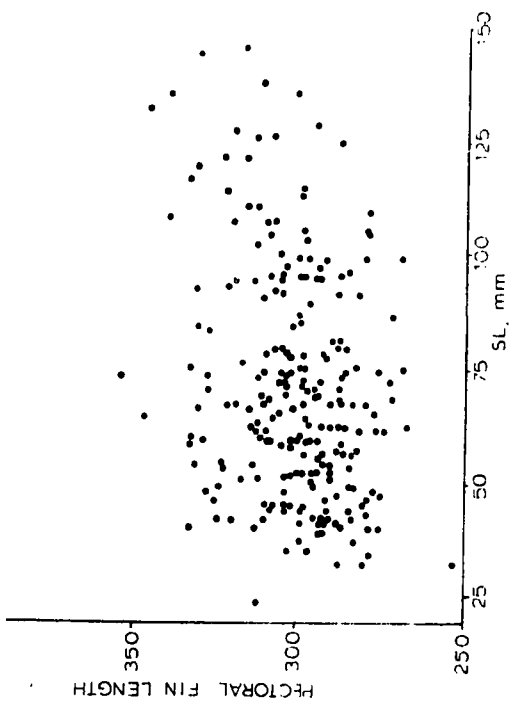
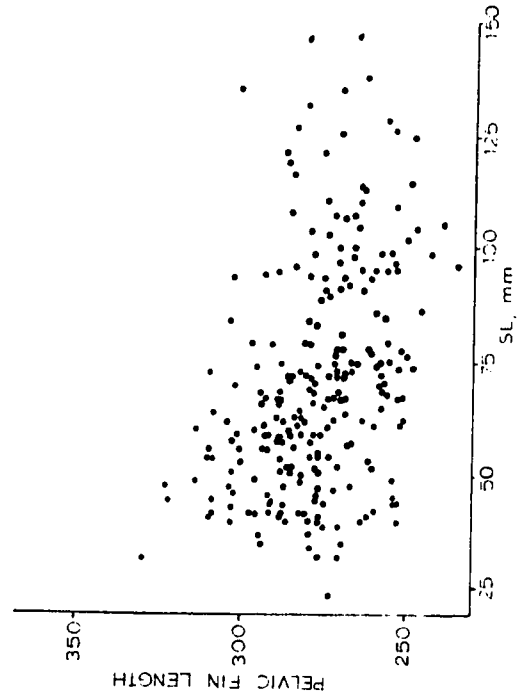


FIGURE 21. Relative change in proportions of various body parts
in a sample of 491 Río Grande cichlids, Herichthys c. cyanoguttatus;
see legend for Figure 16.



be used to compare one character with another, but may be useful in interpopulation comparisons of a given character. Thus, a triad of factors influences variation: 1) the absolute size of the feature being measured, expressed as a proportion of SL, reflected in a low standard deviation for shorter measurements, and the reciprocal relation for longer ones; 2) the degree of allometry (or lack of it) and its influence on the overall standard deviation calculated for the total sample of 491 fish; and 3) relationships of standard deviation to the mean, in light of items 1 and 2 above, which dictated apparent high variation (as indicated by the coefficient of variation). The last occurred in features that are, in fact, quite closely clustered about their calculated line of best fit (Figures 16-20).

The greatest degree of negative or positive allometry relative to SL, involved features that included parts of, or were of, the head (7 of 9 characters; Table 2). Only 5 of the remaining 13 characteristics that were isometric, essentially so, or highly variable, involved skull features. Based on the analyses of this taxon, 10 of 19 features (excluding measurements of the fins, as noted before) are indicated as valid to be used in direct comparisons of populations without consideration of allometric problems. Allometry or isometry and variation in characters of 10 additional populations of cichlids, including both Herichthys and Parapetenia, from Texas and México also were examined. Data derived seemed consistent with those presented in Table 2 and Figures 16-21 for H. c. cyanoguttatus.

In order to compare related species, or species of similar proportional features, as is the instance here, some authors have taken allometry into consideration and have adjusted means to compensate for different sized individuals in available samples. This procedure is of minimal taxonomic value unless thorough and definitive work is done to confirm a constant nature of variation in all species or populations being compared or at least a reasonable percentage of the overall number of animals available. Such consistency seems present in the cichlid fishes studied, and the following formula for adjustment of means is therefore proposed to facilitate comparisons of populations within the geographic area covered here:

$$\bar{X}_a = \bar{X}_b - M_{xy} (\bar{X}_1 - \bar{X}_2),$$

where \bar{X}_a is the adjusted mean of a character; \bar{X}_b is the unadjusted mean of the character; \bar{X}_1 is the mean SL of the sample used in computing the slope of the line of best fit; \bar{X}_2 is the mean SL for the sample for which the mean is being adjusted; and M_{xy} is the slope of the line of best fit for the character against SL.

Table 3 presents data on the 22 features examined for all taxa of cichlids studied. Generalizations for the large sample of Río Grande cichlids hold true for other species and infraspecific groups investigated. Within Herichthys, the Texas and Río Grande cichlids are essentially identical in external morphology. As one moves east and south, however, Río Grande cichlids from the Cuatro Ciénegas basin tend to differ markedly, as they did in the pharyngeal

mill; this again is deferred to later discussion. The Herichthys from the Río Soto la Marina have a number of characteristics that seem indicative of intergradation between the Río Grandean form and the Río Pánuco cichlid, H. c. carpintis. The same general pattern evident in dentition of the jaws (Figure 6), but not so apparent in morphology of the pharyngeal mill and teeth (Table 1; Figure 14).

The estuarine cichlid, represented by relatively few specimens, comprises a complex here proposed as an undescribed species of Herichthys, but may consist of more than one species. As a group, they differ from the Río Pánuco cichlid principally in features of the predorsal area (Table 3). The most geographically adjacent population of estuarine cichlid to H. cyanoguttatus carpintis, in the Río Tancochin (Figure 1), does not show a distinct pattern of intergradation as appears present between the Río Pánuco and Río Grande cichlids to the north. The populations of the ríos Tancochin and Cucharas, both tributary to the large Laguna de Tamiahua, resemble each other more than they do either the Río Pánuco cichlid or samples here also referred to the estuarine cichlid from the Río Pantepec and Río Cazones (Figure 1). External morphological features, plus the presence of the distinctive Río Nautla cichlid immediately south of the Río Cazones populations, prompts the decision to consider all samples from between the Río Pánuco and Río Nautla drainages as one species. Larger samples will be necessary prior to final taxonomic determination.

The dorsal-blotch cichlid in the Río Tancochin is markedly different from the sympatric form of estuarine cichlid in many features of external morphology (Table 3). As noted before it also differs in a number of characters of its basipharyngobranchial bone (Table 1; Figure 14).

The Río Nautla form differs from estuarine cichlids in its short predorsal length and a long snout, a deep body (also found, however, in the Río Pantepec form of estuarine cichlid), long anal fin base, and narrowest basipharyngobranchial bone (Tables 1, 3).

Of the species of Parapetenia examined in detail, external morphology substantiated the presence of two species pairs, Lugo's and caracole cichlids, and long-head and unexpected cichlids. All differ substantially from species of Herichthys in a number of external features, but within each pair they are essentially indistinguishable (Table 3). Pharyngeal teeth readily separate all four kinds as do measurements of the bone itself (Table 1; Figures 9e-h, 14a-j).

External Morphology--Discontinuous Variation

Unlike proportional measurements, which may experience allometric, continuous change with growth (size), most meristic features of American cichlid fishes occur as "normal" distributions about a mean. Within Herichthys c. cyanoguttatus, standard deviations exceeded a value of 1.0 in only one of the 14 features examined (Table 4). It is notable that three of the last four

TABLE 3. Measurements of various body parts of cichlid fishes from southern Texas, U.S.A., and northern-end-eastern-Mexico, calculated as thousands of SL x 10³, except for SL in mm. Means are above adjusted means, where appropriate, and numbers of fish are below.

Characters	Kinds of fishes and localities																				
	Texas cichlid, Rio Grande system	Rio Grande cichlid, Rio Grande system	Rio Grande cichlid, Mexico	Rio Grande cichlid, Rio San Juan basin, Mexico	Rio Grande cichlid, Cuatro Ciénegas basin, Mexico	Rio Grande cichlid, Cuatro Ciénegas basin, Mexico	Rio Grande cichlid, Cuatro Ciénegas basin, Mexico	Rio Grande cichlid, Cuatro Ciénegas basin, Mexico	Rio Grande cichlid, Cuatro Ciénegas basin, Mexico	Rio Grande cichlid, Cuatro Ciénegas basin, Mexico	Rio Grande cichlid, Cuatro Ciénegas basin, Mexico	Rio Grande cichlid, Cuatro Ciénegas basin, Mexico	Rio Grande cichlid, Cuatro Ciénegas basin, Mexico	Rio Grande cichlid, Cuatro Ciénegas basin, Mexico	Rio Grande cichlid, Cuatro Ciénegas basin, Mexico	Rio Grande cichlid, Cuatro Ciénegas basin, Mexico	Rio Grande cichlid, Cuatro Ciénegas basin, Mexico	Rio Grande cichlid, Cuatro Ciénegas basin, Mexico	Rio Grande cichlid, Cuatro Ciénegas basin, Mexico	Rio Grande cichlid, Cuatro Ciénegas basin, Mexico	
Standard length	73	74	67	83	82	84	76	50	57	66	75	65	112	58	86	97	50	99	92	87	95
Predorsal length	327	329	331	340	326	323	324	352	346	366	330	340	361	339	321	315	325	368	362	393	406
Prepelvic length	387	387	399	399	398	394	391	402	401	402	397	394	391	404	397	393	408	417	399	407	444
Dorsal origin to posterior margin bony orbit	124	125	130	132	131	139	122	143	143	143	124	135	146	140	109	119	108	144	135	150	154
Anal origin to caudal base	353	347	344	336	347	342	345	323	335	343	334	320	326	340	338	343	355	331	320	332	329
Greatest depth of body	456	461	460	457	462	474	480	469	455	458	470	452	433	456	493	481	470	429	433	383	371
Width of body	199	195	189	189	198	194	204	191	191	191	197	207	181	194	189	199	201	185	173	169	171
Length of caudal peduncle	104	105	104	118	106	101	100	104	107	104	101	100	93	104	101	97	100	130	125	135	138
Depth of caudal peduncle	164	162	155	155	160	162	160	156	156	156	152	150	150	153	154	149	161	139	142	137	136
Length of head	359	360	360	361	361	358	360	384	392	395	377	379	350	388	360	348	370	378	378	403	413
	93	491	205	130	170	170	59	99	381	392	369	376	361	364	364	355	363	382	383	407	419
	93	491	205	130	170	170	59	99	21	78	31	8	1	8	10	5	10	61	71	27	14

TABLE 3. Concluded.

Width of head	204 93	202 259	201 130	204 170	200 38	213 59	214 99	214 99	216 99	213 216	214 216	214 99	216 99	218 100	219 101	220 102	221 103	222 104	223 105	224 106	225 107	226 108	227 109	228 110	229 111	230 112	231 113	232 114	233 115	234 116	235 117	236 118	237 119	238 120	239 121	240 122	241 123	242 124	243 125	244 126	245 127	246 128	247 129	248 130	249 131	250 132	251 133	252 134	253 135	254 136	255 137	256 138	257 139	258 140	259 141	260 142	261 143	262 144	263 145	264 146	265 147	266 148	267 149	268 150	269 151	270 152	271 153	272 154	273 155	274 156	275 157	276 158	277 159	278 160	279 161	280 162	281 163	282 164	283 165	284 166	285 167	286 168	287 169	288 170	289 171	290 172	291 173	292 174	293 175	294 176	295 177	296 178	297 179	298 180	299 181	300 182	301 183	302 184	303 185	304 186	305 187	306 188	307 189	308 190	309 191	310 192	311 193	312 194	313 195	314 196	315 197	316 198	317 199	318 200	319 201	320 202	321 203	322 204	323 205	324 206	325 207	326 208	327 209	328 210	329 211	330 212	331 213	332 214	333 215	334 216	335 217	336 218	337 219	338 220	339 221	340 222	341 223	342 224	343 225	344 226	345 227	346 228	347 229	348 230	349 231	350 232	351 233	352 234	353 235	354 236	355 237	356 238	357 239	358 240	359 241	360 242	361 243	362 244	363 245	364 246	365 247	366 248	367 249	368 250	369 251	370 252	371 253	372 254	373 255	374 256	375 257	376 258	377 259	378 260	379 261	380 262	381 263	382 264	383 265	384 266	385 267	386 268	387 269	388 270	389 271	390 272	391 273	392 274	393 275	394 276	395 277	396 278	397 279	398 280	399 281	400 282	401 283	402 284	403 285	404 286	405 287	406 288	407 289	408 290	409 291	410 292	411 293	412 294	413 295	414 296	415 297	416 298	417 299	418 300	419 301	420 302	421 303	422 304	423 305	424 306	425 307	426 308	427 309	428 310	429 311	430 312	431 313	432 314	433 315	434 316	435 317	436 318	437 319	438 320	439 321	440 322	441 323	442 324	443 325	444 326	445 327	446 328	447 329	448 330	449 331	450 332	451 333	452 334	453 335	454 336	455 337	456 338	457 339	458 340	459 341	460 342	461 343	462 344	463 345	464 346	465 347	466 348	467 349	468 350	469 351	470 352	471 353	472 354	473 355	474 356	475 357	476 358	477 359	478 360	479 361	480 362	481 363	482 364	483 365	484 366	485 367	486 368	487 369	488 370	489 371	490 372	491 373	492 374	493 375	494 376	495 377	496 378	497 379	498 380	499 381	500 382	501 383	502 384	503 385	504 386	505 387	506 388	507 389	508 390	509 391	510 392	511 393	512 394	513 395	514 396	515 397	516 398	517 399	518 400	519 401	520 402	521 403	522 404	523 405	524 406	525 407	526 408	527 409	528 410	529 411	530 412	531 413	532 414	533 415	534 416	535 417	536 418	537 419	538 420	539 421	540 422	541 423	542 424	543 425	544 426	545 427	546 428	547 429	548 430	549 431	550 432	551 433	552 434	553 435	554 436	555 437	556 438	557 439	558 440	559 441	560 442	561 443	562 444	563 445	564 446	565 447	566 448	567 449	568 450	569 451	570 452	571 453	572 454	573 455	574 456	575 457	576 458	577 459	578 460	579 461	580 462	581 463	582 464	583 465	584 466	585 467	586 468	587 469	588 470	589 471	590 472	591 473	592 474	593 475	594 476	595 477	596 478	597 479	598 480	599 481	600 482	601 483	602 484	603 485	604 486	605 487	606 488	607 489	608 490	609 491	610 492	611 493	612 494	613 495	614 496	615 497	616 498	617 499	618 500	619 501	620 502	621 503	622 504	623 505	624 506	625 507	626 508	627 509	628 510	629 511	630 512	631 513	632 514	633 515	634 516	635 517	636 518	637 519	638 520	639 521	640 522	641 523	642 524	643 525	644 526	645 527	646 528	647 529	648 530	649 531	650 532	651 533	652 534	653 535	654 536	655 537	656 538	657 539	658 540	659 541	660 542	661 543	662 544	663 545	664 546	665 547	666 548	667 549	668 550	669 551	670 552	671 553	672 554	673 555	674 556	675 557	676 558	677 559	678 560	679 561	680 562	681 563	682 564	683 565	684 566	685 567	686 568	687 569	688 570	689 571	690 572	691 573	692 574	693 575	694 576	695 577	696 578	697 579	698 580	699 581	700 582	701 583	702 584	703 585	704 586	705 587	706 588	707 589	708 590	709 591	710 592	711 593	712 594	713 595	714 596	715 597	716 598	717 599	718 600	719 601	720 602	721 603	722 604	723 605	724 606	725 607	726 608	727 609	728 610	729 611	730 612	731 613	732 614	733 615	734 616	735 617	736 618	737 619	738 620	739 621	740 622	741 623	742 624	743 625	744 626	745 627	746 628	747 629	748 630	749 631	750 632	751 633	752 634	753 635	754 636	755 637	756 638	757 639	758 640	759 641	760 642	761 643	762 644	763 645	764 646	765 647	766 648	767 649	768 650	769 651	770 652	771 653	772 654	773 655	774 656	775 657	776 658	777 659	778 660	779 661	780 662	781 663	782 664	783 665	784 666	785 667	786 668	787 669	788 670	789 671	790 672	791 673	792 674	793 675	794 676	795 677	796 678	797 679	798 680	799 681	800 682	801 683	802 684	803 685	804 686	805 687	806 688	807 689	808 690	809 691	810 692	811 693	812 694	813 695	814 696	815 697	816 698	817 699	818 700	819 701	820 702	821 703	822 704	823 705	824 706	825 707	826 708	827 709	828 710	829 711	830 712	831 713	832 714	833 715	834 716	835 717	836 718	837 719	838 720	839 721	840 722	841 723	842 724	843 725	844 726	845 727	846 728	847 729	848 730	849 731	850 732	851 733	852 734	853 735	854 736	855 737	856 738	857 739	858 740	859 741	860 742	861 743	862 744	863 745	864 746	865 747	866 748	867 749	868 750	869 751	870 752	871 753	872 754	873 755	874 756	875 757	876 758	877 759	878 760	879 761	880 762	881 763	882 764	883 765	884 766	885 767	886 768	887 769	888 770	889 771	890 772	891 773	892 774	893 775	894 776	895 777	896 778	897 779	898 780	899 781	900 782	901 783	902 784	903 785	904 786	905 787	906 788	907 789	908 790	909 791	910 792	911 793	912 794	913 795	914 796	915 797	916 798	917 799	918 800	919 801	920 802	921 803	922 804	923 805	924 806	925 807	926 808	927 809	928 810	929 811	930 812	931 813	932 814	933 815	934 816	935 817	936 818	937 819	938 820	939 821	940 822	941 823	942 824	943 825	944 826	945 827	946 828	947 829	948 830	949 831	950 832	951 833	952 834	953 835	954 836	955 837	956 838	957 839	958 840	959 841	960 842	961 843	962 844	963 845	964 846	965 847	966 848	967 849	968 850	969 851	970 852	971 853	972 854	973 855	974 856	975 857	976 858	977 859	978 860	979 861	980 862	981 863	982 864	983 865	984 866	985 867	986 868	987 869	988 870	989 871	990 872	991 873	992 874	993 875	994 876	995 877	996 878	997 879	998 880	999 881	1000 882	1001 883	1002 884	1003 885	1004 886	1005 887	1006 888	1007 889	1008 890	1009 891	1010 892	1011 893	1012 894	1013 895	1014 896	1015 897	1016 898	1017 899	1018 900	1019 901	1020 902	1021 903	1022 904	1023 905	1024 906	1025 907	1026 908	1027 909	1028 910	1029 911	1030 912	1031 913	1032 914	1033 915	1034 916	1035 917	1036 918	1037 919	1038 920	1039 921	1040 922	1041 923	1042 924	1043 925	1044 926	1045 927	1046 928	1047 929	1048 930	1049 931	1050 932	1051 933	1052 934	1053 935	1054 936	1055 937	1056 938	1057 939	1058 940	1059 941	1060 942	1061 943	1062 944	1063 945	1064 946	1065 947	1066 948	1067 949	1068 950	1069 951	1070 952	1071 953	1072 954	1073 955	1074 956	1075 957	
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TABLE 4. Relative variation in meristic characters among forms of cichlid fishes referable to Herichthys c. cyanoguttatus (s.s.) from southern Texas, U.S.A., and northern and eastern México (N = 734).

Character	Mean	Standard deviation	Coefficient of variation
Rays in caudal fin	17.9	0.2	1.1
Branchiostegal rays	4.9	0.1	2.0
Scales between lateral lines	3.9	0.1	2.6
Rays in pectoral fin	14.1	0.4	2.8
Spines in dorsal fin	16.5	0.5	3.0
Scales below lateral line	9.0	0.3	3.3
Scales in upper lateral line	19.0	0.9	4.7
Rays in pelvic fin	5.9	0.3	5.5
Rays in anal fin	9.3	0.6	6.4
Rays in dorsal fin	10.9	0.7	6.4
Gill rakers on first branchial arch	10.8	0.7	6.5
Scales above lateral line	6.9	0.5	7.3
Spines in anal fin	5.4	0.5	9.1
Scales in lower lateral line	10.4	1.0	9.6

features listed in order of increasing coefficients of variation in Table 4 are those which do, in the Río Grande cichlid at least, show some increase in number with size--number of gill rakers on the first branchial arch and scales in the lateral lines. The relatively high variation exhibited by spines in the anal fin ($v = 9.1$) reflects some error in counting as a result of the anteriormost spine often being rudimentary and quite difficult to find, even upon dissection, and especially in smaller fish.

Interpopulation variation in meristic features strongly support the conservative nature of these characters in North American cichlids (Table 5). In only a few instances within Herichthys are means of any characteristic substantially different, with the most variation occurring within the complex assigned to the estuarine cichlid; possibly a result of small sample sizes. The dorsal-blotch form from the Río Tancochin appears distinctive in spines and rays of the anal fin and in scales in the upper and lower lateral lines, but the first two characters fall within (or very nearly so) the ranges of counts of adjacent populations. Its lateral line counts markedly differ from other Herichthys. The Río Nautla cichlid tends to have higher numbers of spines and rays in the dorsal and anal fins than other Herichthys, but in other features resembles its congeners (with the possible exception of a higher number of scales in the upper lateral line).

Species of Parapetenia studied also are remarkably similar in most meristic characters examined. They resemble Herichthys in all but their lower numbers of anal spines, greater numbers of gill rakers,

and greater numbers of lateral line scales. Lugo's and caracole cichlids resemble Herichthys species in scale rows above and below the lateral lines. The long-head and unexpected cichlids differ from Herichthys and from the other two Parapetenia in having fewer scales above the upper lateral line and a greater number below the lower lateral line (Table 5).

Length of the Alimentary Canal

As noted in Table 3, length of the gut in cichlids is highly variable. However, it has been successfully used in conjunction with other features as a taxonomic tool in classification of African forms (Fryer and Iles, 1972). In Herichthys, no patterns were evident in gut length relative to geography, foods, or probable taxonomic relationships (Table 6). Among the Cuatro Ciénegas species of Parapetenia, however, the carnivorous forms, caracole, long-head, and unexpected cichlids, had markedly shorter guts than did Lugo's cichlid, which feeds almost exclusively on bottom sediments. Putative hybrids between caracole and Lugo's cichlids from within the Cuatro Ciénegas basin had mean gut lengths intermediate to those of the suspected parental species. In all instances, variation was quite high, as indicated by the high standard deviations. Coefficients of variation were consistently greater than 10 and ranged to more than 23.

TABLE 5. Meristic features of various cichlid fishes from southern Texas, U.S.A. and northern and eastern Mexico; means are above one standard deviation, and numbers of fish are below (*n* = sum value for all characters).

Characters	Texas cichlid, Rio Grande system	Rio Grande cichlid, date from through-out known range	Herichthys, from Cuatro Ciénegas basin, México	Intergrades, Rio Soto la Marina, México	Panuco cichlid Rio Tamesí-Princo, México	Estuarine cichlid, Vera Cruz state, México	Estuarine cichlid, Rio Tancochín sys-tem, México	Dorsal blotch cichlid, Rio Tancochín system, México	Esuarine cichlid, Rio Cucharas system, México	Esuarine cichlid, Rio Pantepac system, México	Esuarine cichlid, Rio Lezones system, México	Agyle cichlid, Rio Nautle system, México	Lugo's cichlid, Cuatro Ciénegas basin, México	Caracole cichlid, Cuatro Ciénegas basin, México	Unspecked cichlid, Cuatro Ciénegas basin, México	Long-head cichlid, Cuatro Ciénegas basin, México
Spines in dorsal fin	16.6 0.5 119	16.4 0.5 718	16.4 0.6 267	16.1 0.4 59	15.9 0.3 66	16.0 0.4 31	16.2 0.4 8	16.0 0.3 1	15.9 0.3 8	15.8 0.3 10	15.7 0.8 5	16.2 0.3 10	15.9 0.3 108	15.8 0.4 90	16.0 0.3 27	15.7 0.5 14
Rays in dorsal fin	10.7 0.6	11.1 0.5	10.6 0.6	11.5 0.5	11.1 0.5	11.3 0.5	11.0 0.0	11.0 0.0	10.8 0.6	11.3 0.5	11.3 0.5	12.0 0.5	11.2 0.8	11.0 0.5	11.1 0.5	10.8 0.5
Spines in anal fin	5.6 0.4	5.4 0.5	5.4 0.5	5.3 0.4	5.0 0.2	5.9 0.3	5.3 0.5	5.0 0.0	5.5 0.5	5.3 0.5	5.8 0.4	6.1 0.2	4.8 0.3	4.9 0.3	4.9 0.3	4.9 0.2
Rays in anal fin	9.1 0.5	9.3 0.6	8.8 0.6	9.5 0.6	8.9 0.5	9.1 0.5	9.0 0.0	8.0 0.0	8.8 0.6	8.9 0.6	9.5 0.5	9.3 0.2	8.8 0.6	8.8 0.6	8.6 0.5	8.6 0.4
Rays in caudal fin	17.9 0.2	17.9 0.2	18.0 0.0	18.0 0.0	18.0 0.0	18.0 0.0	18.0 0.0	18.0 0.0	18.0 0.0	18.0 0.0	17.5 0.5	18.0 0.0	17.9 0.1	17.9 0.1	18.0 0.0	18.0 0.0
Rays in pectoral fin	14.2 0.4	14.1 0.4	14.0 0.5	14.1 0.5	13.9 0.3	14.3 0.6	14.5 0.5	14.0 0.0	13.9 0.5	14.0 0.0	14.3 0.8	14.5 0.7	14.1 0.3	13.9 0.5	14.0 0.4	13.7 0.7
Rays (including spine) in pelvic fin	5.9 0.3	5.9 0.3	5.9 0.1	6.0 0.0	5.9 0.2	6.0 0.0	6.0 0.0	6.0 0.0	6.0 0.0	6.0 0.0	6.0 0.0	6.0 0.0	5.9 0.2	6.0 0.3	6.0 0.0	6.0 0.0
Gill rakers on first pharyngeal arch	10.8 0.7	10.8 0.7	11.2 0.7	10.1 0.5	10.4 0.6	10.4 0.4	9.5 0.5	10.0 0.0	10.1 0.3	10.9 0.7	10.9 0.7	10.8 0.4	11.4 0.8	11.2 0.7	11.9 0.8	11.5 0.6
Branchiostegal rays	4.9 0.1	4.9 0.1	4.9 0.2	5.0 0.0	5.0 0.0	5.0 0.0	5.0 0.0	5.0 0.0	5.0 0.0	5.0 0.0	5.0 0.0	5.0 0.0	5.0 0.0	5.0 0.0	4.9 0.1	5.0 0.0
Scales in upper lateral line	19.0 0.8	19.0 0.9	18.9 1.2	18.9 0.9	19.0 0.7	18.7 0.7	18.6 0.9	16.0 0.9	17.9 0.9	18.9 0.9	18.9 0.7	19.5 0.6	19.7 1.0	19.4 1.0	19.8 1.0	19.4 1.0
Scales in lower lateral line	10.7 1.0	10.4 1.0	10.7 1.1	10.6 0.8	10.1 0.8	10.1 0.7	9.4 0.9	11.0 0.0	9.8 0.6	10.1 0.9	10.9 0.9	10.6 0.6	12.4 1.0	12.5 1.0	12.7 0.9	12.8 1.1
Scale rows above lateral line	9.0 0.5	9.0 0.5	9.0 0.4	9.0 0.0	8.9 0.0	9.0 0.4	9.0 0.0	9.0 0.0	8.8 0.3	9.0 0.0	9.0 0.0	9.0 0.0	9.3 0.5	9.3 0.6	8.0 0.9	7.3 0.8
Scale rows between lateral lines	3.9 0.1	3.9 0.1	3.2 0.1	4.0 0.0	4.0 0.0	4.0 0.0	4.0 0.0	4.0 0.0	4.0 0.0	4.0 0.0	4.0 0.0	4.0 0.0	4.0 0.4	3.7 0.6	3.8 0.5	3.7 0.4
Scale rows below lateral line	6.9 0.3	6.9 0.3	6.9 0.3	9.0 0.0	7.0 0.0	7.0 0.0	7.0 0.0	7.0 0.0	7.0 0.0	7.0 0.0	7.0 0.0	7.0 0.0	7.1 0.6	7.1 0.4	8.2 1.1	8.8 0.9

TABLE 6. Lengths of alimentary tracts for various North American cichlid fishes; thousandths of SL $\times 10^3$. All data were rounded to the nearest integer.

Species or population	Lengths of alimentary tracts			
	Range	Mean	Standard deviation	Number of fish
Texas cichlids, Río Grande system	1000-3500	2410	550	19
Río Grande cichlids, Río Grande system	1000-4300	2270	350	217
<u>Herichthys</u> sp., Cuatro Ciénegas basin	1000-4000	2280	480	45
Lugo's cichlid, Cuatro Ciénegas basin	2500-4500	3300	400	52
caracole cichlid, Cuatro Ciénegas basin	1000-2500	1570	330	38
long-head cichlid, Cuatro Ciénegas basin	1000-1400	1280	170	10
unexpected cichlid, Cuatro Ciénegas basin	1000-2500	1600	350	26
hybrids, Lugo's X caracole cichlids, Cuatro Ciénegas basin	1000-4000	2130	444	18

Behavior, Ecology, and Pigmentation

Behavior, ecology, and pigmentation of North and South American cichlids are characters of the future in understanding the true systematics of the group. Color patterns of Texas and Río Grande cichlids differ radically from those of the northern Parapetenia of Cuatro Ciénegas (Minckley, pers. comm.). Among the small species flock of Parapetenia in the Cuatro Ciénegas basin, highly stereotyped attack and feeding behavior is species specific, as are habitats and reproductive behavioral patterns. In aquaria many of these apparently stereotyped patterns are evident, but others seem to meld into a collage of basic cichlid activities many of which were described by Baerends and Baerends-van Roon (1950). In African cichlids ecological characteristics have been used in separation of groups (Fryer, 1965) and species (Fryer, 1956b; Greenwood, 1956; Lowe-McConnell, 1956, 1959). In Lake Victoria there exists several nascent supraspecific groups which are more readily identified by ecological than morphological criteria (Greenwood, 1956). The combined study of taxonomy and ecology provided Fryer (1959b) the tools to thoroughly define the evolution of cichlids in the littoral zone of Lake Malawi (= Nyasa). More extensive field work and detailed observations of American cichlids in nature and in the laboratory are required before these powerful tools of systematics may be applied.

CICHLIDS OF THE CUATRO CIÉNEGAS BASIN, COAHUILA, MÉXICO

The basin of Cuatro Ciénegas, central Coahuila, México, is unique for the amount of endemism exhibited in its aquatic and terrestrial biota (Hubbs and Miller, 1965; Taylor and Minckley, 1966; Minckley, 1969). The degree of this remarkable endemism ranges from unique subfamilies of mollusks (Taylor, 1966), through genera of crustaceans (Cole and Minckley, 1970, 1972; Holsinger and Minckley, 1971), species of scorpions (Williams, 1968), crustaceans (Cole and Minckley, 1966), diverse fishes (Minckley, 1962; Miller and Minckley, 1963; Hubbs and Miller, 1965; Miller, 1968; Minckley and Lytle, 1969), and species and subspecies of reptiles (Schmidt and Owens, 1944; Legler, 1960; Webb and Legler, 1960; McCoy, 1970), to a large number of relict populations of organisms, related both to the north and to the south (Milstead, 1966; McCoy and Minckley, 1969; Hubbs and Miller, 1965). Each expedition to the area reveals new information, new taxa, and serves to mark it further as an ancient, relatively stable environment in northern México. The basin floor is known not to have changed radically over at least the last 30,000± years (Meyer, 1973) and may well have been about the same since middle Tertiary times (Taylor, 1966; Miller, 1968; Minckley, 1969).

Cichlid fishes of this basin have been studied since 1958. For years these animals displayed a confusing array, not understood by

any workers. They have been mentioned in the literature only as "Cichlasoma spp.," and Taylor and Minckley (1966) published X-ray photographs of three of the four species of Parapetenia. As detailed in earlier sections, two species pairs of Parapetenia are present in the basin. Perhaps representing a small species flock comparable to some of those of Africa. Herichthys c. cyanoguttatus, also is present, plus some populations which may represent a divergent form of Texas cichlid (or another new species), and hybrids among a number of taxa present.

Drainages of the Basin

As detailed by Minckley (1969) the Cuatro Ciénegas basin has a series of drainages, and habitats ranging from thermal springs, through cool springs, to large (for desert regions) rivers, and back to small creeks. All but two drainages within the basin originally terminated in closed, barrial lakes (incorrectly termed "playa lakes" by many workers). The entire system has suffered drastic modification, slowly at first but now with increasing rapidity as human technology advances. Many of the formerly isolated drainages are interconnected by canal systems, water tables are dropping because of pumpage, and human activities have resulted in movement of fishes from drainage to drainage for use as bait or inadvertently in tank trucks used for transport of water. The original drainage system, modified somewhat from that proposed by Minckley (1969) as a result of recent work is depicted in Figure 22. Minckley considered the basin to have seven

FIGURE 22. Sketch map of the basin of Cuatro Ciénegas, Coahuila, México, modified from Minckley (1969), showing surface drainage patterns outlined in darker lines and numbered 1 - 5; arrows denote general directions of flow, and those arrows associated with question Marks (?) indicate possible interconnections or points of doubt as to true boundaries of drainage systems--see text for further explanation.

subsystems prior to canalization, as opposed to the five mapped. Reduction results from combination of two subsystems, Minckley's numbers VI and VII, both draining into the Río Salado de los Nadadores (Río Grande system) through Puerto Salado (Figure 22). His fourth system, that lying between numbers 2 and 3 on Figure 22, was deleted although outlined by a dotted line because of uncertainties as to its affinities to the third and fifth drainages, and the distinct possibility that it connected through subsurface channels to the northern lobe of drainage 5 (Minckley, pers. comm.). The surface waters were isolated from one another by large dune fields (e.g., 1 - 2, 2 - 3, 3 - 4, and 4 - 5), by extensive alluvial fans from montane washes (2 - 3 and in part 4 - 5), or by travertine formations (especially 2 - 3).

As stressed by Minckley (1969) a complex underground system of travertine lined channels exists beneath the floor of the basin, and fishes are known to pass into and through these waterways. In addition, such channels may well interconnect the basic drainages which appear discrete from surface observation, as canals obviously do at present (Figure 22). It is likely that canalization of the various waters of the Cuatro Ciénegas basin occurred very early in Spanish exploration of what now is northern México. The earliest historically documented canal within the basin was constructed in 1898 (Lugo, in Minckley, 1969). In the period since 1970, major connections have been made among drainages and construction proceeds apace with each succeeding year.

The Cichlid Fauna

The four kinds of Parapetenia of the Cuatro Ciénegas basin (Figures 33-34) are generally sympatric in major springs and their

outflows of drainages 1 through 4 (Figure 22). Herichthys is present downstream in drainages 3 and 4 and throughout drainage 5, some of which are obviously H. c. cyanoguttatus, but others which represent one of three alternatives: 1) an undescribed Herichthys likely derived from the Texas cichlid and now in secondary contact and sympatry, or hybridizing, with the Río Grande cichlid that invaded the basin through canal connection; 2) Río Grande cichlids participating in miscegenation with caracole cichlids to produce a hybrid swarm, especially in drainage 5 and the lowermost part of drainage 4; or 3) a combination of primary hybridization and some introgression among Texas, Río Grande, and caracole cichlids.

Examination of more than 200 specimens of Herichthys-like fish from the three drainages (3, 4, and 5; see Figure 22) detected no tendency toward development of round, produced canine teeth. All were consistent in having awl-like oral dentition identical to that illustrated in Figures 4 through 6a-d. Their external morphology showed little evidence of introgression with any Parapetenia, other than variation toward being more robust in body proportions (Table 3), which nevertheless, fell within the range of variation of Río Grande and/or Texas cichlids. Massiveness of the basipharyngobranchial bone of these Herichthys and the broad spread of variation (Table 7) might be interpreted as evidence for alternatives 2 and/or 3 given above. However, the most sensitive measurement used, mean width of the largest, mesial posterior tooth, does not approach that of the caracole cichlid. The upper range of variation for that feature, however, is only slightly less in the Cuatro Ciénegas fish

TABLE 7. Comparisons of proportional measurements as thousandths of $SL \times 10^3$, of basipharyngobranchial bones and teeth of Texas, Río Grande, caracole cichlids, and Herichthys from Cuatro Ciénegas, Coahuila, México; data from Table 1 with ranges above means.

Fishes and localities	Maximum width	Width occlusial surface	Maximum depth	Maximum depth bone + teeth	Width middle tooth
Texas cichlid, Río Grande system, N = 66	109-160 130	70- 93 77	28- 48 34	40- 56 45	6.2-21.0 12.5
Río Grande cichlid, Río Salado basin, N = 226	110-160 123	63- 88 75	23- 41 32	38- 55 44	3.7- 5.6 4.4
<u>Herichthys</u> , from Cuatro Ciénegas basin, N = 94	106-184 128	62-113 80	29- 93 35	40- 66 46	3.6-19.8 6.8
caracole cichlid, Cuatro Ciénegas basin, N = 88	111-182 167	69-111 87	31- 63 45	46- 71 68	9.7-22.0 15.7

than the mean width for the caracole Parapetenia. Of the five proportional measurements of the basipharyngobranchial bone and teeth, data for Herichthys from Cuatro Ciénegas fall far nearer Texas cichlids in mean values than toward caracole cichlids. Two of the five measurements are intermediate between Río Grande cichlids from the Río Salado (into which the Cuatro Ciénegas waters now drain) and the Texas form, and three of the five are only slightly extreme as compared to Texas cichlids. The fact that three of the five measurements for Herichthys from Cuatro Ciénegas range higher than those for the caracole Parapetenia may lend credence to alternative 1, given above. A Texas cichlid progenitor may have invaded an area of abundant molluskan foods and converged toward the caracole cichlid in morphology of some features of its pharyngeal mill.

Figure 23 compares the width of the widest, medial posterior tooth on the basipharyngobranchial bone for the various populations of Herichthys and Parapetenia. For the Cuatro Ciénegas Herichthys, a bimodal pattern is indicated. This is comparable to a situation expected if Texas and Río Grande cichlids occurred together (since the ranges of relative size of the tooth overlap). They are not yet separable on the basis of other features. A similar situation would accrue if the two forms were in secondary contact and were hybridizing, with some blockage to complete introgression allowing both extremes to persist in the population. The last seems most plausible because of the weak bimodality and is supported by qualitative features of the pharyngeal dentition of samples from the eastern part of the Cuatro Ciénegas system(s) (Figure 24).

FIGURE 23. Frequency distributions of width of the largest, mesial posterior tooth on basipharyngobranchial bones of various species or populations of North American cichlid fishes; width of tooth expressed as thousandths of $SL \times 10^3$; see text for further explanation.

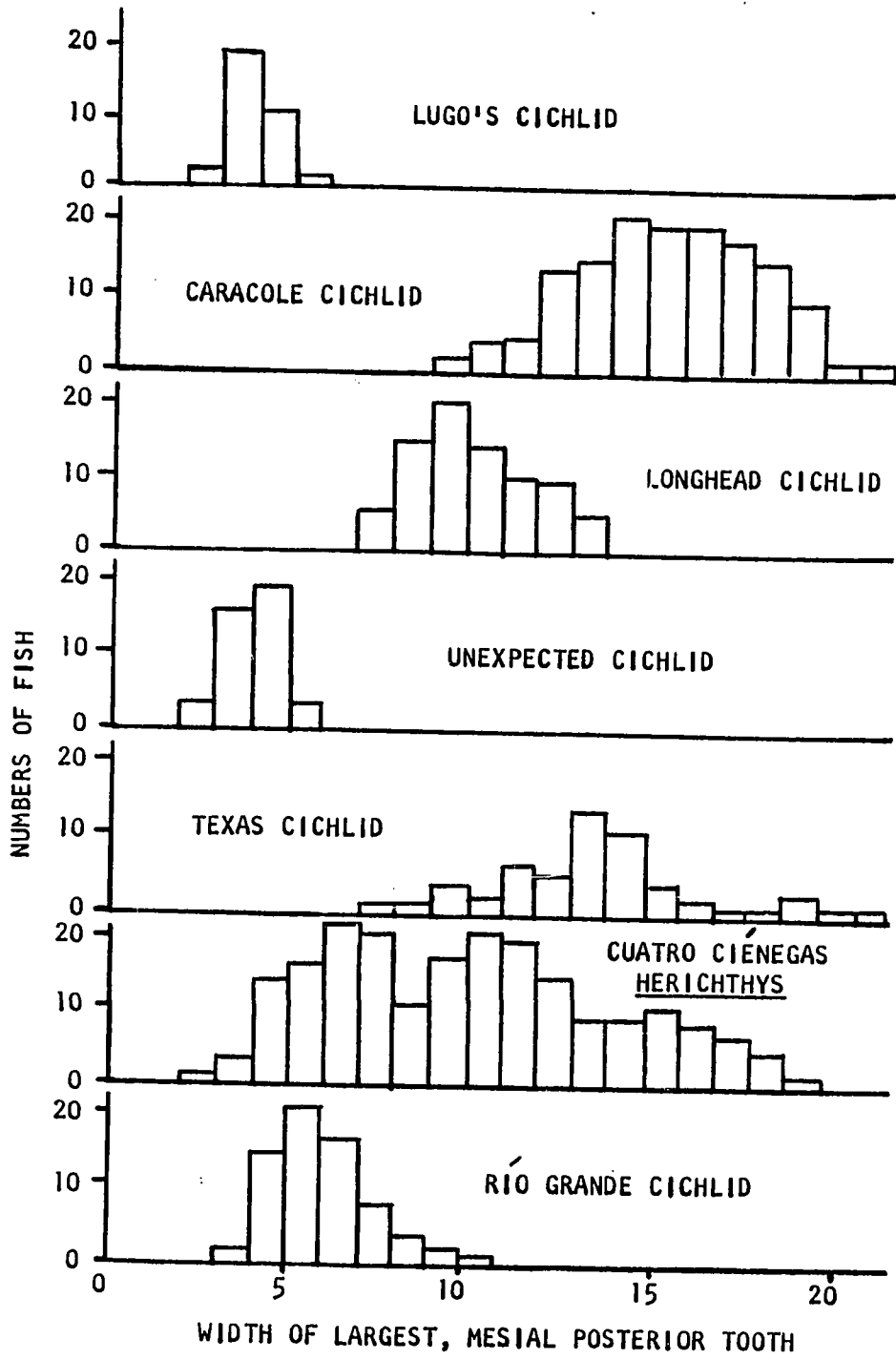
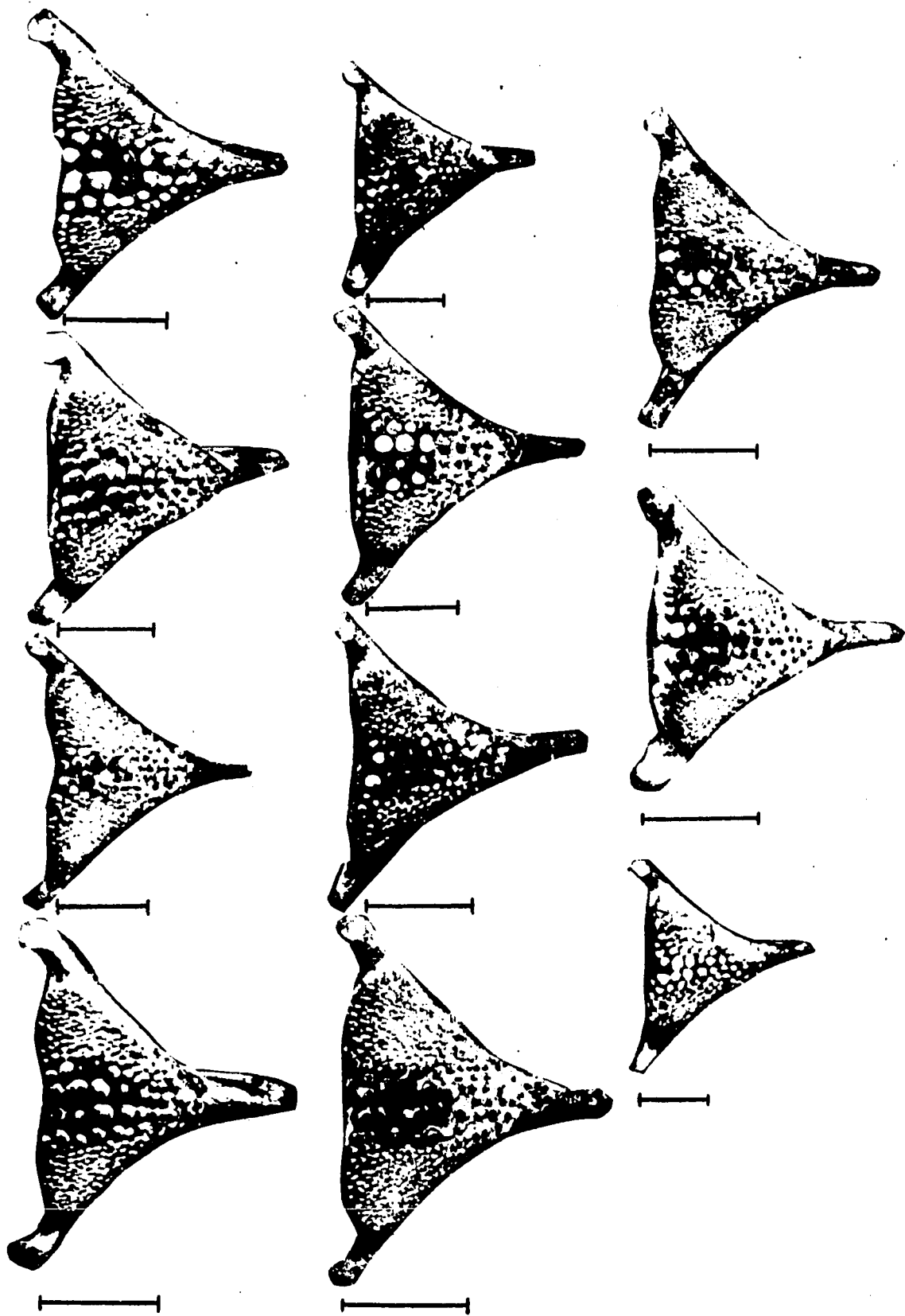


FIGURE 24. Basipharyngobranchial bones of 11 Herichthys collected from a spring-fed pool in drainage 5 of the Cuatro Ciénegas basin (see Figure 22). Note the tooth patterns of the Río Grande cichlid, Texas cichlid, and possible intermediates in this single collection; see text for further explanation.



Some fish from intermediate points between headsprings and sumps of drainages 2 through 4, and individuals from upstream localities in drainages 1 through 4, show superficial intermediacy between Parapetenia and Herichthys in characters of the pharyngeal mill. However, no evidence of spatulate or awl-like jaw teeth was found. On the bases of dentition of the premaxillae and dentaries, proportional measurements, and meristic characters, these fish represent first generation hybrids between caracole and Lugo's cichlids. Their pharyngeal tooth patterns are almost exactly intermediate between the two proposed parental species, thereby strongly resembling the pattern seen in Texas cichlids (Figure 25). The incidence of such fish at various localities has increased in recent years (Table 8). Breakdown of isolating mechanisms allowing the two forms to hybridize may easily be attributed to man's accelerated modification of the habitats in which they occur (Hubbs, 1955). Many populations now are forced into canals which drained their former habitats in headsprings, or occur in springs greatly reduced in size and diversity of habitat.

In no instance have morphological intermediates been found between the long-head and unexpected cichlids, nor between either of those forms and Lugo's or caracole cichlids. The long-head and unexpected Parapetenia are restricted to headsprings, on the basis of collections, and are rare. All available specimens from more than 30 collecting trips between 1958 and 1972 number 14 and 27, respectively.

FIGURE 25. Basipharyngeal bones and teeth of Lugo's cichlid (A), caracole cichlid (D), and putative F₁ hybrids between the two Parapetenia; all fish from drainage 3 of the Cuatro Ciénegas basin, Coahuila, México (see Figure 22).

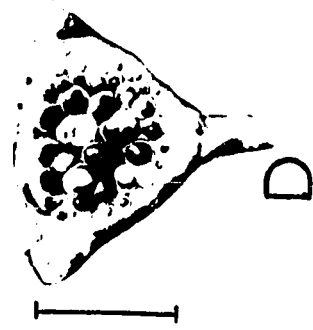
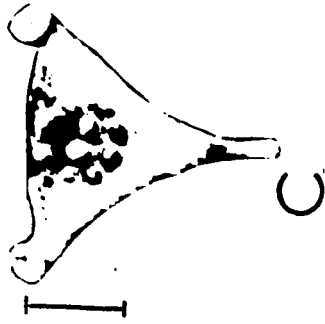
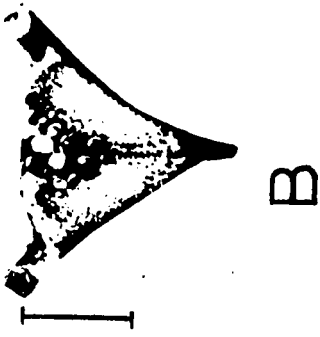
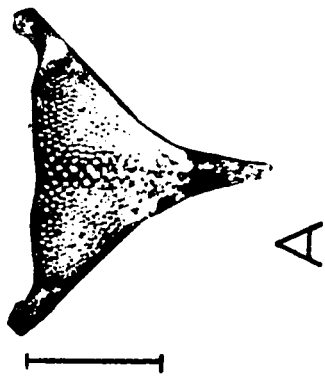


TABLE 8. Records of occurrences of various cichlid fishes in headspring collections from the Cuatro Ciénegas basin, Coahuila, Mexico, 1958 to 1973. Symbols: E = expected; X = collected; and (2) = rounded percentage of localities worked in which hybrids occurred. Drainage 5 (refer to Figure 22) was not included in compilations. Numbers of collection localities varied from one (in 1973) to 53, with a mean of 21 over the years. The Río Grande cichlid and Herichthys sp. were not expected, nor collected, in 1973, since neither is known from the spring from which samples were obtained. In all other instances, three dashes (---) indicate that collections were made from places where the species or a hybrid form might well have occurred.

	Years of collections															
	1958	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	
Río Grande cichlid	---	---	---	---	---	---	---	X	E	---	X	X	X	E	---	
<u>Herichthys</u> sp. (Texas cichlid???)	---	---	---	X	E	E	E	X	E	X	X	E	X	E	---	
Lugo's cichlid	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
caracole cichlid	X	X	X	X	X	E	X	X	X	X	X	X	X	X	X	
long-head cichlid	X	E	E	X	X	E	E	E	E	E	E	X	X	X	E	
unexpected cichlid	X	X	E	E	X	X	X	E	E	X	E	E	X	X	X	
Río Grande cichlid X <u>Herichthys</u> sp.	---	(0)	(0)	X	X	---	---	X	---	---	X	X	X	X	---	
Lugo's cichlid X caracole cichlid	---	(0)	(0)	---	---	---	X	E	X	X	X	X	X	X	X	
	(0)	(0)	(0)	(0)	(0)	(0)	(2)	(0)	(0)	(0)	(5)	(8)	(12)	(19)	(100)	

CONCLUSIONS

The primary objective of this study was to evaluate characteristics of North American cichlid fishes which might be useful in future taxonomic work. It must be concluded that North American cichlids parallel many of those of the Eastern Hemisphere in restricting their adaptive radiations toward modifications of those structures related principally to feeding. External morphology, both proportional measurements and meristic features, are far less valuable than dentitional or osteological characters at both generic and specific levels, and are often essentially useless. Feeding adaptations often are considered labile, subject to rapid change with changes in available foods or modes of life (Gosline, 1973). However, certain families of fishes have become specialized in such a way that changes in only a few specific features result in speciation, as has occurred in many groups of Cichlidae. Another excellent example of this is in the livebearers, family Poeciliidae, where sexual modifications provide essentially the only base for their classification (Rosen and Bailey, 1963).

Fryer (1959b) proposed four basic types of feeding adaptations in one monophyletic group of rock-frequenting cichlid fishes from Lake Malawi (= Nyasa), Africa. These included algal browsers, invertebrate predators, planktivores, and piscivores. Based upon examination of contents of alimentary canals, morphology of the pharyngeal mills, and on extensive observation of the various species in the laboratory and field by Minckley and others (pers. Comm.), four

basic kinds of feeding adaptations seem present in Cuatro Ciénegas cichlids: 1) long-head and unexpected cichlids are piscivores; 2) caracole cichlids are mollusk feeders; 3) Lugo's cichlid feeds upon detritus; and 4) Herichthys spp. may be classed as omnivorous.

Piscivorous cichlids tend to have elongated shallow bodies, suitable for rapid, short term propulsion in contrast to all other kinds that are likely to be deep-bodied. Along with this basic modification is an elongation of the predorsal area, reflecting a narrowing and lengthening of the anterior portion of the neurocranium and elongation of the jaws, and a shortening of the gut (Fryer and Iles, 1972). All these features may be seen in the long-head and unexpected cichlids. Of 21 elongate, slender cichlid species of African lakes, all but one kind was piscivorous (Greenwood, 1962). When piscivorous cichlids feed upon relatively large fishes, the pharyngeal bones are generally used for maceration of the prey (Keiner and Mauge, 1966; Fryer and Iles, 1972), and the almost molariform pharyngeal teeth of the long-head cichlid relate to its feeding mostly on relatively large pupfishes (Cyprinodon bifasciatus Miller). The fine, grasping pharyngeal teeth of the unexpected cichlid may relate more to its feeding upon smaller prey, Gambusia spp. and young cyprinids.

The invertebrate (molluskan) predator of the basin is far deeper bodied than the piscivorous forms, and in general has a thicker, shorter head. This again holds true for African species of the same general feeding habits (Greenwood, 1965). The caracole

cichlid of Cuatro Ciénegas therefore fits nicely within this category of adaptive specialization. Use or disuse of the pharyngeal mill of mollusk feeding species may interact with genetically determined tendencies toward hypertrophy of the complex components of the structure (Greenwood, 1965; Fryer and Iles, 1972). This was not substantiated by laboratory reared North American cichlids when compared to their parental stocks (Figure 11).

Detritus feeding cichlids such as Lugo's cichlid, resemble African zooplanktivores in morphology of their pharyngeal mills. The basipharyngobranchial bone is small, lightly built, distinctly Y-shaped and with long, slender posterior rami and a thin anterior extension. The pharyngeal teeth are slender, elongate, and numerous. The epipharyngobranchial bones also are delicate and small and ride against a thin neurocranial apophysis. Gut length is typically several times the body length.

Herichthys have pharyngeal teeth ranging from variably molariform in the Texas cichlid, through two mesial rows of enlarged teeth on the basipharyngobranchial bone in Río Grande, Río Pánuco, estuarine, and Río Nautla cichlids, to fine, delicate teeth in the single specimen of dorsal-blotch cichlid. Distribution of the Texas cichlid in clearer, upstream or springhead habitats where numerous small mollusks are present (Taylor, 1966), allowed convergence toward the same line of feeding adaptation as the caracole cichlid. Herichthys cyanoguttatus (sensu lato) and its coastal relatives have remained in an intermediate state, utilizing any foods available.

Based on its pharyngeal bones, the dorsal-blotch cichlid may be a detritivore. Nutritional adaptations in Herichthys, contrasted with those of Parapetenia, are far less spectacular.

SUMMARY

1. Dentition of the jaws seemed remarkably conservative in the fishes studied, with ontogenetic variation being minimal. Proceeding from north to south within the range of the forms of Herichthys studied there is a distinct cline, with variation from river to river. Study of the various species of Parapetenia from within the region also inhabited by Herichthys indicated similar variations. **Oral dentition of the two genera differs radically, Parapetenia teeth being canine, sharp, and conical, while those of Herichthys are incisor-like and obtuse through truncate distally.**
2. Little allometric change was found in five measurements of the basipharyngobranchial bone and teeth. Pharyngeal dentition provides a broad spectrum of variability within both Herichthys and Parapetenia with a number of taxa within each genus being readily identified by examination of the pharyngeal mill.
3. Variation within 22 external measurements on Herichthys c. cyanoguttatus resulted from negative or positive allometry, normal or near normal variation in certain characters that were basically isometric, and a combination of these factors. The greatest degree of allometry relative to SL, involved features that included parts of, or were of, the head. Based on the analyses of this taxon, 10 of 19 features (excluding measurements of the fins) are indicated as valid

to be used in direct comparisons of populations without consideration of allometric problems.

4. Interpopulation variation in meristic features strongly support the conservative nature of these characters in North American cichlids; little information of taxonomic value was obtained.
5. Length of the gut is highly variable, but in some genera may be successfully used in conjunction with other features as a taxonomic tool. Among Herichthys no patterns were evident in gut length relative to geography, foods, or probable taxonomic relationships. Among the Cuatro Ciénegas species of Parapetenia, however, length of the gut is usable to separate species.
6. Within Herichthys, the Texas and Río Grande cichlids are essentially identical in external morphology, but differ in their pharyngeal teeth. Herichthys from the Río Soto la Marina have a number of characteristics that seem indicative of intergradation between the Río Grandean form and the Río Pánuco cichlid, H. c. carpintis. External morphology diagnosed the Río Pánuco cichlid. The estuarine cichlid comprised a complex here proposed as an undescribed species of Herichthys, but may consist of more than one species. The lack of a sufficient number of specimens of the estuarine cichlid precludes further taxonomic decision at this time. The dorsal-blotch cichlid in the Río Tancochin is markedly different from the sympatric form of estuarine cichlid in both external and pharyngeal morphological features. The Río Nautla form also differs from other Herichthys.

Of the species of Parapetenia examined, external morphology substantiate the presence of two species pairs, Lugo's and caracole cichlids, and long-head and unexpected cichlids. Pharyngeal teeth and measurements of the basipharyngobranchial bone may be used to separate all four forms.

7. The four kinds of Parapetenia of the Cuatro Ciénegas basin are generally sympatric in some major springs and their outflows. Herichthys is also present in some drainages of the basin. The form(s) of Herichthys present may be the Río Grande cichlid, the Texas cichlid, or both with hybrids of the two. The Río Grande cichlid is likely a recent invader of the basin, moving in through man-made canals. There is some possibility of miscegenation between Herichthys and Parapetenia, and almost certainly hybridization between caracole and Lugo's cichlids, genus Parapetenia, in habitats modified by man. In no instances have intermediates been found between the long-head and unexpected cichlids nor between either of those forms and Lugo's or caracole cichlids, or any Herichthys.

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APPENDICES

APPENDIX I: TAXONOMIC CONSIDERATIONS

A number of generic names have been applied to nominal species of cichlid fishes from within the region from which collections were studied. For example, the type species of Herichthys Baird and Girard (1854) is H. cyanoguttatus Baird and Girard. This species was transferred to Heros Heckel (1840) by Günther (1862). It was then relegated to Astronotus Swainson (1839) (by placement of the species in the subgenus Cichlasoma Swainson [1839], originally described as a full genus) by Eigenmann and Bray (1894). Then, it was placed into the genus Cichlasoma Swainson by Meek (1904, 1908). Regan (1905) retained the name Herichthys for H. cyanoguttatus, placing Neetroplus carpintis Jordan and Snyder (1900) as a junior synonym upon recognition of the incisor-like teeth in Herichthys. Meek (1904) recognized Neetroplus carpintis and recorded it as sympatric with Cichlasoma (= Herichthys) cyanoguttatum throughout much of northern Mexico. Thus Regan recognized variation in jaw dentition of Herichthys which must have been missed by Meek. Jordan, et al. (1930) and Hubbs (1936), on the basis of Regan's (1905) work, retained the name Herichthys for a number of Mexican cichlids, and H. cyanoguttatus, but since the 1930s and in some instances before, Herichthys was slipped into and out of various synonymies. It was finally settled (along with a number of other nominal genera) for undertermined reasons into "firm synonymy" with Cichlasoma, since perhaps 1960. Other fishes mentioned later have suffered similarly in their generic allocations, involving Neetroplus Günther (1862), Acara Heckel (1840), and Parapentenia Regan (1905).

Firm application of extant names to various taxa in the present study was essentially impossible because of constraints of travel and time, precluding access to type materials. These problems were largely circumvented by R. R. Miller, University of Michigan, who provided access to a manuscript by Carl L. Hubbs and the late Myron Gordon, in which many data on types of various nominal taxa are presented. Miller has examined many of the same fishes and he provided direct assistance. Generic allocations are tentative with full knowledge that studies of the many North American cichlid species may dictate future change.

GENUS HERICHTHYS BAIRD AND GIRARD (1854)

Diagnosis.--Anterior, premaxillary and dentary teeth in outermost row incisor-like at tips, sharp pointed to truncate, and with posterior cusp ranging from broad and truncate in northern forms, to delicate and obtuse in southern forms; premaxillary teeth increasing progressively in size from posterior to anterior; teeth on dentary abruptly enlarged anteriorly, sharply set off from smaller, lateral, conical teeth; inner rows of teeth on both premaxillae and dentaries scarcely aligned, essentially villiform, and much smaller than outer incisors; lower basipharyngobranchial bone relatively conservative, rarely bearing molariform teeth, and if so only posteriorly in four mesial rows; typically with sharp pointed, variable oriented dentition (antrorse posteriorly, vertical medially, and retrorse anteriorly); body deep, more than 45 percent of SL; head and snout short, usually less than 40 and 13 percent, respectively, of SL; predorsal profile convex.

Type species.--Herichthys cyanoguttatus Baird and Girard (1854), by monotypy, "Brownsville, Texas (fresh water)."

Referred Taxa

Scientific names of new taxa are not included in the firm belief that such should only appear in formal publication (Blackwelder, 1967). Only the oldest and most pertinent synonyms for each proposed taxon are listed. Diagnoses of species and subspecies also are excluded since those forms intensively studied are already diagnosed in text; referred forms not extensively examined are diagnosed in papers cited for each, or especially for a number of southern Parapetenia (see also Miller, 1907). **Figure 1 delineates** the ranges for the forms specifically studied. Statements of ranges for species referred to the genera Herichthys and Parapetenia on the basis of literature are provided below.

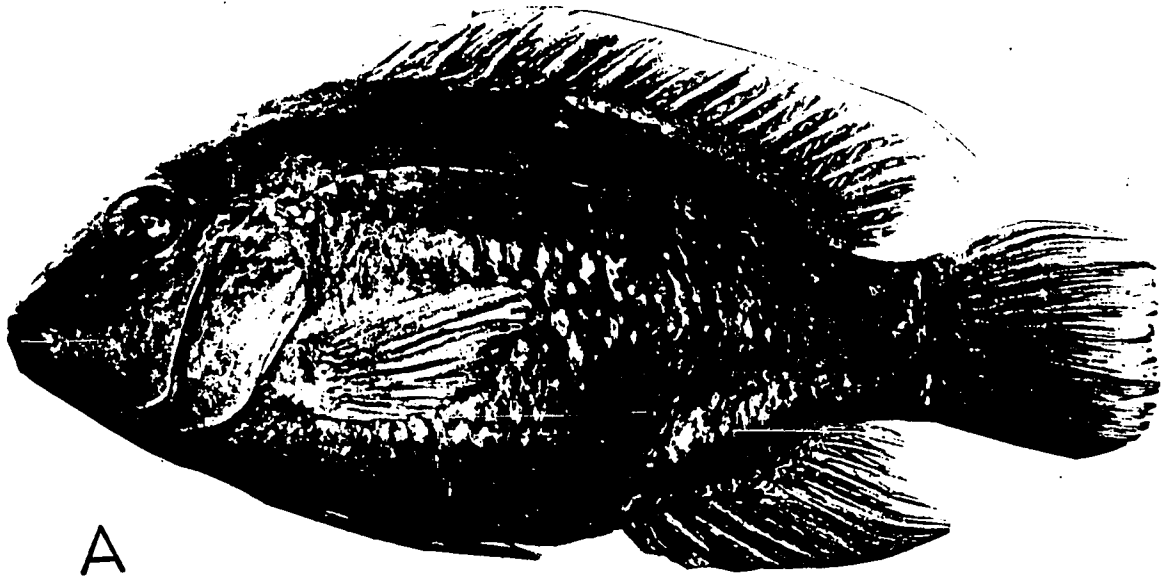
Río Grande cichlid,

Herichthys cyanoguttatus cyanoguttatus Baird and Girard

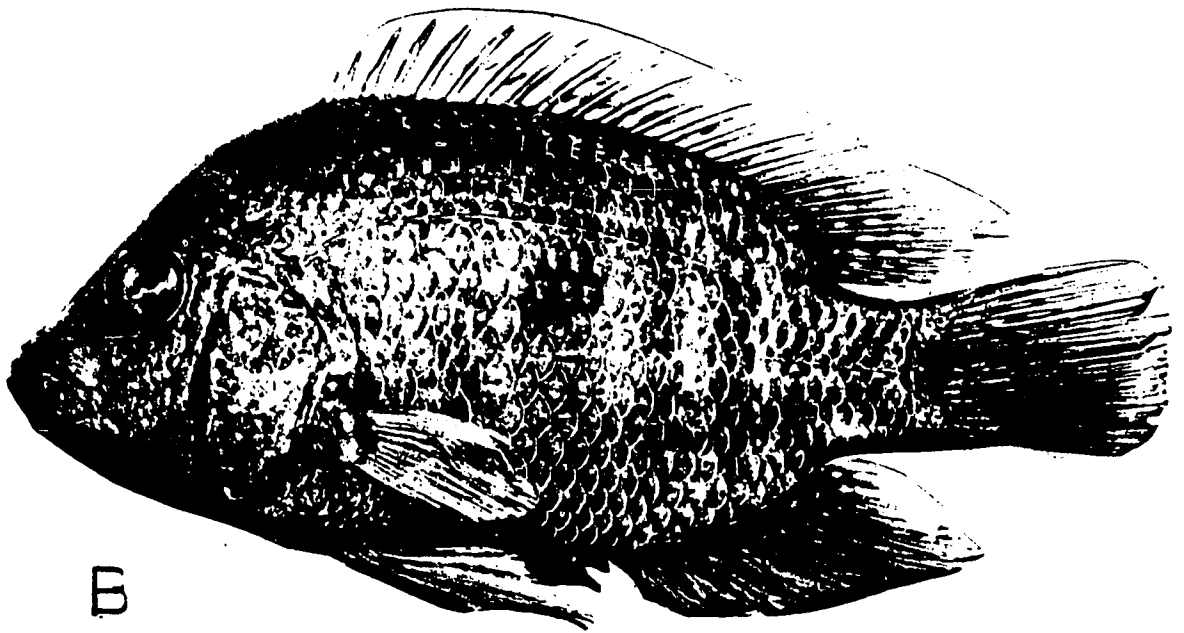
(Figure 26a-b)

Primary synonyms.--Herichthys cyanoguttatus Baird and Girard, 1854 (original description); Jordan, et al., 1930 (listed); and Hubbs, 1936 (comparisons, listed, locality). Herichthys cyano-guttatus, Girard, 1859 (part, description, localities). Heros cyanoguttatus, Günther, 1862 (part, listed); Jordan and Gilbert, 1882 (part, listed); Evermann and Kendall, 1894 (part, range, localities); Jordan and

FIGURE 26. Río Grande cichlids, Herichthys cyanoguttatus cyanoguttatus:
A = Río San Juan basin, Río Grande system, México--UANL 750, SL 98.5 mm;
and B = Río San Fernando system, México--UANL 684, SL 103.7 mm.



A



B

Evermann, 1898 (part, description, range); Jordan and Snyder, 1900 (part, description, range); Evermann and Goldsborough, 1902 (part, range, listed); and Pellegrin, 1904 (part, listed). Heros pavonaceus Garman, 1881 (original description, "From a spring near Monclova, Dr. Palmer [Coahuila, México]".); Jordan and Gilbert, 1882 (listed, range); Evermann and Kendall, 1894 (listed, range); and Jordan and Evermann, 1898 (description, range). Astronotus (Cichlasoma) cyanoguttatus, Eigenmann and Bray, 1894 (part, synonymized). Cichlasoma cyanoguttatum, Meek, 1904 (part, description, range), 1908 (description). Neetroplus carpintis, Meek, 1904 (part, listed, description, range, misidentification); Pellegrin, 1904 (part, listed, misidentification); and Regan, 1905 (part, synonymized with H. cyanoguttatus). Cichlasoma pavonaceum, Regan, 1905 (range, description). Herichthys pavonaceus, Jordan et al., 1930 (listed).

Type locality.--"Brownsville, Texas (fresh water).--Capt. Van Vliet and John H. Clark."

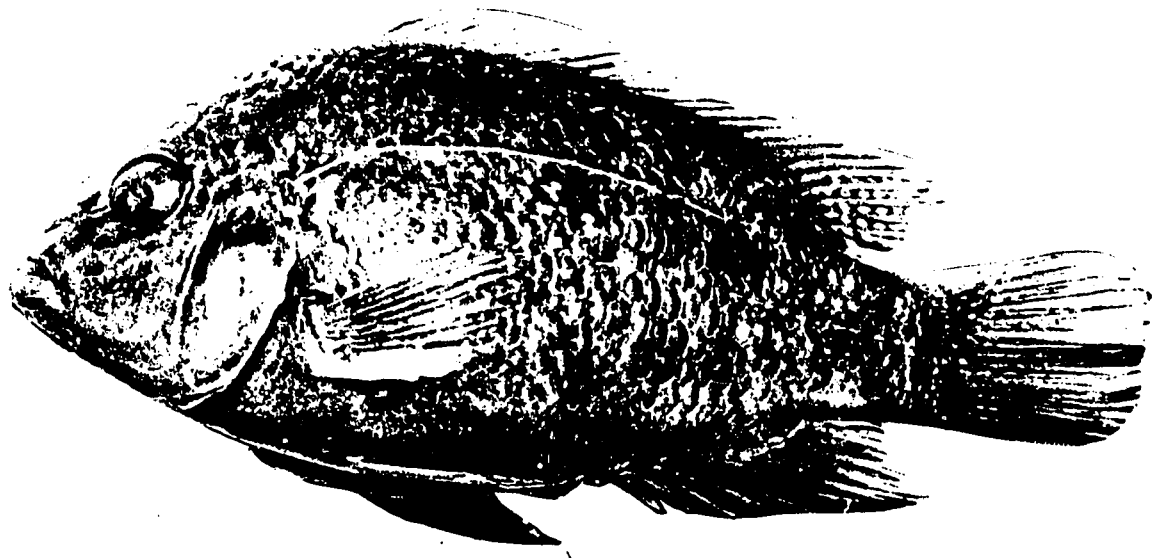
Types.--Original 14 co-types (syntypes) Academy of Natural Sciences of Philadelphia No. 851 (Girard, 1859, noted "Jno. H. Clark" as the sole collector); lectotype now catalogued at UMNZ, and lectoparatypes at United States Museum of Natural History.

Río Pánuco cichlid,

Herichthys cyanoguttatus carpintis (Jordan and Snyder)

(Figure 27)

FIGURE 27. Río Pánuco cichlid, Herichthys cyanoguttatus carpintis.
Laguna de Ebaño, Río Tamesí-Pánuco system, México--UANL 1306, SL
72.4 mm.



Primary synonyms.--Neetroplus carpintis Jordan and Snyder, 1900 (original description); Evermann and Goldsborough, 1902 (part, range, listed); Meek, 1904 (misidentification, part, range, description); Pellegrin, 1904 (listed); Jordan and Evermann, 1900 (listed, description, range); and Jordan and Dickerson, 1908 (listed, locality). Cichlasoma laurae Regan, 1908 (original description, "Tampico"). Herichthys carpintis, Jordan et al., 1930 (listed). Cichlasoma cyanoguttatum, Meek, 1908 (synonymized N. carpintis).

Type locality.--"Laguna del Carpinte, near Tampico, Tamaulipas, México. Collected by J. O. Snyder, January 15, 1899."

Types.--Original 10 co-types Stanford University Collection of Fishes, No. 6,162; lectotype and lectoparatypes now catalogued at California Academy of Sciences.

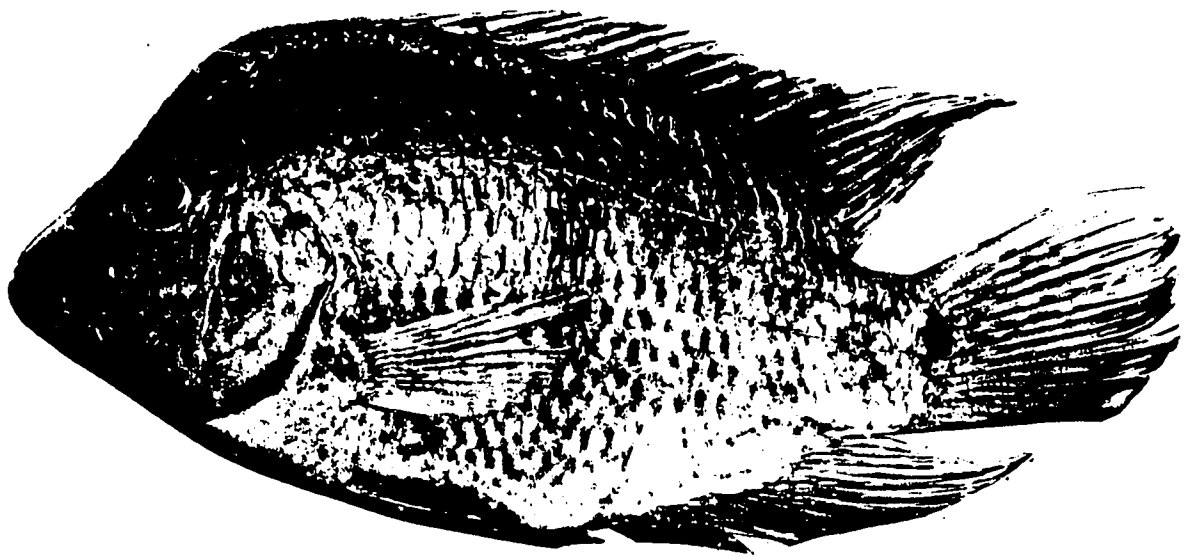
Intergrades,

Herichthys cyanoguttatus: cyanoguttatus X carpintis

(Figure 28)

Primary synonyms.--Heros teporatus Fowler, 1903 (original description, "Victoria on the Victoria River, a tributary of the Río Soto la Marina, Tamaulipas, Mexico. Coll. S. N. Rhoads."); "Type No. 24,242, A.N.S.P. [Academy of Natural Sciences of Philadelphia]); synonymized with H. cyanoguttatus (s.s.) by Meek (1904; erroneously termed Heros temporatus [sic.] Fowler) and by Jordan, et al. (1930).

FIGURE 28. Intergrade, Herichthys cyanoguttatus: cyanoguttatus X carpintis. Río Purificación, Río Soto la Marina system--UANL 303, SL 115.0 mm.



Texas cichlid, Herichthys, n. sp.

(Figure 29)

Primary synonyms.--Herichthys cyano-guttatus, Girard, 1859 (part, description, localities). Herichthys cyanoguttatus, Günther, 1862 (part, listed); Jordan and Gilbert, 1882 (part, listed); Evermann and Kendall, 1894 (part, range, localities); Jordan and Evermann, 1898 (part, description, range); Jordan and Snyder, 1900 (part, description, range); Pellegrin, 1904 (part, listed); and Jordan et al., 1930 (part, listed, range). Astronotus (Cichlasoma) cyanoguttatus, Eigenmann and Bray, 1894 (part, synonymized along with H. cyanoguttatus). Cichlasoma cyanoguttatum, Meek, 1904 (part, description, range). Neetroplus carpintis, Meek, 1904 (part, listed, description, misidentification); Pellegrin, 1904 (part, listed, misidentification); and Regan, 1905 (part, synonymized with H. cyanoguttatus with which the Texas cichlid was then confused).

Type locality and types.--The type locality and type specimens for this new form will be designated at the time of its description in the open literature.

Estuarine, dorsal-blotch, and Río Nautla cichlids,

Herichthys, n. spp.

(Figures 30-32)

Primary synonyms.--The estuarine, dorsal-blotch, and Río Nautla cichlids have no known primary synonyms. General statements of range of Herichthys cyanoguttatus, or its synonyms given above,

FIGURE 29. Texas cichlid, Herichthys, n. sp. Las Moras Creek, Río Grande system, Texas, U.S.A.--TNHM 1857, SL 97.4 mm.

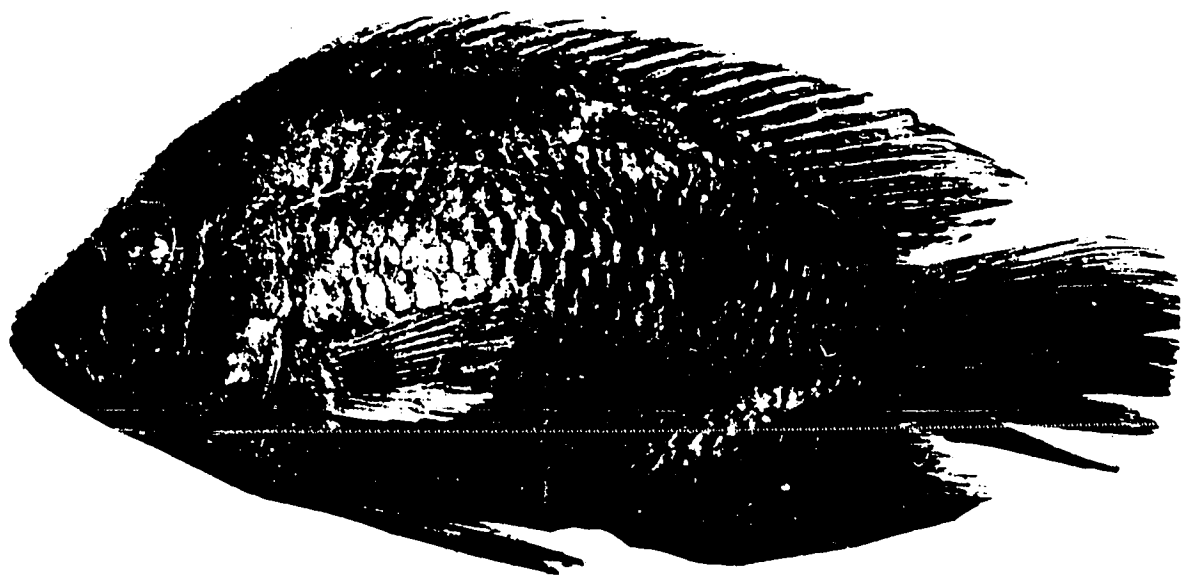
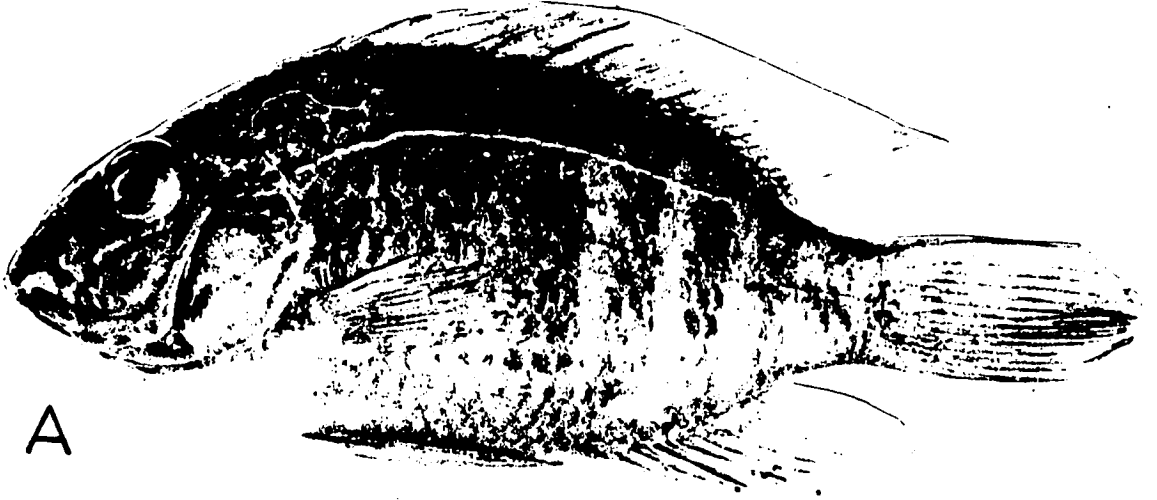
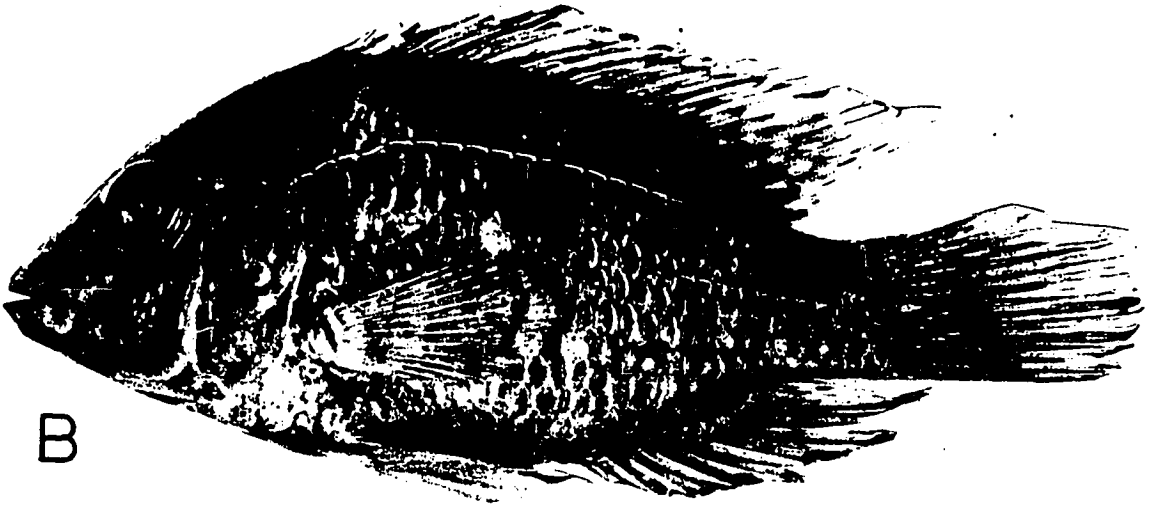


FIGURE 30. Estuarine cichlids, Herichthys, n. sp.: A = Río Tancochin system--UMMZ 97713, SL 112.0 mm; and B = Río Cucharas system (tributaries to Estero Tamaihua)--UMMZ 97707, SL 80.2 mm.

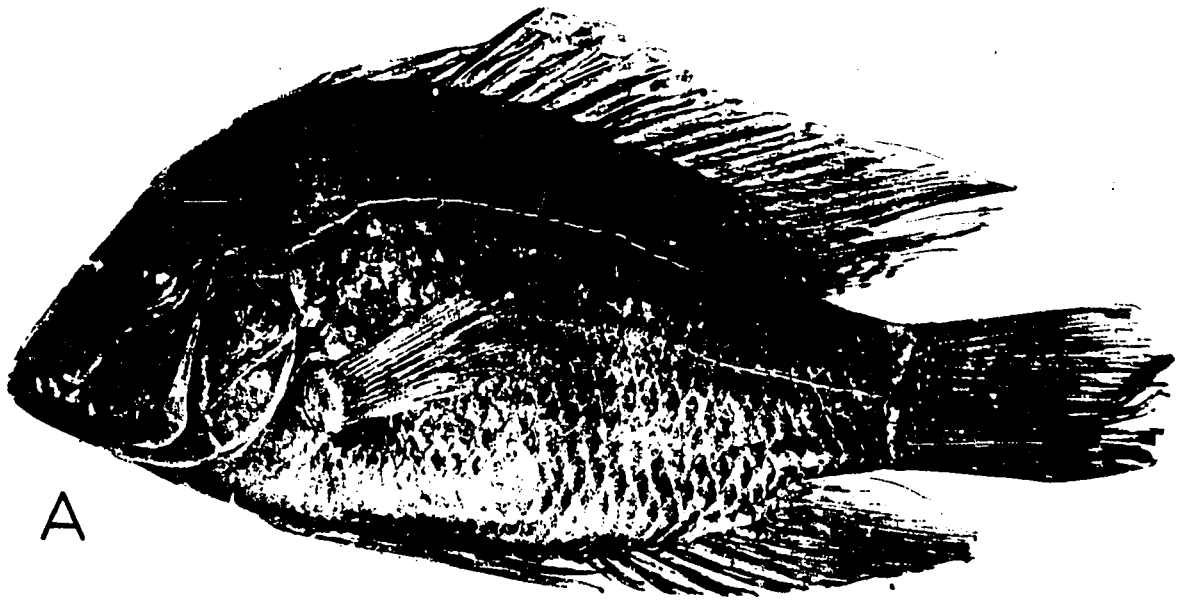


A

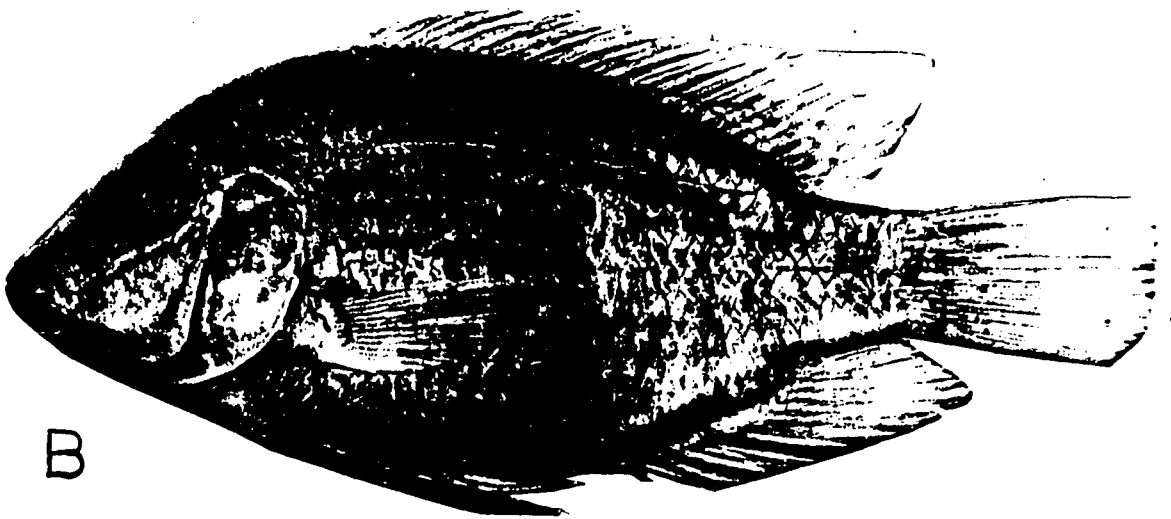


B

FIGURE 31. Estuarine cichlids, Herichthys, n. sp.: A = Río Pantepec-Tuxpan system--UMMZ 16759, SL 132.4 mm; and B = Río Cazonés system (direct tributaries to the Gulf of Mexico)--UANL 1154, SL 115.4 mm.



A

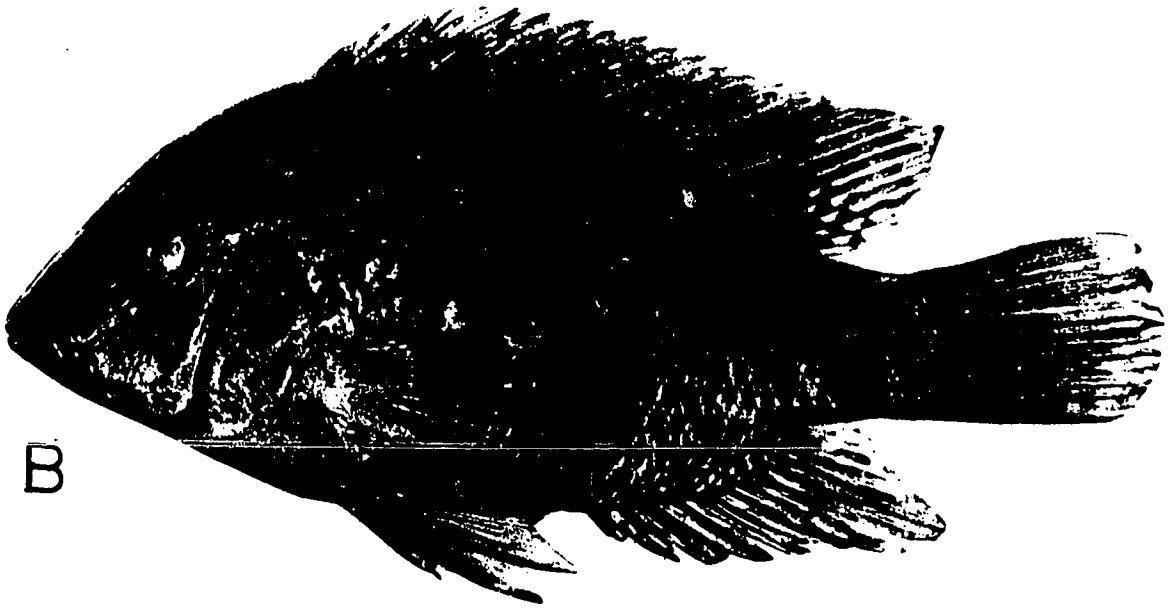


B

FIGURE 32. A = Dorsal-blotch cichlid, Herichthys, n. sp., Río Tancochin system, México--UMMZ 97713 (sorted from series of seven estuarine cichlids--to be recatalogued at UMMZ), SL 112.0 mm; and B = Río Nautla cichlid, Herichthys, n. sp., Río Nautla system, México--UMMZ 167491, SL 80.7 mm.



A



B

may generally include, the range of some of these forms (e.g., "...northeastern México;" Jordan and Evermann, 1898).

Type locality and types.--The type localities and type specimens of these new forms will be designated at the time of their description in the open literature.

Boucourt's cichlid,

Herichthys bocourti (Vaillant and Pellegrin)

Originally described by Vaillant and Pellegrin (1902) as Neetroplus Bocourti, this form was re-described by Regan (1905), and placed into Herichthys. It was also placed by Miller (1966) into his "Cichlasoma, section 'Herichthys'." According to Miller the species is distributed in Lake Izabal and in the lower Río Polochic, Atlantic slope, Guatemala. The type locality is Lake Izabal, Guatemala (Regan, 1905).

Pearse's cichlid, Herichthys pearsi Hubbs

This species was described by Hubbs (1936) from the "...Río Champoton, Campeche, 7 leagues (34 km.) east of Champoton, collected by Creaser and Pearse on July 9, 1932..." It ranges along the Atlantic slope of México to northern Guatemala in the Río Usumacinta basin, including the Río Champoton, Campeche (Miller, 1966).

Genus Parapetenia Regan

Diagnosis.--All premaxillary and dentary teeth in outermost row rounded and sharp tipped unless worn, cusps absent from all jaw

teeth; two anteriormost premaxillary teeth produced into canines, markedly larger than lateral teeth; anterior 6 to 10 canines abruptly enlarged anteriorly on both premaxillary and dentary, sharply set off from smaller, lateral, teeth on dentary, as in Herichthys; inner rows of teeth on both premaxillae and dentaries scarcely aligned, essentially villiform, but generally more conic and canine-like than in Herichthys; lower basipharyngobranchial bone diversely modified among species, ranging from thickened and bearing molariform teeth, to delicate and bearing only sharp-tipped villiform teeth, variably oriented (the last as in many Herichthys); body depth variable, but tending to be less than 45 percent of SL; head and snout long, usually more than 40 and 14 percent, respectively, of SL; predorsal profile concave.

This diagnosis, based on species from northern and eastern México, is supplemented by the following quotation of Regan's (1905) original description of the taxon:

Typically with larger, more oblique and more protractile mouth than in other groups of Cichlasoma and usually with maxillary more distinctly expressed distally; but none of these features are constant. Upper jaw with the anterior pair of teeth slightly enlarged in the more generalized forms, strongly enlarged in the more specialized ones. Lower jaw with the 3 anterior teeth on each side more or less canine-like, with the anterior pair somewhat smaller than the others (corresponding to the enlargement of the anterior pair in the upper jaw) in the more generalized forms. The anterior pair wanting, the next pair strong, and the third pair forming very strong canines in the more specialized forms. Scales of lateral line of the same size as those below it on the side of the body; scales of the thoracic region much smaller than those on the side of the body. Dorsal XV-XIX 8-13; posterior part of the spinous dorsal and soft fin with a scaly sheath at the base and with short series of scales on the interradiial membranes. Anal IX-X 7-10. Caudal rounded or subtruncate.

Parapetenia was described by Regan (1905) as a subgenus of the genus Cichlosoma (= Cichlasoma). No type species was originally designated, but the first species following the description was Cichlasoma adpersum, originally described as Acara adpersa Günther (1862). Jordan et al. (1930) first elevated Parapetenia to generic rank, and designated Acara adpersum as type species. Parapetenia adpersa is known from the Barbados Islands (Jordan et al., 1930). Many species of this genus are Caribbean in distribution, and poorly known; only mainland forms are included below.

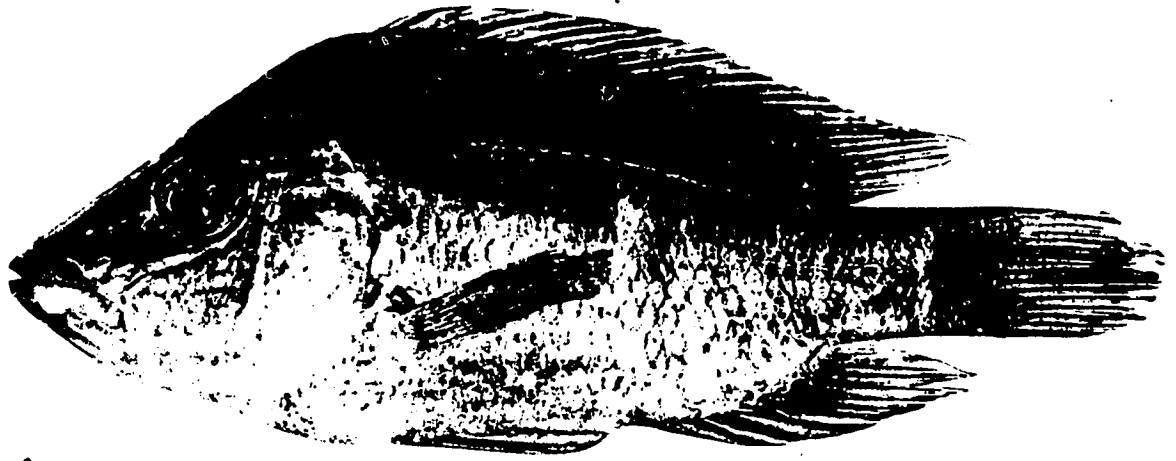
Lugo's, caracole,
long-head, and unexpected cichlids, Parapetenia, n. spp.

(Figures 33 and 34)

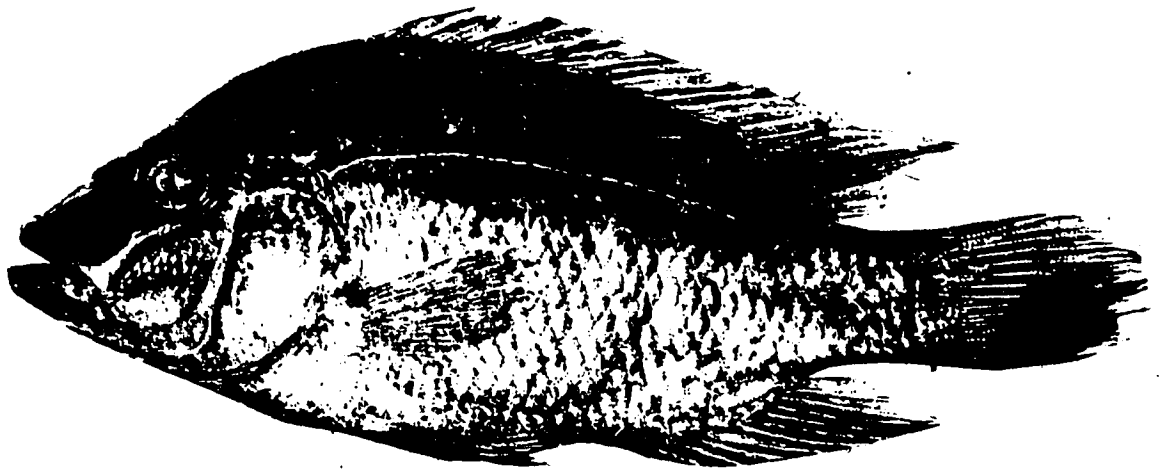
Primary synonyms.--In Minckley (1962), and in most subsequent papers dealing with fishes of the Cuatro Ciénegas basin, these species have been referred only to undescribed species of Cichlidae or to "Cichlasoma spp."

Types and type localities.--Type specimens and type localities for each of these four Parapetenia will be presented with their formal descriptions in the open literature. All known specimens of these four species are from the Cuatro Ciénegas basin, Coahuila, México. Type materials will be housed at UMMZ, ASU, KU, and UANL.

FIGURE 33. Parapetenia, n. spp. from the Cuatro Ciénegas basin, Río Grande system, México: A= Lugo's cichlid, Poso de la Becerra-- UMMZ 179832, SL 94.0 mm; and B= paracole cichlid, same locality and UMMZ number, to be recatalogued at UMMZ, SL 83.5 mm.



A

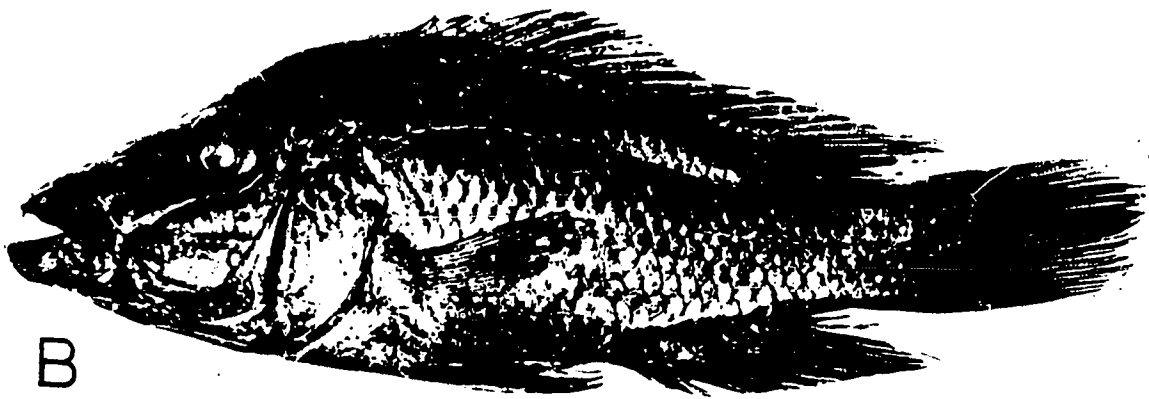


B

FIGURE 34. Parapetenia, n. spp. from the Cuatro Ciénegas basin, Río Grande system, México; A ~~is~~ long-head cichlid, Posos de la Becerra-- UMMZ 179832, SL 95.3 mm; and B ~~is~~ unexpected cichlid, same locality and UMMZ number, to be recatalogued at UMMZ, SL 92.1 mm.



A



B

Bean's cichlid, Parapetenia beani (Jordan)

Bean's cichlid, described from the Río Presidio near Mazatlán, México, as Heros beani Jordan (1888), ranges to the north on the Pacific slope of México farther than any other cichlid species. To my knowledge, it occurs from the Río Mayo, Sonora, southward in lowland streams into Jalisco. A photograph of its basipharyngobranchial bone is in Figure 15k in text.

Speckled cichlid, Parapetenia, n. sp.

This form is widespread in the northern portion of the Río Pánuco system, particularly in the Río Tamesí, and had generally been identified with Cichlasoma (= Parapetenia) steindachneri Jordan and Snyder (1900) (see, e.g. Darnell, 1962). Its status and relationships to other Parapetenia remain to be worked out (R. R. Miller, pers. comm.). Speckled cichlids are broadly sympatric with Herichthys c. carpintis.

Barton's cichlid, Parapetenia bartoni (Bean)

Barton's cichlid was described as Acara bartoni Bean (1892) from "Huasteca Potosina, San Luis Potosi, México," the name of a region not to be confused with Huasteca Canyon near Monterrey, Nuevo León, México, in the Río San Juan basin (Río Grande system; Contreras B., 1967, 1969). This species seems restricted to the southern portion of the Río Pánuco system, particularly to the Río Verde of San Luis Potosi (Meek, 1904; Contreras B., 1969).

Steindachner's cichlid,

Parapetenia steindachneri (Jordan and Snyder)

This species also seems a component of the unique southern Río Pánuco fauna, again from the Río Verde basin (described as Cichlasoma steindachneri Jordan and Snyder, 1900). A recent collection of topotypes confirms the elongate, shallow-bodied aspect of this fish, as illustrated by Jordan and Snyder, and duplicated by Meek (1904) (R. R. Miller, pers. comm.).

Río Verde cichlid, Parapetenia labridens (Pellegrin)

Meek (1904) illustrated this form in considerable detail, even depicting the enlarged, canine, premaxillary and dentary teeth. It was described from the Río Verde, Río Pánuco system as Heros (Cichlasoma) labridens Pellegrin (1903). He considered labridens closely related to P. bartoni. However, on the basis of examination of specimens at the University of Michigan, and of a large collection from la Media Luna (a large spring complex, immediately tributary to the Río Verde; Miller, 1956), P. labridens and P. steindachneri may well represent a species pair similar to the long-head and unexpected cichlids of the Cuatro Ciénegas basin.

Río Negro cichlid, Parapetenia mento

(Vaillant and Pellegrin)

Vaillant and Pellegrin (1902) named this species Heros mento from the Río Negro, southern México, a drainage to which it

appears restricted (Meek, 1904; Miller, 1966). Vaillant and Pellegrin, and Meek, emphasize the enlarged canines in this form, substantiating its identity as a Parapetenia.

Smalleye cichlid, Parapetenia urophthalmus (Günther)

This is one of the few Parapetenia found in Lake Petén, Guatemala, from which it was described as Heros urophthalma Günther (1862). It ranges from the Río Goatzacoalcos basin south into British Honduras and Nicaragua, including the Yucatán Peninsula and the offshore Isla Mujeres (Jordan, et al., 1930; Miller, 1966).

Río Choleteca cichlid, Parapetenia hogaboomorum
(Carr and Giovannoli)

This form, described as Cichlasoma hogaboorum Carr and Giovannoli (1950), is a member of the comparatively impoverished fish fauna of the Chiapas-Nicaraguan Province of Central America (Miller, 1966), extending somewhat outside that province (as defined by Stuart, 1964) in occurring from the lower part of the Río Choluteca drainage to the Pacific slope of Honduras.

Three spotted cichlid, Parapetenia trimaculata (Günther)

This widespread fish was described as Heros trimaculatus Günther (1869). Miller (1966) included Cichlasoma mojarra Meek (1904), C. centrale Meek (1906), C. gordonsmithi Fowler (1922), and C. cajali Alvarez and Gutierrez (1952) as synonyms of P. trimaculatum.

He outlined the range of P. trimaculatum as the Pacific slope of Middle America from Laguna Coyuca northwest of Acapulco, México, south through the Río Lempa, El Salvador.

Salvin's cichlid, Parapetenia salvini (Günther)

This Parapetenia was described as Heros salvini Günther (1862) from the Río de Santa Isabel (= Izabal), Guatemala, occurs on the Atlantic slope of Middle America from the Río Papaloapam, Vera Cruz, México, south to the Sulphur River near Puerto, Barrios, Guatemala (Miller, 1966).

Tenuous cichlid, Parapetenia tenuis (Meek)

Originally described from Achotal, Vera Cruz, México, as Cichlasoma tenue Meek (1906), and said to range along the Atlantic slope of the Isthmus of Tehuantepec (Jordan, et al., 1930), this species seems restricted in distribution to the Río Papaloapam basin, on the Atlantic slope of México (Miller, 1966).

Friedrichsthal's cichlid,

Parapetenia friedrichsthali (Heckel)

This species was also described from Lake Petén, Guatemala, as Heros friedrichsthali Heckel (1840). It now is known from along the Atlantic slope of southern México (east of the Río Coatzacoalcos) to Costa Rica (Miller, 1966; Caldwell, et al., 1959). The nominal form may be synonymous with Heros (= Parapetenia) motaguensis Günther

(1869) from the Atlantic slope of Guatemala in the Río and Lago Motagua down the Pacific drainages of Guatemala, to El Salvador and Honduras (Hubbs, 1936; Miller, 1966).

Managua cichlid, Parapetenia managuense (Günther)

The Managua cichlid is present in the great lakes of Nicaragua and in streams along the Atlantic coast of Costa Rica (Rivas, in Miller, 1966). It was described from the great Lake Managua, Nicaragua, as Heros managuensis Günther (1869).

Dow's cichlid, Parapetenia dowi (Günther)

Heros (= Parapetenia) dovi (= dowi) Günther (1864) occurs from the great lakes of Nicaragua through streams on both slopes of Honduras.

Motagua cichlid, Parapetenia motaguensis (Günther)

The range and possible synonymy of Heros (= Parapetenia) motaguensis Günther (1869) are discussed above under Parapetenia friedrichsthali.

Río Grijalva cichlid, Parapetenia, n. sp.

This fish, referred by Miller (1966) to his "Cichlasoma, section Parapetenia" is from the Río Grande de Chiapa basin, Río Grijalva system, Chiapas, México, on the Atlantic slope. Diagnosis of the species is to appear under authorship of R. R. Miller (pers. comm.).

Río Comitán cichlid, Parapetenia, n. sp.

The Río Comitán cichlid occurs through the Río Comitán and adjoining lakes in Chiapas, México, in an interior stream draining toward the Río Usumacinta basin. Reasons for its referral to Parapetenia, and anticipated description are the same as for the Río Grijalva cichlid, just above (Miller, 1966; pers. comm.).

APPENDIX II: LOCALITIES FOR SPECIMENS EXAMINED

Río Grande and tributaries upstream from Laredo: ASU 1022-San Felipe Canal near Del Rio, Val Verde C., Texas; ASU 3596-Pecos River below inflow of Independence Creek, Terrell Co., Texas; ASU 3609-Independence Creek 0.8 km from Pecos River, Terrell Co., Texas; ASU 3636-Pecos River 0.8 km above mouth, Val Verde Co., Texas; ASU 3704-Las Moras Creek, 4.8 km S Brackettville, Kinney Co., Texas; ASU 4517-Devil's River, at highway loop 460, Val Verde Co., Texas; TNHM 1857-Las Moras Creek at Brackettville, Kinney Co., Texas; TNHM 1972-San Felipe Creek 1.6 km E Del Rio, Val Verde Co., Texas; TNHM 3267-Dolan Creek at Dolan Springs, Val Verde Co., Texas; TNHM 3419-Devil's River, 0.4 km N Dolan Falls, Val Verde Co., Texas; TNHM 3617-Devil's River 16 km NW Del Rio, Val Verde Co., Texas; TNHM 4439-Rio Grande at Eagle Pass, Maverick Co., Texas; TNHM 5680-Devil's River, above head of Devil's Lake, Val Verde Co., Texas; UANL 433-Rio San Carlos, 27 km S Villa Acuña, Coahuila, México; UNM uncat.-Pecos River, 1.6 km E of Sheffield, Pecos Co., Texas.

Río Grande system downstream from Laredo: TNHM 4637-Río Grande at Hidalgo, Hidalgo Co., Texas; TNHM 4671-Río Grande at Roma International bridge, Starr Co., Texas; TNHM 4673-Río Grande, Brownsville, Cameron Co., Texas; UMMZ 92113-Río Grande, Fort Brownsville, near Río Grande mouth, Texas (co-type).

Nueces-Frio River system, Texas: ASU 996-Nueces River, 18.4 km SSW Uvalde, Uvalde Co., Texas; ASU 1008-Rio Frio at Concom, Uvalde Co., Texas; ASU 2843-Nueces River at Highway 90, Uvalde Co., Texas; TNHM 1326-East Nueces River at Barksdale, Real Co., Texas; TNHM 1334-Pinto Creek, 11.2 km W Brackettville, Kinney Co., Texas;

TNHM 1434-Río Frio 7 km NE Leakey, Real Co., Texas; TNH M 1640-Río Frio 5.6 km N Leakey, Real Co., Texas; TNH M 1987-East Nueces River near Barksdale, Real Co., Texas; TNH M 3112-Montell Creek, 9.6 km NW Montell, Uvalde Co., Texas; TNH M 8206-East Nueces River at Real-Edwards County line, Texas.

San Antonio and Colorado rivers of Texas (Introduced; Kuehne, 1955; Hubbs, 1957): TNH M 246-San Marcos River, 0.8 km SE Prairie Lea, Caldwell Co., Texas; TNH M 2350-Laguna Park Lake in New Braunfels, Comal Co., Texas.

ríos Salado-Sabinas basins, México: ASU 329-Río Salado de los Nadadores 3.2 km NW Sacramento, Coahuila, México; ASU 919-Río Salado de los Nadadores at Celemania, Coahuila, México; ASU 2850-Río Salado de los Nadadores at El Cariño, Coahuila, México; ASU 2854-Río Salado de los Nadadores 4.8 km S Hermanas, Coahuila, México; TNH M 1712-Río Salado 12.8 km W Salinillas, Nuevo León, México; TNH M 1735-Río Sabinas de Coahuila, 3.2 km S Musquiz, Coahuila, México; TNH M 1745-Río Sabinas de los Nadadores, 3.2 km NW Sacramento, Coahuila, México; TNH M 5757-Río Sabinas de Nuevo León, México; TNH M 5761-Río Salado at Laredo-Monterrey Highway, Nuevo León, México; TNH M 5826-Río Salado at Rodrigues, Nuevo León, México; TNH M 5832-Río Salado, 16 km W Anahuac, Coahuila, México; TNH M 5841-Río Salado at outlet of Río Candela, Nuevo León, México; TNH M 5847-Río Salado 12.8 km SW Anahuac, Nuevo León, México; TNH M 5989-Río Salado de los Nadadores, 3.2 km NW Sacramento, Coahuila, México; UANL 405-Río Sabinas 25 km NW Ville Union, Tamaulipas, México; UANL 437-Río

Sabinas at Villadama, Nuevo León, México; UANL 694-Río Salado de los Nadadores 12 km W Nadadores, Coahuila, México; UANL 701-Río Salado de los Nadadores, 16 km W Nadadores, Coahuila, México; UANL 750-Río Alamo 4.4 km W Nueva Rosita, Coahuila, México; UANL 762-Río Sabinas, 11.7 km WSW Nueva Rosita, Coahuila, México; UANL 1027-Río Sabinas at Sabinas, Coahuila, México; UMMZ 95837-Spring near Monclova, Coahuila, México; UMMZ 130365, UMMZ 179809-Río Salado de los Nadadores at Hermanas, Coahuila, México; UMMZ 130374-Río Salado at Monclova, Coahuila, México; UMMZ 130431-Río San Juan near San Juan, Coahuila, México; UMMZ 179818-Río Salado de los Nadadores at Celemania, Coahuila, México; UMMZ 179844-La Polilla 4.8 km S San Juan, Coahuila, México.

Rio San Juan basin, Mexico: UANL 42-Tributary to Presa de la Boca, 2 km NW Santiago, Nuevo León, México; UANL 50-Río de la Silla 2 km SE Guadalupe, Nuevo León, México; UANL 52-Río San Juan en Cienguilla, Nuevo León, México; UANL 154-Arroyo Chapultepec, Guadalupe, Nuevo León, México; UANL 176-Río San Juan 4 km NE Dr. Cross, Nuevo León, México; UANL 202-Tributary to Presa de la Boca, 7 km NE Santiago, Nuevo León, México; UANL 219-Río San Juan, in San Juan, Nuevo León, México; UANL 430-Río Salinas at Salinas Victoria, Nuevo León, México; UANL 433-Río San Diego 9.4 km NNW Salinas Victoria, Nuevo León, México; UANL 441-Río Salinas at Sabinas Hidalgo, Nuevo León, México; UANL 444-Río Salinas at Ciénega de Flores, Nuevo León, México; UANL 448-Río Pesqueria at Highways 85 and 15, Tamaulipas, México; UANL 454-Tributary to Presa de la Boca, Nuevo León, México; UANL 614-Río de la Boca, 4 km W Santiago, Nuevo León, México; UANL 626-

Río Ramos, 26 km SE Allende, Nuevo León, México; UANL 635-Río San Juan at Presa Don Martín, Tamaulipas, México; UANL 641-Río Lazarillos 7.1 km SE Allende, Nuevo León, México; UANL 653-Río Montemorelos, 1 km SE Montemorelos, Nuevo León, México; UANL 660-Río Cabezones 25 km SE Montemorelos, Nuevo León, México; UANL 1143-Río Pilon 4 km de Magueyes, Tamaulipas, México.

San Fernando System, México: UANL 21-Río Pablillo near Linares, Nuevo León, México; UANL 272, UANL 684-Río San Fernando 40 km E San Fernando, Tamaulipas, México; UANL 667- Río Camacho at Hualahuises, Nuevo León, México; UANL 765-Río San Fernando 1 km S San Fernando, Tamaulipas, México.

Soto la Marina system, México: UANL 284-Río Soto la Marina, 7.8 km E Abasold, Tamaulipas, México; UANL 293-Río Pilon at Highway 101, Tamaulipas, México; UANL 303-Río Purificación at Padilla, Tamaulipas, México; UANL 846-Río Purificación 38.5 km NW Cd. Victoria, Tamaulipas, México; UANL 1138- Río Pilon at Highway 85, Tamaulipas, México; UANL 1146-Arroyo 7.5 km ESE of Maqueyes, Tamaulipas, México.

Ríos Pánuco-Tamesí system: ASU (uncat.)-la Media Luna, San Luis Potosi, México; UANL 378, UANL 312-Río Guayalejo 31.1 km SE Cd. Mante, Tamaulipas, México; UANL 327-El Higo, 4.6 km NE Highway 5, Vera Cruz, México; UANL 338-Tributary to Río Temporal, 13.5 km SE San Sebastian, Vera Cruz, México; UANL 368-Río Buenavista 24 km W Potrero del Llano, Vera Cruz, México; UANL 416-Río Guavalejo at Llera de Canales, Tamaulipas, México; UANL 866-Río Guaylejo at El

Limon, Tamaulipas, México; UANL 874-Río Tanquilin 76.2 km S Valles, San Luis Potosi, México; UANL 903-Río Guayalejo 29 km SE Cd. Mante, Tamaulipas, México; UANL 1250-Laguna de Ebaño, San Luis Potosi, México; UANL 1265-Río Amajaque at Tamazunchale, San Luis Potosi, México; UANL 1277-Río Tanquilin at Comeca, San Luis Potosi, México; UANL 1297-Río Coy, S of Valles, San Luis Potosi, México; UANL 1306-Río Valles at Valles, San Luis Potosi, México; UANL 1365-Río Axtla in A.M. Terrezas, San Luis Potosi, México.

Estero Tancochin (part of Estero Tamiahua): UMMZ 97713-Tributary to Estero Tamiahua E of Naranjos, Vera Cruz, México.

Estero Cacharas (part of Estero Tamiahua): UMMZ 97707-Río Cacharas, 40 km above mouth, Vera Cruz, México.

Río Tuxpan-Pantepec system, México: UMMZ 167519-Río Pantepec, 32 km W of Tuxpan, Vera Cruz, México; UMMZ 191749-Río Pantepec at Alamo, Vera Cruz, México.

Río Cazones system, México: UANL 1154-Río Cazones in Poza Rica, Vera Cruz, Mexico.

Río Nautla system, México: UMMZ 167491-Ixtacocoa, 6.3 km W Martinez de la Tarre, Vera Cruz, México.

Cuatro Ciénegas basin México (localities arranged in original drainages as given on Figure 22 in text): ASU 2329, ASU 2331, ASU 3673, and ASU 7388-Río Churince; ASU (uncat.), ASU 694, ASU 1750, ASU 2857, ASU 3663, ASU 4562, ASU 4584, ASU 5919, KU 7381, KU 7388, and UMMZ 17988-Laguna Churince; UMMZ 179200-Laguna San Marcos (now Dry); ASU 1663, ASU 1732, ASU 2267, KU 7375, KU 7430, and UMMZ 179184-

La Angostura Canal; KU 4411 and KU 7440-Laguna Anteojo; ASU 4557 and ASU 4559-Anteojo Canal; ASU 613, ASU 1656, ASU 2263, ASU 2264, ASU 2314, ASU 2315, ASU 4591, KU 4400, and UMMZ 179832-Posos de la Becerra; ASU 3656, ASU 3657, ASU 3658, ASU 4745, and ASU 4746-Lagunas de Chiqueros; ASU 4526, ASU 4537, and UMMZ 179194-Río Garabatal; ASU 4891-East Cold Spring; ASU 1741, ASU 2259, ASU 2260, ASU 2274, ASU 2313, ASU 2321, ASU 2322, ASU 3689, ASU 3690, ASU 3705, ASU 4509, ASU 4529, ASU 4542, ASU 4575, ASU 4576, ASU 4585, and ASU 4586-El Mojarral; ASU 3650-Juan Santos Laguna; UMMZ 17987-Río Puente Chiquito; ASU 972, ASU 5992, and UMMZ 179838-Río Puente Colorado; ASU 3647 and ASU 3649-Río Mesquites at Tierra Blanca; ASU 961, and UMMZ 179216-Río Mesquites 9 km SW Cuatro Ciénegas; ASU 3641-Río Mesquites 6 km SW Cuatro Ciénegas; ASU 3696-Río Mesquites 2.7 km SW Cuatro Ciénegas; ASU 2262, and UMMZ 179859-Rancho Tierra Blanca; ASU 2271-Marsh south of El Mojarral; ASU 4593-Laguna about 1 km SSW tip of San Marcos Mt.; ASU 1681, ASU 1682, ASU 2339, ASU 2340, ASU 4491, ASU 4492, ASU 5966, and UMMZ 179180-Escobeda; ASU 1667, ASU 1668, ASU 2312, and UMMZ 179220-Laguna de Tio Candido; ASU (uncat.), KU 7420, and UMMZ 179844-Canal from Los Fresnos at 12.4 km; ASU 1672, ASU 2338, and KU 7417-Quintero Laguna; ASU 983, and ASU 4496-Laguna de San Pablo; ASU 3682, and UMMZ 179870-Laguna Santa Tecla.

APPENDIX III: METHODS OF COUNTING AND MEASURING

Spines and fin rays.--Counts include spines and soft fin-rays of dorsal and anal fins, with posterior ray, divided to common base and typically counted as one, counted here as two (violating recent tradition and resulting in all my counts being one higher than other recent data); all rays of both pectoral fins counted, necessitating magnification, illumination, and dissection to reveal rudiments along ventral margin, lowest count recorded; spine and all rays of both pelvic fins counted, as above, lowest count recorded; count of caudal fin-rays include all branched rays, plus two.

Scales.--Members of the family Cichlidae are characterized in part by a disrupted lateral line (Figure 2). Counts of scales along each pored section made separately--upper lateral-line series counted from first pored scale in contact with cleithrum to last pored scale in series; lower lateral series counted from anteriormost pored scale in series; lower lateral series counted from anteriormost pored scale to structural base caudal fin, magnification often necessary to determine position of first pored scale lower series, especially in juveniles, and if end of hypural plate lay near middle last scale, or posterior, scale included in count, otherwise excluded. Scale rows above lateral line counted from origin dorsal fin downward and backward following natural row to, but not including, pored upper lateral line scale; scale rows between lateral lines beginning with last pored scale upper series, ventrally to, and including first pored scale in line with lower series; scale rows below lateral line counted upward and posteriad from origin anal fin to first pored scale lower lateral

line, but not including that scale--if, in continuing upward and backward, series could be with equal propriety regarded as jogging backward or forward, backward shift selected (see also Figure 2).

Gill rakers.--All gill rakers on first branchial arch, including rudiments, requiring much care, considerable magnification, and bright illumination.

Branchiostegal rays.--All rays, with anteriormost ray short, slender, and embedded in tissue, requiring dissection, considerable magnification, and bright illumination.

Standard length.--Distance from tip upper lip with mouth closed to structural base caudal fin.

Predorsal length.--Distance from tip upper lip with mouth closed to origin dorsal fin.

Prepelvic length.--Distance from insertion pelvic fin to tip upper lip with mouth closed.

Dorsal origin to posterior margin bony orbit.--Horizontal distance from origin dorsal fin to bony, posterior orbital rim at midline.

Anal origin to caudal base.--Distance from origin anal fin to midline structural base caudal fin.

Greatest depth of body.--Greatest distance between dorsal and ventral surfaces body, excluding modified vertical fin bases.

Width of body.--Greatest width body, usually in abdominal area about a third posterior to origin dorsal fin, measured from above.

Length of caudal peduncle.--Distance from base last ray anal fin to midline structural base caudal fin.

Depth of caudal peduncle.--Vertical distance from dorsal to ventral surface caudal peduncle at slenderest point.

Length of head.--Distance from tip upper jaw with mouth closed to most posterior point on opercular membrane.

Width of head.--Greatest distance across opercles, measured from above.

Length of upper jaw.--Distance from tip upper jaw with mouth closed to most posterior extension.

Length of snout.--Distance between tip upper jaw with mouth closed and anterior margin bony orbit at midline.

Length of bony orbit.--Greatest horizontal distance across bony orbit.

Interorbital width.--Least distance between bony rims orbits, across top of head.

Distance from preopercular margin to bony orbit.--Maximum distance from ventroposterior margin bony orbit to most posterior point on opercular membrane (Figure 2).

Distance from bony orbit to ventro-posterior margin of opercular membrane.--Maximum distance from posterior margin bony orbit to ventro-posterior margin opercular membrane (Figure 2).

Distance from posterior margin of preopercule to ventro-posterior margin opercular membrane.--Maximum distance from posterior margin of preopercular bone to most ventro-posterior margin opercular membrane (Figure 2).

Basilar lengths of vertical fins.--Greatest distances between origins of fins and points where membranes posterior to last ray contact body surface.

Length of middle caudal-ray.--Distance between structural base caudal fin and tip shortest, mid-caudal fin-ray.

Length of pectoral fin.--Distance between middle structural base pectoral fin and longest ray or rays; basilar starting point determined by deflecting fin anteriorly to produce marked crease.

Length of pelvic fin.--Distance between structural base fin and tip longest ray or rays.

Width of lower pharyngeal bone.--Greatest distance across posterior rami of fused lower pharyngeal bones (Figure 3).

Tangential length of occlusal surface of lower pharyngeal bone.--Distance between left posterior corner occlusal surface to anteriormost point bearing teeth, on tangential line and measured at base of teeth (Figure 3).

Depth of lower pharyngeal bone.--Greatest distance between base of center teeth on bone and deepest vertical point (Figure 3).

Depth of lower pharyngeal bone and teeth.--Greatest distance between occlusal surface lower pharyngeal bone and deepest vertical point (Figure 3).

Width of posterior tooth nearest center of pharyngeal bone.--Greatest width center most, posterior tooth, measured from above by ocular micrometer (Figure 3).

Gut length.--Greatest length alimentary canal, measured from oropharynx, including stomach, to anus, following removal, uncoiling, and gentle straightening.

BIOGRAPHICAL SKETCH

James F. LaBounty was born in Minneapolis, Minnesota, on December 14, 1942. He received his elementary education at Burwell Public School, Minnetonka, Minnesota, and his secondary education at Hopkins Public Junior and Senior High Schools, Hopkins, Minnesota, and Rancho High School, Las Vegas, Nevada. He graduated from the latter in 1960, and entered the University of Nevada-Las Vegas that fall majoring in biology. He graduated with a Bachelor of Science in Biology in June, 1967. He received his Master of Science in Biology from that same university in June, 1968. He held a teaching assistantship while studying for his M.S. He began work on his Doctor of Philosophy in zoology at Arizona State University in fall, 1968. He held a teaching assistantship until June, 1969. He accepted a position with the Bureau of Reclamation, Boulder City, Nevada, as a biologist in November, 1969, and was transferred to Phoenix in September, 1970, where he concurrently held a position and worked toward a Ph.D. He is married and has a daughter.