ECOLOGICAL PROFILES FOR SELECTED STREAM-DWELLING TEXAS FRESHWATER FISHES II

A Report
to
The Texas Water Development Board

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Introduction

One major goal of the Water Development Board's research, monitoring, and assessment programs is to minimize the effects of water development projects on the affected native aquatic fauna and to maintain the quality and availability of instream habitats for the use of dependent aquatic resources. The instream flows necessary for the successful survival, growth and reproduction of affected aquatic life are a major concern. Unfortunately, instream flow data with respect to the ecological requirements of Texas riverine fishes are largely unknown. While some information can be found in the published literature, a substantial but unknown quantity of information is also present in various agencies and research museums around the state. In order to minimize the disruptions to the native fauna, quantitative and qualitative information concerning life histories, survival, growth, reproduction, and habitat utilization is needed. Also of importance is the nature of the habitats that these lotic species inhabit, especially during critical life stages. Some habitat features that are known to influence certain fishes include: water depth, current speed, cover, substrate size and type, and stream widths.

The purpose of this study is to develop species profiles, primarily from the literature (published and unpublished), personal observations from established researchers and museum records for nineteen obligate or mostly obligate riverine species. Nineteen of these profiles include qualitative and quantitative information, so far as known, relating to the factors which influence the survival, growth, and reproduction of these species in Texas streams appear in a previous volume (Edwards, R. J. 1997. “Ecological profiles for selected stream-dwelling Texas freshwater fishes”).

In Part Two of this report series, additional information has been gathered to augment the discussion found in Part One. Species accounts are presented for six species not covered in the first report including a new species discovered in the course of completing this contract in the vicinity of Del Rio, and additional information about a seventh species, which was previously reported but for which nearly no life history information was available. Similar to the first report, efforts were made to determine which life history factors are unknown but which are likely contributors to the continued survival of these riverine fishes in order to direct future studies by the TWDB. Finally, an additional analysis of previously reported data by Longley et al. (1998) was conducted to aid the TWDB in their correlation of these present reports with other researcher's findings.

Analysis of Previous Microhabitat Utilization and Fish Surveys

During the review process of a previous report to the Texas Water Development Board (Edwards 1997), it was noted that not enough consideration was paid to the series of reports Longley et al. (Longley et al. 1998a, b, and c). These are herein reviewed. The Longley studies were conducted by electroshocking in different habitats in Cibolo Creek, the Guadalupe River and San Antonio River in the southeast-central Texas area. The results were reported using modified area (importance) diagrams that are meant to accentuate and illustrate shared relative abundance and habitat characteristics of the species captured. Unfortunately, the circles formed from this analysis often overlap neighboring, but unrelated categories of species and habitat types. This would not be a problem if categories of species and habitats were gradational, however, this is not the case for microhabitats in aquatic environments or the organisms involved. For this reason, the data for the fish habitat utilization's presented in Longley's studies were recalculated back into their original relative percentages for analysis. Two series are shown for each environment: a summary of the overall data for each stream surveyed (Tables 1-3) and in depth analysis of the more abundant species taken broken down by different flow regimes (Tables 4-6).

In Cibolo Creek, 22 species of fishes were taken in 15 different microhabitats types. In the San Antonio and Guadalupe Rivers, 24 species of fishes were taken in 17 different microhabitat types. It would be expected that more species and more microhabitats would be found in the two larger rivers than would be found in the smaller Cibolo Creek.

It appears from an analysis of Tables 4-6 that pools, backwaters, riffles, undercut banks and snag-type microhabitats are important habitats for fishes. Runs, although used by various species, are not as often used. These results would be expected from an electrofishing study where a boat traveling through a stream, would cause fishes to seek shelter wherever they could. This is not a not critique of this method of fish collecting, only a reiteration of what is already known.

Table 1. Cibolo Creek Overall Percentages from All Collections and Flow Regimes -- Summary Data

Species	Undercut Bank	Bank Snag	Eddy Pool	Pool	Run-bank Snag	Backwater	Channel Snag	Edge	Pool-Channel Snag	Riffle	Run	Snag	Run-channel Snag	Pool-Bank Snag	Pool-Snag Complex	N Collections	N Specimens
Anguilla rostrata	100.0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	1
Lepisosteus osseus	---	100.0	---	---	---	---	---	---	---	---	---	---	---	---	---	3	3
Dorosoma cepedianum	---	100.0	---	---	---	---	---	---	---	---	---	---	---	---	---	1	1
Astyanax mexicanus	---	---	40.0	40.0	20.0	---	---	---	---	---	---	---	---	---	---	2	5
Cyprinella lutrensis	6.5	10.9	6.5	15.2	---	6.5	13.0	10.9	6.5	10.9	6.5	6.5	---	---	---	10	46
Notropis stramineus	---	---	---	16.7	---	---	33.3	33.3	---	---	16.7	---	---	---	---	4	6
Notropis volucellus	---	16.7	---	16.7	---	16.7	---	33.3	---	16.7	---	---	---	---	---	7	12
Pimephales vigilax	5.3	10.5	5.3	21.1	5.3	5.3	13.2	18.4	---	---	13.2	2.6	---	---	---	9	38
Campostoma anomalum	---	---	---	---	---	---	---	---	---	---	100.0	---	---	---	---	2	2
Moxostoma congestum	---	14.3	---	---	42.9	---	---	---	---	---	42.9	---	---	---	---	4	7
Ictiobus bubalus	3.8	23.1	---	15.4	11.5	7.7	7.7	---	---	3.8	19.2	7.7	---	---	---	9	26
Pylodictis olivaris	12.5	37.5	---	25.0	---	---	25.0	---	---	---	---	---	---	---	---	5	8
Ameirus natalis	30.0	---	---	20.0	---	---	---	---	20.0	20.0	---	---	10.0	---	---	4	10
Gambusia affinis	8.7	13.0	---	8.7	---	17.4	8.7	17.4	8.7	---	8.7	---	---	8.7	---	7	23
Poecilia latipinna	---	18.2	---	22.7	---	---	18.2	4.5	---	9.1	18.2	---	---	9.1	---	7	22
Micropterus salmoides	---	40.0	---	40.0	20.0	---	---	---	---	---	---	---	---	---	---	4	5
Lepomis gulosus	---	---	---	---	---	---	---	---	---	33.3	33.3	33.3	---	---	---	2	6
Lepomis auritus	---	---	---	---	---	---	---	---	---	---	100.0	---	---	---	---	1	1
Lepomis macrochirus	22.6	9.7	---	6.5	---	12.9	12.9	22.6	---	---	9.7	---	3.2	---	---	9	31
Lepomis megalotis	7.5	13.2	---	9.4	9.4	11.3	9.4	11.3	1.9	5.7	9.4	7.5	1.9	---	1.9	10	53
Etheostoma spectabile	---	---	---	---	---	---	---	33.3	---	33.3	33.3	---	---	---	---	3	6
Cichlasoma cyanoguttatum	11.9	9.5	---	7.1	9.5	11.9	4.8	14.3	7.1	4.8	9.5	2.4	---	7.1	---	8	42

Table 2. San Antonio River Overall Percentages from All Collections and Flow Regimes -- Summary Data

Species	Pool	Chute	Rapid	Pool Root Wad	Run	Run Undercut Bank	Riffle Bank Snag	Backwater	Riffle	Riffel Snag Complex	Riffle Channel Snag	Eddy Pool	Pool Bank Snag	Pool Snag Complex	Pool Channel Snag	Run Bank Snag	Run Channel Snag	N Collections	N Specimens
Lepisosteus oculatus	21.5	---	---	6.9	16.7	8.3	6.9	9.0	4.2	0.7	8.3	---	6.3	---	7.6	3.5	---	8	144
Dorosoma cepedianum	---	---	---	25.0	25.0	---	---	---	50.0	---	---	---	---	---	---	---	---	3	8
Campostoma anomalum	---	---	---	---	100.0	---	---	---	---	---	---	---	---	---	---	---	---	1	1
Cyprinella lutrensis	23.5	3.0	5.7	14.3	7.0	3.5	9.6	9.1	6.1	3.9	8.7	---	---	0.4	0.4	4.3	0.4	11	230
Notropis stramineus	5.3	---	4.2	17.9	4.2	23.2	21.1	10.5	---	---	12.6	---	---	---	---	---	1.1	10	95
Pimephales vigilax	100.0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	2
Ictiobus bubalus	36.6	7.3	43.9	12.2	---	---	---	---	---	---	---	---	---	---	---	---	---	1	41
Minytrema melanops	42.9	---	14.3	---	---	---	28.6	---	---	---	---	---	---	---	---	14.3	---	5	7
Moxostoma congestum	---	---	---	---	33.3	---	---	---	33.3	33.3	---	---	---	---	---	---	---	2	6
Erimyzon oblongus	38.5	7.7	---	---	---	7.7	30.8	---	---	---	15.4	---	---	---	---	---	---	6	13
Poecilia latipinna	6.8	8.5	5.1	11.9	3.4	6.8	16.9	30.5	---	---	3.4	---	3.4	---	3.4	---	---	8	59
Gambusia affinis	18.0	---	---	0.8	23.4	---	26.6	---	17.2	---	6.3	---	7.8	---	---	---	---	7	128
Lepomis auritus	---	---	---	---	100.0	---	---	---	---	---	---	---	---	---	---	---	---	2	2
Lepomis gulosus	---	---	---	---	30.0	---	30.0	---	---	---	---	---	---	---	---	40.0	---	4	10
Lepomis macrochirus	31.8	---	---	9.1	4.5	---	---	---	---	---	54.5	---	---	---	---	---	---	4	22
Lepomis megalotis	38.1	11.2	5.8	2.7	1.9	3.1	12.7	4.2	3.5	2.7	5.4	1.5	---	---	7.3	---	---	11	260
Lepomis microlophus	21.7	---	---	26.1	---	---	8.7	34.8	8.7	---	---	---	---	---	---	---	---	8	23
Lepomis punctatus	31.3	17.6	5.6	11.3	4.2	0.7	9.2	7.7	---	0.4	9.9	0.7	---	---	---	1.4	---	10	284
Micropterus punctulatus	27.3	---	---	---	---	40.9	---	---	9.1	---	---	---	---	---	18.2	---	4.5	4	22
Micropterus treculi	30.3	11.0	23.9	---	9.2	0.9	9.2	5.5	0.9	1.8	3.7	---	---	---	---	3.7	---	10	109
Percina macrolepida	22.2	---	---	---	---	---	---	---	---	---	---	74.1	---	---	---	3.7	---	2	27
Etheostoma spectabile	---	---	---	---	---	---	100.0	---	---	---	---	---	---	---	---	---	---	1	1
Cichlasoma cyanoguttatum	---	---	---	---	---	---	100.0	---	---	---	---	---	---	---	---	---	---	3	3
Mugil cephalus	---	---	---	---	---	100.0	---	---	---	---	---	---	---	---	---	---	---	1	2

Table 3. Guadalupe River Overall Percentages from All Collections and Flow Regimes -- Summary Data

Species	Pool	Pool Root Wad	Run	Run Undercut Bank	Riffle Bank Snag	Backwater	Riffle	Riffel Snag Complex	Riffle Channel Snag	Eddy Pool	Glide	Run Root Wad	Pool Bank Snag	Pool Undercut Bank	Pool Snag Complex	Pool Channel Snag	Pool Debris Dam	N Collections	N Specimens
Dorosoma cepedianum	6.1	8.1	---	---	2.0	---	---	26.3	25.3	28.3	---	---	---	2.0	---	2.0	---	12	99
Lepisosteus oculatus	---	---	---	---	---	---	---	50.0	50.0	---	---	---	---	---	---	---	---	4	4
Cyprinella lutrensis	---	0.2	2.2	9.3	4.8	0.3	5.4	1.9	20.2	0.3	45.7	---	2.7	4.2	---	1.8	0.9	13	1160
Hybopsis aestivalis	---	---	---	---	---	---	38.2	---	---	---	61.8	---	---	---	---	---	---	2	131
Notropis volucellus	---	3.8	7.7	---	---	---	46.2	---	3.8	---	38.5	---	---	---	---	---	---	6	26
Pimephales vigilax	---	4.8	---	---	---	9.5	9.5	4.8	---	---	71.4	---	---	---	---	---	---	7	42
Astyanax mexicanus	---	---	---	14.3	57.1	---	---	---	28.6	---	---	---	---	---	---	---	---	4	14
Ictiobus bubalus	5.7	5.7	15.2	---	13.3	1.9	1.9	11.4	21.0	5.7	---	3.8	2.9	1.9	1.0	8.6	---	12	105
Moxostoma congestum	---	---	35.7	---	---	---	---	---	21.4	---	---	---	---	---	---	42.9	---	4	14
Ameirus natalis	---	---	---	---	---	---	99.0	---	---	1.0	---	---	---	---	---	---	---	3	202
Ictalurus punctatus	---	---	---	---	8.3	---	---	---	50.0	8.3	4.2	4.2	16.7	4.2	---	4.2	---	10	24
Pylodictis olivaris	---	---	---	---	---	50.0	---	---	50.0	---	---	---	---	---	---	---	---	4	4
Gambusia affinis	---	---	---	---	---	100.0	---	---	---	---	---	---	---	---	---	---	---	2	2
Lepomis auritus	---	50.0	---	---	---	---	50.0	---	---	---	---	---	---	---	---	---	---	1	2
Lepomis cyanellus	---	---	---	20.0	40.0	20.0	---	20.0	---	---	---	---	---	---	---	---	---	7	10
Lepomis gulosus	---	---	---	---	---	---	---	---	100.0	---	---	---	---	---	---	---	---	2	4
Lepomis macrochirus	---	15.8	---	28.9	---	5.3	10.5	10.5	7.9	---	---	---	7.9	5.3	5.3	2.6	---	10	38
Lepomis megalotis	---	4.4	---	22.2	6.7	13.3	4.4	22.2	4.4	6.7	---	4.4	4.4	---	---	4.4	2.2	13	45
Lepomis microlophus	---	---	---	---	---	---	---	---	100.0	---	---	---	---	---	---	---	---	3	3
Micropterus salmoides	---	17.4	8.7	8.7	---	---	17.4	8.7	17.4	---	---	8.7	---	13.0	---	---	---	11	23
Micropterus treculi	---	42.9	---	11.4	11.4	8.6	14.3	---	11.4	---	---	---	---	---	---	---	---	4	35
Pomoxis annularis	---	---	---	100.0	---	---	---	---	---	---	---	---	---	---	---	---	---	2	2
Cichlasoma cyanoguttatum	---	---	---	---	---	---	---	66.7	33.3	---	---	---	---	---	---	---	---	3	6
Mugil cephalus	---	---	---	---	37.5	---	12.5	25.0	25.0	---	---	---	---	---	---	---	---	6	8

Table 4. Cibolo Creek -- Most abundant species by different flow regimes.

Cyprinella lutrensis	Pool	Root Wad	Run	Undercut Bank	Bank Snag	Backwater	Riffle	Snag Complex	Channel Snag	Eddy Pool	Pool-Channel Snag	Total Specimens	Total Collections
Low	---	3.6	3.6	---	53.6	---	3.6	---	3.6	---	32.1	28	1
Medium	32.7	3.5	3.5	7.1	15.0	5.3	7.1	6.2	8.0	2.7	8.8	113	8
High	57.1	3.6	---	---	3.6	17.9	---	---	14.3	3.6	---	28	1

Notropis volucellus	Pool	Root Wad	Bank Snag	Backwater	Riffle	Total Specimens	Total Collections
Low	---	---	---	---	100.0	1	1
Medium	8.3	33.3	16.7	33.3	8.3	12	5
High	14.3	28.6	---	57.1	---	7	1

Pimephales vigilax	Pool	Root Wad	Run	Undercut Bank	Bank Snag	Backwater	Snag Complex	Channel Snag	Eddy Pool	Run-Bank Snag	Total Specimens	Total Collections
Low	60.0	13.3	26.7	---	---	---	---	---	---	---	15	1
Medium	28.2	20.9	5.5	1.8	13.6	10.0	0.9	15.5	0.9	2.7	110	7
High	26.7	11.7	3.3	---	18.3	18.3	---	18.3	1.7	1.7	60	1

Ictiobus bubalus	Pool	Root Wad	Bank Snag	Backwater	Riffle	Total Specimens	Total Collections
Low	---	---	---	---	100.0	1	1
Medium	8.3	33.3	16.7	33.3	8.3	12	5
High	14.3	28.6	---	57.1	---	7	1

Table 4. Cibolo Creek -- Most abundant species by different flow regimes (continued).

Gambusia affinis	Pool	Root Wad	Run	Undercut Bank	Bank Snag	Backwater	Channel Snag	Eddy Pool	Pool-Bank Snag	Pool-Channel Snag	Total Specimens	Total Collections
Low	11.1	---	11.1	---	---	55.6	---	---	11.1	11.1	9	1
Medium	2.9	14.7	2.9	11.8	29.4	26.5	5.9	---	2.9	2.9	34	5
High	---	20.0	---	---	---	80.0	---	---	---	---	5	1

Poecilia latipinna	Pool	Root Wad	Run	Bank Snag	Riffle	Channel Snag	Pool-Bank Snag	Total Specimens	Total Collections
Low	14.6	---	22.9	25.0	22.9	4.2	10.4	48	1
Medium	15.8	1.3	25.0	28.9	14.5	7.9	6.6	76	5
High	100.0	---	---	---	---	---	---	4	1

Lepomis macrochirus	Pool	Root Wad	Run	Undercut Bank	Bank Snag	Backwater	Channel Snag	Run-Channel Snag	Total Specimens	Total Collections
Low	25.0	---	25.0	---	---	50.0	---	---	4	1
Medium	1.3	19.5	3.9	28.6	26.0	6.5	13.0	1.3	77	7
High	---	16.7	---	---	---	50.0	33.3	---	6	1

Table 4. Cibolo Creek -- Most abundant species by different flow regimes (continued).

Lepomis megalotis	Pool	Root Wad	Run	Undercut Bank	Bank Snag	Backwater	Riffle	Snag Complex	Channel Snag	Pool-Bank Snag	Pool-Snag Complex	Pool-Channel Snag	Run-Bank Snag	Run-Channel Snag	Total Specimens	Total Collections
Low	34.7	1.3	18.7	5.3	5.3	6.7	10.7	1.3	---	5.3	---	6.7	4.0	---	75	2
Medium	10.1	18.6	7.8	6.2	13.2	9.3	7.0	6.2	14.0	---	0.8	0.8	5.4	0.8	129	8
High	6.3	12.5	6.3	---	6.3	50.0	---	---	12.5	---	---	---	6.3	---	16	1

Cichlasoma cyanoguttatum	Pool	Root Wad	Run	Undercut Bank	Bank Snag	Backwater	Riffle	Snag Complex	Channel Snag	Pool-Bank Snag	Pool-Channel Snag	Run-Bank Snag	Total Specimens	Total Collections
Medium	17.6	6.6	16.5	8.8	9.9	7.7	3.3	1.1	13.2	5.5	6.6	3.3	91	6
High	---	42.9	---	---	14.3	28.6	---	---	---	---	---	14.3	7	1

Table 5. San Antonio River -- Most abundant species by different flow regimes.

Lepisosteus oculatus	Pool	Pool Root Wad	Run	Run Undercut Bank	Riffle Bank Snag	Backwater	Riffle	Riffel Snag Complex	Riffle Channel Snag	Pool Bank Snag	Pool Channel Snag	Run Bank Snag	Total Specimens	Total Collections
Low	32.6	2.2	19.6	8.7	---	8.7	6.5	---	---	8.7	10.9	2.2	46	1
Medium	17.6	6.6	16.5	8.8	9.9	7.7	3.3	1.1	13.2	5.5	6.6	3.3	91	6
High	---	42.9	---	---	14.3	28.6	---	---	---	---	---	14.3	7	1

Cyprinella lutrensis	Pool	Chute	Rapid	Pool Root Wad	Run	Run Undercut Bank	Riffle Bank Snag	Backwater	Riffle	Riffel Snag Complex	Riffle Channel Snag	Pool Snag Complex	Pool Channel Snag	Run Bank Snag	Run Channel Snag	Total Specimens	Total Collections
Low	37.9	---	---	---	17.2	---	13.8	3.4	17.2	3.4	---	---	---	6.9	---	29	1
Medium	10.1	---	---	18.6	7.8	6.2	13.2	9.3	7.0	6.2	14.0	0.8	0.8	5.4	0.8	129	8
High	41.7	9.7	18.1	12.5	1.4	---	1.4	11.1	---	---	2.8	---	---	1.4	---	72	2

Notropis stramineus	Pool	Rapid	Pool Root Wad	Run	Run Undercut Bank	Riffle Bank Snag	Backwater	Riffle Channel Snag	Run Channel Snag	Total Specimens	Total Collections
Low	25.0	---	---	25.0	---	---	50.0	---	---	4	1
Medium	1.3	---	19.7	3.9	27.6	26.3	6.6	13.2	1.3	76	7
High	21.4	28.6	14.3	---	---	---	21.4	14.3	---	14	2

Poecilia latipinna	Pool	Chute	Rapid	Pool Root Wad	Run	Run Undercut Bank	Riffle Bank Snag	Backwater	Riffle Channel Snag	Pool Bank Snag	Pool Channel Snag	Total Specimens	Total Collections
Low	11.1	---	---	---	11.1	---	---	55.6	---	11.1	11.1	9	1
Medium	2.9	---	---	14.7	2.9	11.8	29.4	26.5	5.9	2.9	2.9	34	5
High	12.5	31.3	18.8	12.5	---	---	---	25.0	---	---	---	16	2

Table 5. San Antonio River -- Most abundant species by different flow regimes (continued).

Lepomis megalotis	Pool	Chute	Rapid	Pool Root Wad	Run	Run Undercut Bank	Riffle Bank Snag	Backwater	Riffle	Riffel Snag Complex	Riffle Channel Snag	Eddy Pool	Pool Channel Snag	Total Specimens	Total Collections
Low	---	---	---	3.6	3.6	---	53.6	---	3.6	---	3.6	---	32.1	28	1
Medium	32.7	---	---	3.5	3.5	7.1	15.0	5.3	7.1	6.2	8.0	2.7	8.8	113	8
High	52.1	24.4	12.6	1.7	---	---	0.8	4.2	---	---	3.4	0.8	---	119	2

Lepomis microlophus	Pool	Pool Root Wad	Riffle Bank Snag	Backwater	Riffle	Total Specimens	Total Collections
Low	---	---	---	---	100.0	1	1
Medium	8.3	33.3	16.7	33.3	8.3	12	5
High	40.0	20.0	---	40.0	---	10	2

Lepomis punctatus	Pool	Chute	Rapid	Pool Root Wad	Run	Run Undercut Bank	Riffle Bank Snag	Backwater	Riffel Snag Complex	Riffle Channel Snag	Eddy Pool	Run Bank Snag	Total Specimens	Total Collections
Low	60.0	---	---	13.3	26.7	---	---	---	---	---	---	---	15	1
Medium	28.2	---	---	20.9	5.5	1.8	13.6	10.0	0.9	15.5	0.9	2.7	110	7
High	30.8	31.4	10.1	4.4	1.3	---	6.9	6.9	---	6.9	0.6	0.6	159	2

Micropterus treculi	Pool	Chute	Rapid	Run	Run Undercut Bank	Riffle Bank Snag	Backwater	Riffle	Riffel Snag Complex	Riffle Channel Snag	Run Bank Snag	Total Specimens	Total Collections
Low	---	---	---	20.0	---	60.0	---	---	---	---	20.0	5	1
Medium	21.2	---	---	24.2	3.0	15.2	9.1	3.0	3.0	12.1	9.1	33	7
High	36.6	16.9	36.6	1.4	---	2.8	4.2	---	1.4	---	---	71	2

Table 6. Guadalupe River -- Most abundant species by different habitats. Shown are percent occupation of different habitats under three flow regimes.

Dorosoma cepedianum	Pool	Pool Root Wad	Riffle Bank Snag	Riffel Snag Complex	Riffle Channel Snag	Eddy Pool	Pool Undercut Bank	Pool Channel Snag	Total Specimens	Total Collections
Low	---	---	---	6.3	6.3	81.3	6.3	---	32	3
Medium	17.1	---	5.7	11.4	60.0	---	---	5.7	35	4
High	---	25.0	---	62.5	6.3	6.3	---	---	32	5

Cyprinella lutrensis	Pool Root Wad	Run	Run Undercut Bank	Riffle Bank Snag	Backwater	Riffle	Riffel Snag Complex	Riffle Channel Snag	Eddy Pool	Glide	Pool Bank Snag	Pool Undercut Bank	Pool Channel Snag	Pool Debris Dam	Total Specimens	Total Collections
Low	---	---	---	---	---	1.1	2.2	94.4	---	---	2.2	---	---	---	89	4
Medium	---	---	10.4	20.8	---	19.7	0.7	5.2	---	11.2	9.3	11.5	7.4	3.7	269	4
High	0.2	3.2	10.0	---	0.5	1.1	2.2	17.0	0.5	62.3	0.5	2.2	0.1	---	802	5

Pimephales vigilax	Pool Root Wad	Backwater	Riffle	Riffel Snag Complex	Glide	Total Specimens	Total Collections
Low	---	---	100.0	---	---	1	1
Medium	40.0	---	60.0	---	---	5	3
High	---	11.1	---	5.6	83.3	36	3

Table 6 (continued). Guadalupe River -- Most abundant species by different habitats. Shown are percent occupation of different habitats under three flow regimes.

Ictiobus bubalus	Pool	Pool Root Wad	Run	Riffle Bank Snag	Backwater	Riffle	Riffel Snag Complex	Riffle Channel Snag	Eddy Pool	Run Root Wad	Pool Bank Snag	Pool Undercut Bank	Pool Snag Complex	Pool Channel Snag	Total Specimens	Total Collections
Low	---	8.7	---	17.4	---	---	17.4	30.4	---	17.4	8.7	---	---	---	23	4
Medium	---	---	10.5	42.1	---	---	---	10.5	---	---	---	---	---	36.8	19	3
High	9.4	6.3	21.9	3.1	3.1	3.1	12.5	21.9	9.4	---	1.6	3.1	1.6	3.1	64	5

Ictalurus punctatus	Riffle Bank Snag	Riffle Channel Snag	Eddy Pool	Pool Bank Snag	Pool Undercut Bank	Pool Channel Snag	Run Debris Dam	Run Bank Snag	Total Specimens	Total Collections
Low	---	66.7	---	33.3	---	---	---	---	6	3
Medium	33.3	33.3	---	---	16.7	16.7	---	---	6	3
High	---	50.0	16.7	16.7	---	---	8.3	8.3	12	4

Lepomis macrochirus	Pool Root Wad	Run Undercut Bank	Backwater	Riffle	Riffel Snag Complex	Riffle Channel Snag	Pool Bank Snag	Pool Undercut Bank	Pool Snag Complex	Pool Channel Snag	Total Specimens	Total Collections
Low	15.4	23.1	15.4	7.7	15.4	7.7	15.4	---	---	---	13	3
Medium	22.2	44.4	---	16.7	---	11.1	---	---	---	5.6	18	4
High	---	---	---	---	28.6	---	14.3	28.6	28.6	---	7	3

Table 6. Guadalupe River -- Most abundant species by different habitats. Shown are percent occupation of different habitats under three flow regimes.

Lepomis megalotis	Pool Root Wad	Run Undercut Bank	Riffle Bank Snag	Backwater	Riffle	Riffel Snag Complex	Riffle Channel Snag	Eddy Pool	Run Root Wad	Pool Bank Snag	Pool Channel Snag	Pool Debris Dam	Total Specimens	Total Collections
Low	---	16.7	---	16.7	---	66.7	---	---	---	---	---	---	12	4
Medium	---	50.0	18.8	---	---	---	---	6.3	---	6.3	12.5	6.3	16	4
High	11.8	---	---	23.5	11.8	11.8	11.8	11.8	11.8	5.9	---	---	17	5

Micropterus salmoides	Pool Root Wad	Run	Run Undercut Bank	Riffle	Riffel Snag Complex	Riffle Channel Snag	Run Root Wad	Pool Undercut Bank	Total Specimens	Total Collections
Low	33.3	---	---	---	33.3	---	---	33.3	6	4
Medium	18.2	18.2	18.2	---	---	36.4	---	9.1	11	3
High	---	---	---	66.7	---	---	33.3	---	6	4

With respect to an analysis of the abundance of different species in differing flows regimes, it is my conclusion that the data presented in Longley's studies must be considered in lieu of the collecting technique. One factor missing in each of the reports is an analysis of size distributions of the captured fishes. As this is related to the age of fishes, definitive predictions of the habitat utilizations of each species is limited since fishes often show age-specific habitat changes. The technique of electroshocking fishes is also not without its own source of error. While the method is a good means of obtaining fishes in microhabitats that are difficult to sample using other methods, it is generally not known whether the fishes were using the microhabitat as a normal part of their daily range or whether they sought this habitat as a refuge from the disturbance caused by the electrofishing boat. Further exploration and analysis of this dataset would allow for a greater interpretation of the data.

Species Accounts of Selected Obligate Riverine Species

Minnows (Family Cyprinidae)

Devils River minnow—*Dionda diaboli* Hubbs and Brown 1956

Etymology:

Dionda--from the Greek *Dione*, the mother of Venus

diaboli--Latin for "devil" in reference to the type locality in the Devils River.

Identification:

Scales above lateral stripe are darkly outlined, giving a cross-hatched appearance; black spot on caudal fin base often wedge-shaped; black stripe along side, through eye and onto snout; double dashes of melanophores along lateral line; lateral line scales 32-36; head small and narrow; subinferior mouth reaches to a point below anterior nostril; eye diameter slightly greater than snout length; origin of dorsal fin slightly posterior to pelvic fin origin; intestine long and coiled; black peritoneum; pharyngeal teeth 0,4-4,0; breeding males have tubercles evenly distributed over top of head and on pectoral fin rays. Adults are typically 25 - 53 mm (Harrell 1980).

Similar species:

D. argentosa - sympatric in Devils River, Sycamore Creek and San Felipe Creek. Adults are much longer and stouter. Lateral line scales 36-41. They also lack the cross-hatched scales and double dashes along the lateral line.

D. serena - Occurs in the headwaters of the Nueces River system. Cross-hatched scale markings are present, but not as distinct as those in *D. diaboli*. Double dashes along lateral line also present. Differs in having 7 dorsal fin rays and lateral line scales 34-40.

D. episcopa - Very similar to *D. argentosa* and differs from *D. diaboli* in the same way, but this species is restricted to streams in which the previously mentioned species are not found.

Distribution:

The type locality for the Devils River minnow is at Baker's Crossing in the Devils River, Val Verde Co. Texas (Hubbs and Brown 1956). The species has also been collected from other parts of the Devils River, San Felipe and Sycamore creeks, Val Verde Co., Texas, Las Moras Creek, Kinney Co., Texas and the ríos San Carlos and Sabinas, Coahuila, Mexico. The Las Moras Creek population was extirpated (Smith and Miller 1978; Garrett et al. 1992*)* and *D. diaboli* are thought to be rare in Mexico (Miller 1978) and they face significant threats from industrial development (Contreras-Balderas and Lozano-Vilano 1994). The *D. a*rgent*osa* and *D. diaboli* sympatric species pair is one of several *Dionda* species that apparently evolved allopatrically and whose current sympatry is a the result of the often complex paleohydrology of the region (Hubbs and Miller 1977, Mayden et al. 1992).

Habitat:

Devils River minnow is apparently habitat specific, but the precise details are not known. It is often found in association with spring outflows and adjacent to rooted aquatic plants. It may be that the species inhabits a microhabitat associated with the interface between spring runs and the river (Hubbs and Garrett 1990).

Habitat losses have occurred through minimal flows in Sycamore Creek and the inundation of habitat in the lower Devils River by lakes Walk and Devils and later, by Amistad Reservoir. The perennial flow of the river is approximately 80 kilometers (50 miles), from Pecan Springs to its confluence with the Rio Grande (Taylor 1904). Many springs in the area now have diminished flows, and some (e.g., Beaver Springs, Juno Springs and Dead Man's Hole) have totally ceased flowing (Brune 1981). Many of the perennial streams reported by Gray (1919) also no longer flow. In the early 1950's, Dietz (1955) noted that pumping from irrigation wells was lowering the aquifer. Brune (1981) asserted (but provided no data) that the reduction in spring flows in this area was due to heavy pumping from wells and to overgrazed soils with lowered capacity to absorb water and thus recharge local aquifers. Local ranchers dispute Brune's (1981) assertions, stating that there has been no irrigation since 1987 and prior to that (during the 1950s to 1960s) only 80 - 200 ha (200 to 500 acres) were ever in irrigation.

Biology and Ecology:

Populations of *D. diaboli* appear to have become reduced in number and size in recent history (Garrett et al. 1992). The reasons for this decline are not well understood. Collections in the past decade by Garrett et al. (1992) and others indicate a diminution in abundance of several flowing-water species, particularly the Devils River minnow. In 1953, a collection at Baker's Crossing showed *D. diaboli* to be the fifth-most abundant fish species there and the sixth-most abundant in the upper river (Brown 1954). In the mid-1970s Harrell (1978) found the Devils River minnow to be the sixth-most abundant fish in the river . By 1989, collections from 24 locations throughout the range of the minnow yielded a total of only 7 individuals (Garrett et al. 1992). Only one fish was obtained from Baker's Crossing and no more than two were obtained at any site. In 1979, Devils River minnow made up 6-18% of the *Dionda* population at the head springs area of San Felipe Creek) in 1989, none were present.

The most recent information on the distribution and abundance of *D. diaboli* was obtained during status surveys conducted in November 1997 and May 1998. We, along with other personnel from the Texas Parks and Wildlife Department sampled the fish community at sites on the upper Devils River and San Felipe Creek. No *D. diaboli* were collected from the Devils River but they were very common in two tributaries, Dolan Creek (14 specimens) and Phillips Creek (142 specimens) and in San Felipe Creek, downstream of San Felipe Springs (more than 100 fish collected). Valdes Cantu and Winemiller (1997) reported that the species was also still present, but rare, in the Devils River at the confluence with Dolan Creek in 1994.

Although morphology (Hubbs and Brown 1956), allozymes (Mayden et al. 1992) and genome size (Gold et al. 1992) of *D. diaboli* have been well documented, little is known of life history. The species is likely to spawn in the spring with non-adhesive and demersal eggs, similar to *D. serena* (Hubbs 1951).

Nonnative species that have become established within the range of *D. diaboli* are: *Cyprinus carpio* (common carp), *Ameiurus melas* (black bullhead), *Fundulus grandis* (gulf killifish), *Poecilia latipinna* (sailfin molly), *Menidia beryllina* (inland silverside), *Lepomis auritus* (redbreast sunfish), *Lepomis microlophus* (redear sunfish), *Micropterus dolomieu* (smallmouth bass) and *Oreochromis aureus* (blue tilapia). Although fishes throughout the Chihuahuan Desert have been negatively impacted by introduced species (Hubbs 1990) and such factors as predation by smallmouth bass may cause negative impacts, specific effects on Devils River minnow have not been documented.

Conservation Status:

Because of its restricted range and low numbers (Garrett et al. 1992), *D. diaboli* is listed as threatened by the Texas Parks and Wildlife Department, the Texas Organization for Endangered Species (TOES 1995) and the Endangered Species Committee of the American Fisheries Society (Williams et al. 1989). A Conservation Agreement has been developed among the Texas Parks and Wildlife Department, the City of Del Rio and the U.S. Fish and Wildlife Service and is designed to "eliminate or significantly reduce the probability that potential threats to the minnow will actually harm this species and to recover populations of the minnow to viable levels".

Remaining populations are potentially threatened by a) loss of habitat through reduction in spring flows, b) reduction in water quality and c) predation and competition with nonnative species. However, since so little is known of the life history requirements or the ecological interactions of the Devils River minnow, it is not possible at this time to properly assess threats or fully implement recovery actions.

Texas Shiner—*Notropis amabilis* (Girard 1856)—new information

In my previous report, I noted that although the range of the Texas shiner is fairly well documented, little biological information about this species is known. Texas shiners were collected by seine from much of their range at nine different sites during July 24-26, 1997. At each site, information concerning microhabitat occupation and flow rates were recorded. This information, along with the size distributions of captured specimens is presented in Table7 and Figure 1. Texas shiners were captured at current speeds ranging from 3.0 fps to 0.1 fps if the isolated pool (with no flow) found at Sisterdale (Guadalupe River drainage) is excluded. The

Table 7. Flow and habitat characteristics for *Notropis amabilis* collected at nine sites in central Texas.

Microhabitats In Which *Notropis amabilis* were captured

Site	Habitat Description	Current Speed (fps)	Depth (m)	N Captured in Microhabitat
Blanco River south of Kyle Hwy 140 7/24/97 30C	Main channel: broad riffle; stream gravels left from recent flooding; fallen tree in midstream	2.64	0.25	35
Blanco River south of Kyle Hwy 140 7/24/97 30C	Main channel: broad riffle; stream gravels left from recent flooding; fallen tree in midstream	2.10	0.65	67
Blanco River south of Kyle Hwy 140 7/24/97 30C	below small riffle	1.17	0.40	21
Blanco River south of Kyle Hwy 140 7/24/97 30C	Shallow riffle area 3-5 m across; mod. flow above riffle; swift in riffle; stream gravel and cobbles left from recent flooding; little vegetation	0.85	0.15	10
Blanco River south of Kyle Hwy 140 7/24/97 30C	below island	0.16	1.00	8
San Marcos at Old Town 7/24/96 27C	Small stream gravels 1/2-1/3" in diameter above shall riffle off of island	1.10	0.20	11
San Marcos at Old Town 7/24/96 27C	Small stream gravels 1/2-1/3" in diameter above shall riffle off of island	0.78	0.15	10
San Marcos at Old Town 7/24/96 27C	Small stream gravels 1/2-1/3" in diameter above shall riffle off of island	0.66	0.18	17
San Marcos at Old Town 7/24/96 27C	Below riffle; larger gravels;off to side; no vegetation	0.10	0.35	123
Comal River Railroad bridge 7/24/97 26C	Midstream above sand and vegetation	0.68	0.75	8
Comal River Railroad bridge 7/24/97 26C	Width 15 m; old channel at railroad bridge off the main channel; near the flow; no vegetation; partial shade, sand and gravel	0.63	0.55	130
Guadalupe River at Sisterdale—Mouth of Sister Creek 7/25/97 28C	Evidence of large flood; mouth closed off by fallen logs and debris; water high and swift; flood up to 50 ft high.	0.00	1.20	19

Table 7. Flow and habitat characteristics for *Notropis amabilis* collected at nine sites in central Texas (continued).

Microhabitats In Which *Notropis amabilis* were captured

Site	Habitat Description	Current Speed (fps)	Depth (m)	N Captured in Microhabitat
Guadalupe River west of Hunt North Fork 7/25/99 30C	Riffle	3.00	0.70	11
Guadalupe River west of Hunt North Fork 7/25/99 30C	Quiet water on upstream side has Campostoma young; substrate-gravel, cobbles and small boulders; moving pool is where most treculi found	0.90	0.80	2
Guadalupe River west of Hunt North Fork 7/25/99 30C	Amabilis found in and adjacent to moving water; not the most turbulent; area on downstream side of islands where two riffles come together; amabilis found in midwater (0.2 m from surface) always; rarely tries to go under net; more often with venusta than lutrensis or Campostoma	0.50	0.85	140
Guadalupe River west of Hunt North Fork 7/25/99 30C	Below low water crossing; substrate of gravel and small rocks; fish at 0.2 m below surface	0.49	0.70	125
Guadalupe River west of Hunt North Fork 7/25/99 30C	Below low water crossing; substrate of gravel and small rocks; fish at 0.2 m below surface	0.28	0.80	90
Guadalupe River 5 mi E of Comfort 7/25/97 29C	Amabilis taken in side channel 3-10 m wide; below low water crossing in middle of pool rath than up against the fall of water from crossing; water covers road and plenty of evidence of recent flooding (30 ft high debris in trees)	0.50	0.40	45

Table 7. Flow and habitat characteristics for *Notropis amabilis* collected at nine sites in central Texas (continued).

Microhabitats In Which *Notropis amabilis* were captured

Site	Habitat Description	Current Speed (fps)	Depth (m)	N Captured in Microhabitat
South Llano River Tx Tech Center Rd. 7/26/97 27C	Sand and gravel left over from flood next to cut bank between two shallow pools; water travels over fine sand and gravel substrate, then drops down toward cut bank; amabilis in deeper flowing water near cut bank (ca a million amabilis); found in 5-70 cm in depth; most are just under the surface to ca 0.25 m in depth	0.63	1.00	1056
South Llano River Tx Tech Center Rd. 7/26/97 27C	Sand and gravel left over from flood next to cut bank between two shallow pools; water travels over fine sand and gravel substrate, then drops down toward cut bank; amabilis in deeper flowing water near cut bank (ca a million amabilis); found in 5-70 cm in depth; most are just under the surface to ca 0.25 m in depth	0.25	1.00	1000
South Llano River Tx Tech Center Rd. 7/26/97 27C	Sand and gravel left over from flood next to cut bank between two shallow pools; water travels over fine sand and gravel substrate, then drops down toward cut bank; amabilis in deeper flowing water near cut bank (ca a million amabilis); found in 5-70 cm in depth; most are just under the surface to ca 0.25 m in depth	0.10	1.00	56
San Saba River ca 16 km E of Mendard on Hwy 2092 7/26/97 30 C	Above a shaded pool is a long boulder and cobble riffle; stream width 10 m; riffle ends at fallen log and flows into slow moving pool around bend. Amabilis found below riffle adjacent to fastest moving water halfway between shore and midstream; slightly murky; gravel and cobble substrate; in riffles mostly C. venusta and lots of log perch	1.98	1.20	89

Table 7. Flow and habitat characteristics for *Notropis amabilis* collected at nine sites in central Texas (continued).

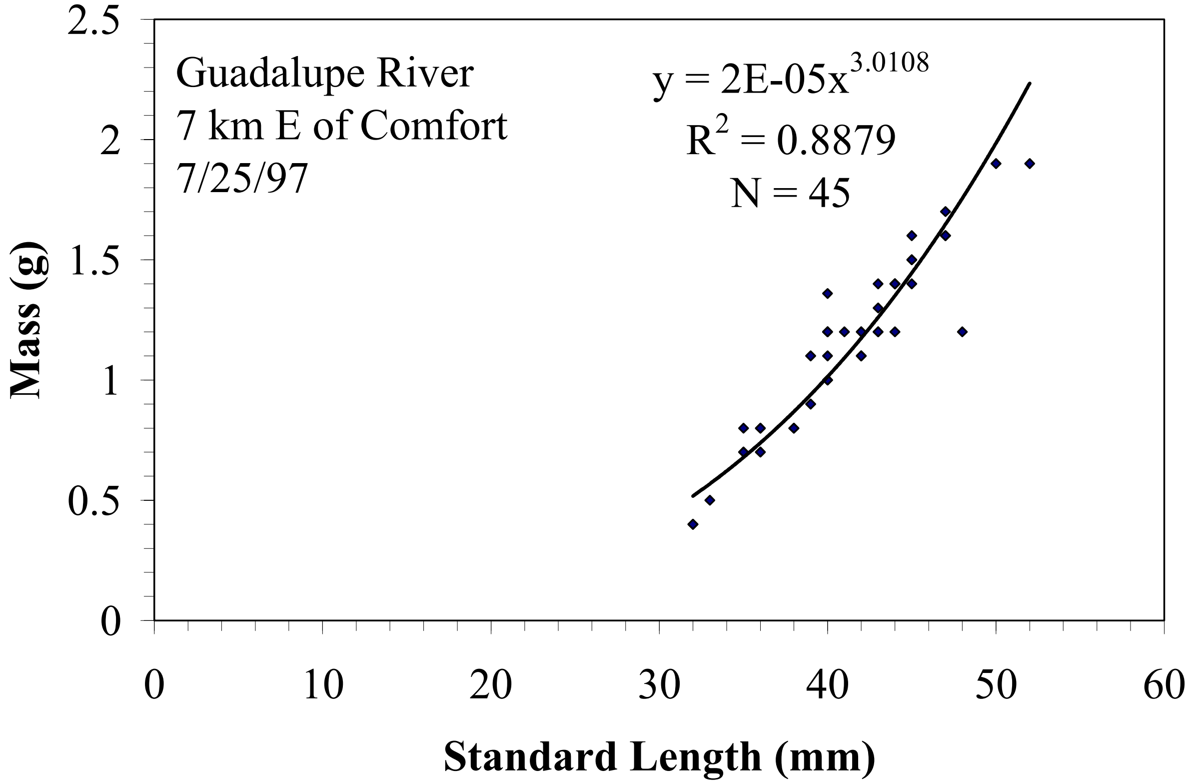
Microhabitats In Which *Notropis amabilis* were captured

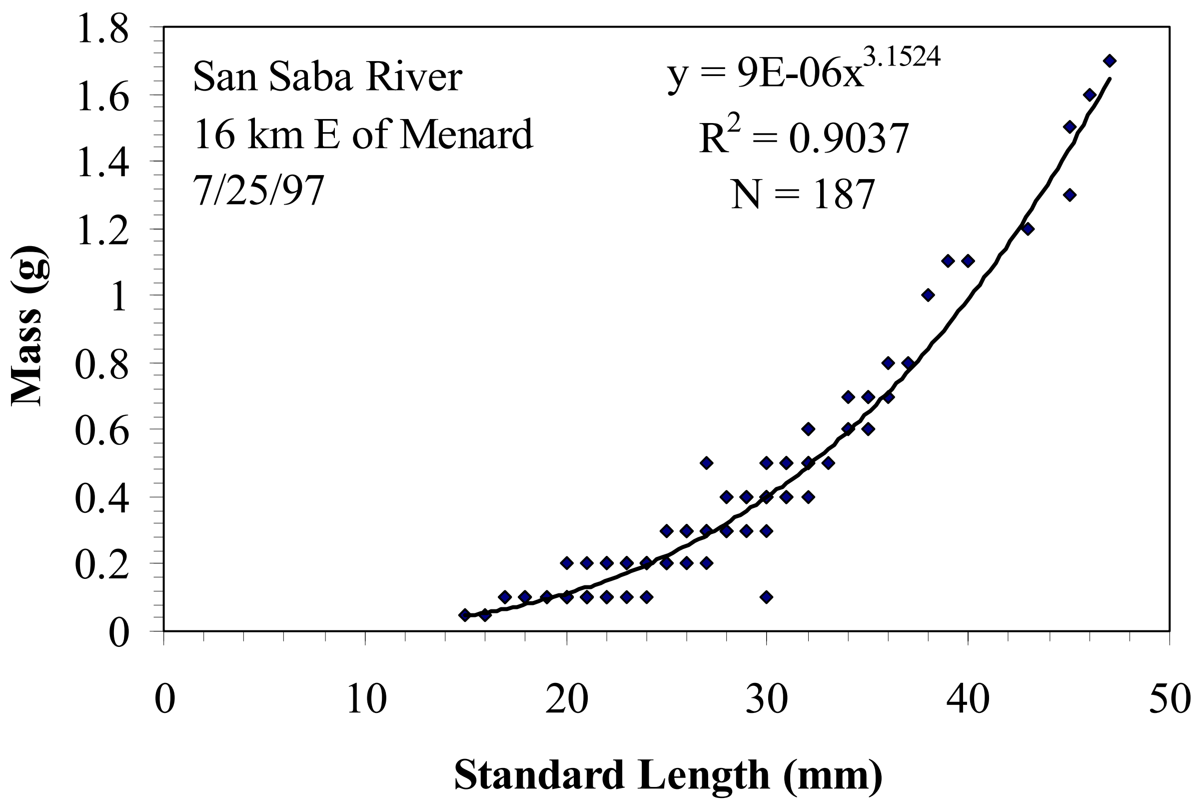
Site	Habitat Description	Current Speed (fps)	Depth (m)	N Captured in Microhabitat
San Saba River ca 16 km E of Mendard on Hwy 2092 7/26/97 30 C	Immediately above riffle at Hwy crossing; water is poinded upstream for ca 500-700m; riffle is shallow with cobbles and gravel; flow in not noticeable	0.60	0.25	26
San Saba River ca 16 km E of Mendard on Hwy 2092 7/26/97 30 C	2. Above a shaded pool is a long boulder and cobble riffle; stream width 10 m; riffle ends at fallen log and flows into slow moving pool around bend. Amabilis found below riffle adjacent to fastest moving water halfway between shore and midstream; slightly murky; gravel and cobble substrate; in riffles mostly C. venusta and lots of log perch	0.10	1.20	72
Pedernales River ca 5 mi S of Fredericksburg—Pfeister Rd. off Hwy 16 7/26/97 31 C	Alternating between riffles and pools above and below highway crossing; sand and gravel substrates; Amabilis found in eddies below low water bridge waterfall; water turbulent and slightly murky; little spring influence; lots of treculi and C. venusta	0.70	1.00	45

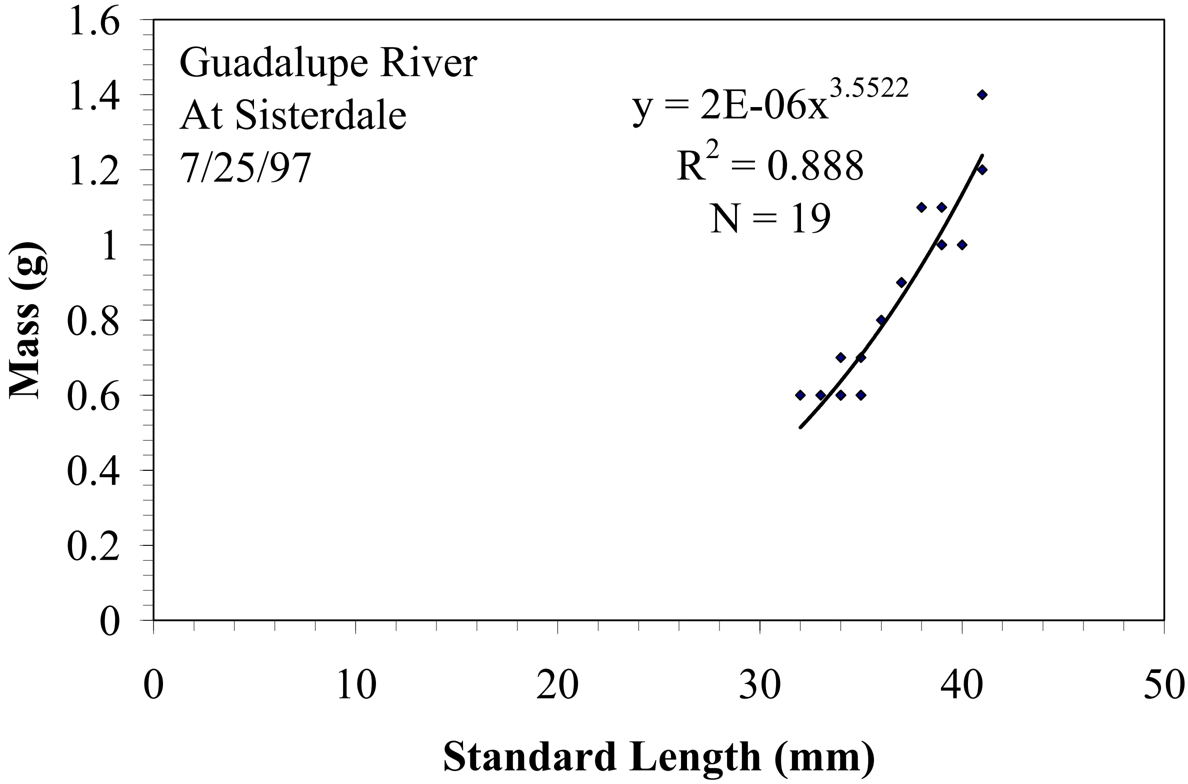
Microhabitats In Which *Notropis amabilis* were not captured

Site	Habitat Description	Current Speed (fps)	Depth (m)	N Captured at Site
Blanco River south of Kyle Hwy 140 7/24/97 30C	Limestone shelf bottom	1	0.25	0
San Marcos at Old Town 7/24/96 27C	Deeper pools; gravel substrate; large sunfish; cichlids; largemouth bass and suckers abundant	0.10	1.00	0
San Saba River east of Ft. McKavett 7/26/97 28C	Limestone shelf and gravel substrate; good population of treculi; most seine hauls had treculi and C. venusta and N. volucellus	0.20	0.50	0
Pedernales River ca 5 mi S of Fredericksburg—Pfeister Rd. off Hwy 16 7/26/97 31 C	Run	3.07	0.50	0

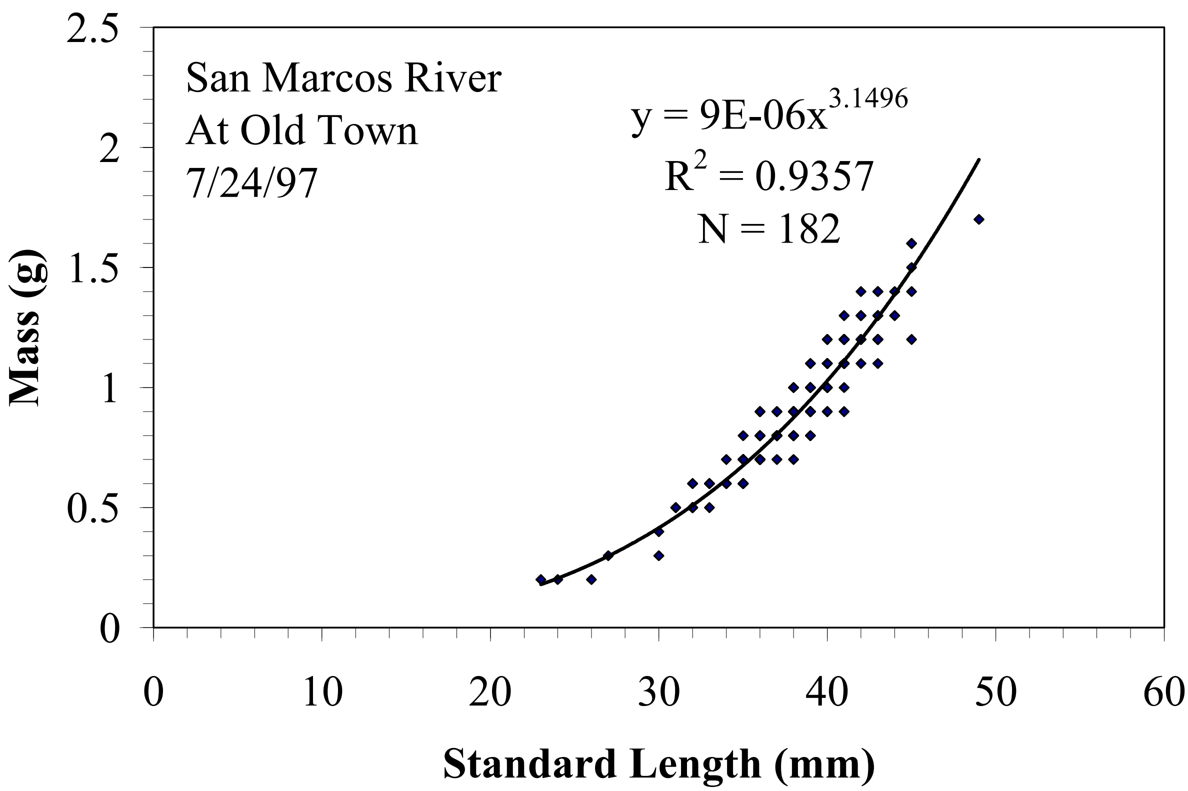
Figure 1. Standard length versus mass of *Notropis amabilis* from nine sites in central Texas. Shown for each population sampled is the best fit curve equation, correlation and sample size.


Guadalupe River
7 km E of Comfort
7/25/97
y = 2E-05x^3.0108
R^2 = 0.8879
N = 45
Mass (g)
Standard Length (mm)
0
0.5
1
1.5
2
2.5
0
10
20
30
40
50
60

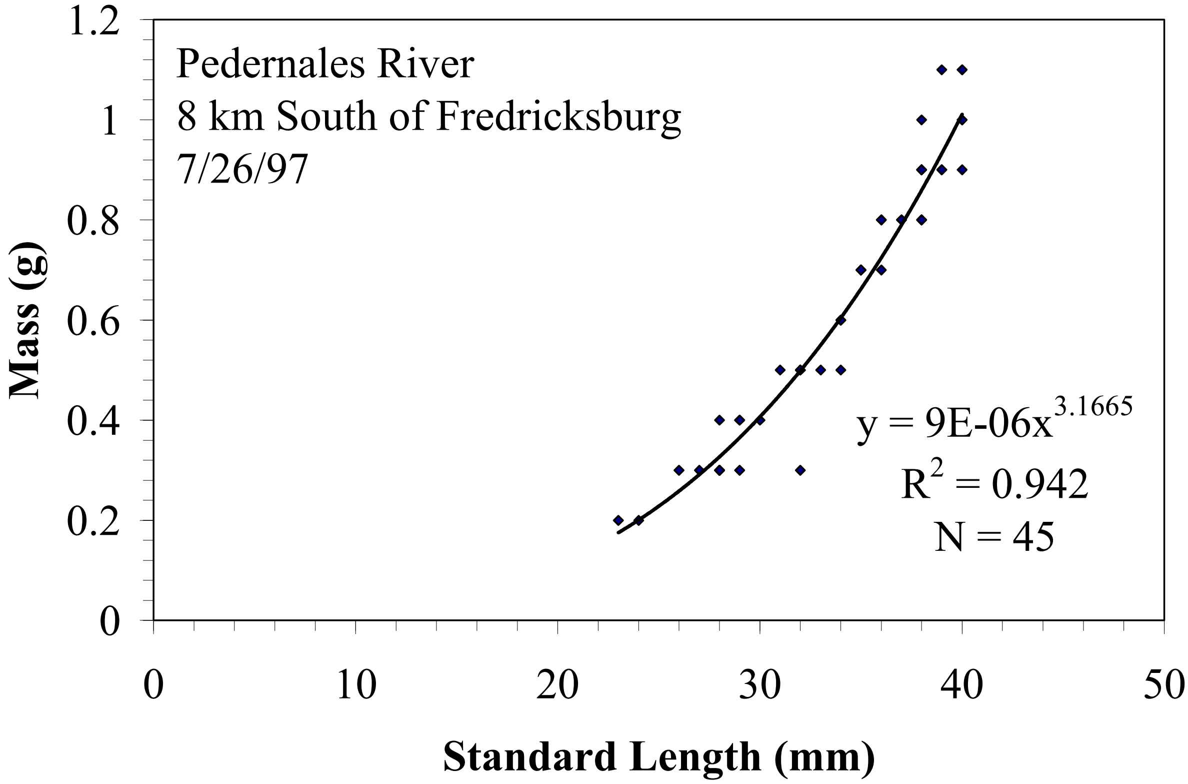

San Saba River
16 km E of Menard
7/25/97
y = 9E-06x^3.1524
R^2 = 0.9037
N = 187
Mass (g)
Standard Length (mm)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
0
10
20
30
40
50

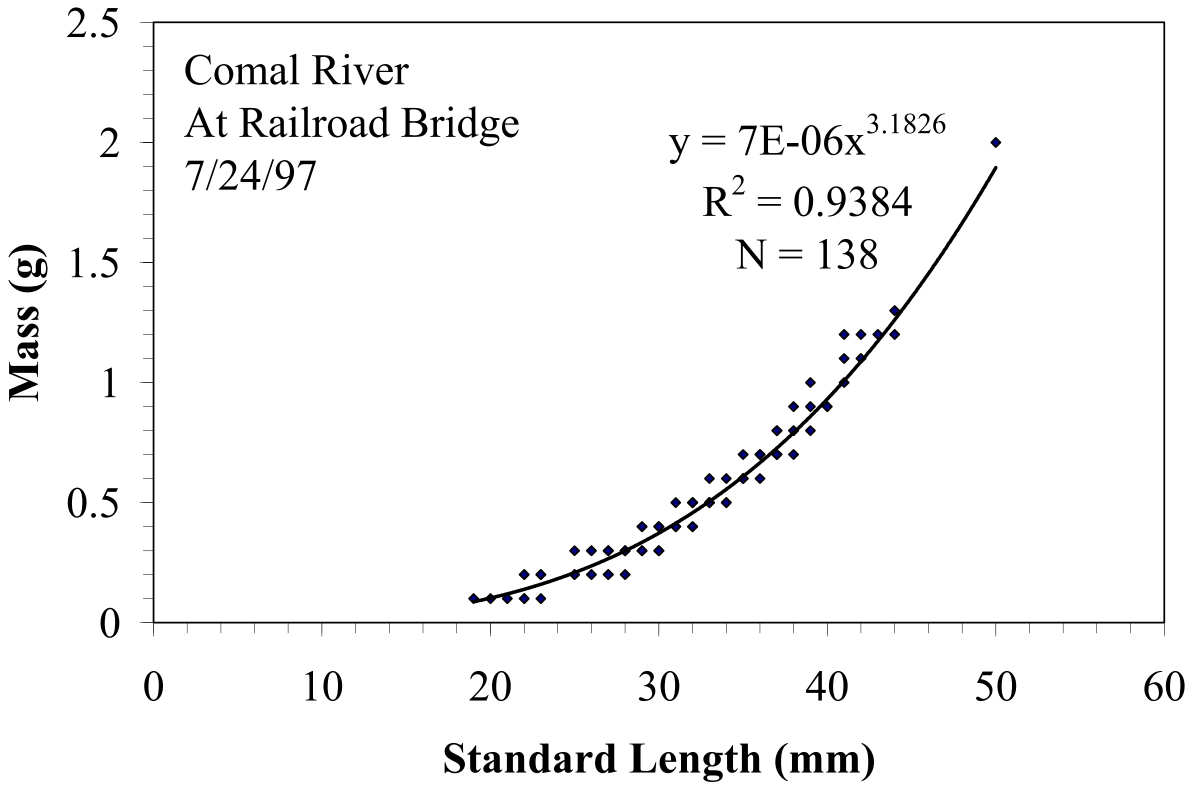


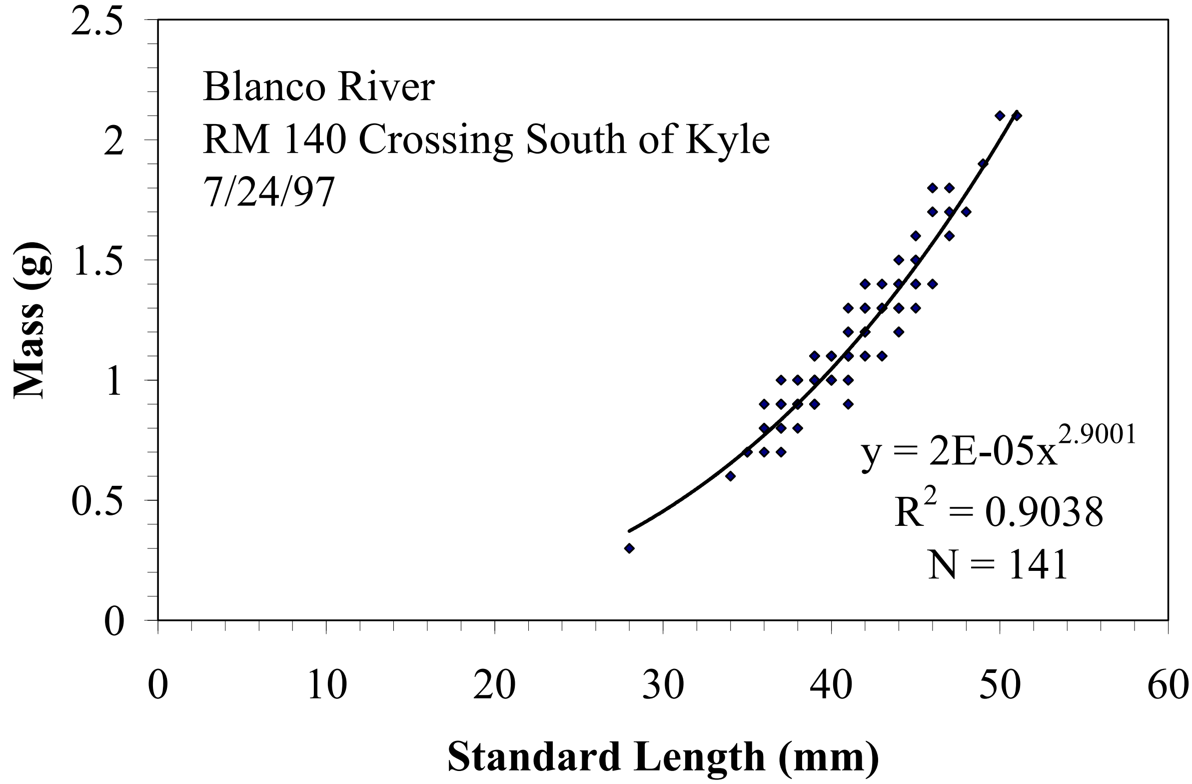
Guadalupe River
At Sisterdale
7/25/97
y = 2E-06x^3.5522
R^2 = 0.888
N = 19
Mass (g)
Standard Length (mm)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50

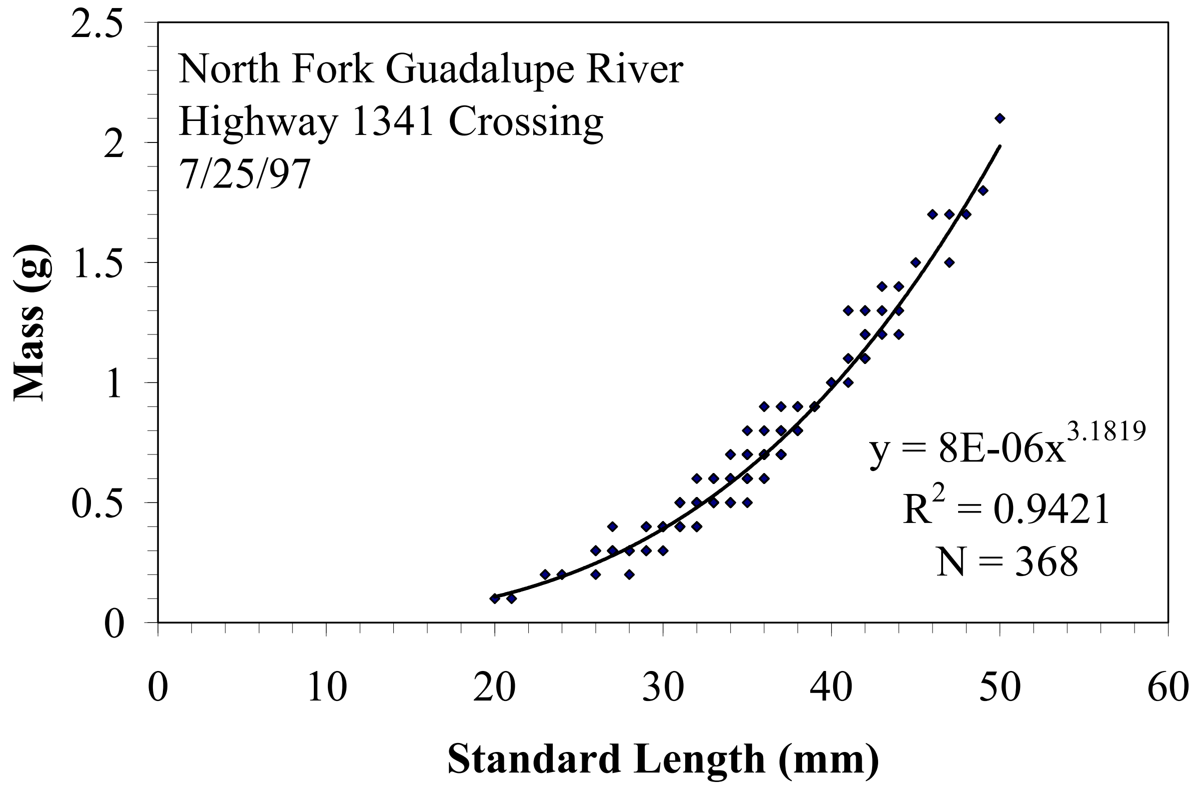


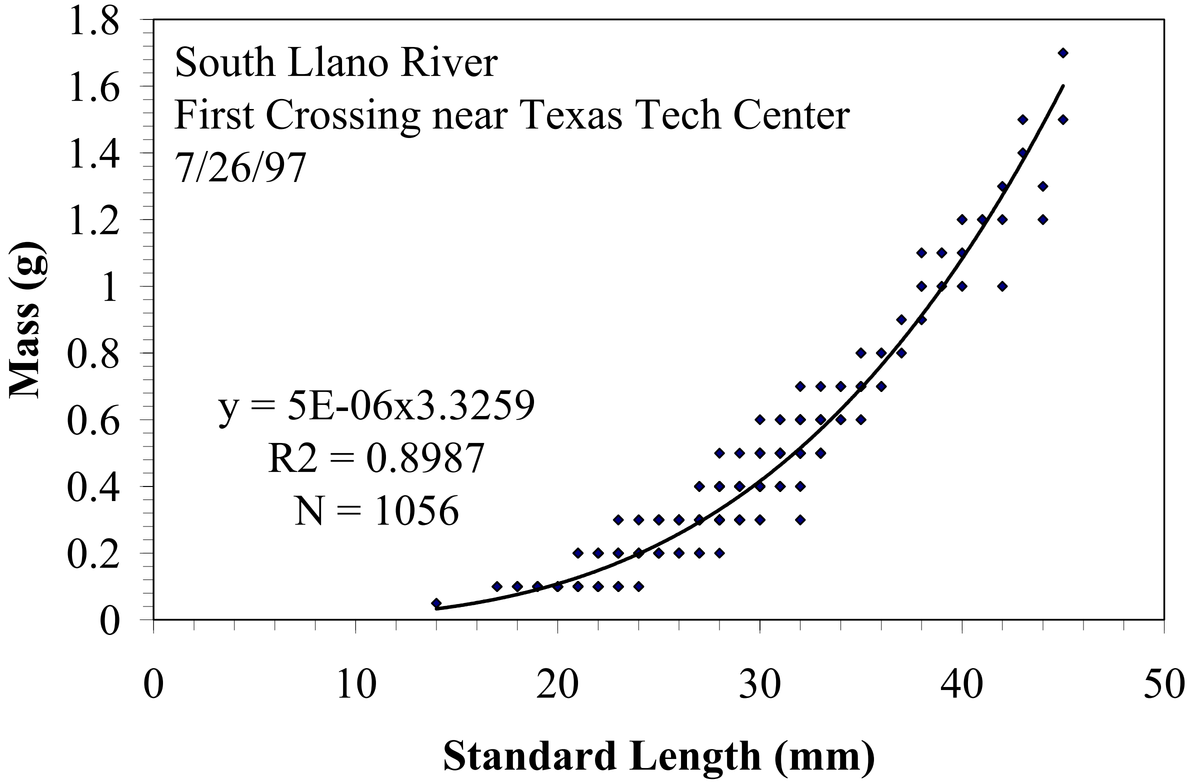
San Marcos River
At Old Town
7/24/97
y = 9E-06x^3.1496
R^2 = 0.9357
N = 182
Mass (g)
Standard Length (mm)
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60


Pedernales River
8 km South of Fredricksburg
7/26/97
y = 9E-06x^3.1665
R^2 = 0.942
N = 45
Mass (g)
Standard Length (mm)
0
0.2
0.4
0.6
0.8
1
1.2
0
10
20
30
40
50


Comal River
At Railroad Bridge
7/24/97
y = 7E-06x^3.1826
R^2 = 0.9384
N = 138
Mass (g)
Standard Length (mm)
0
0.5
1
1.5
2
2.5
0
10
20
30
40
50
60


Blanco River
RM 140 Crossing South of Kyle
7/24/97
y = 2E-05x^2.9001
R^2 = 0.9038
N = 141
Mass (g)
Standard Length (mm)
0
0.5
1
1.5
2
2.5
0
10
20
30
40
50
60


North Fork Guadalupe River
Highway 1341 Crossing
7/25/97
y = 8E-06x^3.1819
R^2 = 0.9421
N = 368
Mass (g)
Standard Length (mm)
0
0.5
1
1.5
2
2.5
0
10
20
30
40
50
60


South Llano River
First Crossing near Texas Tech Center
7/26/97
y = 5E-06x3.3259
R2 = 0.8987
N = 1056
Mass (g)
Standard Length (mm)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
0
10
20
30
40
50

largest number of individuals captured were taken in currents approximately 0.25 fps to 1.0 fps. Current speeds in microhabitats where no *N. amabilis* were taken also ranged from 0.25 fps to 1.0 fps indicating that current alone is insufficient to explain the presence or absence of this species in a given microhabitat. Water depths in the various microhabitats showed a similar pattern. Texas shiners were captured in water from 0.15 m to 1.2 m in depth with the greatest number of individuals taken in habitats deeper than approximately 0.2 m. Microhabitats that did not contain *N. amabilis* ranged between 0.25 and 1.0 m, indicating that depth alone is also not sufficient to explain Texas shiner abundance. An analysis of variance was carried out and there were no significant interaction effects between depth and current speed that would explain this species abundance patterns. Texas shiners are dependent upon currents, however. In most cases, they are abundant in swift water areas, often swimming near the surface in eddies created by upstream obstructions and in dense schools in swift moving water. Little size related habitat segregation was noted. Smaller individuals were somewhat more associated with slower and shallower microhabitats, but this can only be considered a weak generalization in the 30 to 50 mm (SL) sizes captured (Figure 1).

Characins (Family Characidae)

Mexican tetra—*Astyanax mexicanus* (Filippi 1853)

Etymology:

Astyanax—Greek for "a son of Hector"

mexicanus—Latin "from Mexico"

Identification:

A small fish with a minnow-like shape. It can be distinguished by the presence of a adipose fin, a strong black stripe on the posteriormost part of its body extending onto the caudal fin. It's teeth are strong and incisor-like. During breeding dorsal, anal and caudal fins take on a red to yellowish cast.

Similar species:

This is the only characin native to the United States.

Distribution:

Mexican tetras are native to the Rio Grande and its tributaries and the Nueces River system in Texas. It native range extends into the Pecos River in east central New Mexico and southward into the Gulf coastal streams of Mexico. The species has been introduced as far north and east as Lake Texoma, Cross Lake near Shreveport, Louisiana, the Neosho River drainage at Lake Spavinaw in northeastern Oklahoma, Hildebrandt Bayou, Jefferson Co., Texas and in many of the spring systems in the central part of the state (Brown 1953, Edwards 1977, Birkhead 1978, Hubbs et al. 1991 and Bechler and Harrel 1994). They have been introduced into the Colorado River system in Arizona. Their northern distribution appears to be limited by their relative lack of cold tolerance although they have been shown to migrate to warmer environments during winter months to be able to survive in areas where tetra occurrence would normally be considered unlikely (Edwards 1977, Bechler and Harrel 1994). A number of populations of *A. mexicanus* exist in northeastern Mexico inhabiting caves in the region. Individuals in these populations are often blind (and formerly known as *Anoptichthys jordani*) or partially eyed (Sadoglu 1979, Burchards et al. 1985,Tabata 1982, Zilles et al. 1983).

Habitat:

Mexican tetras occupy a wide variety of habitats within their native and naturalized range. In the Rio Grande they can be found occupying most flowing water habitats and in limited numbers in reservoirs. They appear to be in greatest abundance in spring runs where schools of several hundred to thousands can be observed swimming in the swiftest currents.

Biology and Ecology:

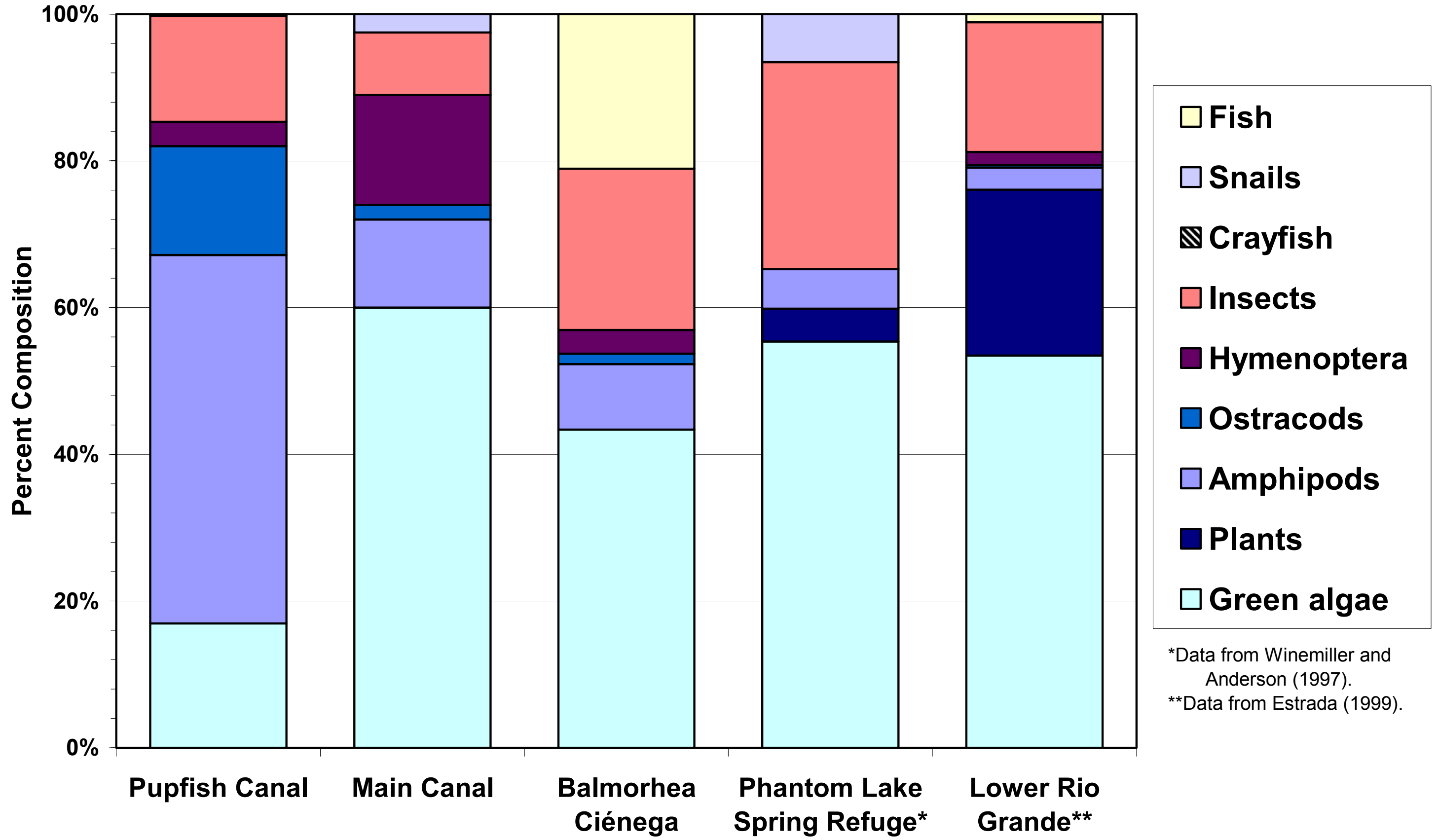
Mexican tetras reach sizes of approximately 80 mm standard length and grow at approximately 10 mm/month in the lower Rio Grande (Estrada 1999). Males and females exhibit similar growth rates and there is little sexual dimorphism between males and females. Individuals born early in the spring apparently begin to reproduce during the autumn of their first year and continue to reproduce thereafter. Reproduction occurs throughout the year in the lower Rio Grande and few individuals live longer than two years (Estrada 1999).

Few dietary studies have been conducted on Mexican tetras. In the lower Rio Grande, Estrada (1999) found that tetras consume a wide variety of foods, especially green algae and plants, various aquatic and terrestrial insects and occasionally, fish (nearly all *Gambusia affinis*). In a study of changes in fish abundances in a newly created habitat at Phantom Springs near Toyavale, Texas, Winemiller and Anderson (1997) found that tetras consume similar foods, although no fishes were observed in the diets of Mexican tetras from their study area. However, they noted that this would not be unexpected given the predatory feeding habits that are commonly hypothesized for many members of the characin family (including pirahnas). Two endangered species (the Comanche Springs pupfish, *Cyprinodon elegans*, and Pecos gambusia, *Gambusia nobilis*) inhabit Phantom Springs and the nearby aquatic environments of the San Solomon Springs and Balmorhea area. The recovery plans for these species both indicate that Mexican tetras might be significant natural predators upon the endangered fishes, however, both plans note that information concerning predation has not been demonstrated.

To determine the extent of predation by Mexican tetras on endangered fishes in the Balmorhea area, samples of Mexican tetras were obtained from three endangered species habitats on 26 August 1998 and 26 May 1999. The habitats sampled were the main canal leading away from the swimming pool area at San Solomon Springs, the artificial pupfish refugia (pupfish canal), and the newly created ciénega all within Balmorhea State Park. Tetras were captured by seine and preserved in 10% formalin. Stomachs of the collected specimens were excised and the food contents identified and their relative contribution to the total diet of all individuals at each site determined. These data and the size distributions of the specimens captured are reported in Figures 2-5 and Table 8. Data from Winemiller and Anderson's (1997) and Estrada's (1999) studies are shown for comparison.

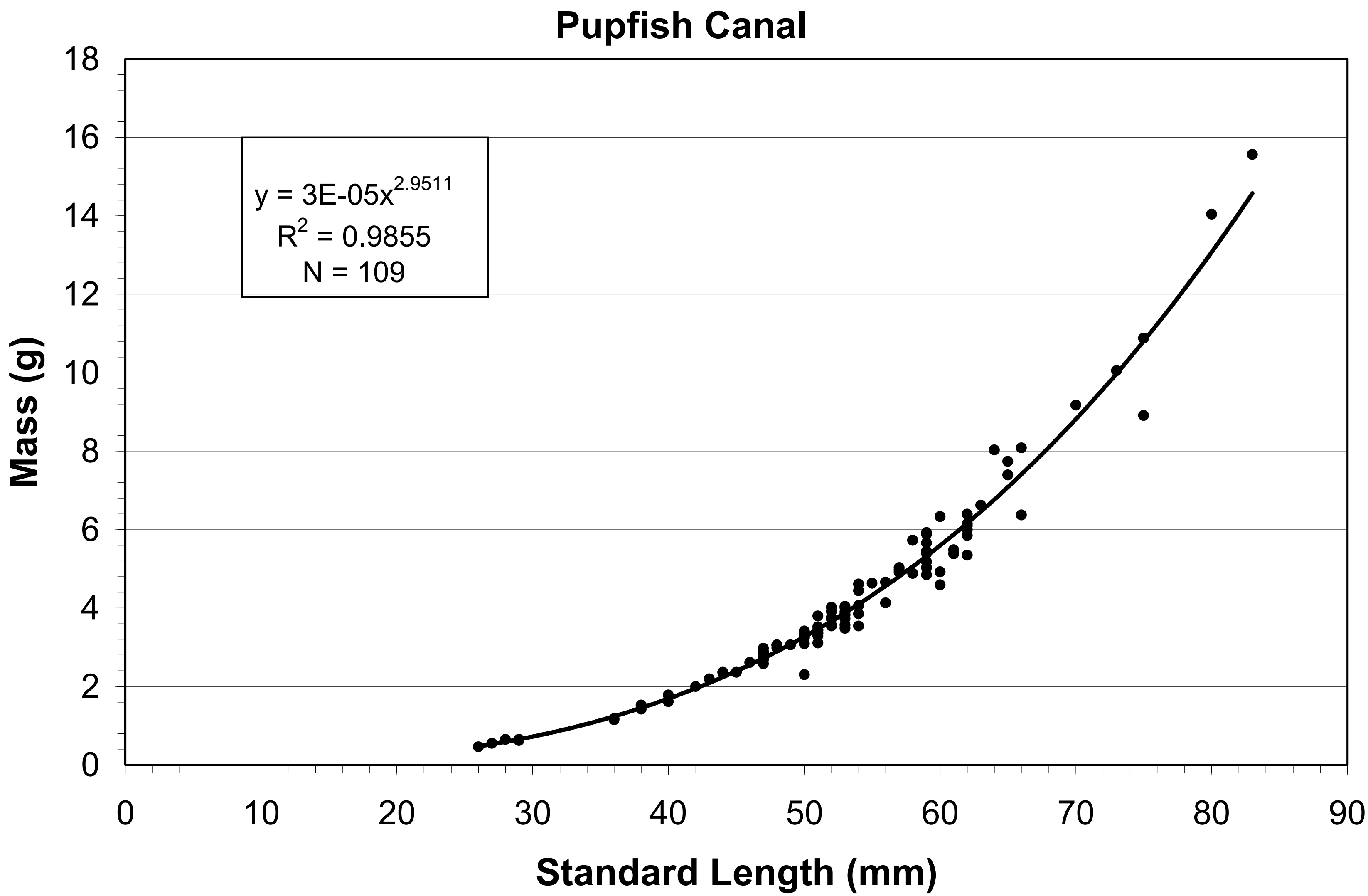
In each of the three Balmorhea environments, a variety of foods were consumed, including green algae, amphipods, ostracods, insects, crayfish, snails and at the ciénega only, fish. Diets of tetras in the pupfish refugia canal contained far more amphipods than the other sites sampled presumably due to the high number of amphipods found in the relatively slow flowing water in that location. The overall diets of tetras inhabiting the main canal and the ciénega were found to be similar to the diets of tetras inhabiting the newly created habitat at Phantom Springs reported by Winemiller and Anderson (1997). Because of concern that tetras may pose a significant predation threat to the endangered species in this area, the fishes consumed were identified to species. All fishes that could be identified were young juvenile *Gambusia geiseri* (the largespring gambusia). Most fishes in the stomachs were approximately 10-15 mm in length indicating that they were recently born. During the May sampling in the ciénega, efforts were expended to determine the location of very young fish. Many *Gambusia geiseri* and *G. nobilis* young were found associated with bullrushes, however, *G. geiseri* young were much more often found higher in the water column and further from the vegetation in contrast to *G. nobilis*. *Cyprinodon elegans* young were also found inhabiting the bullrush microhabitat but were nearly universally found near the

Figure 2. Percent composition of foods taken by *Astyanax mexicanus* in different microhabitats.



100%
80%
60%
40%
20%
0%
Percent Composition
Pupfish Canal
Main Canal
Balmorhea Ciénega
Phantom Lake Spring Refuge*
Lower Rio Grande**
Fish
Snails
Crayfish
Insects
Hymenoptera
Ostracods
Amphipods
Plants
Green algae
*Data from Winemiller and Anderson (1997).
**Data from Estrada (1999).

Figure 3. Standard length versus mass of *Astyanax mexicanus* taken from the Pupfish Canal. Also shown is the best fit curve equation, correlation and sample size.



Pupfish Canal
y = 3E-05x2.9511
R2 = 0.9855
N = 109
Mass (g)
Standard Length (mm)
0
2
4
6
8
10
12
14
16
18
0
10
20
30
40
50
60
70
80
90

Figure 4. Standard length versus mass of *Astyanax mexicanus* taken from the Main Canal. Also shown is the best fit curve equation, correlation and sample size.

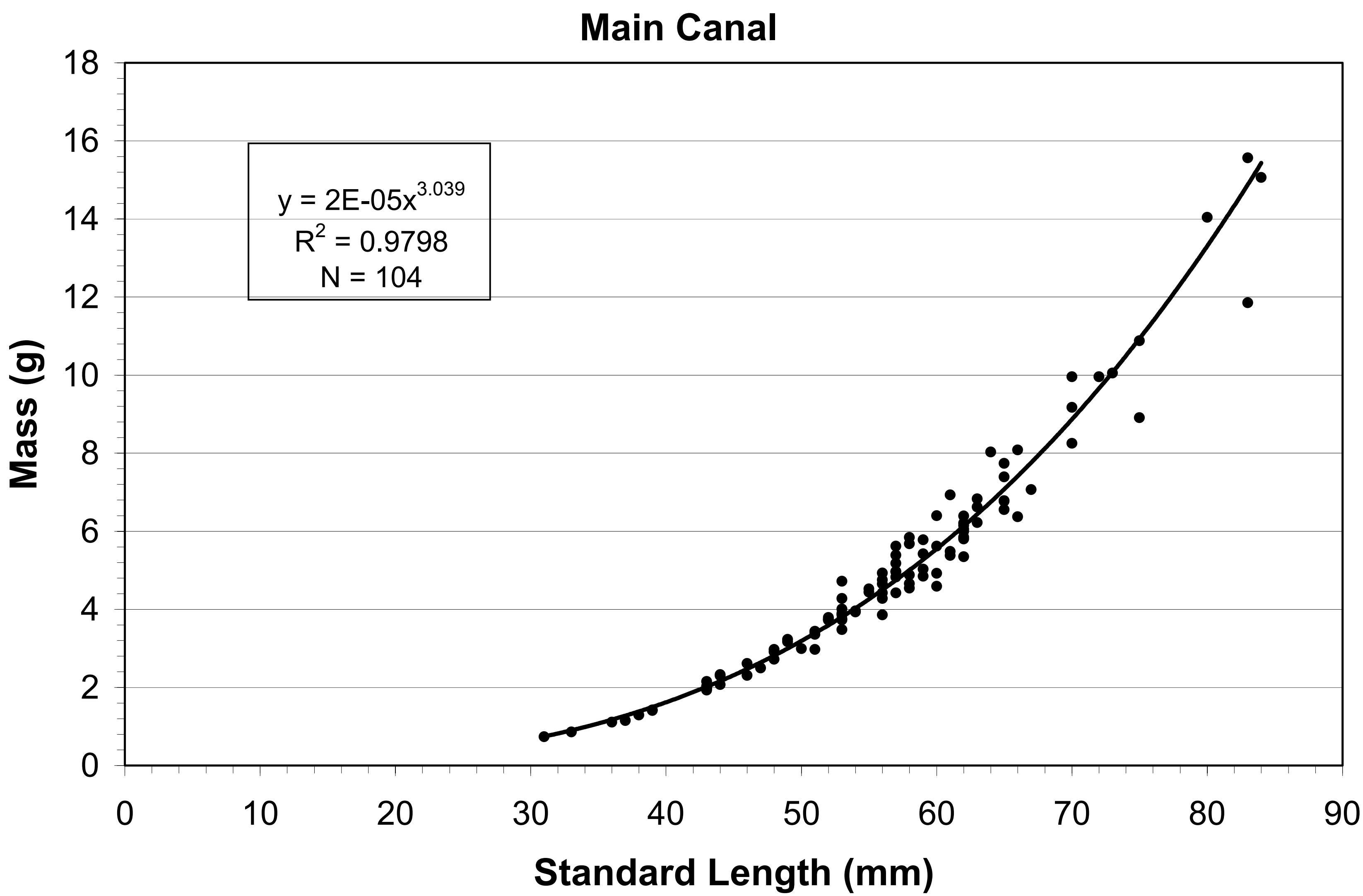

Main Canal
y = 2E-05x^3.039
R^2 = 0.9798
N = 104
Mass (g)
Standard Length (mm)
0
2
4
6
8
10
12
14
16
18
0
10
20
30
40
50
60
70
80
90

Figure 5. Standard length versus mass of *Astyanax mexicanus* taken from the Cienega. Also shown is the best fit curve equation, correlation and sample size.

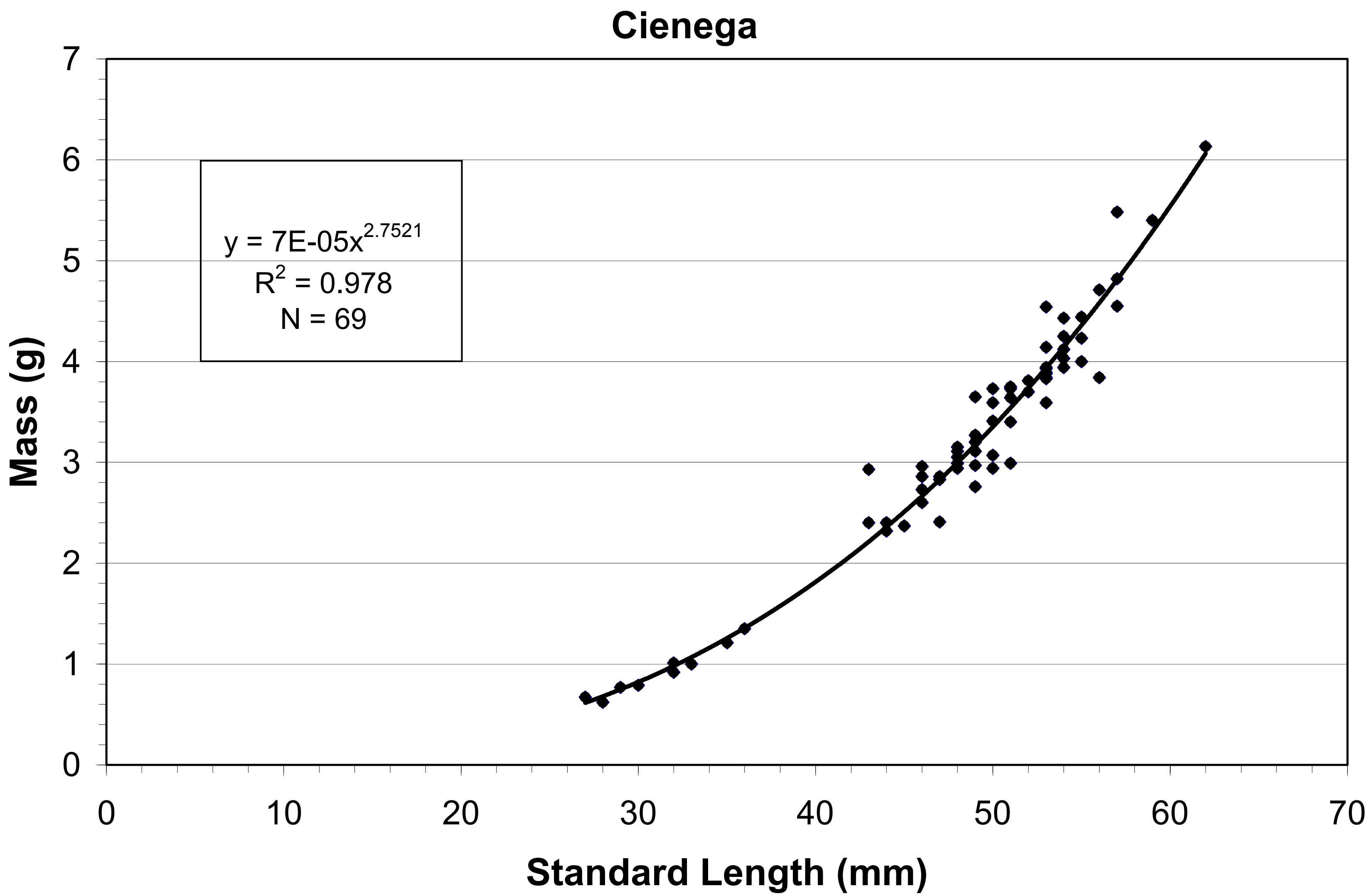

Cienega
y = 7E-05x^2.7521
R^2 = 0.978
N = 69
Mass (g)
Standard Length (mm)
0
1
2
3
4
5
6
7
0
10
20
30
40
50
60
70

Table 8. Percent composition of foods taken by *Astyanax mexicanus* in different microhabitats

Food Item	Pupfish Canal	Main Canal	Balmorhea Ciénega	Phantom Lake Spring Refuge*	Lower Rio Grande**
Amphipods	50.2	12.0	8.9	5.0	3.0
Crayfish	0.2	0.0	0.0	0.0	0.0
Fish	0.0	0.0	21.1	0.0	1.1
Green algae	17.0	60.0	43.4	51.6	53.4
Hymenoptera	3.3	15.0	3.2	0.0	1.8
Insects	14.4	8.5	22.0	26.3	17.7
Ostracods	14.9	2.0	1.4	0.0	0.3
Snails	0.0	2.5	0.0	6.1	0.0
Plants	0.0	0.0	0.0	4.2	22.6
	100.0	100.0	100.0	93.2	99.9
Number with Food	63	41	49	24	70
Number Empty	3	4	20	---	6

* Data from Winemiller and Anderson (1997).

**Data from Estrada (1999).

substrate. This would allow tetras greater contact with young *G. geiseri* than *G. nobilis* or the bottom dwelling *Cyprinodon elegans*. This was similar to the findings of Hubbs et al. (1995) where *G. geiseri* adults were found inhabiting the surface waters near vegetation or in the open water while *G. nobilis* adults were found in deeper parts of the pupfish canal. One overall conclusion from this study is that in all likelihood predation by *Astyanax* on the endangered species found in the Balmorhea system is inconsequential as a threats to these species' survival.

Conservation Status:

Mexican tetras are not at present in danger of extinction and are not listed by governmental entities in the state of Texas. The species appears to be less well off in New Mexico and are a state listed Threatened species in that state (Propst 1999). Some factors contributing to their decline in New Mexico is destruction of stream habitats caused by overgrazing, siltation, channelization and water diversions.

Killifishes (Family Cyprinodontidae)

Comanche Springs pupfish—*Cyprinodon elegans* Baird and Girard 1853

Etymology

C*yprinodon* - Greek meaning "toothed carps"

elegans - Latin meaning "elegant"

Identification

Cyprinodon elegans is one of the most distinctive members of the genus *Cyprinodon*. Males possess a unique speckled color pattern and all individuals have a relatively streamlined body shape. They lack the vertical bars on the sides of their bodies that are found in most other *Cyprinodon*. Comanche Springs pupfish are small fishes, individuals only attain a maximum size of approximately 50 mm SL (Itzkowitz 1969, Echelle and Hubbs 1978).

There is significant intraspecific variation. Echelle (1975) found that *Cyprinodon elegans* from early Comanche Springs collections are distinct in several morphological features. The Phantom Lake Springs population differs from the Toyah Creek population in ventral scalation and number of dorsal and caudal fin rays and San Solomon and Giffin springs populations are intermediate.

Distribution

Comanche Springs pupfish originally inhabited two isolated spring systems approximately 90 km apart in the Pecos River drainage of west Texas (Baird and Girard 1853). The type locality, Comanche Springs, inside the city limits of Fort Stockton (Pecos County), is now dry and the population extinct. The other population is restricted to Phantom, San Solomon, and Giffin springs, and Toyah Creek, all near Balmorhea (Reeves County), as well as their outflows and interconnecting irrigation canals..

Habitat

Comanche Springs pupfish habitat has been markedly altered into an irrigation network of concrete-lined canals with swiftly flowing water and dredged earth-lined laterals. Water from Phantom Lake Springs originally emerged from a cave and formed a small ciénega (desert marsh) that drained into another cave, but it is now captured in an irrigation canal where it emanates from the cave. Water from San Solomon and Giffin springsflows into additional irrigation systems, some of which is stored in an irrigation supply lake known as Lake Balmorhea. This habitat is highly unnatural, ephemeral and wholly dependent upon local irrigation practices and other water-use patterns, and in order to repair or dredge them, flows are sometimes diverted causing massive mortalities of *C. elegans* (Davis 1979). For the most part, irrigation canals provide little suitable habitat for *C. elegans* (U.S.F.W.S. 1990).

Half of the known habitat of the Comanche Springs pupfish is dry (Comanche Springs and outflow) and the remaining springs near Balmorhea are failing (Brune 1981, U.S.F.W.S. 1990). As Phantom Lake Springs are is at a higher elevation than the other springs in the Balmorhea area, it will likely fail first, and is predicted to go dry within 50 years (White et al. 1938, Brune 1981).

An effort has been made to improve habitat in the Balmorhea area. A small refugium canal was constructed in 1974 in Balmorhea State Recreational Area (Echelle and Hubbs 1978). Its presence on state park land provides a measure of security and for two decades has given park visitors the opportunity to view an endangered species.

In 1993, the Bureau of Reclamation constructed a modified 110 m canal at Phantom Lake Spring (Young et al. 1994) specially designed as pupfish habitat with sloped, sinuous sides to resemble a portion of a ciénega.

In 1996, the construction of the 1-hectare San Solomon Ciénega was completed (McCorkle et al. 1998). This wetland is situated within the boundaries of the original, natural ciénega on state park land. Designed to resemble and function like the original ciénega, the native fish fauna, including *C. elegans*, has flourished.

Biology and Ecology

Comanche Springs pupfish belongs to a clade of pupfishes including *C. eximius* of the Río Grande basin and its major tributary, the Río Conchos in México, and two single spring endemics (*C. pachycepahalus* and *C. macrolepis*) also from the Río Conchos basin. This group is in turn related to a clade of pupfishes from the Río Nazas – Aguanaval system, south of the Río Conchos (Echelle and Echelle 1998).

Comanche Springs pupfish are short-lived fish with most individuals living about 1 year (U.S.F.W.S. 1990). This, coupled with highly seasonal reproduction results in large annual fluctuations in population numbers (U.S.F.W.S. 1990). Adult population densities were at least 1,000 in the vicinity of San Solomon Springs and several thousand in the irrigation canals in 1974 (Echelle 1975). Later, in a two-year study, Garrett and Price (1993), estimated the population in the park refugium canal to be as low as 968 (May 1990) and as high as 6,480 (September 1990). Construction of the modified canal at Phantom Lake Spring increased local abundance to an average of 14.7 pupfish/m^2 (Winemiller and Anderson 1997). The population in San Solomon Ciénega has not yet been estimated, but large numbers are evident. Numbers will remain low in the irrigation canals due to lack of suitable habitat. However, large numbers of *C. elegans* are expected in the next few years in Lake Balmorhea following removal of sheepshead minnows, *C. variegatus* (see Conservation Status, below).

Comanche Springs pupfish prefer swift flows, especially in comparison to habitats preferred by other species of *Cyprinodon* (Miller 1961, Itzkowitz 1969, U.S.F.W.S. 1990). Comanche Springs pupfish are rarely found in habitats that are less than 10 cm deep, scoured or devoid of debris or vegetation such as *Chara*. Water emanating from the springs are stenothermal (22-26º C (Stevenson and Buchanan 1973, Gehlbach et al. 1978, Brune 1981), however, exposure to ambient temperatures make the waters in which Comanche Springs pupfish are found somewhat more eurythermal. Temperature preference experiments indicate that temperatures between 20-30º C during August and September are optimal (Gehlbach et al. 1978). Comanche Springs pupfish have a critical thermal maximum of approximately 40.5º C and there is significant diurnal variation in the critical thermal maximum, being higher in the afternoon than in the morning (Gehlbach et al. 1978).

Gut analysis of 20 specimens by Winemiller and Anderson (1997) revealed *C. elegans* eat mostly filamentous algae and some snails (*Cochliopa texana*).

Breeding occurs over territories maintained by males. These territories are variable in size (averaging approximately 0.5 m^2) and most often over algal mats. Eggs are guarded by males until hatching and they aggressively defend their territories against intruders (Itzkowitz 1969). *Cyprinodon elegans* breeds in swifter water than all other known *Cyprinodon*. Males orient and maintain position upstream from their territories and drift with the water flow into an intruder where ritualized displays, chasing or biting will occur (Itzkowitz 1969), or drift down to join a female that positions herself near the algal mat substrate for spawning (Itzkowitz 1969). Courtship behaviors are similar to other species of *Cyprinodon* based upon the direct observations of (Itzkowitz 1969) and existence of natural hybrids between *C. elegans* and introduced *C. variegatus* (Stevenson and Buchanan 1973). Eggs are apparently laid singly onto the algal mat substrates of the male's territory (Itzkowitz 1969). Aquarium studies suggest females may lay 30 eggs per day and eggs hatch in 5 days at 20º C (Cokendolpher 1978).

A relatively large number of introduced fishes are found in Comanche Springs pupfish habitats. These include: *Cyprinus carpio* (common carp), *Notemigonus crysoleucas* (golden shiner), *Pimephales promelas* (fathead minnow), *Ictalurus melas* (black bullhead), *Fundulus grandis* (gulf killifish), *Cyprinodon variegatus* (sheepshead minnow), *Gambusia geiseri* (largespring gambusia), and *Menidia beryllina* (inland silversides). Many of these compete for food and space with *C. elegans*, and one, *C. variegatus*, has threatened the genetic integrity of the Comanche Springs pupfish through introgressive hybridization (Stevenson and Buchanan 1973, Hubbs 1982, U.S.F.W.S. 1990).

Native fishes that may co-occur with Comanche Springs pupfish are: *Dorosoma cepedianum* (gizzard shad), *Astyanax mexicanus* (Mexican tetra), *Dionda episcopa* (roundnose minnow), *Hybognathus placitus* (plains minnow), *Cyprinella lutrensis* (red shiner), *Pimephales vigilax* (bullhead minnow), *Ictalurus punctatus* (channel catfish), *Fundulus zebrinus* (plains killifish), *Gambusia affinis* (western mosquitofish), *Gambusia nobilis* (Pecos gambusia), *Lepomis cyanellus* (green sunfish), *Lepomis humilis* (orangespotted sunfish), *Lepomis megalotis* (longear sunfish) and *Cichlasoma cyanoguttatum* (Rio Grande cichlid) (Stevenson and Buchanan 1973, Echelle 1975, U.S.F.W.S. 1990).

The U. S. Fish and Wildlife Service is maintaining cultures of *Cyprinodon elegans* at the Dexter National Fish Hatchery in Dexter, New Mexico and the Uvalde National Fish Hatchery, in Uvalde, Texas. The Dexter population stems from 30 individuals taken from an irrigation canal leading from Giffin Springs (U.S.F.W.S. 1990) and the Uvalde population originated with 73 individuals from the distinctive subpopulation at Phantom Lake Springs (Garrett and Price 1993).

Conservation Status

The large flow of Comanche Springs was used as a water source as early as 1875 to irrigate over 6,000 acres of farmland (Brune 1981). The springs failed in 1962, however,because of over-utilization of groundwater resources feeding it (Brune 1981) and its population of *Cyprinodon elegans* was extirpated (Stevenson and Buchanan 1973). Many canals were dug for irrigation in the Balmorhea region beginning in the mid-1870's (Brune 1981, U.S.F.W.S. 1990)and continuing through the present. Marshes presumed to have supported large numbers of Comanche Springs pupfish were drained and spring flows diverted into fields. Local pumping of groundwater on privately owned lands has exacerbated the decline in spring flows and pupfish in this area. The park refugium canal, the Phantom Lake Springs refugium canal and the San Solomon Ciénega have increased numbers and security for the species, but each is dependent on spring flows.

In 1998, Lake Balmorhea was partially drained and all fish were eliminated by application of the piscicide, rotenone. The *Cyprinodon variegatus* (sheepshead minnow) population of the lake was estimated a more than 5,000,000 during the renovation. Removing this non-native not only eliminated the hybridization threat, but also made more habitat available for *C. elegans*.

Livebearers (Family Poeciliidae)

San Marcos gambusia—*Gambusia georgei*

Etymology

Gambusia--a provincial Cuban term, *Gambusinos*, which signifies "nothing." Thus, according to Poey, the original describer of the genus, when one catches nothing, he should say he was "fishing for *Gambusinos*."

georgei--named in honor of Dr. George S. Myers, an eminent student of poeciliid biology in part because *Gambusia myersi* was determined to be a junior synonym of this species a short time previously.

Identification

The San Marcos gambusia is plainly marked and is subtly different from the western mosquitofish, *G. affinis*. Scales tend to be strongly crosshatched in contrast to the less distinct markings on the scales of *G. affinis*. In addition, *G. georgei* tend to have a prominent dark pigment stripe across the distal edges of their dorsal fins. A diffuse mid-lateral stripe extending posteriorly from the base of the pectoral fin to the caudal peduncle is also often present, especially in dominant individuals. As in *G. affinis*, a dark subocular bar is visible and is elicited easily from frightened fish. Compared to *G. affinis*, *G. georgei* has fewer spots and dusky pigmented regions on the caudal fin. The median fins of wild-caught specimens of San Marcos gambusia tend to be lemon yellow. In a dominant or "high" male, this color can approach a bright yellowish-orange, especially around the gonopodium. A bluish sheen is evident in more darkly pigmented individuals, especially near the anterior dorsolateral surfaces of adult females.

Gonopodial structures of males classically have been employed in dealing with Gambusia systematics. *Gambusia georgei* is unique morphologically from other species in several characters, including the presence of more than five segments in ray 4a which are incorporated into the elbow and also by the presence of a compound claw on the end of ray 4p (Hubbs and Peden 1969).

Similar Species:

Gambusia affinis—See identification section above for differences between *G. affinis* and *G. georgei*.

Gambusia geiseri—The largespring gambusia, G. geiseri, can be easily distinguished from the San Marcos gambusia by their color pattern as well as gonopodial characters of the males. Largespring gambusia have a prominent post-anal streak, spots along their sides and obvious dusky markings on their lips; characters all lacking in the San Marcos gambusia. Male largespring gambusia have a recurved hook on one of the ray 3 spines which is a unique character in this species.

Distribution:

The San Marcos gambusia is restricted to the headwaters of the San Marcos River, within the City of San Marcos, Hays County, Texas. The San Marcos gambusia is represented in collections taken in 1884 by Jordan and Gilbert during their surveys of Texas stream fishes and in later collections (as a hybrid) taken in 1925 (Hubbs and Peden 1969). Unfortunately, records of exact sampling localities are not available for these earliest collections. Localities were merely listed as "San Marcos Springs." These collections likely were taken at or near the headsprings area. If this is true, then *G. georgei* appears to have significantly altered its distribution over time. Importantly, samples taken prior to 1950 from the San Marcos River downstream from the headsprings are extremely scarce.

During 1953, a single individual was taken below the low dam at Rio Vista Park, in mid-town San Marcos. However, since that time, nearly every specimen of *G. georgei* has been taken in the vicinity of the Interstate Highway 35 bridge crossing downstream approximately 1 km to the area surrounding what is locally known as Thompson's Island. The single exception to this was a male taken with an Ekman dredge approximately I km below the outfall of the San Marcos Secondary Sewage Treatment Plant in 1974 (Longley 1975).

During the last extensive study of the species during the late 1970s, *G. georgei* was apparently restricted to the approximately 1 km portion of the San Marcos River between Interstate Highway 35 and the USGS gaging station immediately downstream from Thompson's Island. San Marcos gambusia populations are extremely sparse; intensive collections during 1978 and 1979 yielded only 18 *C. georgei* from 20,199 Gambusia total (0.09%) (Edwards et al. 1980). Collections taken in the early 1980s within the range of *G. georgei* indicated a slight decrease (0.06% of all *Gambusia* captured) in the relative abundance of this species (Edwards, unpubl. data).

Habitat

The San Marcos gambusia apparently prefers quiet waters adjacent to sections of moving water, but seemingly of greatest importance, thermally constant waters. *G. georgei* is found mostly over muddy substrates but generally not silted habitats, and shade from overhanging vegetation or bridge structures is a factor common to all sites along the upper San Marcos River where apparently suitable habitats for this species occur (Hubbs and Peden 1969, Edwards et al. 1980).

Compared to *G. georgei, G. affinis* tends to show similar preferences for shallow, still waters, but differs strikingly from *G. georgei* in ability to colonize environments with greater temperature fluctuations. These environments include the partially isolated sloughs, intermittent creeks, and drainage ditches found in the upper San Marcos River and in the nearby Blanco and lower San Marcos rivers, as well.

Abundance

The San Marcos gambusia is probably extinct. The last collection of a living San Marcos gambusia was in the early 1982. Since that time, none have been collected despite moderate efforts to obtain specimens of the species. The proportion of hybrid individuals captured compared to “pure” specimens rose dramatically in the late 1970s and early 1980s, suggesting that “pure” individuals were having an increasing difficult time finding suitable mates, adding further evidence to the rarity of the species and providing further evidence that the species is, in all likelihood, extinct.

Biology and Ecology

Although nothing is known of the food habitats of *G. georgei*, it is thought that presumably, as in other poecillids, insect larvae and other invertebrates accounted for most of the dietary intake of this species. Similarly, there is little information on the reproductive capabilities of *G. georgei*. Two individuals kept in laboratory aquaria produced 12, 30 and 60 young, although the largest clutch appeared to have been aborted and did not survive (Edwards et al. 1980). Hybridization between *G. georgei* and *G*. affinis was first noted by Hubbs and Peden (1969) and the production of hybrid individuals between them continued for many years without obvious introgression of genetic material into either of the parental species. Given the history of hybridization between these two species, this factor was not thought to be of primary importance in considerations of the status of *G. georgei*. It was thought that so long as the proportion of hybrids remained relatively low compared to the abundance of "pure" *G. georgei*, few problems associated with genetic swamping or introgression would occur (Hubbs and Peden 1969; Edwards et al. 1980). However, during the series of collections taken during the early 1980s, hybrid individuals were many times more abundant than the "pure" *G. georgei* and it was concluded that the hybrid individuals might have placed an additional stress through competitive interference with the small remaining population of San Marcos gambusia.

Conservation Status

Because of its limited range and rarity, the San Marcos gambusia is listed as Endangered by the U.S. Fish and Wildlife Service, the Texas Parks and Wildlife Department and the Texas Organization for Endangered Species. An endangered species recovery plan is in effect for the conservation of this species (U.S. Fish and Wildlife Service 1996), however, the prognosis for recovering this species is, at best, remote. Still, if further collection attempts determine that the species still exists, efforts should be made immediately to begin laboratory cultures of the species.

Clear Creek gambusia—*Gambusia heterochir* Hubbs 1957

Etymology:

Gambusia--a provincial Cuban term, *Gambusinos*, which signifies "nothing." Thus, according to Poey, the original describer of the genus, when one catches nothing, he should say he was "fishing for *Gambusinos*."

heterochir, Greek meaning "different hand" in reference to the distinctive shape of the pectoral fins of this species.

Identification:

A stocky species of *Gambusia* with a rather chunky head and a metallic sheen on its top and sides. Males differ from all other known species of *Gambusia* by the possession of an extremely deep notch in their pectoral fins (Hubbs and Reynolds 1957, Warburton et al. 1957). Scattered dark markings form distinctive crescents on sides of body. There is no predorsal streak or caudal spots. Usually 7 (sometimes 8) dorsal fin rays. The male gonopodium has short spines on ray 3, a well-defined elbow and separated distal elements on ray 4 with long serrae. There is a simple terminal hook on ray 4p and a rounded terminal hook with a blunt tip on ray 5. Females have a pronounced and large anal spot (Hubbs 1957).

Similar species:

Gambusia affinis—spines on ray 3 of gonopodium short and an elongated terminal hook on ray 4p. Sides with only scattered melanophores, not approaching a distinctive crescent shape. Often with spots on caudal fin. Females with only a small anal spot. Usually 6 dorsal fin rays.

Gambusia nobilis—lateral stripe on sides of body thin and threadlike. Caudal fin has a dark margin. Sides with small spots, but not in crescent shapes. Strong predorsal streak.

Distribution:

This species is restricted to the headwater springs of Clear Creek, a tributary to the San Saba River, Menard County, Texas.

Habitat:

The species is found in the clear spring pool and upper spring run of Clear Creek which consists of a series of limestone springs originating from the Edwards aquifer (Brune 1975). Clear Creek gambusia inhabit the stenothermal (temperature in Clear Creek is 20°C.), low pH (6.1-6.5) waters in areas with abundant aquatic vegetation composed mostly of a *Ceratophyllum* sp.

The headwaters of Clear Creek are also inhabited by *Dionda episcopa* (roundnose minnow), *Ictalurus natalis* (yellow bullhead), *Lucania parva* (rainwater killifish, an introduced species), *Micropterus salmoides* (largemouth bass), *Lepomis megalotis* (longear sunfish), *L. microlophus* (redear sunfish, probably an introduced species) and *Etheostoma lepidum* (greenthroat darter). An endemic amphipod, *Hyallela texana*, is also found in Clear Creek gambusia habitat.

Biology:

Reproduction in these viviparous fishes occurs from February through September with an apparent peak during August (Hubbs 1971). Masculinized females are known to occur in the population (Yan 1986a) and temperature and photoperiod have been demonstrated to influence reproductive periods in this species (Yan 1986b, 1987). Females store sperm and females produce young approximately every 60 days during the breeding season (Hubbs 1971).

A long-standing hybrid swarm between the Clear Creek gambusia and the western mosquitofish, *G. affinis*, has existed since at least 1953, when the species was first discovered. Hybrids are fertile and thus, there is the potential for genome contamination, as well as competition for resources, especially considering the very limited range of the species (Hubbs

1957, 1959, 1971, Yardley and Hubbs 1976, Edwards and Hubbs 1985). The introduced species, *Lucania parva,* a killifish, apparently depress *G. affinis* abundances where Clear Creek gambusia are present which helps to sustain the *G. heterochir* population (Edwards and Hubbs 1985).

A series of dams along the length of Clear Creek for the irrigation of the surrounding countryside have created more eurythermal conditions (conducive to large *G. affinis* populations) close to the headspring habitat of *G. heterochir*. Seasonal movements of *G. affinis* have been shown to exacerbate the hybridization problems for *G. heterochir*. By selecting warmer environments (downstream areas during summer and the spring-pool during winter), *G. affinis* is thought to maintain a higher metabolism, resulting in increased growth, reduced interbrood intervals and higher fecundities than the Clear Creek gambusia (Hubbs 1971). An earthen dam immediately below the headsprings, constructed in the late 1800s, was in a state of serious disrepair by the time the species was discovered. This increased the threat of invasion of the upper spring habitat by large number of *G. affinis*. During the late 1970s, the dam was repaired and strengthened as a part of endangered species recovery activities and the incidence of hybridization above the dam decreased (Edwards and Hubbs 1985).

Conservation Status:

The Clear Creek gambusia is listed as Endangered by the U.S. Fish and Wildlife Service, the Texas Parks and Wildlife Department, and by the Texas Organization for Endangered Species (Hubbs et al. 1991). The rarity of the species, its limited range and its dependence upon flowing spring waters, and its potential for genetic contamination by *G. affinis* remain the primary threats to the existence of this species.

San Felipe gambusia—*Gambusia* sp.

Identification:

In a routine collection of fishes taken in the San Felipe Springs and creek area in December 1997 by the Texas Parks and Wildlife Department, two forms of *Gambusia* were noted. One appeared as typical *G. speciosa*; the other had numerous spots over the sides of its body, reminiscent of *G. senilis* or the extinct *G. amistadensis*, both species known from the surrounding area historically but now either extirpated or extinct. Closer examination of the specimens indicated that the spotted form was neither species, nor even in the "*G. senilis*" species group which includes, in Texas, *G. senilis, G. amistadensis, G. gaigei* and *G. geiseri* in addition to four other species found in Mexico. Rather, this form appeared to be a member of the "*G. nobilis*" species group, characterized in part by the elongated extension of ray 4a in the modified anal fin (gonopodium) of males and also by the position of the serrae on ray 4p being opposite the elbow instead of proximal to it as is found in the "*G. senilis*" species group (Rauchenger 1989). The "*G. nobilis*" species group is represented in Texas by *G. nobilis, G. heterochir* and *G. georgei* and by three additional species in Mexico. The color pattern of this form is unique among the other members of the "*G. nobilis*" species group, although it appears to be a sister group to *G. krumholtzi*, which is only found at a single locality approximately 100 km to the southwest, in the vicinity of Nava, Coahuila, Mexico (Minckley 1963).

This undescribed species of *Gambusia* appears to exist nowhere outside of the stenothermal spring run area within the city of Del Rio and historic collections as well as additional collections taken as a part of this contract in July 1999 in nearby aquatic environments yielded no specimens of the undescribed species. Where it is found, it most often inhabits edge habitats that are often vegetated and in partial shade. It is generally not found in rocky or large gravel substrate environments, but is found in edge and relatively shallow habitats adjacent to areas with flow. The largest individual captured (a female approximately 60 mm SL) was taken near the downstream shore of a small island in the middle of the creek. It appears that this species has similar habitat requirements to the other member of its subgenus which inhabit the larger spring systems of the central and southwestern parts of the state.

In the process of describing this species (in preparation), counts and measurements were taken on 40 individuals (23 males and 17 females). These counts and measurements are reported in Tables 9-11 and photographs of a specimen showing the overall color pattern and a male gonopodium are shown in Figures 6 and 7. *Gambusia krumholtzi* is very similar morphologically and meristically, but its color pattern is much different, having medial fins that are very dark, a thin predorsal streak and more prominent markings around the anus of females.

Because of the extremely limited range of this undescribed form (its entire range is within the city limits of Del Rio and appears absolutely dependent upon the stenothermal flows from San Felipe Springs) and the similar threats facing nearly all of the members of the entire subgenus (all Texas species are listed by the U.S. Fish and Wildlife Service as Endangered), this species is also an uncontestable candidate for federal and state endangered species protection.

Figure 6. Photo of female San Felipe gambusia (*Gambusia* sp.)

Figure 7. Photo of gonopodium of male San Felipe gambusia (*Gambusia* sp.)

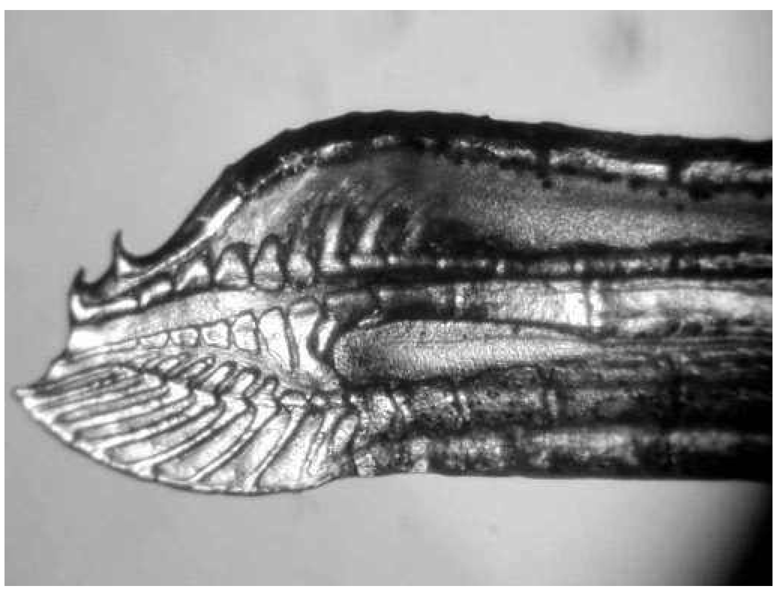


Table 9. Data sheet for San Felipe *Gambusia*

Specimen Number	Sex (0=male 1=female)	Dorsal Rays	Anal Rays	Pelvic Rays	Pectoral Rays	Lateral scales	Predorsal scales
1	0	9		6	13	30	15
2	0	10		6	14	30	14
3	0	9		6	14	29	15
4	0	9		6	14	30	16
5	0	9		6	14	29	14
6	0	9		6	14	30	15
7	0	9		6	13	30	15
8	0	9		6	13	29	15
9	0	9		6	14	30	14
10	0	9		6	14	30	15
11	0	9		6	14	31	15
12	0	9		6	14	30	14
13 (Holotype)	0	9		6	14	30	15
14	0	9		6	14	30	15
15	0	9		6	14	31	16
32	0	9		6	13	30	15
33	0	9		6	13	30	15
35	0	9		6	14	29	14
36	0	9		6	13	30	15
37	0	9		6	13	29	14
38	0	10		6	14	30	14
39	0	9		6	14	30	15
40	0	9		6	13	29	15
16	1	9	10	6	14	30	16
17	1	9	10	6	14	31	16
18	1	9	10	6	14	31	16
19	1	9	10	6	13	30	16
20	1	9	10	6	14	31	16
21	1	10	10	6	13	31	16
22 (Allotype)	1	9	10	6	14	30	16
23	1	9	10	6	14	31	16
24	1	9	10	6	13	30	16
25	1	9	10	6	13	31	15
26	1	9	10	6	13	30	15
27	1	9	10	6	13	29	16
28	1	9	10	6	14	31	15
29	1	9	10	6	14	30	15
30	1	9	10	6	14	30	15
31	1	9	10	6	13	30	15
34	1	9	9	6	14	31	15

Table 9. Data sheet for San Felipe *Gambusia* (continued)

Specimen Number	Standard Length (SL)	Head Length (HL)	Head Depth (HD)	Predorsal length	Caud. Ped. Depth	Caudal fin length
1	26	7	4.9	14	4	5.2
2	27	7.2	5	15.1	5	6
3	28	7.7	5	16	4.2	6
4	25	7	4	15	4	6
5	28.8	8.8	6	18	5	6.2
6	26	7	5	15.7	4.2	5.2
7	25.8	7.5	5	14.3	4.2	6.2
8	34	9	6	20	6	8
9	29	9	5.4	17	5	6
10	30	7.9	5.8	17.1	5	6
11	29	9	5	16.5	5	6.8
12	29.5	9	5.1	18.2	5	6.5
13 (Holotype)	30	9	5	17.5	5	6.7
14	28.2	8.4	5.8	18	4.8	6
15	27.2	8.8	5	16	5	6
32	26.4	6.8	5.1	15.1	4.8	5.1
33	27.5	7	5	16.1	4.7	6.5
35	28.7	8.3	5	16.1	4.8	6.8
36	27.7	8.3	5	16.1	4.5	5.8
37	24	7.2	4.9	14	4.2	5.8
38	23.9	6.8	5	14	4	5
39	24.9	7.6	4.9	14.9	3.9	6
40	23.5	7	4.5	14	4	5
16	43.3	9.5	7.1	27.7	6.3	8.2
17	40.5	11.1	9.9	25.3	7.2	8.2
18	37.1	9.5	6.1	24	5.4	6.8
19	36.7	10	5.9	23.2	5	6.9
20	35.7	9.8	6.1	22.1	5	7
21	33.4	8.2	5.6	22.1	4.8	6.3
22 (Allotype)	34.2	10	5.6	22	5.4	6.6
23	32.4	8	5.2	19.6	4.2	6.1
24	38.2	10.8	6.8	22	6	7
25	31	8	6	20	4.5	7.1
26	29.8	8	6	18.2	5	7
27	30.2	8.5	6	19.8	5	6
28	26.2	8.1	5	16.5	4	6
29	31.7	9	7	20.8	5	6.3
30	30	9	6.8	19	5	6
31	27.1	8	5	16.9	4.1	6
34	25.8	7.5	5.1	16	4.1	6.1

Table 9. Data sheet for San Felipe *Gambusia* (continued)

Specimen Number	D fin bar 0=absent; 1=weak; 2=strong	Rows of spots - Dorsal fin	Spotting pattern caudal fin	Body spotting code	Snout Pigment Intensity	Predorsal streak width (mm)	Post anal streak presence
1	0	0	0	3	2	0.7	0
2	0	0	0	4	2	0.5	0
3	1	0	0	4	2	0.9	0
4	0	0	0	4	2	0.4	0
5	1	1	0	4	2	0.5	0
6	1	0	0	4	2	0.7	0
7	0	0	0	4	2	0.7	0
8	0	0	0	3	2	0.4	0
9	1	0	0	4	2	0.5	0
10	1	0	0	4	2	0.6	0
11	0	0	0	4	2	0.6	0
12	1	0	0	4	2	0.6	0
13 (Holotype)	1	0	0	4	2	0.8	0
14	1	0	0	4	2	0.6	0
15	1	0	0	4	2	0.4	0
32	1	0	0	4	2	0.5	0
33	1	0	0	4	2	0.5	0
35	0	0	0	4	2	0.6	0
36	1	0	0	4	2	0.8	0
37	0	0	0	4	2	0.6	0
38	1	0	0	4	2	0.5	0
39	0	0	0	3	2	0.6	0
40	2	0	0	3	2	0.7	0
16	0	0	0	4	2	1.5	0
17	1	2	0	4	2	1.4	0
18	0	0	0	4	2	0.8	0
19	0	0	0	4	1	0.6	0
20	1	0	0	3	1	1.3	0
21	0	1	0	4	1	0.9	0
22 (Allotype)	0	0	0	4	2	0.9	0
23	1	0	0	4	1	1	0
24	1	0	0	4	2	0.8	0
25	0	0	0	4	2	1	0
26	0	0	0	3	2	1.1	0
27	1	0	0	3	2	0.7	0
28	1	0	0	4	2	0.6	0
29	0	0	0	4	2	0.8	0
30	0	0	0	3	2	0.8	0
31	0	0	0	4	2	0.6	0
34	0	0	0	4	2	0.5	0

Table 9. Data sheet for San Felipe *Gambusia* (continued)

Specimen Number	Intensity of Anal spot in females	Subocular bar present	HL / SL	HD / SL	PDL / SL	CPD / SL	CL / SL
1		0	0.27	0.19	0.54	0.15	0.20
2		0	0.27	0.19	0.56	0.19	0.22
3		0	0.28	0.18	0.57	0.15	0.21
4		0	0.28	0.16	0.60	0.16	0.24
5		0	0.31	0.21	0.63	0.17	0.22
6		0	0.27	0.19	0.60	0.16	0.20
7		0	0.29	0.19	0.55	0.16	0.24
8		0	0.26	0.18	0.59	0.18	0.24
9		0	0.31	0.19	0.59	0.17	0.21
10		0	0.26	0.19	0.57	0.17	0.20
11		0	0.31	0.17	0.57	0.17	0.23
12		0	0.31	0.17	0.62	0.17	0.22
13 (Holotype)		0	0.30	0.17	0.58	0.17	0.22
14		0	0.30	0.21	0.64	0.17	0.21
15		0	0.32	0.18	0.59	0.18	0.22
32		0	0.26	0.19	0.57	0.18	0.19
33		0	0.25	0.18	0.59	0.17	0.24
35		0	0.29	0.17	0.56	0.17	0.24
36		0	0.30	0.18	0.58	0.16	0.21
37		0	0.30	0.20	0.58	0.18	0.24
38		0	0.28	0.21	0.59	0.17	0.21
39		0	0.31	0.20	0.60	0.16	0.24
40		0	0.30	0.19	0.60	0.17	0.21
16	0	0	0.22	0.16	0.64	0.15	0.19
17	0	0	0.27	0.24	0.62	0.18	0.20
18	0	0	0.26	0.16	0.65	0.15	0.18
19	0	0	0.27	0.16	0.63	0.14	0.19
20	0	0	0.27	0.17	0.62	0.14	0.20
21	0	0	0.25	0.17	0.66	0.14	0.19
22 (Allotype)	0	0	0.29	0.16	0.64	0.16	0.19
23	1	0	0.25	0.16	0.60	0.13	0.19
24	0	0	0.28	0.18	0.58	0.16	0.18
25	0	0	0.26	0.19	0.65	0.15	0.23
26	1	0	0.27	0.20	0.61	0.17	0.23
27	0	0	0.28	0.20	0.66	0.17	0.20
28	0	0	0.31	0.19	0.63	0.15	0.23
29	0	0	0.28	0.22	0.66	0.16	0.20
30	0	0	0.30	0.23	0.63	0.17	0.20
31	1	0	0.30	0.18	0.62	0.15	0.22
34	0	0	0.29	0.20	0.62	0.16	0.24

Table 10. Summary Statistics for San Felipe *Gambusia* Morphometrics

	Males			Females		
	Mean	SD	N	Mean	SD	N
Dorsal Rays	9.09	0.29	23	9.06	0.24	17
Anal Rays	---	---	---	9.94	0.24	17
Pelvic Rays	6.00	0.00	23	6.00	0.00	17
Pectoral Rays	13.65	0.49	23	13.59	0.51	17
Lateral Scales	29.83	0.58	23	30.41	0.62	17
Predorsal Scales	14.78	0.60	23	15.59	0.51	17
Standard Length	27.40	2.43	23	33.14	4.97	17
Bar on Dorsal fin margin code	0.65	0.57	23	0.35	0.49	17
Rows of spots - Dorsal fin code	0.04	0.21	23	0.18	0.53	17
Spotting pattern caudal fin	0.00	0.00	23	0.00	0.00	17
Body spotting code	3.83	0.39	23	3.76	0.44	17
Snout Pigment Intensity	2.00	0.00	23	1.76	0.44	17
Predorsal streak width (mm)	0.60	0.13	23	0.90	0.29	17
Post anal streak presence	0.00	0.00	23	0.00	0.00	17
Intensity of Anal spot in females	---	---	---	0.18	0.39	17
Subocular bar present	0.00	0.00	23	0.00	0.00	17
HL / SL	0.29	0.02	23	0.27	0.02	17
HD / SL	0.19	0.01	23	0.19	0.03	17
PDL / SL	0.59	0.02	23	0.63	0.02	17
CPD / SL	0.17	0.01	23	0.15	0.01	17
CL / SL	0.22	0.02	23	0.20	0.02	17

Table 11. Gonopodium data for San Felipe *Gambusia* males

Specimen #	Elbow Segments Ray 4a	N Fused Elbow Elements	# Serrae Ray 4p	Hook Angle Ray 4p	Hook Angle Ray 5a	# Spines Ray 3
1	0-3-0	3	6	90	90	9
2	0-2-1	2	5	90	90	10
3	1-1-1	0	4	90	90	11
4	0-3-0	3	5	90	85	9
5	0-2-1	0	4	90	90	9
6	1-2-1	2	4	90	85	9
7	1-2-0	2	4	85	85	9
8	0-3-0	3	5	90	90	10
9	1-3-1	3	6	90	85	9
10	0-3-1	3	4	90	90	9
11	1-2-1	2	4	90	75	9
12	0-2-1	2	4	90	90	10
13	0-3-0	3	4	90	90	9
14	0-3-0	3	4	90	90	9
15	0-3-0	3	5	90	90	9
32	0-2-1	2	4	90	85	9
33	0-3-0	3	5	90	90	9
35	Damaged	---	4	Damaged	Damaged	Damaged
36	0-3-0	0	4	90	90	10
37	0-2-0	2	5	90	85	9
38	0-2-0	2	5	90	90	9
39	1-3-1	3	4	90	90	9
40	1-2-1	2	5	90	90	10

Conclusions and Recommendations

In Part One of this series, I noted that obligate stream dwelling fishes inhabit a wide diversity of habitats within the state and also exhibit a high diversity of habits and other life history traits, in most cases covering the range of habits and habitats throughout each species' range. I concluded that because of these factors, it would seem unlikely that a water development strategy, which only considers the needs or preferences of one or a few species, would be successful for the whole suite of species found in the communities of most Texas aquatic environments. In this volume, additional species, with additional ecological requirements are reported which supplement these conclusions.

The Texas Water Development Board and other management and regulatory agencies should continue to collect rigorous quantitative basic data on the life histories of native species in their natural environments since much of the existing information is of a qualitative nature and difficult to use directly in the aquatic ecosystem simulations used to model different water development scenarios. As but one example of the need for agencies to continue to collect basic data, is the discovery of a fish species new to science that might have gone unnoticed except for the opportunities afforded by this type of research. The new species, a member of the *Gambusia nobilis* species group, joins three other Texas members of this group, each of those in danger of extinction because of limitations in water quantity and flows. The importance of spring flows to these spring-dependent species, cannot be overstressed. The Texas Water Development Board and other management and regulatory agencies should continue efforts to bring springs and their underlying aquifers into the public trust in order to protect and conserve aquatic resources dependent upon them.

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