THE HISTORY, STATUS AND IDENTIFICATION OF CICHLID FISHES IN THE SOUTHERN UNITED STATES

by

Lynn Elizabeth Noble

Wildlife and Fisheries Sciences

Submitted in Partial Fulfillment of the Requirements of the University Undergraduate Fellows Program

1979-1980

Approved by:

Fred S. Hendricks/wK
Fred S. Hendricks

April 1980

ABSTRACT

Members of the family Cichlidae are native to Africa, Asia, and South America, with the exception of the Rio Grande Perch (*Cichlasoma cyanoguttatum*) which is native to South Texas. Several species of cichlids have been introduced into the United States, primarily for aquatic weed control (Courtenay and Robins 1973).

The locations of introduced cichlid populations and the purpose for this introduction were investigated through a literature review and comprehensive survey.

Specimens from 26 locations, including 10 species of cichlids, were examined to provide information for the construction of a key to those species. Both standard statistics and multivariate statistics were used to analyze the data collected.

Several groups of samples can be separated from each other using the SAS MANOVA and NT-SYS programs. It is believed that some of the specimens examined were misidentified. Comparison of the data obtained in this study with descriptions of the type specimens should prove useful in their positive identification.

Control methods available for introduced cichlid populations are discussed, and a tentative key to the species examined is offered.

ACKNOWLEDGEMENTS

Several individuals aided me in this study. I would like to thank Dr. Fred S. Hendricks for his advice, time, and patience during the study. Gary E. Binderim provided assistance in several phases of the research, and for all of his time, I am grateful.

Special thanks are due to Millard E. Stutts, Lynn M. Hancock, and my parents, Betty and Ralph Noble, who provided encouragement and help throughout the study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

INTRODUCTION

Members of the family Cichlidae are native to freshwater areas in Africa, Central and South America. One species, the Rio Grande perch (*Cichlasoma cyanoguttatum*) is native to Central America, Mexico, and South Texas (Eddy 1957). The cichlid family is the second largest family in the Order Perciformes, with at least 680 species.

In this study, I was primarily concerned with fishes of the genera *Cichlasoma*, *Sarotherodon*, and *Tilapia*. These last two genera are often collectively termed "tilapia" since the two genera have been synonymous until recently and the literature frequently makes no distinction between the various species.

Tilapia have been cultured for centuries as a primary protein source in developing countries. These fishes have even been commemorated in some form in many areas of the world.

With the exception of the Rio Grande perch (*Cichlasoma cyanoguttatum*), cichlids are exotic to the United States. Several reasons given for introducing exotic organisms include biological control, food production, and sport purposes (McBay 1961, Buntz and Manooch 1968). Exotic introduction of organisms, if properly managed, can be beneficial. Examples of successful introductions include the Florida largemouth bass in Texas, the brown trout,

---

Citations and style of this thesis follow the *Transactions of the American Fisheries Society*.

ringneck pheasant, and Axis deer. Unfortunately, a number of exotic introductions have gotten out of man's reasonable control, as demonstrated by the common carp, Cyprinus carpio Linneaus, grass carp, Ctenopharyngodon idellus Cuvier and Valenciennes, starling, (Sturnus vulgaris) Linnaeus, and house sparrow, Passer domesticus (Linnaeus). Shafland (1978) lists several reasons why most biologists oppose the indiscriminate release of non-native fish. These include the possibility that an introduced species will: (1) compete with native species; (2) occupy an unexpected niche by changing its behavior; (3) hybridize with closely related native or non-native fishes; and (4) that it may introduce foreign diseases and parasites which could result in serious health hazards for native species and possibly humans. Another problem with exotic organisms which concerns biologists and ecologists is that it is virtually impossible to predict with certainty the results of such introductions (Fryer and Iles 1972).

Magnuson (1976) likened the ecology of ponds and lakes to island ecology, with their faunas highly susceptible to the invasion of new species. The activities of man have increased the immigration of species, including fishes, into fairly isolated environments by physical movement and by habitat alterations. The net effect being an increased intensity of species interactions and increased local extinctions.

The introduction of exotic species commonly occurs as the result of accidents or carelessness. Escape of fish from fish farms, importation of unwanted species along with desired species, and dumping of excess stocks are but a few of the means of accidental introduction of exotics (Courtenay and Robins 1973). Exotic fish species have been purposefully introduced for research, biological control, sport and recreation. Various species of cichlids native to warm African waters have been brought to the warmwater regions of the United States primarily as biological controls. Recently, many cichlids have been imported for use in studies of the behavioral sciences (Courtenay and Robins 1973).

Although cichlids, particularly tilapia, were originally heralded as biological controls, forage for native carnivorous fish, and occupants of highly productive niches, they have since been labelled as undesirable by many. One of the most favorable characteristics that has been attributed to tilapia was their inability to withstand temperatures below 9-12° C. It was thought they could not overwinter and establish populations in the United States. However, since purposeful introduction of tilapia began, during the late 1950's, adaptations have occurred which have allowed them to successfully reproduce and become established in the warmer areas of the nation, particularly in South Texas and in Florida. Tilapia have also lost favor with the public because of low catchability, high resistance to chemical control, and the absence of effective predators (Buntz and Manooch 1968). The absence of efficient predators blocks the recycling of nutrients which should occur in natural systems (Hubbs 1968).

In addition to their use by biologists and fish culturists, cichlids are used extensively in the tropical fish trade because of their striking spawning coloration and unique breeding behavior. Most of these species cannot survive the temperature of the United States; however, it has recently been discovered that some genera such as Cichlosoma, Sarotherodon, and Tilapia can overwinter and maintain populations (Lachner et al.1970). Some cichlids are capable of surviving in brackish or estuarine water in addition to freshwater, thereby increasing their potential to become established over a large area.

These fishes, many of which occupy habitats similar to our native centarchids(bass and sunfish), have been able to out-compete the native fauna for food and nest sites (Noble et al. 1975). Cichlids have a fairly high rate of reproductive success. These fishes, many of which are mouthbrooders, have high reproductive potentials which facilitate their populating an area and driving out native species. The density of individuals need not be large for cichlids to successfully reproduce. Smaller numbers of fish may act as founding populations, establishing the fish in an area. Once established, they may compete with native species for food and space, and often destroy habitats.

Many of the species of cichlids introduced into the United States can undergo some degree of hybridization which may result in altered reproductive potentials and reduced genetic viability (Hickling 1963). This situation can cause confusion in the identification of these fishes. Also, colonizing new areas with few individuals can result in unique, local characteristics due to the Founder Principle.

The objectives of this research included: (1) tracing the history of the introduction of cichlid fishes in the southern United States; (2) determining the systematic status of cichlids in the southern United States; (3) developing keys to selected species of cichlids; (4) preparing species accounts; and (5) offering recommendations for controlling introduced cichlid populations.

METHODS

The procedures used to complete this study consisted of four major steps: (1) extensive literature review; (2) survey of the distribution of cichlids in the United States; (3) examination of specimens; and 4) statistical analysis of the data.

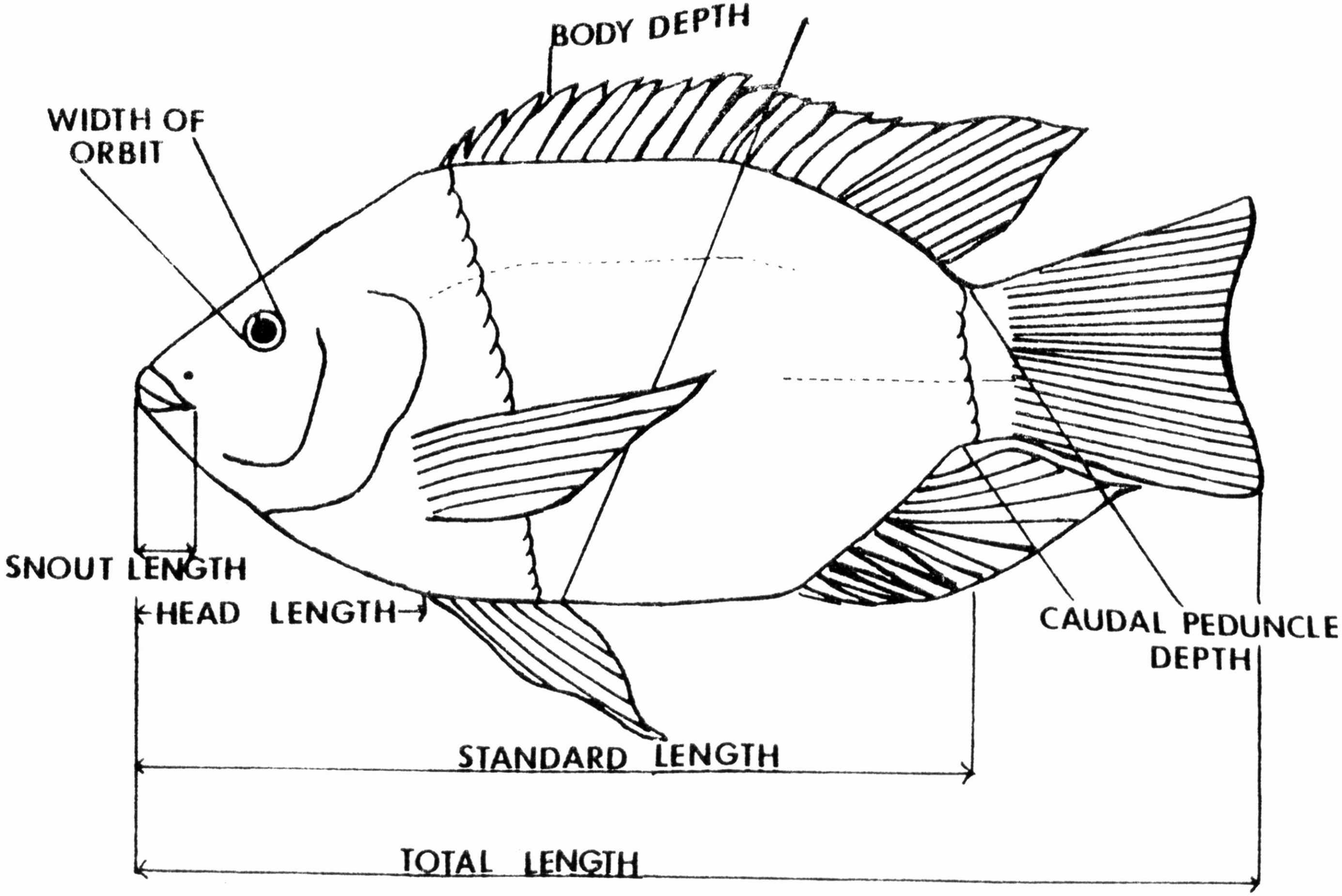
To perform the survey, a list of biologists--university, private, and governmental--and informed laymen was compiled. This list was obtained primarily through the use of the Conservation Directory, and the American Fisheries Society membership list. Seven hundred and fifty letters and survey forms, requesting information on populations, history, and publications dealing with cichlids were distributed and the information received was then synthesized. Follow-up letters were sent to those who indicated that specimens might be available for loan.

The 229 specimens examined were made available by John McEachran of Texas A&M University (Texas Cooperative Wildlife Collection),Doyle Mosher of the University of Texas (Texas Natural History Collection), C. R. Inman of Texas Parks and Wildlife, and W. R. Courtenay of Florida Atlantic University. These specimens represented 26 samples including 10 species. Before actually performing any counts or measures, the literature was searched to determine which characteristics might be useful in distinguishing between species. The external characteristics used were head length (HL), standard length (SL), total length (TL), snout length (snout), width of orbit (orbit), body depth (body), and depth of caudal peducle(cauped) anterior lateral line scales (LL 1 scale), posterior lateral line scales (LL 2 scale), scales above lateral line (above), scales below lateral line (below), scales in caudal peduncle depth (capedsc), gill rakers (gilrak), and spines and rays for all fins. The locations for counting or measuring characters are shown in Figure 1. Dial vernier calipers were used for all measurements, with the exception of a few unusually large specimens whose standard lengths and total lengths were obtained by using a measuring board.

The data were statistically analyzed using the Statistical Analysis System (SAS) library by sample, sex within sample, species, and by sex within species, using standard statistics (mean, range, standard deviation, standard error of the mean, variance, and coefficient of variation). Multivariable statistical analyses including a multivariate analysis of variance (MANOVA) and clustering using the distance method were performed by sample in an effort to eliminate apriori grouping of the samples into species. In order to insure that none of the characteristics studied were ontogenetically variable, characters were plotted against the standard length. Those characters that changed with the standard length were discarded. To maximize the differences between samples, a multivariate analysis of variance was used. In this program, characteristics roots and vectors are extracted and variates for each location are computed. The first two vectors accounted for 82 percent of the variation between samples. The vector values are constructed in such a way that those variates

Figure 1. External measurements used in the examination of cichlid specimens.

EXTERNAL MEASUREMENTS



with the least variation within a sample and the most variation between samples are extracted.

The percent influence of characteristics on the vectors was obtained by multiplying the vector variable coefficient by the mean of the dependent variable, summing all variable values for a particular vector, and then computing the percent of relative importance of each variable per vector.

Phenetic distance was further investigated using the NT-SYS program. The first five vectors from the multivariate analysis of variance were used as variables for each sample. The samples were dispersed using the distance method (Sneath and Sokal 1973). The first vectors used as variables in this program accounted for 97% of the variation between samples.

RESULTS AND DISCUSSION

The states in which cichlids occur are shown in Figure 2. In the majority of these states, cichlids were reported to have been introduced for purposes of biological control, released by aquarists, or escaped from commercial impoundments. Florida, the location of several major ports of entry, has been the recipient of hundreds of thousands of imported fish (Courtenay et al. 1975). The numbers of fish being moved across the state, in addition to the tropical climate, makes it very easy for populations of some exotic organisms from tropical areas to become established. Table 1 lists the species established in the United States at this time. Their identification is not verified, and because of the complexity of cichlid taxonomy, it is possible that some of them are misidentified. In several instances, conflicting information was received; for example, in Kentucky, Mississippi, and Tennessee, the very presence or absence of cichlids is in disagreement. The distribution of cichlids in the United States is depicted by species in Figures 3-15.

In addition to information about extant populations, several extinct populations were reported. Unsuccessful attempts to establish populations of the Mozambique tilapia (*Sarotherodon mossambicus*) occurred at Lonoke, Arkansas (1958), (Mike Gibson, in litt.); Granite County, Montana, 1962-1963 (Brown and Fox 1966); San Juan County, New Mexico (late 1960's).

TABLE 1. Locations of present populations of cichlids in the United Sates. The identifications of these specimens are not verified.

STATE		
Alabama	*Sarotherodon aureus*	Experimental
	Tilapia zillii	Experimental
Arizona	*Sarotherodon aureus*	Weed Control
	Sarotherodon mossambicus	Experimental
	Tilapiazillii	Weed Control
California	*Sarotherodon mossambicus*	Unknown
	Tilapia zillii	Experimental
Colorado	*Tilapia* sp.	Weed Control
Florida	*Astronotus ocellatus*	Commercial
	Cichlasoma bimaculatum	Commercial
	Cichlasoma cyanoguttatum	Unknown
	Cichlasoma meeki	Commercial
	Cichlasoma nigrofasciatum	Commercial
	Cichlasoma octogasciatum	Commercial
	Cichlasoma severum	Comemrcial
	Hemichromis bimaculatus	Commercial
	Sarotherodon aureus	Weed Control
	Sarotherodon melanotheron	Unknown
	Sarotherodon mossambicus	Commercial, Experimental
	Tilapia mariae	Weed Control
	Tilapia zillii	Experimental, Weed Control
Georgia	*Sarotherodon mossambicus*	Weed Control
Idaho	*Sarotherodon mossambicus*	Commercial
	Tilapia zillii	Cqmmercial
Louisiana	*Sarotherodon aureus*	Experimental
Mississippi	*Astronotus ocellatus*	Commercial
New Mexico	*Sarotherodon aureus*	Experimental
	Sarotherodon mossambicus	Experimental
	Tilapia zillii	Experimental
North Carolina	*Sarotherodon aureus*	Experimental
	Sarotherodon mossambicus	Experimental
	Tilapia zillii	Experimental
Oklahoma	*Sarotherodon aureus*	Commercial, Weed Control

Table 1. continued

STATE	SPECIES	INTRODUCTION PURPOSE
South Carolina	*Sarotherodon aureus*	Experimental
	Sarotherodon nilotucus	Experimental
	Tilapia hornorum	Experimental
	Tilapia zillii	Experimental
Tennessee	*Sarotherodon aureus*	Experimental
	Sarotherodon mossambicus	Weed Control
Texas	*Cichlasoma cyanoguttatum*	Native
	Sarotherodon aureus	Weed Control
	Sarotherodon mossambicus	Experimental
	Sarotherodon nilotucus	Experimental
	Tilapia zillii	Experimental

Figure 2. Distribution of cichlids in the United States. Dotted areas indicate states in which cichlids are found. "E" designates states where cichlids are only present in experimental ponds.

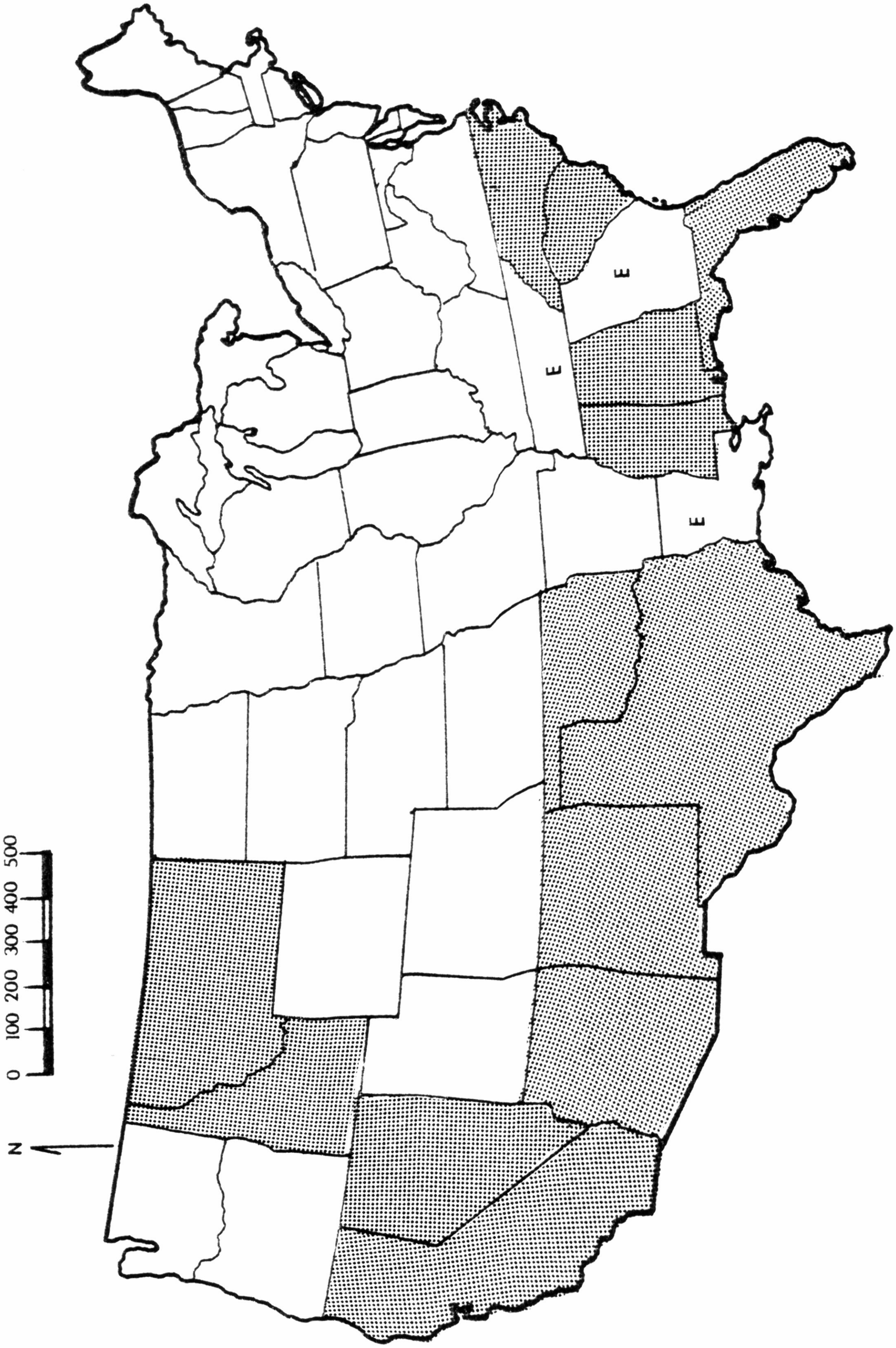
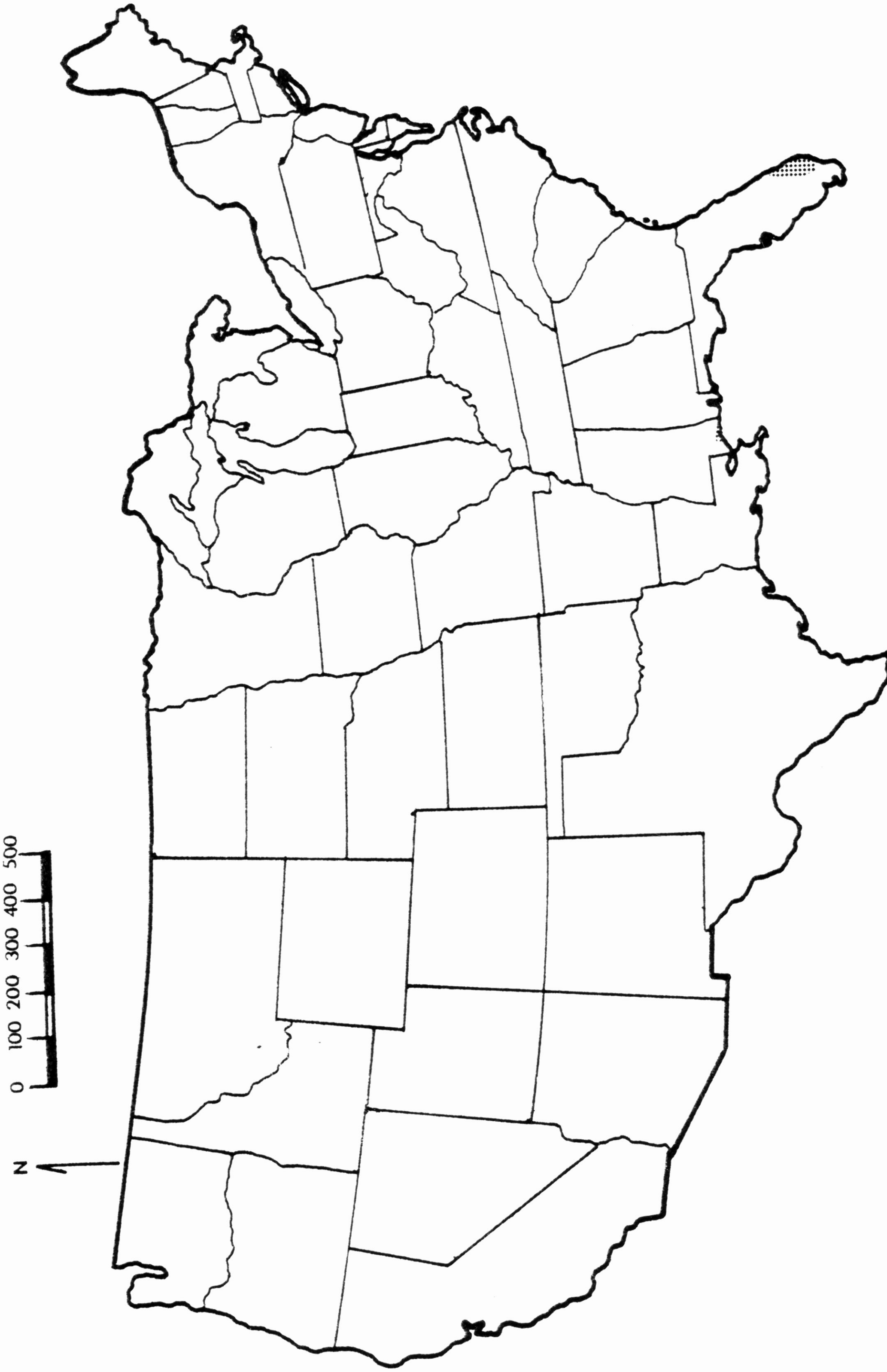
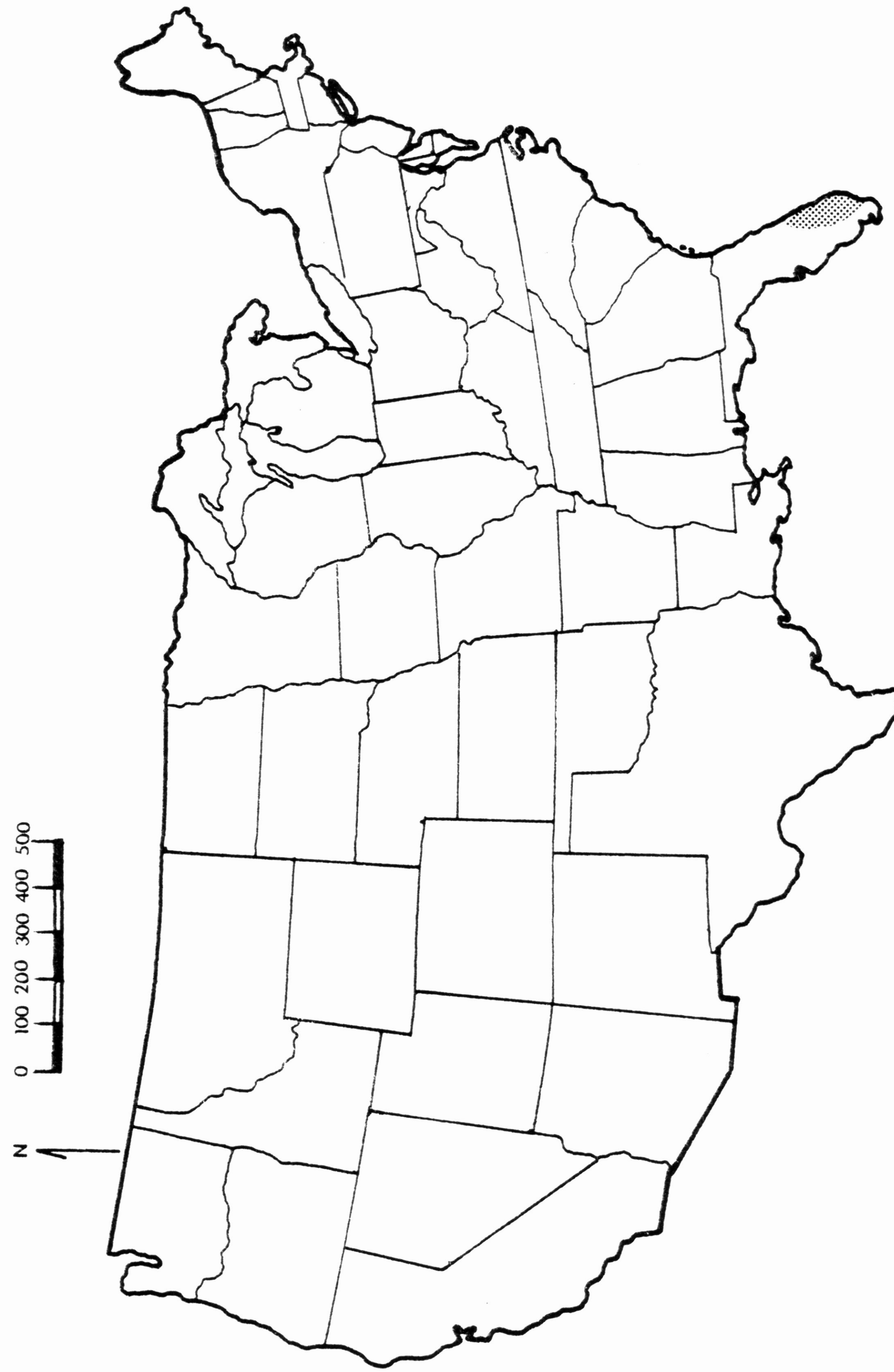

0 100 200 300 400 500
N
E
E
E

Figure 3. Distribution of the oscar (*Astronotus ocellatus*) in the United States.



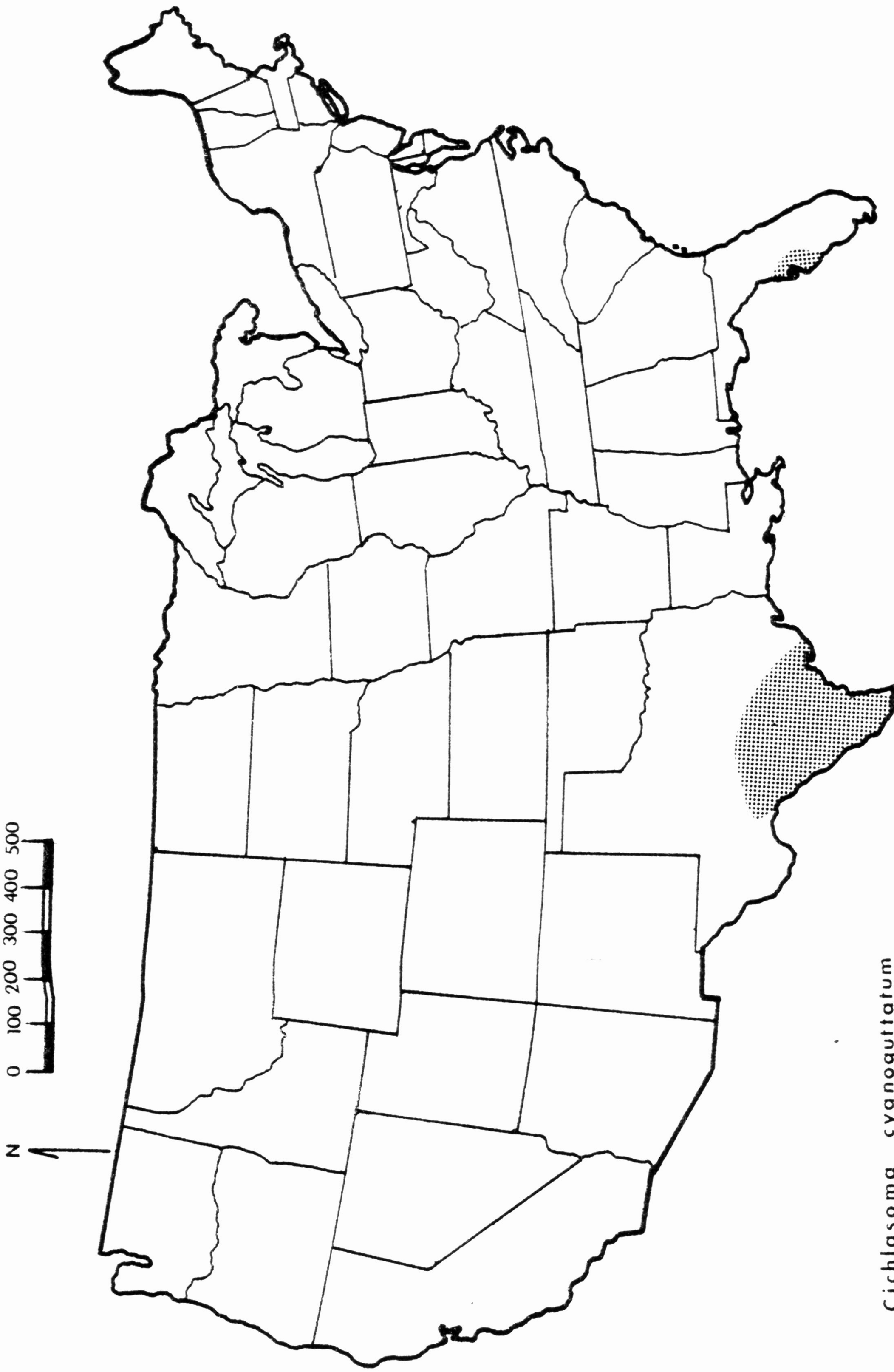
Astronotus ocellatus

Figure 4. Distribution of the black acara (Cichlasoma bimaculatum) in the United States.



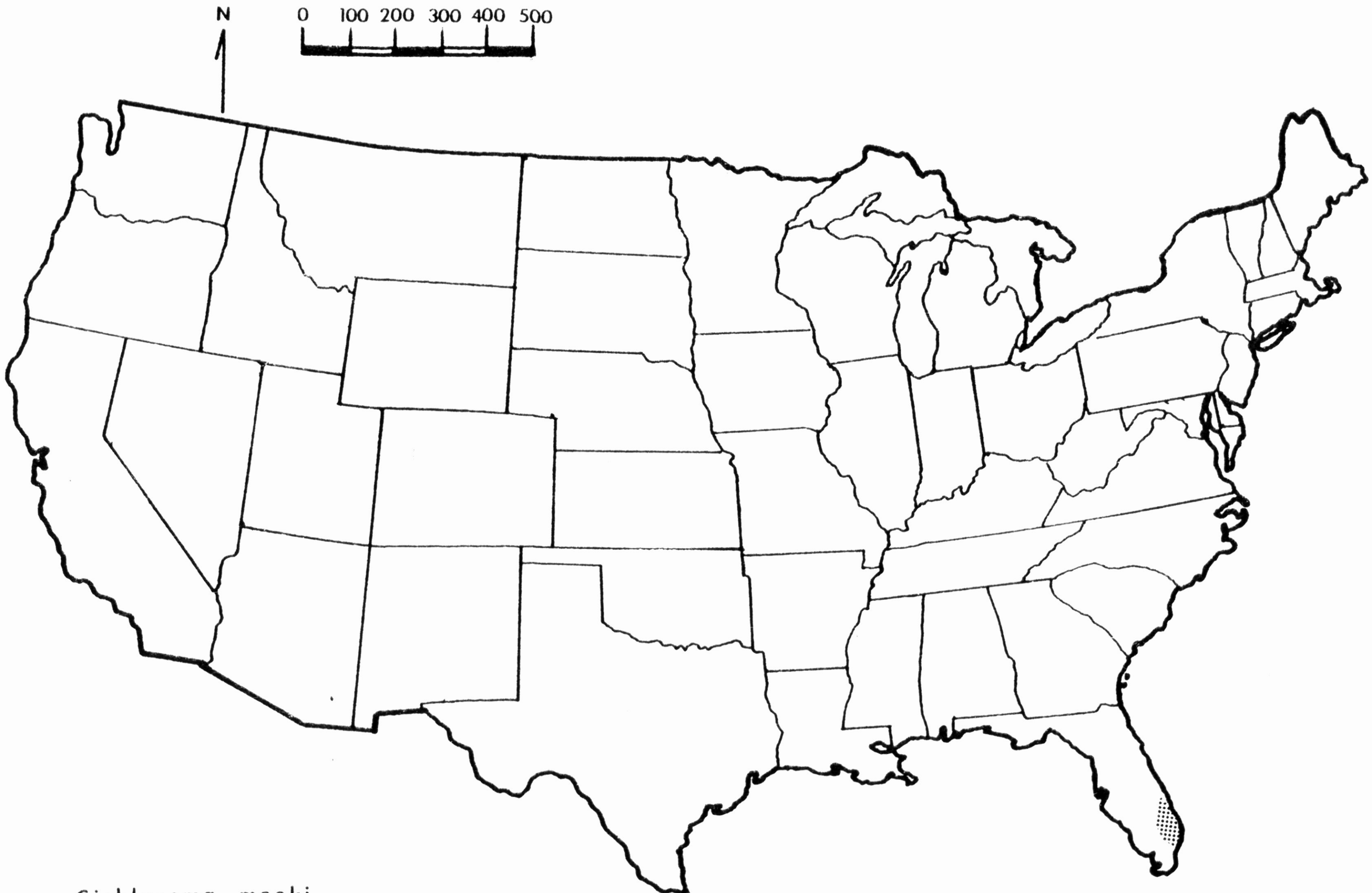
Cichlasoma bimaculatum

Figure 5. Distribution of the Rio Grande Perch (*Cichlasoma cyanoguttatum*) in the United States.



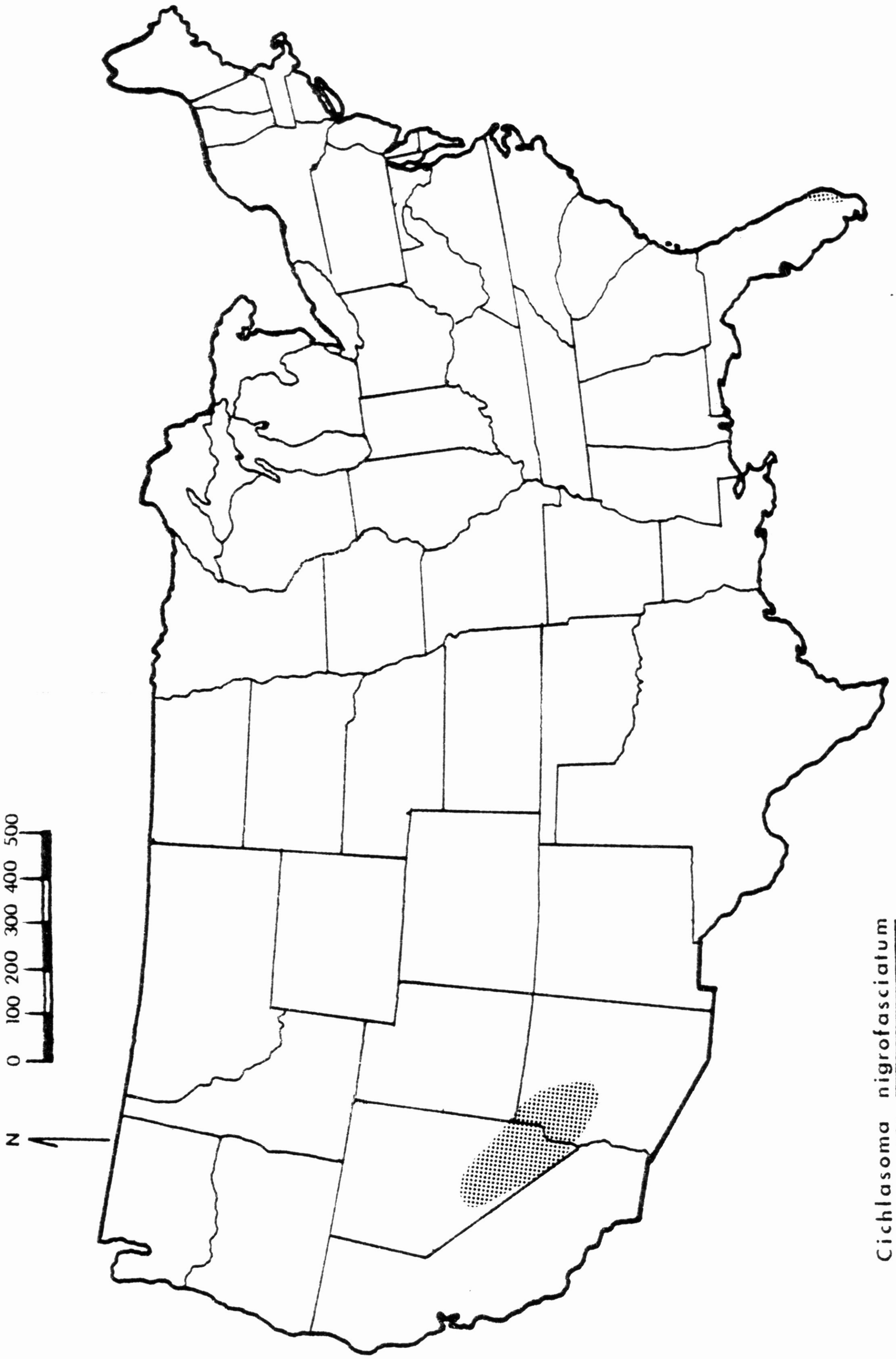
Cichlasoma cyanoguttatum

Figure 6. Distribution of the firemouth cichlid (*Cichlasoma meeki*) in the United States.



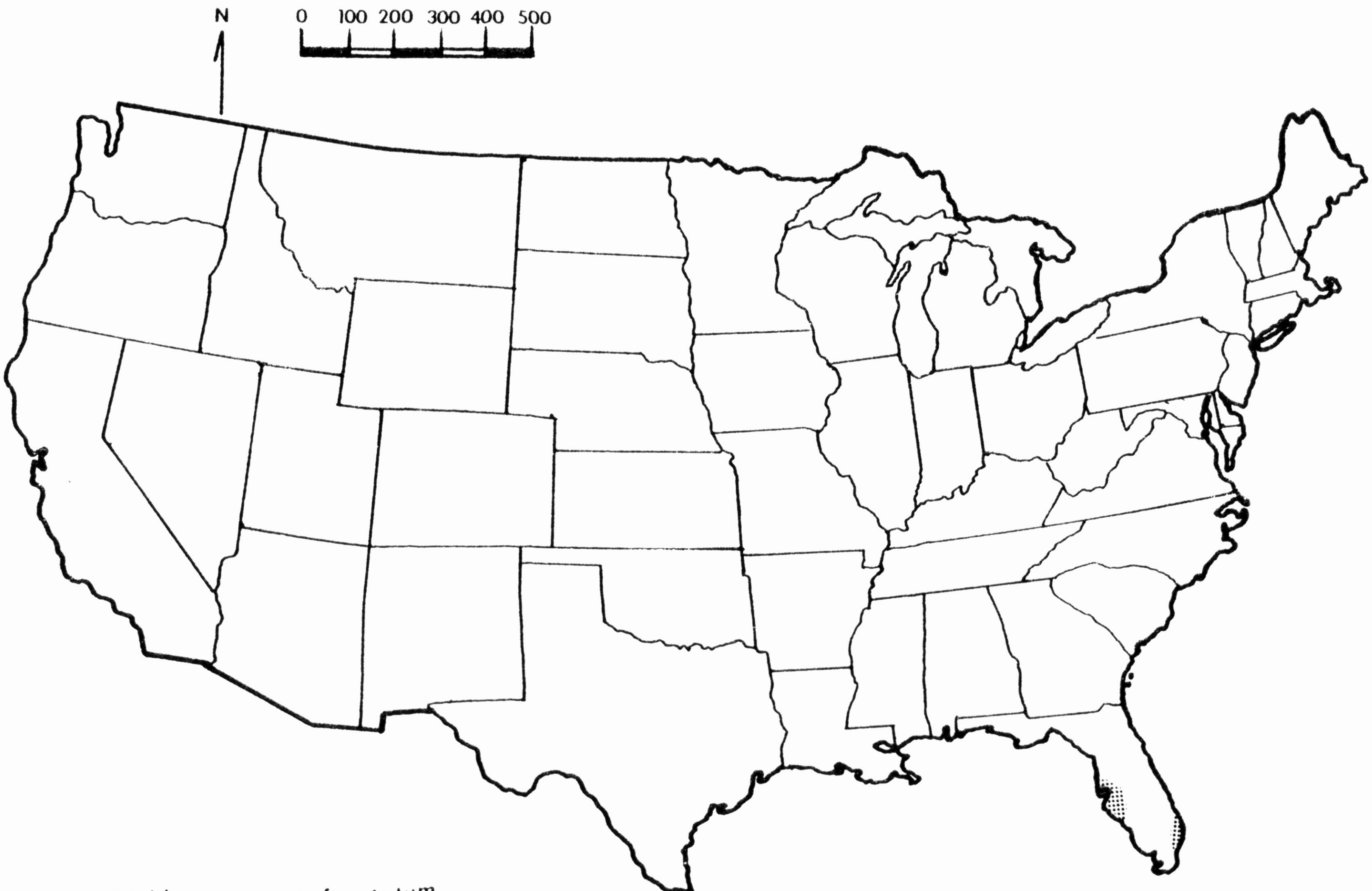
Cichlasoma meeki

Figure 7. Distribution of the convict cichlid (*Cichlasoma nigrofasciatum*) in the United States.



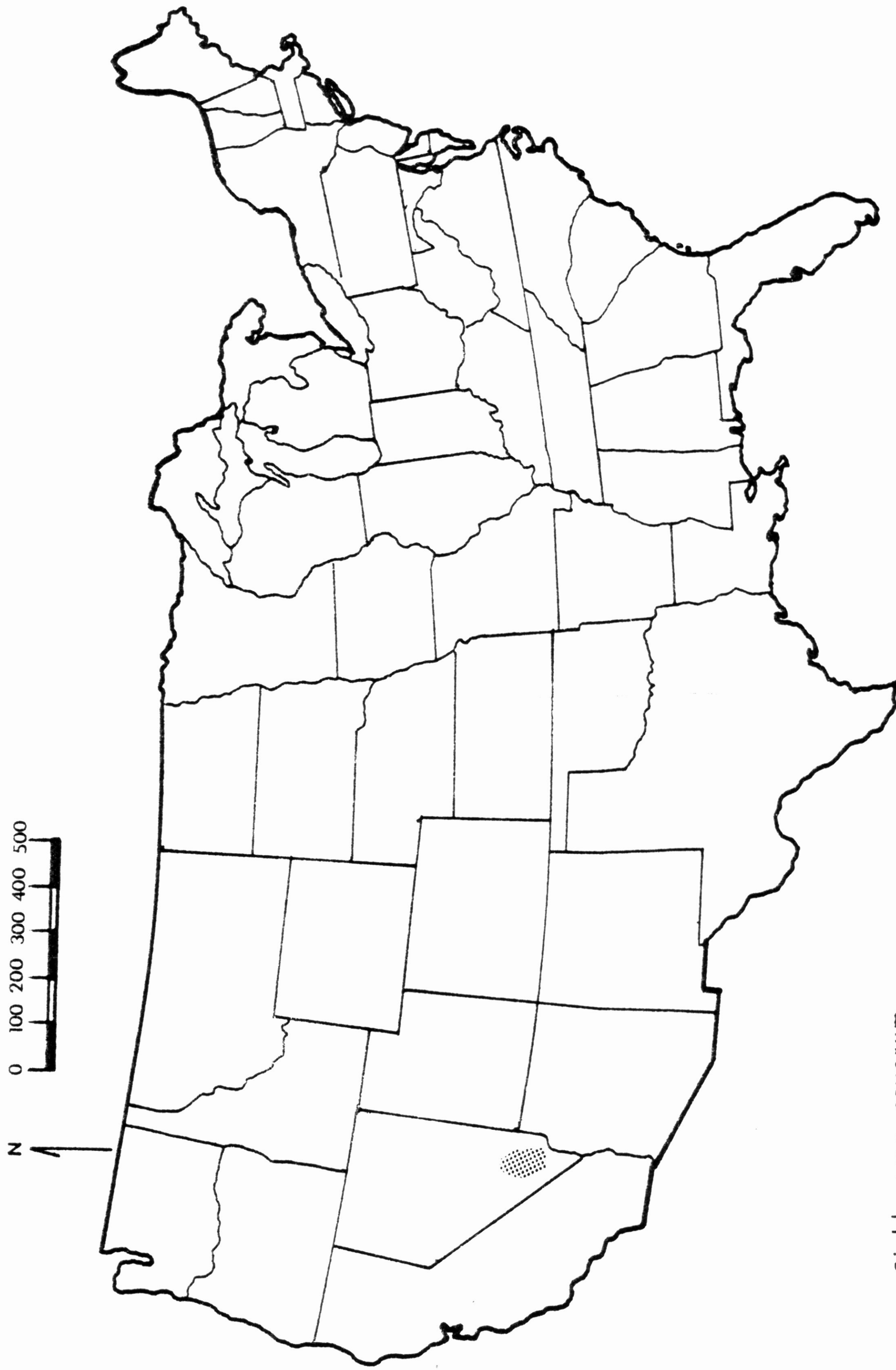
Cichlasoma nigrofasciatum

Figure 8. Distribution of the Jack Dempsey (*Cichlasoma octofasciatum*) in the United States.



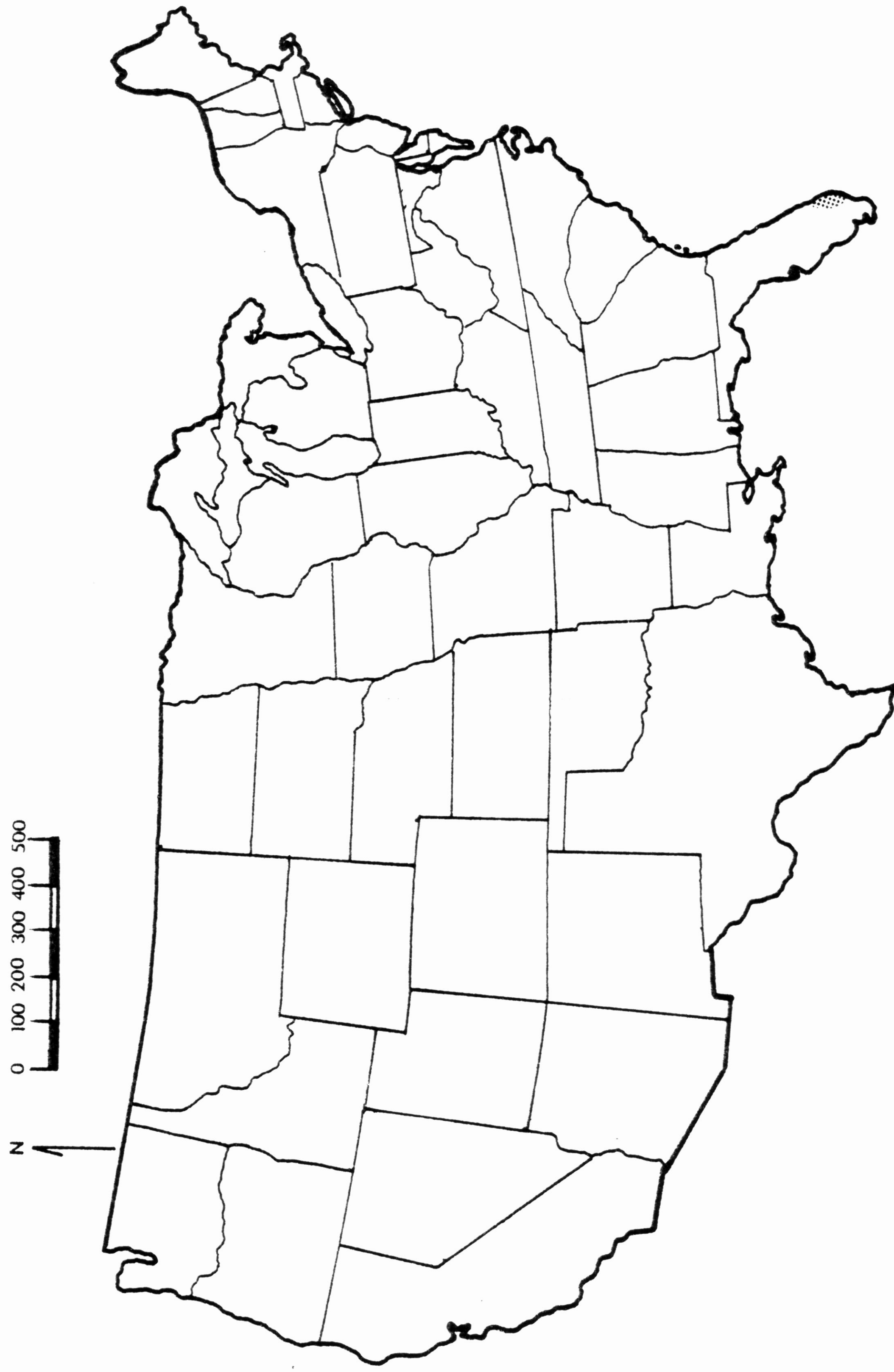
Cichlasoma octofasciatum

Figure 9. Distribution of the banded cichlid (*Cichlasoma severum*) in the United States.



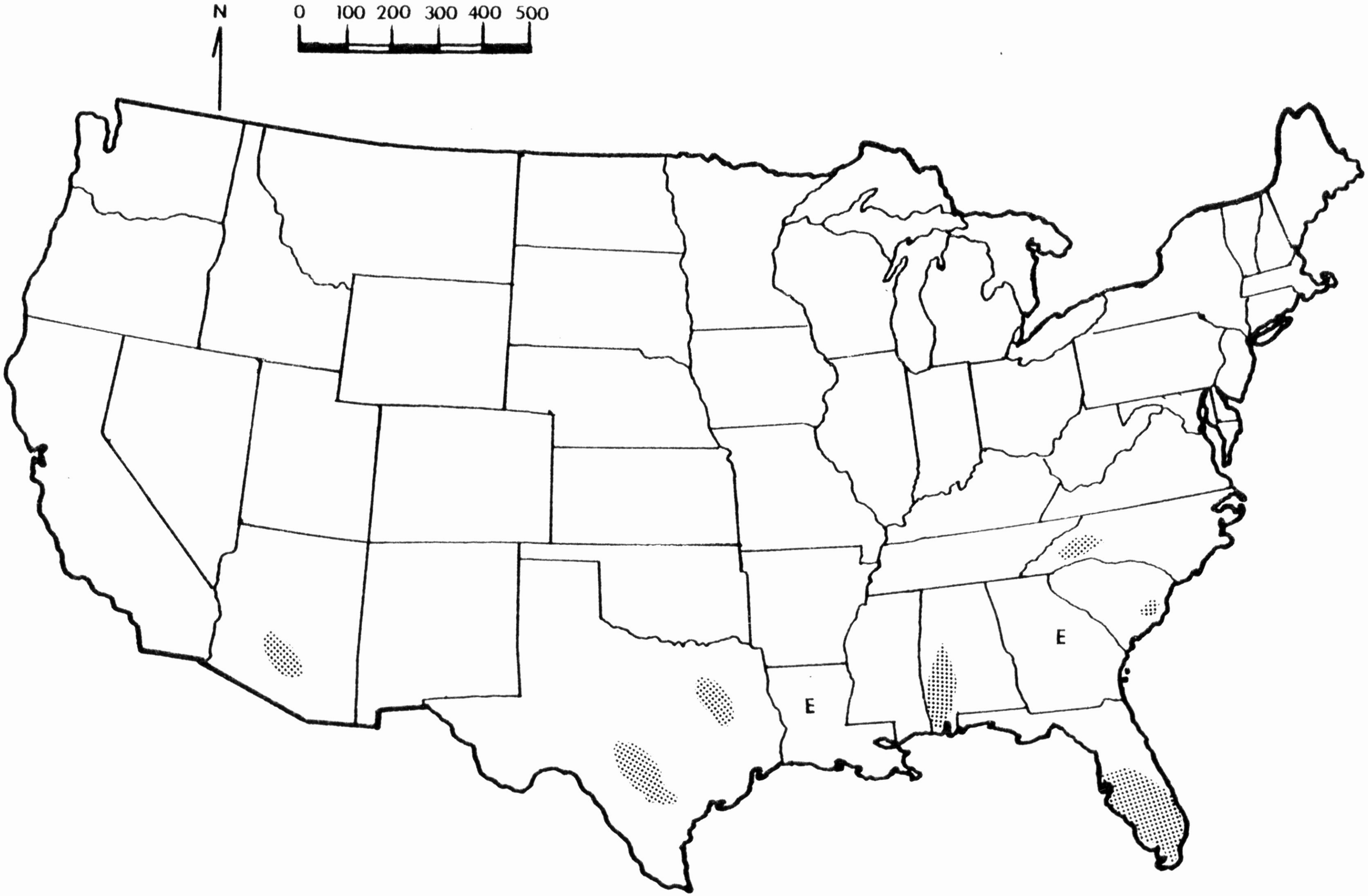
Cichlasoma severum

Figure 10. Distribution of the jewelfish (*Hemichromis bimaculatus*) in the United States.



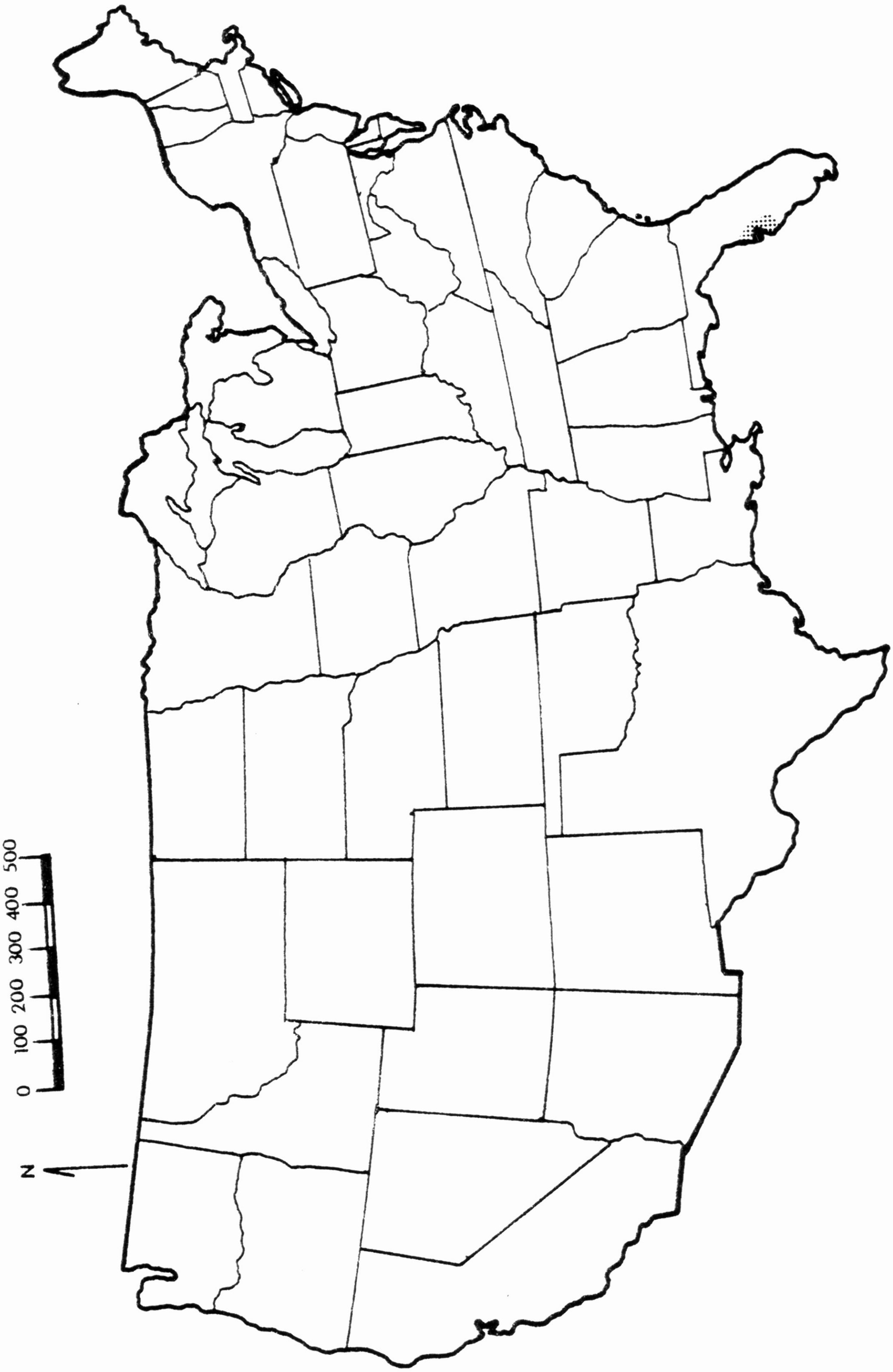
Hemichromis bimaculatus

Figure 11. Distribution of the blue tilapia (*Sarotherodon aureus*) in the United States.



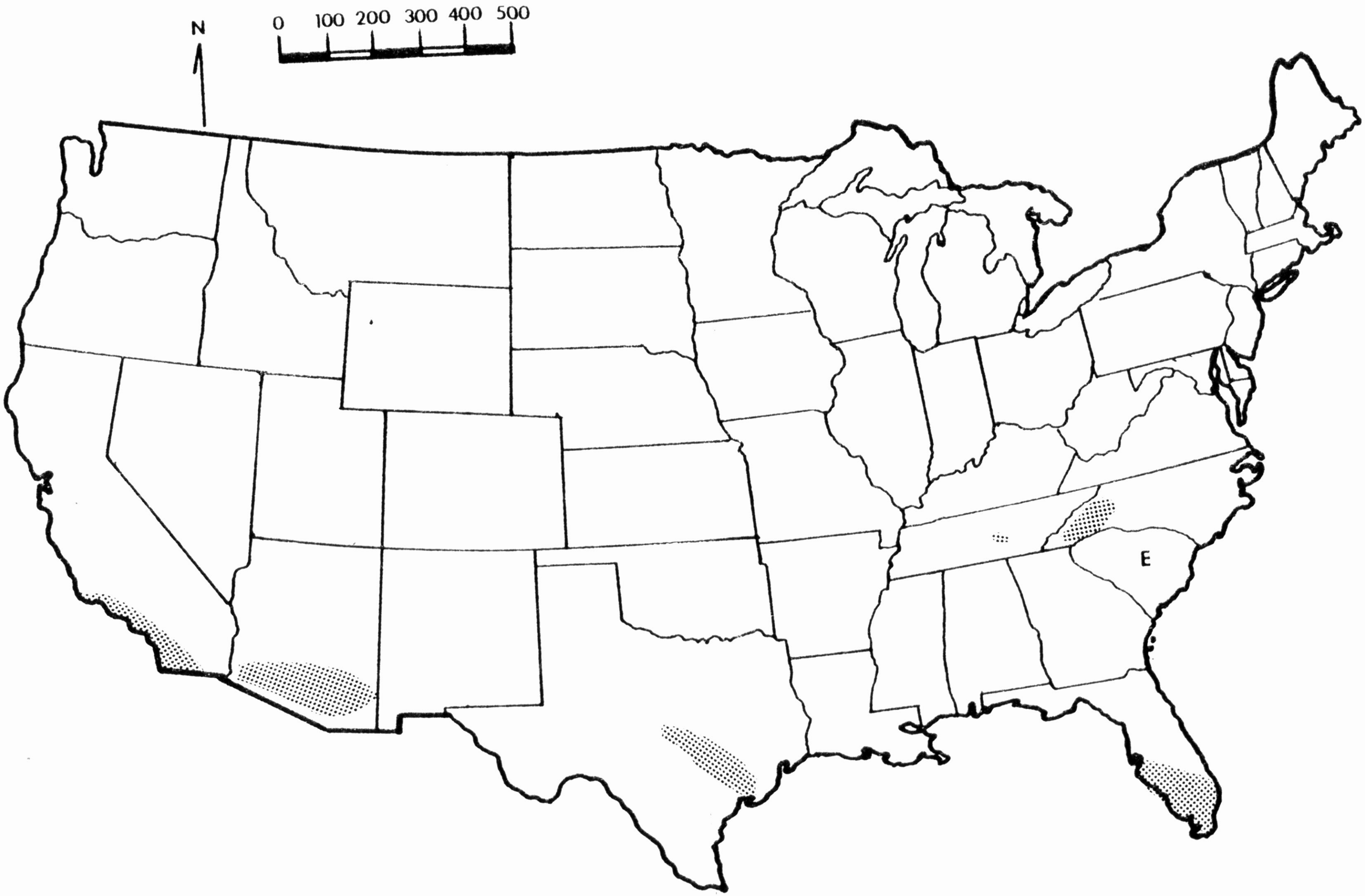
Sarotherodon aureus

Figure 12. Distribution of the blackchin tilapia (*Sarotherodon melanotheron*) in the United States.



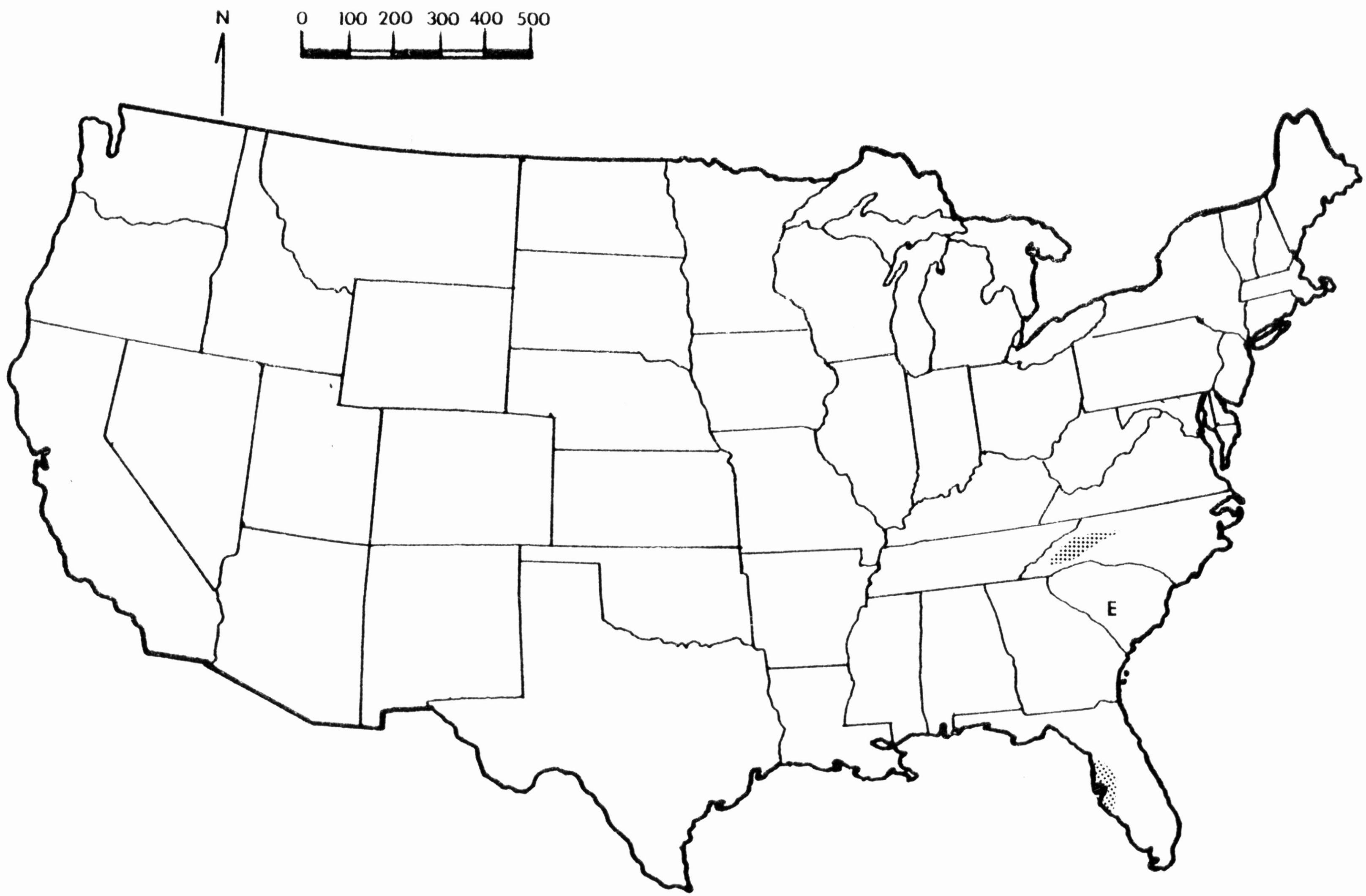
<u>Sarotherodon</u> <u>melanotheron</u>

Figure 13. Distribution of the Mozambique tilapia (*Sarotherodon mossambicus*) in the United States.



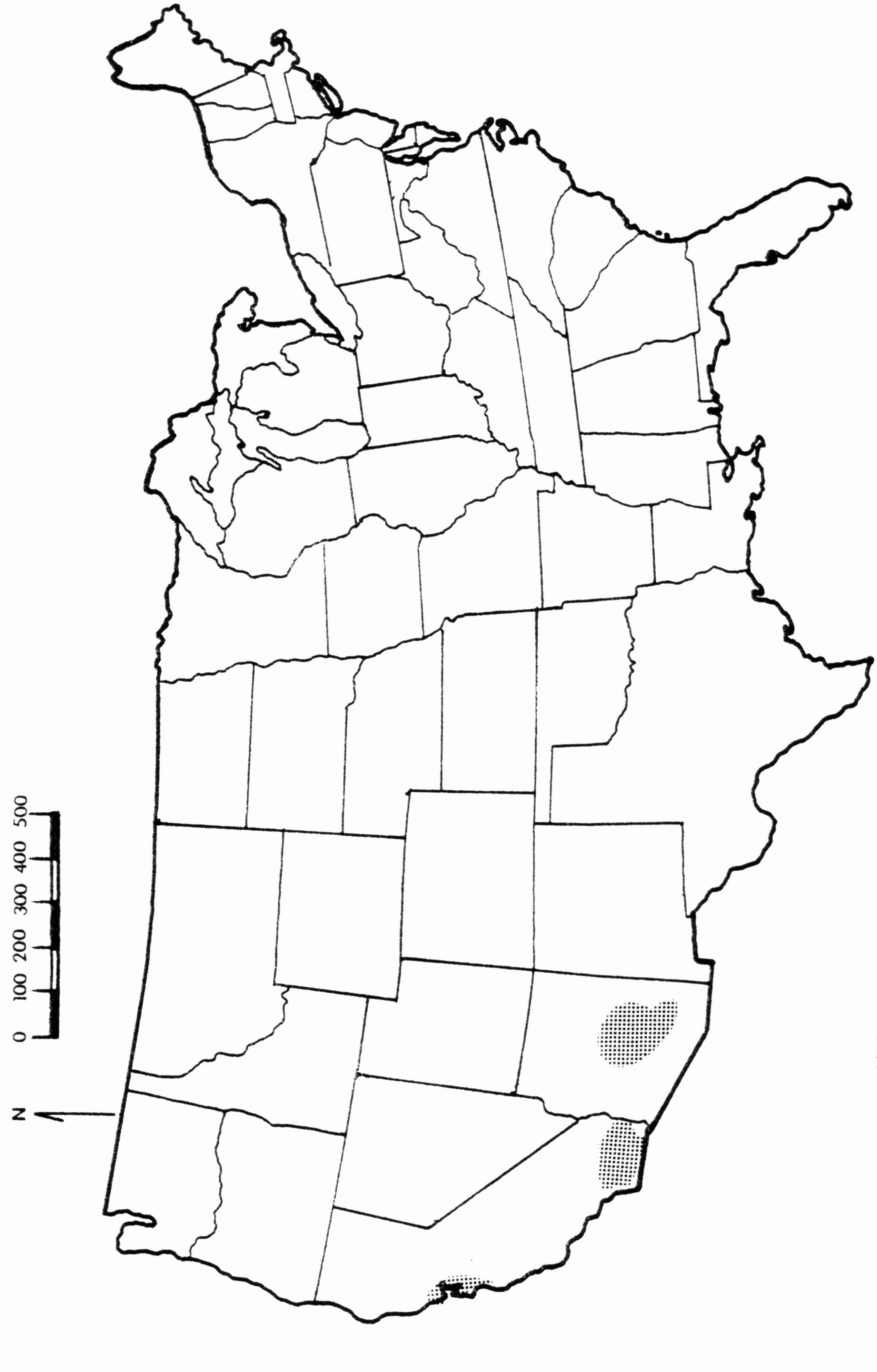
Sarotherodon mossambicus

Figure 14. Distribution of the spotted tilapia (*Tilapia mariae*) in the United States.



Tilapia mariae

Figure 15. Distribution of the redbelly tilapia (*Tilapia zillii*) in the United States.



Tilapia zillii

The redbelly tilapia (*Tilapia zillii*) was eradicated from a quarry in Dade County, Florida, in 1976 (Courtenay, in litt.) and the Arizona Department of Fish and Game regularly stocks *T. zillii* for aquatic weed control, but it dies out every winter.

Two populations of black acara (*Cichlasoma bimaculatum*) were eradicated in Palm Beach County, Florida (Courtenay, in litt.) and in Levy County, Florida (Daniel Levine, in litt.).

The blue tilapia (*Sarotherodon aureus*) was effectively removed from Trinidad Lake, Texas (Noble et al. 1975) and from Horseshoe Lake in Harrah, Oklahoma (Oklahoma Gas and Electric Company, in litt.)

Results of Examination of Specimens

Standard statistics, using the General Linear Models procedure, show a high degree of overlap in measurable characteristics between samples and between species (Table 2, 3). Species names are tentatively used, as the identification of several samples have not been verified.

In the multivariate analysis of variance, the number of caudal rays, number of scales above the lateral line, and number of scales in the depth of the caudal peduncle were determined to have high values for percent influence for each variable on each vector. (See Table 4 for means, variable coefficients, and values for percent influence of characteristics.) Fairly distinct groups of samples can be determined from Figures 16, 17, and 18. Sample numbers 5, 6, 26, and 7 appear to be a fairly homogeneous

Table 2. Standard Descriptive Statistics by Sample for Cichlids Examined

("$\bar{x}$": mean; "S.D.": 1 standard deviation)

	Astronotus		Cichlasoma sp.								Tilapia sp.						Sarotherodon sp.									
Sample #	2	5	6	26	7	8	9	10	11	12	14	25	13	15	16	17	18	19	20	21	22	23	24	3	1	4
N	6	22	8	8	12	25	20	2	2	7	1	4	2	8	16	7	4	4	4	6	8	5	11	15	15	7
Caudal Rays																										
$\bar{x}$	16	18	18	18	17.83	16	16	16.5	16	16	20	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Range	16	18	18	18	16-18	16	16	16-17	16	16	20	16	20	16	16	16	16	16	16	16	16	16	16	16	16	16
S.B.	0	0	0	0	0.58	0	0	0.71	0	0	--	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scales above lateral line																										
$\bar{x}$	7	5	5	5	5	4	4.95	5	4	4	6	5	6	5	5	5	5	5	5	5	5	5	5	5	4	7
Range	7	5	5	5	5	4	4-5	5	4	4	6	5	6	5	5	5	5	5	5	5	5	5	5	5	4	0
S D.	0	0	0	0	0	0	0.22	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scales below lateral line																										
$\bar{x}$	19	14	14	12.63	14	12.8	13	11	11	11	11	12.5	10	12	12	12	11.75	13.25	12.75	12.67	12.42	12.2	12.64	13.27	10	16.14
Range	0	14	14	12-13	14	12-13	13	11	11	11	11	12-13	10	12	12	12	11-12	13-14	12-13	12-13	12-13	12-13	12-14	13-14	10	16-17
S.D.	0	0	0	0.52	0	0.41	0	0	0	0	--	0.58	0	0	0	0	0.50	0.50	0.50	0.52	0.53	0.45	0.67	0.46	0	0.38
Scales in Depth of Caudal Peduncle																										
$\bar{x}$	13	9	9	9.38	9	8	8.95	9	9	9	--	9.75	9	8	8	8	8.75	8.5	8.75	9	9	8.80	8.91	9	9	12
Range	0	9	9	9-10	9	8	8-9	9	9	9	--	9-10	9	8	8	8	8-9	8-9	8-10	9	9	8-9	8-9	0	9	12
S.D.	0	0	0	0.52	0	0	0.22	0	0	0	--	0.50	0	0	0	0	0.50	0.58	0.96	0	0	.45	0.30	0	0	0
Gil Rakers																										
$\bar{x}$	5.67	20.86	21.63	17.25	19.45	16	15.2	19	19	19	17	14.0	17	10	10	9	5.25	5.0	4.75	5.67	5.63	4.80	5.91	8	4	6
Range	4-6	19.23	19.23	16-19	19-23	16	15-16	19	19	19	17	12-15	17	10	10	9	5-6	4-6	4-5	5-6	5-6	4-6	5.7	8	4	6
S.D.	0.82	1.25	1.30	1.04	1.21	0	.41	0	0	0	--	1.41	0	0	0	0	0.50	0.82	0.50	0.52	0.52	0.84	0.70	0	0	0
Dorsal Spines																										
$\bar{x}$	13	15.95	16	15.75	15.08	15.96	16	16	16	16.71	16	16.0	16	15.86	15.94	15.71	16	15.75	16.25	16	16.5	16.8	16.45	15.87	15.27	18
Range	13	15-16	16	15-16	14-16	15-16	16	16	16	16.21	16	15-17	16	15-16	15-16	15-16	16	15-16	16-17	16	16-17	16	16-17	15-17	9-11	18
S.D.	0	0.21	0	0.46	0.51	0.20	0	0	0	1.89	--	0.82	0	0.38	0.25	0.49	0	0.50	0.50	0	0.53	0.45	0.52	0.52	0.46	0

Table 3. Standard Descriptive Statistics by Species for Cichlids Examined

("x̄": Mean; "S.D.": 1 standard deviation)

	Astronotus ocellatus	Cichlasoma bimaculatum	Cichlasoma cyanoguttatum	Cichlasoma octofasciatum	Sarotherodon melanotheron	Sarotherodon mossambicus	Sarotherodon aureus	Sarotherodon niloticus	Tilapia mariae	Tilapia zillii
N	6	15	57	7	25	35	50	3	24	7
Caudal Rays										
x̄	16	16	16	16	16	16.03	17.96	20	16	16
Range	16	16	16	16	16	16-17	16-18	20	16	16
S.D.	0	0	0	0	0	.17	.28	0	0	0
Scales above lateral line										
x̄	7	4	5	7	4	4.76	5	6	5	5
Range	7	4	5	7	4	4-5	5	6	5	5
S.D.	0	0	0	0	0	.44	0	0	0	0
Scales below lateral line										
x̄	19	10	12.73	16.14	12.8	12.39	13.78	10.33	12.	12
Range	19	10	11-14	16-17	12-13	11-13	12-14	10-11	12	12
S.D.	0	0	.67	.38	.41	.90	.55	.58	0	0
Scales in depth of caudal peduncle										
x̄	13	9	8.86	12	8	9.06	9.06	9	8	8
Range	13	9	8-10	12	8	8-10	9-10	9	8	8
S.D.	0	0	.40	0	0	.34	.24	0	0	0
Gill rakers										
x̄	5.67	4	6.11	6	16	16.26	20.08	17	10	9
Range	4-6	4	4-8	6	16	12-19	16-23	17	10	9
S.D.	.82	0	1.30	0	0	1.99	1.87	0	0	0
Dorsal Spines										
x̄										

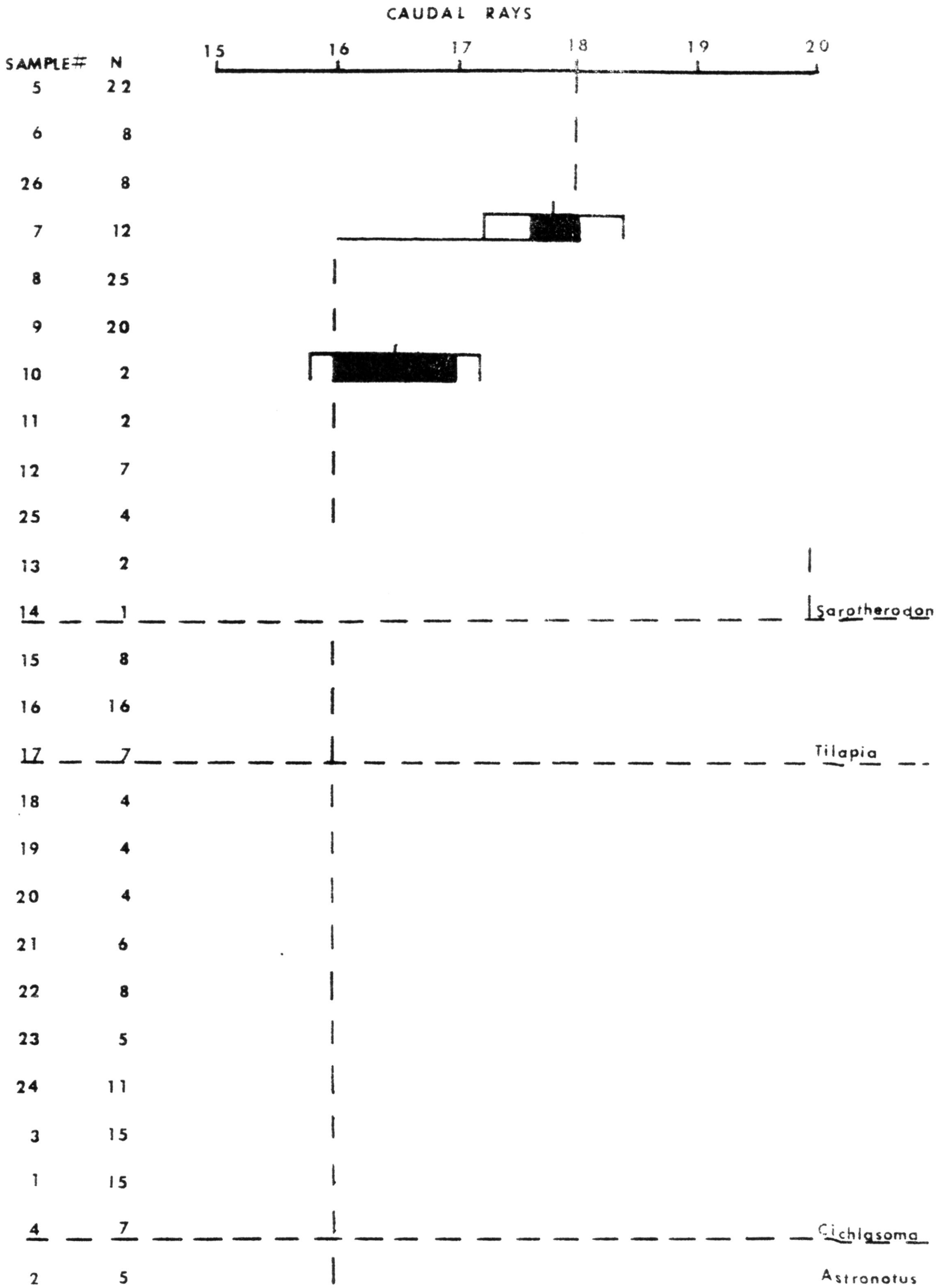
Table 3. Standard Descriptive Statistics by Species for Cichlids Examined, continued

	Astronotus *ocellatus*	Cichlosoma *bimaculatum*	Cichlasoma *cyanoguttatum*	Cichlasoma *octofasciatum*	Sarotherodon *melanotheron*	Sarotherodon *mossambicus*	Sarotherodon *aureus*	Sarotherodon *niloticus*	Tilapia *mariae*	Tilapia *zillii*
Dorsal Spines										
$\bar{x}$	13	15.27	16.19	18	15.96	16.14	15.72	16.	15.91	15.71
Range	13	15-16	15-17	18	15-16	15-21	14-16	16	15-16	15-16
S.D.	0	.46	.55	0	.20	.88	.50	0	.29	0.49

Table 4. Means, variable coefficient and percent influence of characters on the first two vectors generated by a NT-SYS distance program.

Character	Mean	Vector 1 Variable Coefficient	Vector 1 Percent Influence	Vector 2 Variable Coefficient	Vector 2 Percent Influence
Dorsal Spine	15.90	0.03048855	6	-0.01232869	-2
Dorsal Ray	11.31	0.00527532	1	0.05939287	7
Anal Spine	6.84	0.09076238	4	-0.08209745	-3
Anal ray	8.94	0.04784738	5	0.01111294	1
Caudal ray	16.50	-0.04145036	-9	0.24090393	39
Caudal peduncle scales	8.92	0.10825895	12	0.06847379	6
Scales in lateral line 1	19.51	-0.00151103	-1	0.01624269	2
Scales in lateral line 2	12.19	-0.00521103	-1	0.01624269	2
Scales above lateral line	4.90	0.71669110	45	0.15763669	19
Scales below lateral line	12.88	0.05000844	8	-0.10275348	11
Gill Rakers	12.37	-0.05321253	-8	0.00287553	8

Figure 16. Variation between samples of cichlids for caudal rays. Open rectangles indicate one standard deviation; black rectangles, two standard errors on either side of the mean; vertical line, the mean; horizontal line, the range of values.



CAUDAL RAYS
15
16
17
18
19
20
SAMPLE#
N
5 22
6 8
26 8
7 12
8 25
9 20
10 2
11 2
12 7
25 4
13 2
14 1
Sarotherodon
15 8
16 16
17 7
Tilapia
18 4
19 4
20 4
21 6
22 8
23 5
24 11
3 15
1 15
4 7
Cichlasoma
2 5
Astronotus

Figure 17. Variation between samples of cichlids for scales in caudal preduncle depth.

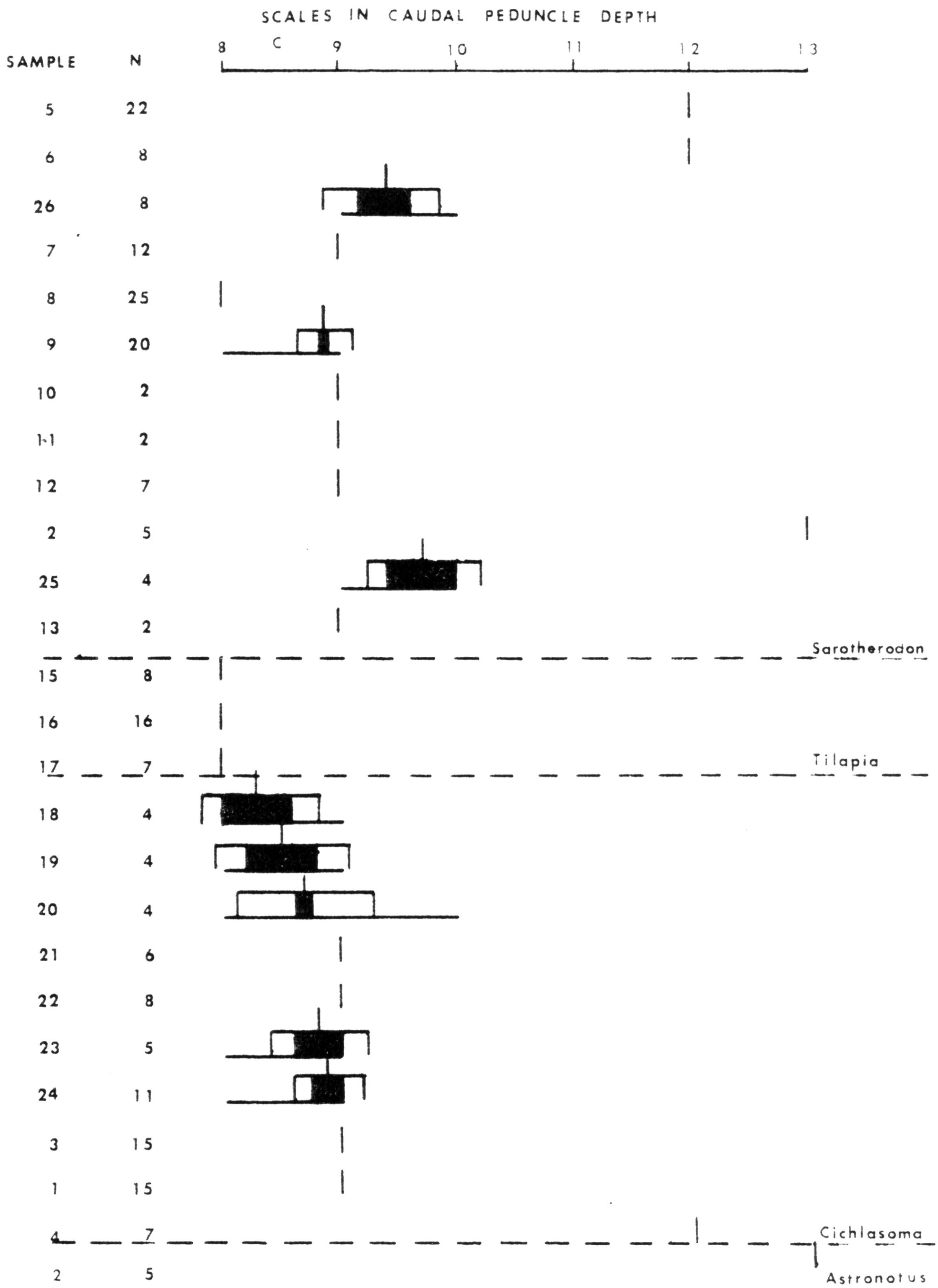
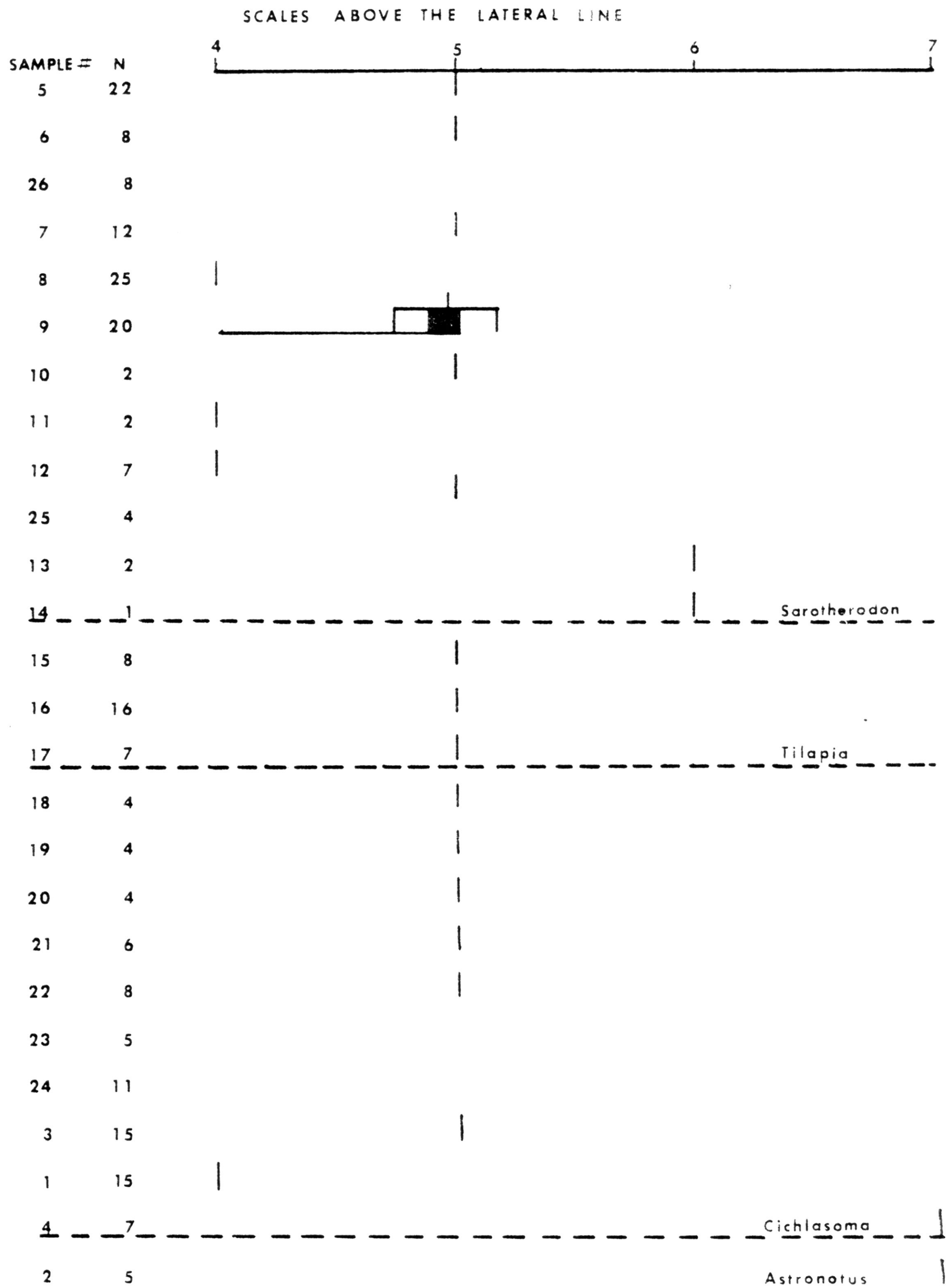

SCALES IN CAUDAL PEDUNCLE DEPTH
SAMPLE
N
8
C
9
10
11
12
13
5 22
6 8
26 8
7 12
8 25
9 20
10 2
11 2
12 7
2 5
25 4
13 2
Sarotherodon
15 8
16 16
17 7
Tilapia
18 4
19 4
20 4
21 6
22 8
23 5
24 11
3 15
1 15
4 7
Cichlasoma
2 5
Astronotus

Figure 18. Variation between samples of cichlids for scales above the lateral line.


SCALES ABOVE THE LATERAL LINE
4
5
6
7
SAMPLE # N
5 22
6 8
26 8
7 12
8 25
9 20
10 2
11 2
12 7
25 4
13 2
14 1
Sarotherodon
15 8
16 16
17 7
Tilapia
18 4
19 4
20 4
21 6
22 8
23 5
24 11
3 15
1 15
4 7
Cichlasoma
2 5
Astronotus

group as do sample numbers 8, 9, 10, 11, 12, and 25. Samples 15, 16, and 17 are all identical, with no standard deviation and samples 18, 19, 20, 21, 22, 23, 24, 3, and 1 also appear to be a very homogeneous group. Samples 2 and 4 separate from a large number of the samples in these three characteristics. Other characteristics which possess a large influence include the number of scales below lateral line, dorsal rays, anal rays, dorsal spines, anal spines, scales in anterior lateral line, and scales in posterior lateral line, and gill rakers on the lower part of the first gill arch (Figure 19).

The results of the MANOVA tests, used to evaluate discrimination between samples, resulted in clusters of samples that were difficult to separate. The analysis was performed by sample so that the disperson would not be biased by apriori species designations. The combinations of Vector 1 and Vector 2 accounted for 41.5 and 40.5% respectively, of the variation between samples. In Figure 20, it is shown that several groups of samples appear to be distinct from other groups or samples. Within these groups, the analysis was unable to distinguish clearly between samples. In Figure 21., species names are applied to the samples. These identifications were supplied with the specimens which were examined. Several authorities after examining some of the specimens disagreed on the identifications; these samples were provided with two names. Regrouped according to this new information, the samples are shown in Figure 22, with solid lines indicating reasonable groups, and dashed lines indicating possible finer delineations.

Figure 19. Influence of the characters on the first two vectors for all samples of cichlids examined.

INFLUENCE OF CHARACTERS BY PERCENT

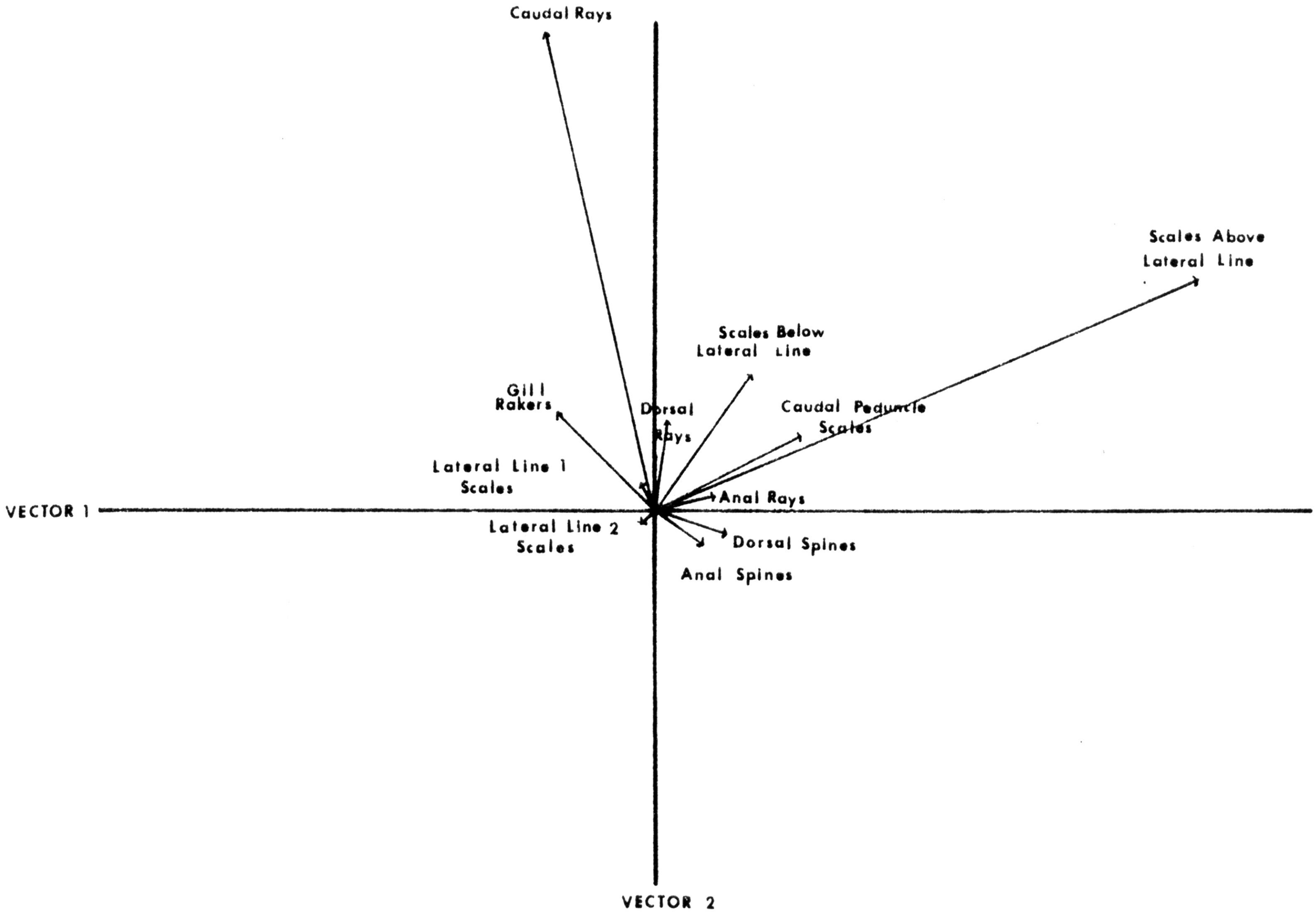


Figure 20. Projections of the first two vectors generated by a NT-SYS computer program for 26 cichlid samples. Vector 1 accounted for 41.5% of the variation between samples. Vector 2 accounted for 40.5% of the variation between samples.

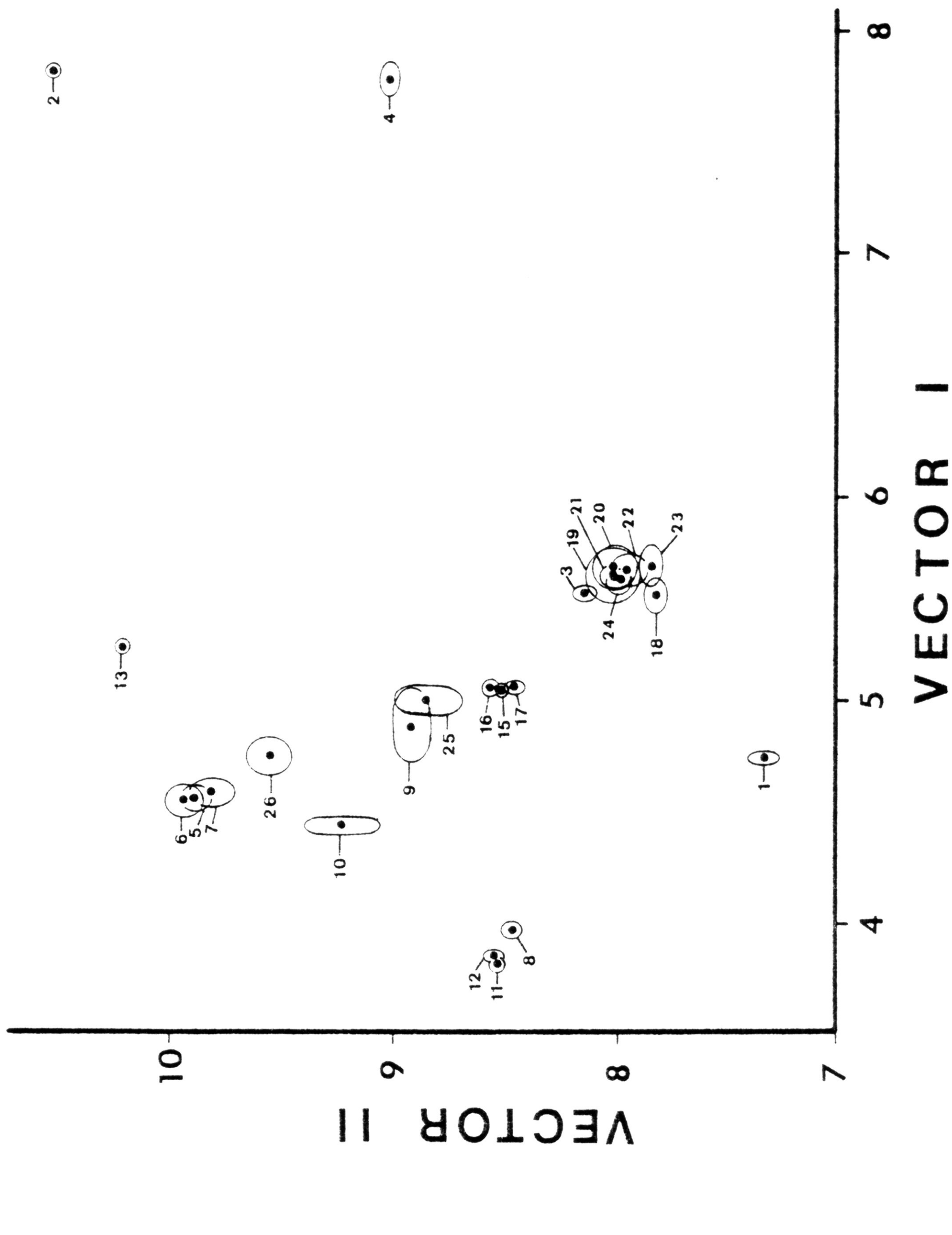

VECTOR I
VECTOR II
4
5
6
7
8
7
8
9
10
1
2
3
4
5
6
7
8
9
10
11
12
13
15
16
17
18
19
20
21
22
23
24
25
26

Figure 21. Projections of the first two vectors generated by a NT-SYS computer program for 26 cichlid samples with species names included. Species names are used tentatively, as their identifications have not been verified. Together, Vectors 1 and 2 accounted for 82% of the variation between samples.

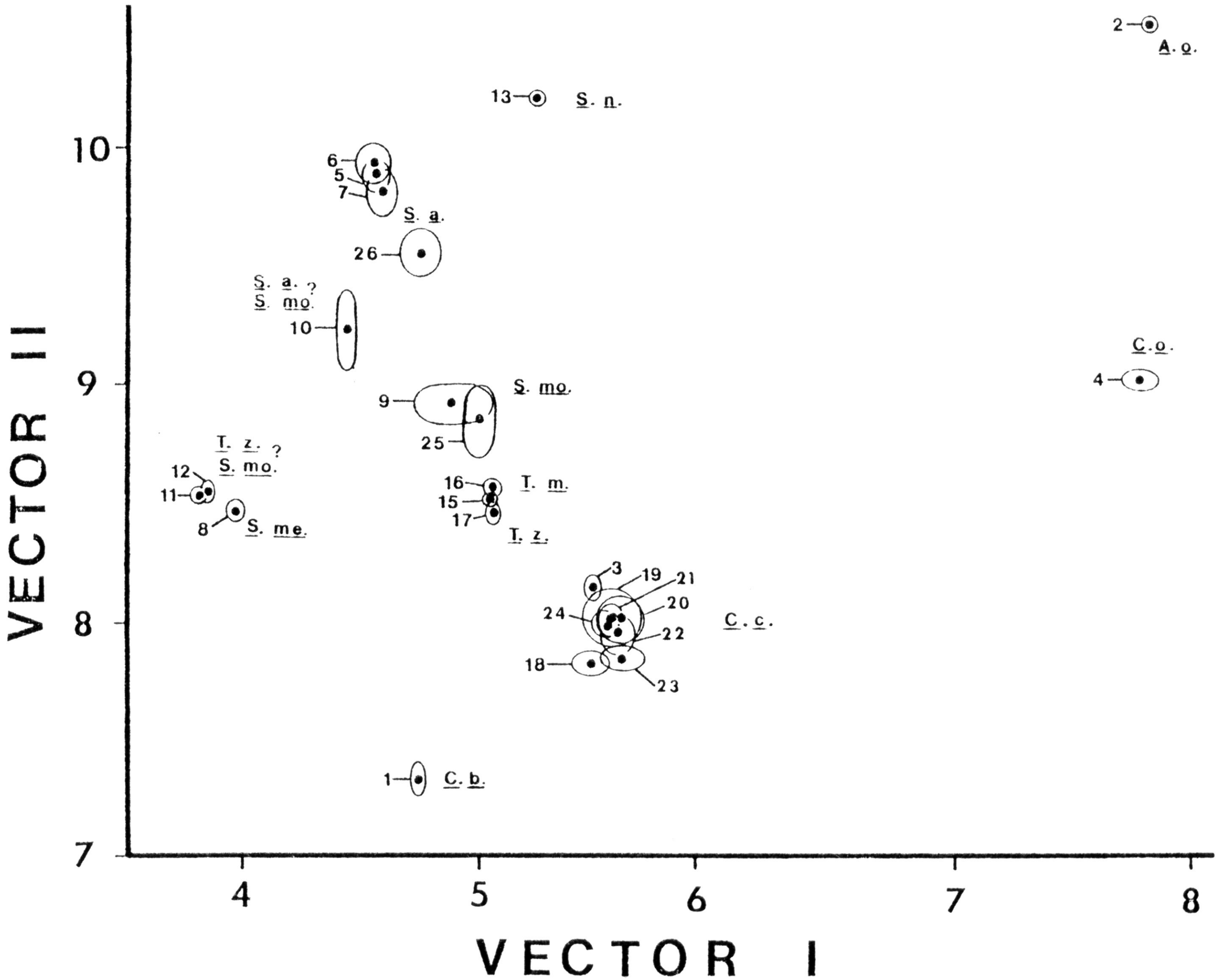
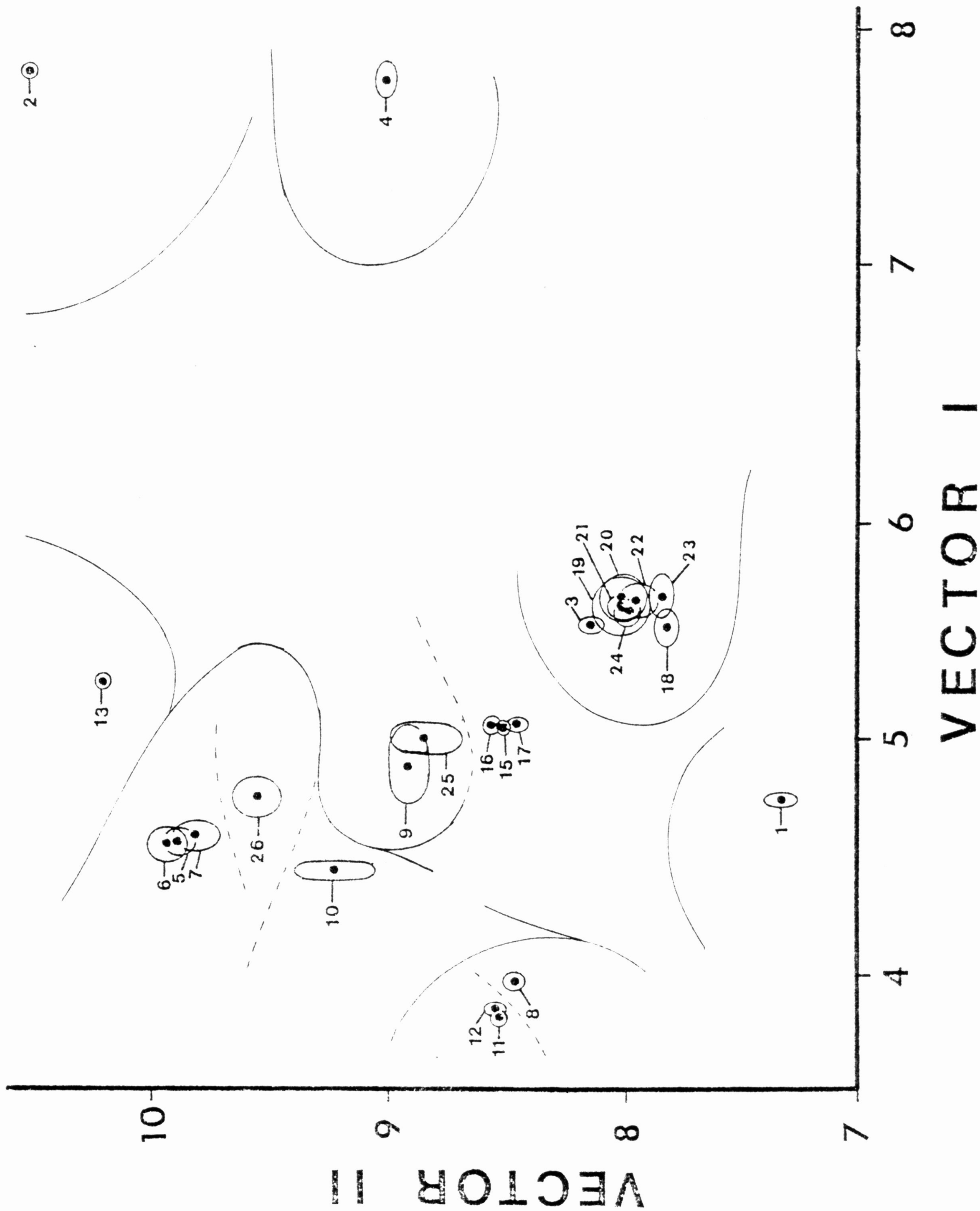
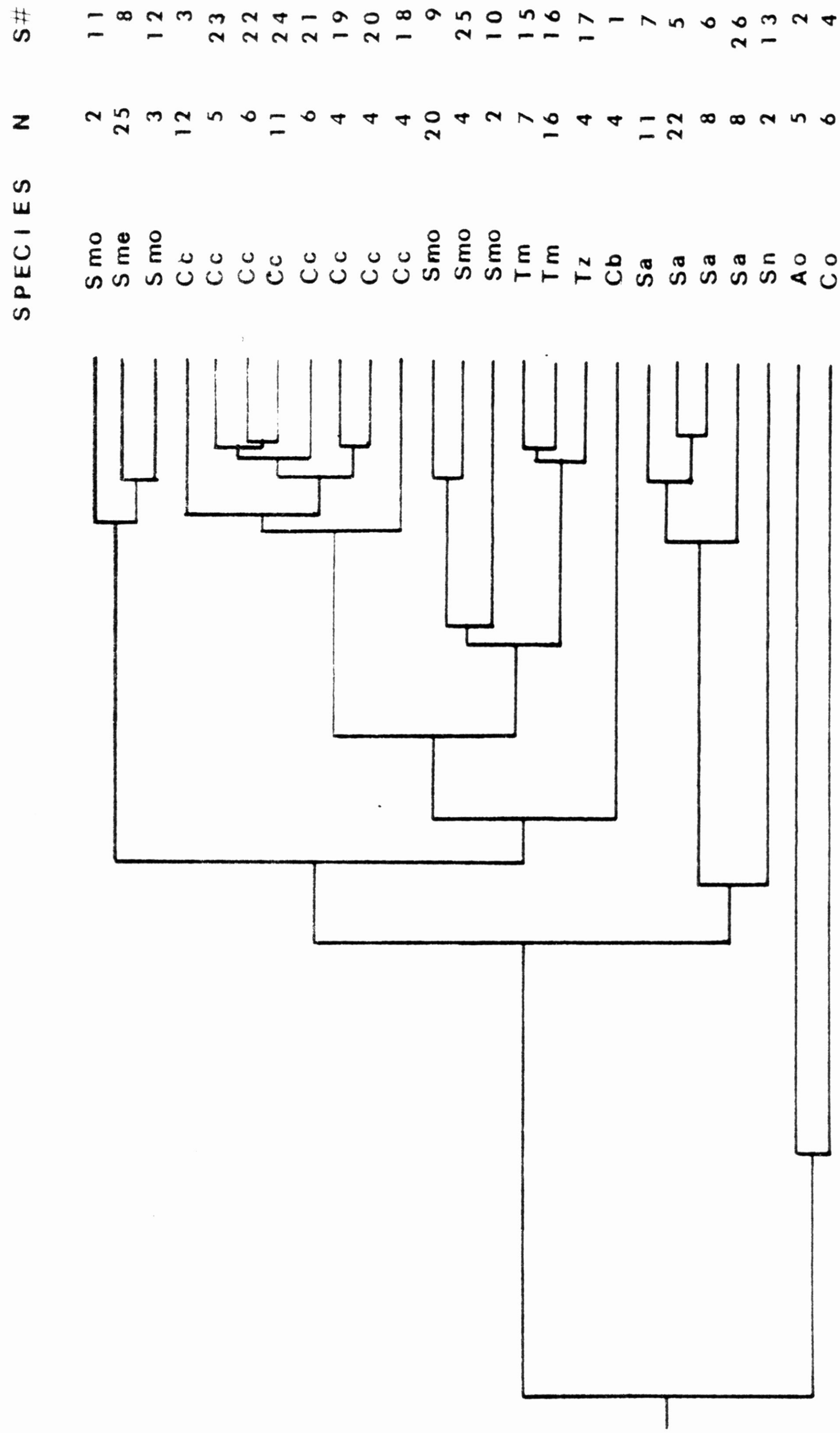

2
A. o.
13
S. n.
6
5
7
S. a.
26
S. a. ?
S. mo.
10
C. o.
4
9
S. mo.
25
T. z. ?
S. mo.
12
11
8
S. me.
16
15
17
T. m.
T. z.
3
19
21
20
24
22
C. c.
18
23
1
C. b.
VECTOR II
10
9
8
7
4
5
6
7
8
VECTOR I

Figure 22. Projections of the first two vectors generated by a NT-SYS computer program for 26 cichlid samples, with grouping delineations included. Solid lines indicate groupings which appear to be reasonable, based on the tightness of the clusters and the distance between clusters. Dashed lines indicate possible finer groupings.


VECTOR I
4
5
6
7
8
VECTOR II
7
8
9
10

It appears that most of the samples can be separated by genus, but only some can be separated by the species names provided. The distance phenogram (Figure 23) illustrates the relationships between the samples. The vectors used as variables in this phenetic analysis accounted for 97% of the variation between samples in the MANOVA. All of the Rio Grande perch, (*Cichlasoma cyanoguttatum*) samples group together tightly, with no differences due to geographic location even though there were samples from Texas and Florida, where this fish has been recently introduced. The first major break occurs between samples 2 (*Cichlasoma octofasciatum*) and 4 (*Astronotus ocellatus*) and the rest of the samples. This indicates that these two samples ae easily distinguishable from the other samples. Another major break is that between Samples 5, 6, 7, and 26 separating these samples from the rest. Samples 15, 16 (*Tilaipia mariae*), and 17 (*Tilapia zillii*) break from the remaining samples, as does sample 1 (*Cichlasoma mossambicus*). It is believed that some of these samples or specimens within the samples have been misidentified.

Figure 23. Distance phenogram resulting from 26 different geographical samples of cichlids. Species names are tentatively used as identifications have not been verified.


SPECIES N S#
Smo 2 11
Sme 25 8
Smo 3 12
Cc 12 3
Cc 5 23
Cc 6 22
Cc 11 24
Cc 6 21
Cc 4 19
Cc 4 20
Cc 4 18
Smo 20 9
Smo 4 25
Smo 2 10
Tm 7 15
Tm 16 16
Tz 4 17
Cb 4 1
Sa 11 7
Sa 22 5
Sa 8 6
Sa 8 26
Sn 2 13
Ao 5 2
Co 6 4

SPECIES ACCOUNTS

OSCAR

Astronotus ocellatus Cuvier (1831)

Natural Range: Venzuela, Guyana, Surinam, French Guinea, Amazonia, Peru, Paraguay (Courtenay, in litt.)

U.S. Range: Established population in Dade, Broward, and Palm Beach Counties, Florida (Courtenay, et al. 1974, Hogg 1976, 1976a). Found in fishermen's catches through Mississippi (J.D. Cirino, in litt.) (See Figure 3.)

Diagnosis: Mottled coloration on body, dark spot at base of caudal peduncle. Robust fish, with body depth almost 1/2 of standard length. Variations within the 6 specimens examined showed: D = XIII/19; A = III/16, 17; C = 16, P 14; V = I /5; lateral line scales before break = 20-22; lateral line scales after break = 14-15; scales above lateral line=7, scales below lateral line = 19, gill rakers = 4-6.

Natural History: These fishes are carnivorous, feeding on insect parts, fishes, larval amphibians, seeds, fish scales, molluscan shell fragments, chironomid larvae, coleopterans, Cichlasoma bimaculatum fry, oligochaetes, bryozoans, fish eggs, and vascular plant fiber (Hogg 1976). Just prior to spawning, pairs of A. *ocellatus* clean an area of hard substrate on which eggs will be deposited, and dig pits in the softer substrate near the nest. After fertilization, the eggs are guarded and fanned by the parents until hatching, which occurs at 3-4 days. The fry are moved to sand pits and guarded until the fry disperse (Lowe-McConnell 1975). Spawning is inhibited in temperatures below 26°-28° C (Breder and Rosen 1966).

BLACK ACARA

Cichlasoma bimaculatum Linnaeus 1758.

Native Range: Brazil, Surinam, Guyana, French Guinea, Venezuela, Trinidad (Regan 1905).

U.S. Range: Dade, Broward, Palm Beach, Monroe, Collier, and Hendry County, Florida (Courtenay et al. 1975, Hogg 1976, 1976a, Kushlan 1972, Lachner et al. 1970, and Rivas 1965). (Figure 4.)

Diagnosis: C. bimaculatum is characterized by a short caudal peduncle, a spot at the base of the caudal peduncle, spots on the fins, and a large spot below the lateral line. Based on the examination of 15 specimens, the characteristics of C. bimaculatum are as follows: D = XV - XVI/9-11; A = IV, V = 8.9;; C = 16; P = 13, 14; V = I/5; scales in depth of caudal peduncle = 9; lateral line scales before break = 13-17; lateral line scales after break = 5-10; scales above lateral line = 4; scales below lateral line = 10; number of gill rakers = 4; SL/HL = 1.96-2.62; SL/BD = 1.83-2.20; HL/SNOU = 3.59-5.89. There is no apparent sexual dimorphism.

Natural History: Lowe-McConnell (1964) reports that C. bimaculatum is omnivorous, feeding on mollusc shells, palaemonid shrimps, insects, fish scales and bones, vegetable debris, filamentous algae, and seeds. These fish possess an interesting adaption to low oxygen levels in that they may have a stomach modified to form an accessory respiratory organ. The stomach is highly vascularized and usually contains air. The reproductive behavior of C. bimaculatum is much like that of Astronotus ocellatus. Pits are dug, then the eggs are deposited on smooth flat surfaces. After fertilization, both parents guard the eggs until hatching, at which time they are moved to the previously dug pits and guarded. Spawning may occur throughout the year, with temperatures as low as 19° - 20° C.

RIO GRANDE PERCH

Cichlasoma cyanoguttatum (Baird and Girard, 1956)

Native Range: Lower Rio Grande River, south to the Rio Panuco-Tamesi drainage in eastern Mexico (Danell 1962).

U.S. Range: In addition to the above, the Rio Grande Perch is established in Hillsborough, Pinellas, and Polk County, Florida (W.R. Courtenay, in litt.) as well as several river systems and lakes in Texas. These systems include: (1) San Marcos River (W.S. Birkhead, in litt.), (2) San Antonio River;(3) Colorado River (W.S. Birkhead, in litt.) (4) Comal River (Courtenay, in litt.), (5) Guadalupe River (Courtenay, in litt.); (6) Canyon Reservoir (J.D. Bonn); and (7) Town Lake in Austin (B.G. Whiteside, in litt.) (Figure 5).

Diagnosis: Variation in characteristics based on measurements of 57 specimens shows: D= XV/17; A = IV-VI/6-9; C = 16; P = 13, 14; V = I/5; scales in body peduncle depth = 8-10; lateral line scales before break = 17-22; lateral line scales after break = 8-19; scales above lateral line = 5; scales below lateral line = 11-14; gill rakers = 4-8; SL/HL = 2.28-3.03, SL/BD = 1.67-2.30; HL/SNOU = 3.02-5.40. There is no apparent sexual dimorphism.

Natural History: Darnell (1962) reports that the Rio Grande Perch is omnivorous, feeding on vascular plants, filamentous algae, and fungi, benthic diatoms, insect larvae, caterpillars, beetles, water mites, cladocera, protozoans, detritus, fish eggs, and fish. This fish spawns at different times in different areas, with spawning occurring in Rio Tamesi in late May and from March to August in the San Marcos River. This species of cichlid is monogamous, with pairs forming for a duration of several years. These fish may breed several times in one season, with each female releasing 250-300 eggs which hatch in 20 hours at 28.9° C, 30 hours at 26.7° C and 60 hours at 23.9° C. Hubbs (1951) reports that the lower lethal temperature for this species is 14.2-19.0° C.

The Rio Grande perch has the potential to build up large populations and compete with native centrarchids (Buchannon 1971).

FIREMOUTH CICHLID

Cichlasoma meeki (Brind) 1918.

Native Range: Mexico, in the northern part of the Yucatan Peninsula. (Miller 1966 in Courtenay, in litt.)

U.S. Range: The firemouth cichlid is established in Dade County, Florida (Hogg, 1976, 1976a). Collections have been made in Palm Beach County, Florida, and in Mesa, Arizona (Minckley 1973), but these are not established populations. (Figure 6) The source of introduction of this species is unknown, but probable causes are escape from nearby fish farms, and release by aquarists.

Diagnosis: No specimens were measured. The variation in charactieristics is D = XV-XVI/9-10; A = VIII-IX/7-9, lateral line scales = 28-32 (Sterba 1963).

Natural History: Barlow (1974) describes C. meeki as a substrate sifter, finding food by sifting it through the sand. This fish feeds on both non-filamentous and filamentous green algae, molluscan shell fragments, vascular plant fiber, fish eggs, and insect parts (Hogg 1976a). Smaller firemouths tend to eat more vegetation than the larger individuals, which seemed to prefer fish and insect eggs.

At the beginning of the spawning season, the firemouth digs holes in the substrate in which to incubate the eggs. When the fry are hatched the parents guard the young until they mature and scatter.

CONVICT CICHLID

Cichlasoma nigrofasciatum (Gunther 1869)

Native Range: The convict cichlid is native to the Pacific slope from Guatemala to Puerto Rico.

U.S. Range: The convict cichlid is established in two counties from Nevada (Hubbs and Deacon 1964). Minckley (1973) states that single individuals or small numbers of fish are collected from time to time, but as of yet, no natural populations are present. (Figure 7)

Diagnosis: No specimens were examined. Based on Sterba (1963) D = XVII/6-8; A = IX/16; lateral line scales = 29-30.

Natural History: The natural history of this fish is described from aquariums, where it is known for its extremely aggressive behavior. At the time of spawning, small pits are dug in the substrate so that after fertilization both parents can keep the eggs free of detritus while they are incubating (Miller 1966).

JACK DEMPSEY

<u>Cichlasoma</u> <u>octofasciatum</u> Regan 1903.

Native Range: Central America from Veracruz, Mexico to the Rio Ulua basin, Honduras (Miller 1966).

U.S. Range: Established in Florida in Hillsborough, Dade, Levy, and Palm Beach Counties (Courtenay in litt.) (See Figure 8)

Diagnosis: Based on the examination of 7 specimens, D = XVIII/10, A = VIII-IX/8; C = 16; P = 13, 14; V = I/5; scales in depth of caudal peduncle = 12; lateral line scales before break = 19.20; lateral line scales after break = 10-12; scales above lateral line = 7; scales below lateral line = 16, 17; gill rakers = 6; SL/HL = 2.10-2.52; SL/BD = 1.90-2.22; HL/SNOU = 3.45-4.16. There is no apparent sexual dimorphism.

Natural History: Filamentous chlorophyta, exoskeleton, molluscans, crayfish, shell fragments, insect parts and bryozoans make up the diet of <u>C.</u> <u>octofasciatum</u> (Barlow 1944 and Hog 1976a). During the spawning season, holes are dug in the substrate by the mouths and heads of the parents. After fertilization the eggs are placed in these pits and guarded until hatching. The optimum temperature for incubation is 23.9° C.

BANDED CICHLID

<u>Cichlasoma</u> <u>severum</u>. Heckel, 1840.

Native Range: Brazil, Surinam, Guyana, French Guiana, and southern and eastern Virginia (Regan 1905, in Courtenay, in litt.).

U.S. Range: The banded cichlid was introduced into Roger Spring, Clark County, Nevada. Attempted eradication was not totally successful. (Hubbs and Deacon 1964). (See Figure 9)

Diagnosis: Based on (Sterba 1963) D = XVI-XVIII/13-14, A=VII-VIII/12-13, Lateral line scales = 28-30. Characterized by broad, dark vertical band posteriorly.

Life Hisory: The banded cichlid feeds differentially, according to the weather. Lowe-McConnell (1969) reports that during the rainy season, green algae and other vegetation is predominant in the diet. During the dry season, this fish feeds on bottom debris, sand, and bits of dead plant material and chiton. <u>Cichlasoma</u> <u>severum</u> is a characteristic species of large floating islands of vegetation in floodplain lagoons (Lowe-McConnell 1975). This species spawns before or during the wet season. At this time, holes are dug in the substrate by the head and mouth. The eggs are deposited apart from these holes, and after fertilization and hatching, the young are carried to the holes and guarded by both parents until they reach a considerable size (Lowe-McConnell 1969).

JEWELFISH

Hemichromis bimaculatus Gill, 1863.

Native Range: North and West Africa (Boulenger 1899, in Courtenay in litt.).

U.S. Range: The jewelfish is established in the Hialeah Canal-Miami River canal system and Comfort Canal, Dade County, Florida (Rivas 1965, Courtenay and Robins 1973, Courtenay et al. 1974, Hogg 1976, 1976a). It may also be established in Eureka Springs, Hillsborough County, Florida (Courtenay et al. 1974). (Figure 10).

Diagnosis: Forehead slightly concave; D = XIII-XV/9-13; A = III/7-9; ventrals strongly extended in the second and third rays, and are located on the breast (Frey 1961).

Life History: An omnivore, the jewelfish feeds on non-filamentous chlorophyta, filamentous chlorophyta, Cichlasoma bimaculatum fry, insect parts, vascular plant fibers, oligochaetes, fish eggs, cladocerans, copepods, fish scales, chironomid larvae, and molluscan shell fragments (Hogg 1976a).

The jewelfish is a substrate spawner. Just prior to spawning, an area of substrate is cleared. After deposition and fertilization of the eggs, they are fanned and cleaned until hatching. After hatching, the female orally transports the young to previously dug pits where they are guarded until the young disperse (Fryer and Iles 1972, Hogg 1976a).

Hogg (1976a) recorded spawning at daily maximum temperatures of 26° C to 33° C.

BLUE TILAPIA

Sarotherodon aureus (Steindachner 1864)

Native Range: The blue tilapia is native to West Africa, Israel, and Jordan (Bardach et al. 1972). They are cultured in parts of the United States, El Salvador, and Central America.

U.S. Range: Alabama, Louisiana, South Carolina, and Tennessee culture the blue tilapia for experimental purposes (Parker, Avault, Watson, Hilton, in litt.). Natural populations are found in Gila Bend and in golf course ponds, stock tanks and subdivision lakes throughout Arizona (Ziebell, in litt.). In Florida, this fish is esablished in Polk, Hillsborough Bay, Alchua, Brevard, Dade, DeSota, Hardee, Hernando, Lake Manatee, Marion, Orange, Osceola, Sarasota, Seminole, and Volusia Counties, and in Peace River, Lake George, Lake Monroe, Lake Salt Springs, Blue Springs, St. John's River, and Palm Beach (Courtenay, in litt.). It is found in Lake Julian (Skyland Reservoir) (Ross, in litt.). in Buncombe County, North Caolina, and in Horseshoe Lake, Generating Plant near Harrah, Oklahoma (Ok. Gas and Electric Company, in litt.). In Texas, it is found in Braunig Reservoir, Bexar County (Noble, pers. comm.), Amistad Reservoir (Val Verde County), (Courtenay in litt.), Nasworthy (Tom Green County, Courtenay in litt.), and in the San Marcos River (Whiteside, in litt.) (Figure 11)

Diagnosis: Variation in characteristics, based on the examination of 50 specimens are as follows: D = XIV-XXI/11-14; A = III / 7-10; C = 16-18; P = 11-14; V = 1/5; anterior lateral line scales = 18-23; posterior lateral line scales = 11-16; gill rakers = 16-23.

Natural History: The blue tilapia feeds primarily on phytoplankton (McBay 1961, Manooch 1972, Gleastine 1974, Stickney 1976, Foote 1977), feeding also on insects and small crustaceans (Yashouv and Chervinski 1961). This fish is a mouthbrooder, engaging in schooling, territorial establishment, and prespawning courtship. During spawning the female visits territories established by the male and pairing occurs. After fertilization, the female takes the eggs and milt into her mouth and leaves the male; who may or may not spawn again with another female. The length of incubation depends on the temperature. In waters of 77°-78° F, the yolk sac is completely absorbed in 13-14 days. Fecundity varies with size of female and on a seasonal basis, with spawning occurring at 5-8 week intervals. (McBay 1961). Huet (1955) states that the spawning frequency of tilapias varies with their geographical location.

BLACKCHIN TILAPIA

Sarotherodon melanotheron (Ruppell, 1852)

Native Range: The blackchin mouthbreeder is native to Africa, Syria, India, and Ceylon (Courtenay in litt.)

U.S. Range: In the United States, this fish is found in Tampa Bay (Hillsborough County), Florida (Finucane, in litt.) (Figure 12).

Diagnosis: Based on the examination of 25 specimens, the variation in characteristics is as follows: D = XV-XVI/11, A = III/8, C = 16, P = 13, V = I/5, anterior lateral line scales = 18, posterior lateral line scales = 12, scales above lateral line = 4, scales below lateral line = 12-13, gill rakers =22.

Natural History: S. melanotheron is herbivorous, feeding on the bottom mud, enriched with organic detritus, crustaceans, filamentous algae, diatoms, and gastropods (Fagade 1971). The juveniles (up to 40 mm) feed on phytoplankton, detritus, and benthic diatoms (Pauly, 1976). These fish can reproduce throughout the year, with the male and female both incubating the eggs in the buccal cavity. These fish are able to extend their native range by making use of power plant cooling reservoirs. Spawning does occur in the later months (Finucane and Rinckley 1964).

MOZAMBIQUE TILAPIA

<u>Sarotherodon</u> <u>mossambicus</u> (Peters, 1852)

Native Range: The mosambique tilapia is found (native and introduced) in China, India, Indonesia, Malaysia, Philippines, Taiwan, Uganda, United States, Jamaica, Trinidad, Costa Rica, Guyana, Cuba, Mexico, Columbia, Dominican Republic, Haiti, St. Lucia, and Dominica (Courtenay, in litt.)

U.S. Range: In the United States, S. <u>mossambicus</u> is cultured experimentally or commercially at St. Simons Island, Georgia, (Wyatt, in litt.), Oak Ridge National Laboratory, Tennessee (Adams, in litt.), C. Matthew Pond in Panola County, Texas, and Harrison's Lake in Polk County, Texas, Inman (in litt.). This fish has established populations in the lower Colorado River from Phoenix to Yuma, Arizona and Buckeye, Arizona (Ziebell, in litt.). In California, it is found in Salton Sea (Imperial County), the San Gabriel River, the Santa Ana River, Seal Beach (Orange County), and Long Beach (Orang County). Populations are present at Dade, Indian River, Hillsborough, and Breward Counties in Florida (Courtenay, in litt.). In Idaho, scattered populations occur in the Snake River and in warm drainage ditches (Pollard, in litt.). Texas has established populations of the mosambique tilapia in the San Antonio River (Bexar County) (Hubbs, et. al., 1971) and Canyon Reservoir (Comal County) (Whiteside, in litt.) (Figure 13).

Diagnosis: Based on the examination of 20 specimens the variation in characteristics are as follows: D = XVI/II, A = III-IV/9-10, C = 16, P = 13-14, V = 1/5, anterior lateral line scales 20-21, posterior lateral line scales 12-15, scales above lateral line 4-5, gill rakers 15-16.

Natural History: The mossambique tilapia has been introduced into the U.S. for food, cover, and biological control. High productivity, ease of culturing, and rapid growth rate are the primary reasons for its popularity (Swingle 1960). S. mossambicus is an omnivore, feeding on filamentous and non-filamentous algae, rooted aquatic vegetation, dead vegetation, soy beans, rice bran, crustaceans, bryozoans, oligochaetes, insects, small fish, and chopped meat (Kelly 1957, Childers and Bennet 1967, Fryerand Iles, 1972, Hogg 1976a, and Moyle 1976). Reported to feed heavily on phytoplankton and other aquatic vegetation, the mozambique tilapia may not actually digest a large portion of that material ingested. This is caused by a lack of cellulase, used in cellulose digestion.

In its northern range, S. mossambicus prefers slow moving brackish water, and is abundant in areas influenced by warm, saline irrigation water (Moyle 1976). At the southern end of its range, the Mozambique tilapia is more common in estuaries than in fresh water (Allanson et al. 1971), inhabiting areas with salinity ranges from 9.3 to 34.5 ppt (Gilmore 1977).

During spawning, the males leave the school and establish territories by digging pits in the substrate using their mouths. When the digging of pits is completed, the males attract females into their territories. The female deposits her eggs in a pit, then takes them into her mouth. The male then ejects milt over the area where the eggs were lain and the females take this into their mouths and mix it with the eggs. The female leaves the area, and the male continues to attract other females into the area (Courtenay, in litt.). The female carries the eggs for 10-12 days. When released, the fry form a school around the female. After 4 or 5 days, the young continue to school, but become disassociated from the parent (Baerends and Baerends-Van Roon 1950, in Courtenay, in litt.).

Because of its ability to survive in saline waters, the Mozambique tilapia has the potential to spread farther in coastal areas than the data from the fresh water temperature tolerance studies indicate. This is due to the fact that it can survive lower temperatures in salt water than in fresh water (Allanson et al., 1971). The California Department of Fish and Game determined the lower lethal temperature in fresh water to be 12.8° C.

SPOTTED TILAPIA

<u>Tilapia</u> <u>mariae</u> Boulenger, 1899.

Native Range: The spotted tilapia can be found along the Ivory Coast to southwestern Ghana from Cameron (Thys van den Audenaerde 1968).

U.S. Range: These fishes are also found in Dade, Broward, and Collier counties in Florida (Courtenay, in litt.) and scattered throughout Arizona, where it was stocked for research on aquatic weed control (Minckley, in litt.) (Figure 14).

Diagnosis: Characteristics based on the examination of 24 specimens are as follows: D = XV, XVI/12-14; A = III/9-10; C = 16; D = 13, 14; V = I/5; scales in caudal peduncle depth = 8; lateral line scales before break = 19-21; lateral line scales after break: 12-15; scales above lateral line = 5; scales below lateral line = 12; gill rakers = 10; Sl/HL = 2.77-3.20; SL/BD = 1.82-2.24; HL/SNOU = 3.27-5.72.

Natural History: The spotted tilapia can be considered an intermediate between herbivores and microphages. Their diet consists of algae filaments, diatoms, (Fagade 1971), phytoplankton, (Trewavas, 1974), filamentous and nonfilamentous green algae, vascular plant fiber, bryozoans, cladocerans, fish scales, chironomid larvae, fins, bone (seeds). The smaller fish use vascular plant fibers and larger fish feed on filamentous green algae. The spotted tilapia is a substrate spawner, ovipositing on the undersurface of rock. Both parents guard and aerate the eggs in a previously dug pit. Hatching occurs in a few days (3), with maturation for the next year.

REDBELLY TILAPIA

Tilapia zillii (Gervais, 1848)

Native Range: The Congo, or redbelly, tilapia is native to parts of the Near East and Africa north of the equator (Courtenay, in litt.).

U.S. Range: This fish has established populations of Imperial County (Calexico-Hauser 1975) and San Gabriel and Santa Ana Rivers (Knagg 1977) in California. It has also become established in warm drainage ditches and the Snake River in Idaho (Pollard, in litt.). Congo tilapia are cultured for experimental and commercial purposes at Auburn, Alabama, Maricopa County, Arizona (Minckley 1973), Florida, Guam, Hawaii, Wilmington, North Carolina (Tarplee, in litt.) and South Carolina. (Figure 15)

Diagnosis: Characteristics of the redbelly tilapia, based on the examination of 24 specimens shows: D = XV-XVI/12-14; A = III/9-10; C = 16; P = 13-14; V = I/5; scales in caudal peduncle depth = 8; lateral line scales before break = 5-20 ($\bar{x}$ = 17.5); lateral line scales after break = 10-12; scales above lateral line = 5; scales below lateral line = 12, gill rakers = 9; SL/HL = 2.71-2.96; HL/SNOU = 3.20-4.13.

Natural History: These fish are primarily phytophagous, feeding on diatoms, volvocales, ostracods, vorticellids, rotifers, copepods, cladocerans, hydrachnids, and insects (Buxton 1922, cited by Courtenay, in litt.) T. zillii are monagomous, at least for several broods (Fryer and Iles 1972), and can spawn whenever the temperatures are above 20° C (Fishelson 1967). The female, able to spawn at 13-14 cm., deposits her eggs in rows as the male follows behind her to fertilize them. The male and female then remain together at the nest and keep the eggs clean by removing detritus with their mouths (Fryer and Iles 1972). Daget (1952) found that eggs hatch after 48 hours, at which time the fry are transferred to pits constructed around the nest (Elder 1960, cited by Courtenay, in litt.). The parents remain with the young for approximately 5 days. If environmental conditions are favorable, spawning may occur again in less than 30 days. Huet (1959) reports that these tilapia begin breeding at a small size and tend to overpopulate and stunt a pond.

CONTROL OF INTRODUCED CICHLIDS

Because of their highly efficient mode of reproduction and ability to survive over a wide range of habitats, cichlids must be carefully managed when introduced into natural systems.

Hybridization and production of monosex populations is one control strategy being investigated at this time. Several combinations of species have been hybridized in an effort to produce all male populations. Chervinski and Stickney, in an unpublished paper, report that males are desired for their faster growth rates, and because they do not lose energy in reproduction as do females. Bardach et al. (1972) made the following crosses, producing 100% males:

Sarotherodon macrochir	x	*Sarotherodon niloticus*
Sarotherodon hornorum	x	*Sarotherodon niloticus*
Sarotherodon honorum	x	*Sarotherodon mossambicus*

Balarin (1979) reports that cichlid populations are often controlled by predators. Some predators which are commonly used are the Nile perch (*Lates niloticus*), the bagrid catfish (*Bagrus docmac*), the cichlid (*Hemichromis faciatus*), and the largemouth bass (*Micropterus salmoides*). There are several problems in using predators for cichlid population control. One of the most efficient predators, the Nile perch, is unable to reproduce in ponds, and is very difficult to obtain. The cichlid (*Hemichromis fasciatus*), is too prolific, pushing the carrying capacity of a pond beyond its tolerance limits. Other problems involve estimating the proper ratio between predator and prey species. Generally, 2-3% of the total stock is made up of the predator (Balarin 1979).

Another method used for population control of cichlids, in culture situations, is sexual modification. Two means used for sexual modification are irradiation, still in an experimental stage, and sex reversal. Several compounds have been tested for use in sex reversal. Methallibure (N-methyl-N'-(1-methyl-2-propenyl)-1, 2-hydrazinedicarbothioamide) coated pellets are easily used, but this compound has been removed from the market because of danger to women (Scott 1977, cited by Balarin 1979). Methyltestosterone, administered during the first 69 days of life converted 95% of the females tested to males. The hormone is completely metabolized so the fish can then be used as food (Balarin 1979).

Cage culture is another method which has been developed for controlling cichlid populations. Again, this method is not suitable for use in natural systems. Caged fish, if able to spawn, may not fertilize their eggs because the cages affect their behavior. In addition, the egg may fall through the cages, in which case mouth-brooders have no firm substrate on which to place the eggs before picking them up.

Temperature shock treatment has also been studied as a mechanism of population control in culture situations. After a cold shock of a temperature change from 32° to 11° C for one hour, 75 percent of the fry were polyploid females, which would not be able to produce viable young in the next generation (Balarin 1979).

Pond draining is another control strategy for culture situations. In this method, just after the brood fish release the fry, the pond is drained, with the parents being retained. The pond is then refilled. This process is repeated at two week intervals to maintain population numbers and supply fry for other uses (Chaudhari 1967).

Methods used in population control of cichlids in natural systems include dragging the pond and excessive stocking. Drag chains are not 100 percent effective in destroying the nests and eggs and greatly disturbs the habitat. Allison et al. (1976) found that an inverse relationship existed between the number of fry of the blue tilapia and initial stocking density and that stocking up to 200,000 fish/ha eliminated reproduction.

CONCLUSIONS

Members of the cichlid family, once found only in tropical waters, seem to be adapting to life in the subtropical waters into which they have been introduced. The introductions have occurred with increasing rapidity since the late 1950's. The range of this family in the United States, once restricted to South Texas and peninsular Florida, has expanded. They can not be found in the southern portions of the gulf states, Arizona, New Mexico, and California, as well as other, more northern states. Fortunately, the widespread introductions of these fishes has slowed during the past several years as adverse consequences of their introductions have become apparent.

Geographic variation does not appear to be a major factor in the identification of the blue tilapia (Sarotherodon aureus) or Rio Grande Perch (Cichlasoma cyanoguttatum). However, variations between samples reported to be Mozambique mouthbrooders (Sarotherodon mossambicus) could be attributable to geographic variation, or misidentification.

Sexual dimorphism was not apparent in the specimens examined for this study. Chervinski and Stickney (unpub. paper) report that sexual dimorphism does occur in several species of cichlids which they attributed to the males being larger than females because of less energy lost to reproduction.

Because of the distance between groups of samples and the inability of the NT-SYS program to separate these groups, we can determine reasonable relationships for several samples. It can be postulated that those samples which lie intermediate or do not fall as would be expected (in other words, as identified) between definite groups are: (1) hybrids of two distinguishable clusters; (2) good biological species which are poorly differentiated by external characters; or (3) misidentified.

At this point, more work is necessary to conclusively identify the specimens examined. Examinations of type specimens of the species in question will facilitate allocations of these specimens.

LITERATURE CITED

Allanson, B.R., A. Bok, and N. I. van Wyk. 1971. The influence of exposure to low temperature on Tilapia mossambica Peters (Cichlidae). II. Changes in serum osmolarity, sodium and chloride ion concentrations. J. Fish. Biol., 3(2): 181-185.

Allison, R., Smitherman, R.D. and J. Cabero. 1976. Effects of high density culture on reproduction and yield of Tilapia aurea. FAO Tech. Conf. on Aquaculture, Kyoto, Japan. 3 pp.

Baerends, G.P. and J. M. Baerends-Van Roon. 1950. An introduction to the study of the ethology of Cichlid fishes. Behaviour, Suppl. 1:1-243.

Balarin, J.D. and J.P. Hatton. 1979. Tilapia, a guide to their biology and culture in Africa. Unit of Aquatic Pathology, University of Stirling, Stirling, Scotland. 174 pp.

Bardach, J.E., J. H. Rhyther, and W. O. McLarney. 1972. Aquaculture: The Farming and Husbandry of Freshwater and Marine Organisms. Wiley-Interscience, New York. 868 p.

Barlow, G.W. 1974. Cqntrasts in social behavior between Central American cichlid fishes and coral-reef surgeon fishes. Amer. Zool., 14:9-34.

Breder, C.M., Jr. and D.E. Rosen. 1966. Modes of reproduction in fishes. Natural History Press, Garden City, N.Y. 941 pp.

Buchannon, T.M. 1971. The reproductive ecology of the Rio Grande cichlid, Cichlosoma cynnoguttatum (Baird and Guard). Ph.D. Dissertation, Univ. of Texas, Austin. 242 p.

Buntz, J. and C.S. Manooch III. 1968. Tilapia aurea Steindachner, a rapidly spreading exotic in south central Florida. Proc. a. Conf. S. East Game and Fish Comm., p. 495-500.

Buxton, P. A. 1922. On fish and mosquitoes in Palestine. Bull. Entomol. Res. 13: 203-204. (Not actually read, cited by Courtenay, in litt.).

Chaudhari, H. 1967. Breeding and selection of cultivated warm water fishes in Asia and the Far East--a review. FAO Fish Rep., 44 (4):30-68.

Childers, W.F. and G.W. Bennett. 1967. Experimental vegetation control by largemouth bass--tilapia combinations. J. Wildl. Mgt., 31: 401-407.

Courtenay, W.R., and C.R. Robins. 1973. Exotic aquatic organisms in Florida with emphasis on fishes: a review and recommendations. Trans. Am. Fish. Soc., 102(1):1-12.

Courtenay, W.R., Jr., H.F. Sahlman, W.W. Milig, II and D.J. Heirema. 1979. Exotic fishes in fresh and brackish waters of Florida. Biol. Conserv. 6(4):292-302.

Daget, J. 1952. Observations sur la ponte de Tilapia zillii Gervais, poisson de la famille des Chilaids. Ann. Mag. Nat. Hist., 5(12):309-310.

Darnell, R.M. 1967. Fishes of the Rio Tamesi and related coastal lagoons in east-central Mexico. Publ. Inst. Mar. Sci., Texas. 8:300-365.

Eddy, S. and J.C. Underhill. 1957. How to know the freshwater fishes. Wm. C. Brown, Dubuque, Iowa. 215 pp.

Elder, H.Y. 1960. The breeding of Tilapia zillii. East African Fresh. Fish. Res. Org. Ann. Rept. 1960. Diamond Press Ltd., Nairobi. pp. 21-22.

Fagoade, S.O. 1971. The food and feeding habits of Tilapia species in the Lagos Lagoon. J. Fish. Biol., 3:151-156.

Finucane, J.H., and G.R. Rinckey. 1964. A study of the African cichlid, Tilapia heudeltoi (Dumerit) in Tampa Bay, Florida. 19th Ann. Meet. SE Assoc. Game and Fish Comm.

Fishelson, L. (1967). Cichlidae of the genus Tilapiain Israel, Bamidgeh 10 (3-4) 67-80.

Foote, K.G. 1977. Preliminary status investigations of blue tilapia. State of Florida Annual Performance Report.

Frey, H. 1961. Illustrated dictionary of tropical fishes, T.F.A. ublications, Inc., Jersey City. 768 pp.

Fryer, G. and T.D. Iles. 1972. The cichlid fishes of the great Lakes of Africa. Oliver and Boyd, Edinburgh. 641 pp.

Gilmore, R.G., Jr. 1977. Fishes of the Indian River Lagoon and adjacent waters, Florida, Bull. Fla. State Mus., Biol. Sci., 22 (3):101-148.

Gleastine, B.W. 1974. A study of the cichlid Tilapia aurea (Steindachner) in a termally modified reservoir. M.S. Thesis, Texas A&M University. 258 pp.

Hickling, C.F. 1963. The cultivation of Tilapia. Scient. Am., 208 (5): 143-148, 150-152.

Hogg, R.G. 1976. Established exotic cichlid fishes in Dade County, Florida. Fla. Sci. 39 (2):97-103.

Hogg, R.G. 1976a. Ecology of fishes of the family cichlidae introduced into the fresh waters of Dade County, Florida. Ph.D. Dissertation, University of Miami, Coral Gables. 142 pp.

Hubbs, Clark. 1951. Minimum temperature tolerancies for fishes of the general signalosa and nerichthip in Texas. Copeia. 1951 (4):297.

Hubbs, and J.E. Seacon. 1964. Additional introductions of tropical fishes into southern Nevada. Southwestern Naturalists 9(4):249-251.

Hubbs, C. 1968. An opinion on the effects of cichlid releases in North America. Trans. Am. Fish Soc. 97(2) 197-198.

Hubbs, C., T. Lucier, G.P. Garrett, R.J. Edwards, S.M. Dean, and E. Marsh. 1978. Survival and abundance of introduced fishes near San Antonio, Texas. Texas J. Sci., 30 (4):369-376.

Huet, M. 1955. Culture of Tilapia. Lecture, expanded Technical Assistance Program, International Inland Fisheries Training Center, Bogor, Indonesia, No. 5. 65.

Kelly, H.E. 1956. Preliminary studies of Tilapia mossambica Peters relative to experimental pond culture. Proc. Ann. Conf. S. East Assoc. Game and Fish Comm., 1956, 10:139-149.

Knapp, E.H. 1977. Status of the genus Tilapia in California's estuarine and marine waters. Cal-Neva Wildlife Transactions 1977.

Kushlan, J.A. 1972. The exotic fish (aequidens portalgrensis) in the Big Cypress swamp. Fla. Nat., 45: 29.

Lachner, E.A., Robins, C.R. and W.R. Courtenay. 1970. Exotic fishes and other aquatic organisms introduced into North America. Smithsonian Contr. Zool. No 59, 1970: 1-29.

Lowe-McConnell, R.H. 1975. Fish communities in tropical freshwaters. Longman, London, 337 pp.

McBay, L.G. 1961. The biology of Tilapia nilotica (Linnaeus), Proc. Ann. Conf. S.E. Assoc. Game and Fish Comm. 15 :208-218.

Magnuson, J.J. 1976. Managing with exotics. - a game of chance. Trans Am. Fish. Soc. 105: 1(1-9).

Manooch, C.S., III. 1977. Culturing, a method used to identify algae ingested by tilapia. Southeastern Assoc. of Game and Fish Comm. Proc. 25th Ann Conf.: 626-635.

Mullio, R.R. 1966. Geographical distribution of central American freshwater fishes. Copeia, 1966 (4): 733-802.

Minckley, W.L. 1973. Fishes of Arizona. Ariz. Game and Fish Dept. Pheonix. 293 pp.

Moyle, P.B. 1976. Inland fishes of California. Univ. Calif. Press, Berkeley. 405 pp.

Noble, R.L., R.D. Germany, and C.R. Hall, 1976. Interactions of blue tilapia and largemouth bass in a power plant cooling reservoir. Southeastern Assoc. of Game and Fish Comm. Proc. 25th Ann. Conf.: 247-251.

Pauly, D. 1976. The biology, fishery, and potential for aquasulture of Tilapia melanotheron in a small West African Lagoon. Agriculture 7: 33-49.

Regan, C.T. 1905. A revision of the fishes of the American cichlid genus *Cichlasoma* and of the allied genera. Ann Mag. Nat. Hist. (serv. 7), 16: 60-77, 252-243, 316-340, 443-445.

Rivas, L.R. 1965. Florida freshwater fishes and conservation. Quart. J. Fla. Acad. Sci., 28 (3) 225-258.

Scott, P.W. 1977. Preliminary studies on diseases in intensively farmed *Tilapia* in Kenya. M.S. Thesis, Stirling University, Scotland. 159 pp. (not actually read, cited from Balarin 1979).

Shaffand, P.L. 1978. A Status report on Tilapia in Florida. Contrib No. 16, Non-Native Fish Research Laboratory, Florida Game and Fish Water Comm. 5 pp.

Sneath, P.H.A., and R.R. Sokal. 1973. Numerical Taxonomy. W.H. Freeman and Co., San Franscisco. 573 pp.

Sterba, G. 1963. Freshwater fishes of the world. Viking Press, New York. 878 pp.

Stickney, R.R. 1979. Principles of warm water aquaculture. Wiley-Interscience, New York. 375 pp.

Thys van den Audenaerde, D.F.E. 1968. An Annotated bibliography of *Tilapia* (Pisleg, chichlidae). Mus. Ray. Afr. Centr., Dec. Zool., 14: 1-406.

Trewavas, E. 1974. The freshwater fishes of rivers Mungo and Meni and lakes Kotto, Mboandong, and Soden, West Camerson. Bull. Brit. Mus. (Nat. Hist.), Zool., 26 (s): 331-419.

Yashouv, A., and J. Chervinski. 1961. The food of *Tilapia nilotica* in ponds of the fish culture research station at Dor.

Banmidgeh, 13:33-39.

TENTATIVE KEY TO SPECIES EXAMINED*

1a. Gill rakers 4-7 2
1b. Gill rakers 7-21 5
2a. Dorsal spines 15;
. . . . Astronotus octofasciatum
2b. Dorsal spines 15, coloration not as above. . . 2
3a. Anal spines 7-9 . . . . Cichlasoma octofasciatum
3b. Anal spines 4-5 3
4a. Posterior lateral line scales 10;
deep body; brown, speckled coloration . . . . . Cichlasoma cyanoguttatum
4b. Posterior lateral line scales 10, short
caudal peduncle . . . . Cichlasoma bimaculatum
5a. Lower pharyngeal bone about as long as
broad gill rakes 7-16 6
5b. Lower pharyngeal bone as long or longer
than broad; anterior lamella always longer
than toothed area; gill raker 12-28 7
6a. Outer teeth bicuspid and spatulate; gill
rakers 12-16. Tilapia mariae
6b. Outer teeth bicuspid, not spatulate,
gill rakers 13; dorsal and caudal
fins with yellow dots . . . . Tilapia zillii
7a. Upper margin of dorsal fin with dark margin . . . 8
7b. Upper margin of dorsal fin with transparent
to white margins 9
8a. No stripes on caudal fin; lower pharyngeal
bone almost triangular; gill rakers 18-26 . . . . Sarotherodon niloticus
8b. Pharyngeal bone heart-shaped; gill rakers 12-18 . Sarotherodon melanotheron
9a. Upper margin of dorsal fin white to red, in
sharp contrast to underlying fin parts; gill
rakers 14-23; caudal fin and body black . . . . . Sarotherodon mossambicus
9b. Upper margin of dorsal fin transparent to
reddish, not in sharp contrast to underlying
fin parts; stripes on caudal fin; triangular
or heart-shaped pharyngeal bone . . . . Sarotherodon aureus

* From Chervinski and Stickney (unpublished), Thys van den Audenaerde (1968), and data obtained through examinations of species.