ECOLOGICAL PROFILES FOR SELECTED STREAM-DWELLING TEXAS FRESHWATER FISHES

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 which 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The purpose of this study is to develop species profiles, primarily from the literature (published and unpublished), personal observations from established researchers and museum records for nineteen obligate or mostly obligate riverine species. These species are: central stoneroller (*Campostoma anomalum*), creek chub (*Semotilus atromaculatus*), speckled chub (*Macrhybopsis aestivalis*), mimic shiner (*Notropis volucellus*), red shiner (*Cyprinella lutrensis*), blacktail shiner (*Cyprinella venusta*), Texas shiner (*Notropis amabilis*), silverband shiner (*Notropis shumardi*), pugnose minnow (*Notropis emiliae*), ghost shiner (*Notropis buchanani*), gray redhorse (*Moxostoma congestum*), spotted sucker (*Minytrema melanops*), tadpole madtom (*Noturus gyrinus*), Guadalupe Bass (*Micropterus treculi*), warmouth (*Lepomis gulosus*), longear Sunfish (*Lepomis megalotis*), orangethroat darter (*Etheostoma spectabile*), river darter (*Percina shumardi*), and dusky darter (*Percina sciera*).

The 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. Spawning times, habitat-related spawning requirements, habitat- utilizations for other life stages, and especially habitat utilizations under conditions of normal to low flows are also presented, if the information is known or can be inferred.

The specific objectives include: (1) To develop species profiles including information on life history characteristics for each species which can be found in the published scientific literature, unpublished agency reports, and observational and unpublished scientific data from knowledgeable scientists working with Texas fishes for 19 selected obligate riverine freshwater fishes in Texas. (2) To describe quantitatively and qualitatively ecological factors which limit these species' abundances, especially under periods of low to normal flow regimes. (3) To determine which 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.

Methods

Museum records for the target species were collected, along with various locality and field notes, from the research natural history museums. Out-of-state museums that were assessed for records from Texas for these 19 species were:

The Fish Collection at the Academy of Natural Sciences of Philadelphia
Bishop Museum Ichthyology Collection in Hawaii
Cornell University Ichthyology and Herpetology Collections
Chicago Field Museum of Natural History
Harvard University Museum of Comparative Zoology Fish Collection
University of Kansas Natural History Museum
The Fish Collection of the Swedish Museum of Natural History
Museum of Zoology at the University of Michigan
The Fish Collection at the University of Alabama

Information on specimens housed in research museums in Texas was limited to the fish specimens housed in the University of Texas Natural History Collection (TNHC). The collections in the vertebrate collections at Texas A&M University are currently being put into computer files for electronic access following a severe flooding event in 1994.

Below is a summarization of the number of specimens and lots available for analysis and the locality information that was collected. Considerable variation in the number of specimens from Texas exists in the different museums (e.g. the Swedish Museum of Natural History and the Bishop Museum in Hawaii had no fishes collected from Texas; Cornell and Harvard Universities have only a few specimens; the University of Michigan, University of Kansas, and the University of Alabama have considerable and significant holdings).

From discussions with other ichthyologists and from a perusal of museum collection records and field notes, it was noted that various habitat descriptions, especially with regard to current velocities, are in common usage. These include descriptions such as: "moving," "slow," "fast," and "moderate." However, there appears to be no standardization with respect to these current descriptions and actual measured velocities. In order to estimate these parameters, current velocities were determined using a Marsh-McBirney, Inc. Flo-Mate Model 2000 flow meter at the standard six-tenths of maximum depth at as many different habitat types as possible at 17 sites. The sites were chosen to correspond with localities that either were commonly used by a number of investigators, or localities in which species' habitat utilizations were more-or-less known from previous studies and site utilizations could be partly reconstructed. Sites were visited when water levels were visually judged to be "low water" and sites were chosen to represent a wide range of typical available habitats found in the state, with the exception of those found in the western portion. The sites and dates of current velocity measurements were:

1) Guadalupe River, Highway 3160 Crossing (1/2/96)
2) Guadalupe River, Highway 87 in Comfort (1/2/96)
3) Guadalupe River, Lion's Park in Center Point (1/2/96)
4) Llano River, in Llano below dam (1/3/96)
5) Llano River, Lehmberg's Crossing (1/3/96)
6) Pedernales River, Gellermann Lane, west of Johnson City off Highway 290 (1/4/96)
7) Blanco River, west of Blanco, off Highway 1623 approximately 06 km east of Junction with Highway 1888 (1/4/96)
8) San Marcos River, 1 km upstream from Martindale (1/5/96)
9) San Marcos River, at "Old Town" crossing, Count Road 266 (1/5/96)
10) San Marcos River, above Thompson's Island (1/5/96)
11) Onion Creek, Highway 973 crossing (1/5/96)
12) Village Creek, Highway FM 418 crossing between Kountze and Silsbee (6/20/96)
13) Village Creek, Highway FM 327 crossing south of Kountze (6/20/96)
14) Neches River, Highway 96 crossing near Evadale (6/21/96)
15) East Fork San Jacinto River, Highway 105 crossing in Cleveland (6/21/96)
16) Brazos River, Highway 20 crossing at Soda Springs, west of Fort Worth (6/23/96)
17) Bosque River, in Clifton County Park (6/24/96)

Following the collection of these data, known species occurrences were assigned with either specific current speeds for a particular site or, if the specific position of a fish was known only with respect to the general habitat in which it had been found, the mean current velocity for that particular habitat was substituted. Information about relative and seasonal abundances of these species is summarized in the appendices of Edwards (1980) and in additional unpublished field notes. Two additional independent data sets were also used to develop current utilization patterns of the species of concern. The first set was taken from an examination of all of the extensive field notes of Dr. Clark Hubbs, housed at the Texas Natural History Collections and summarized in Anderson et al. (1995). From these field notes, specific habitat information was gathered for 123 species-locality observations. An additional data set was taken from the appendix of the IFIM study done by the Lower Colorado River Authority (Mosier and Ray, 1992) in which current velocities and species occurrences were documented at the following sites in the Colorado River basin:

Bend (5/23/89 and 5/25/89)
Webberville (9/27/89, 10/24-27/89)
Bastrop (11/2-3/89, 12/12/89, 1/25-26/90, 3/6/90, and 3/8/90)
Eagle Lake (2/6/90 and 2/8-9/90)
Egypt (1/17/90 and 2/13-16/90).

Table 1. Number of lots and specimens of targeted species housed in various research museums that are accessible through the Internet.

			# of Specimens		
Museum	# Species	# of Lots	Alcohol	Skeletons	C&S*
Outside Texas	20**	1,213	27,574	6	60
TNHC	20**	2,481	40,655	0	0
Totals		3,694	68,229	6	60

*Cleared and Stained
**Includes spotted bass (*Micropterus punctulatus*) records in addition to the 19 species listed above.

Table 2. Breakdown of collection records surveyed from 10 Research Museums by species, number of specimens and lots (bottles).

	TNHC		Out-of-state	
Species	N	Lots	N	Lots
Campostoma anomalum	4,478	224	979	66
Cyprinella lutrensis	7,326	208	14,912	250
Cyprinella lutrensis x *venusta* hybrids	72	8	230	17
Cyprinella venusta	8,060	245	4,315	125
Etheostoma spectabile	4,589	200	560	33
Lepomis gulosus	688	187	368	48
Lepomis megalotis	1,796	236	1,563	194
Macrhybopsis aestivalis	1,652	144	392	41
Micropterus punctulatus	460	97	123	55
Micropterus treculi	636	97	58	16
Minytrema melanops	125	30	27	10
Moxostoma congestum	191	57	95	23
Notropis amabilis	4,980	195	908	43
Notropis buchanani	703	45	1,017	51
Notropis emiliae	725	99	178	29
Notropis shumardi	155	16	182	6
Notropis volucellus	2,605	157	597	38
Noturus gyrinus	372	72	121	29
Percina sciera	812	131	844	121
Percina shumardi	122	21	123	14
Semotilus atromaculatus	108	12	48	4
Totals	40,655	2,481	27,640	1,213

Results and Discussion

Minnows (Family Cyprinidae)

1. Central stoneroller—*Campostoma anomalum* (Rafinesque)

Distribution: This widespread species is found throughout the eastern U.S. In Texas it is primarily found in streams of the Edwards Plateau and occurs as far west as the Devils River and Sycamore Creek (Burr 1980, Hubbs et. al. 1991, Milligan and Lemmons 1993).

Habitat Occupation: Stonerollers are characteristic of permanent streams with rocky riffles. They may be found throughout their range abundantly in flowing upland waters in small creeks to large rivers. In coastal plain streams, they appear restricted to isolated higher-gradient streams and creeks with extensive gravel bottoms. They tend to be absent in streams without gravel substrates.

In Texas, as elsewhere, the species is typically found in streams which are small, generally clear, with gravel, rubble, or exposed bedrock substrates. In these streams, they are often the most abundant species found (Miller 1962, Burkhead 1980, Layher et al. 1981, McNeely 1987, Robison and Buchanan 1988). They are also commonly found in smaller creeks that maintain at least some current throughout most of the year, especially during the spring spawning season.

After hatching, young stonerollers school and feed along vegetated stream margins and in quiet warm backwaters in the late spring and early summer. Juveniles are often found inhabiting faster waters surrounding vegetated riffles during the summer and fall, and also oftentimes found inhabiting midstream habitats in pools with both algal mats and moderately flowing water currents (Theodrakis 1987, Leonard and Orth 1988a, 1988b, Mundahl and Ingersoll 1989, Matthews 1990).

The species does seem to be somewhat intolerant to heavy siltation or pollutants which may affect the quantity of algae available in the pools and riffles (Facemire 1989, Chagnon and Hlohowskyj 1989, Kopp 1990, Morales 1990, Hlohowskyj and Chagnon 1991, Cannon and Kimmel 1992, Etnier and Starnes, 1993, Fore et al. 1995). A significant inverse correlation has been found between the abundance of stonerollers and predatory species such as the various members of *Micropterus* and also for the overall quantity of algae in a given stream segment (Power et al. 1985, Stewart 1987, Harvey et al. 1988, Power 1988, Harvey 1991, Harvey and Stewart 1991, Gelwick and Matthews 1992, Vaughn et al. 1992, Braaten 1993). It has been observed that stonerollers often reach their greatest abundances in streams with thick algal mats which are sometimes the result of urban or agricultural organic enrichment (Power and Matthews 1983, Tomelleri and Eberle, 1990).

Table 3. Habitats occupied by *Campostoma anomalum*. Values are percent occupation at sites selected for current speed measurements. Mean velocities for each habitat type are shown.

	N	Back-waters	Shallow Shelf	Moving Pools	Below Dam	Above Riffles	In Riffle	Run/ Glides	Rapids
Mean Velocity (m/sec)		**0.0164**	**0.0882**	**0.2912**	**0.3500**	**0.4001**	**0.5896**	**0.7847**	**1.2211**
Campostoma anomalum	**244**	**10.7**	**1.2**	**54.9**	**1.2**	**6.1**	**9.0**	**16.4**	**0.4**

Feeding: Adult and subadult stonerollers feed primarily on algae and detritus and any encrusted organisms that can be scraped off surfaces with their cartilaginous lower lips. In addition, adults have also been found to feed on diatoms, small aquatic insects, and even an occasional small fish (Johnson and Dropkin 1992, Short and Holomuzki 1992). The young feed on rotifers, filamentous algae, and microcrustacea. Stewart (1987) found that not all algae are consumed equally; some species are avoided altogether. This factor may influence the abundance of *Campostoma* at different localities.

Schools of stonerollers can commonly be seen grazing over rocks or on limestone ledges where they leave distinctive grazing scars (Matthews et al. 1986). Feeding activities appear to be much more extensive during the day than at night when *Campostoma* are normally inactive. In experiments involving a rockbass (*Ambloplites rupestris*), Angermeier (1992) found that daytime activities, but not the water depths used, by *Campostoma* were affected negatively in the presence of a rock bass predator. In general, the presence of a potential predator caused the stonerollers to become wary and this, in turn, affected their normal feeding activities.

Reproduction: Nest building activities begin in Texas around the beginning of February and continue through early July with spawning beginning toward mid-February to mid-July. This is confirmed by both personal observations as well as young specimens being taken that are less than approximately 25 mm SL from late February through mid-August (Edwards, 1976, research museum collection records).

In suitable creeks and streams, males build pits in gravel riffles by “bulldozing” or “rolling” the larger stones out of the way. Pits are usually near pools where females wait. Eggs are adhesive and attach to stones in the nest. There appears to be no parental care. (Johnston 1989, Page and Johnston 1990, Tomelleri and Eberle 1990, Wojtowicz 1992, McGuire 1993). In smaller creeks, adults seeks sites at the upstream portions of pools in slow-moving areas, often in association with significant quantities of sand, small gravels, and abundant algal mats. During record low flow conditions in Clark Creek, Louisiana, a paucity of gravel substrates in the creek led to a high incidence of intrageneric hybridization between *Campostoma* and *Phoxinus erythrogaster* (southern redbelly dace), *Nocomis leptocephalus* (bluehead chub) and *Notropis crysocephalus* (striped shiner), in part because of the similarity in the spawning requirements of each of these species (Grady and Cashner 1988).

Stoneroller fecundities have been estimated to be about 200 to 4800 eggs/female, with females ranging in size from 65 to130 mm SL (Schmulbach 1957).

Growth: Young reach approximately 35 to 65 mm SL in first year and 75 to 110 mm SL after 2 years. Life spans are up to three or possibly four years, however most adults die after their second year. Maximum total length recorded is 287 mm TL (Lennon and Parker 1960).

Velocity Profile:

Table 4. Mean current velocities (in meters/second) and associated descriptive statistics for all *Campostoma anomalum* habitats in which current speed information is known from localities in Texas. See text for explanation of data sets used and localities sampled.

Campostoma anomalum	N	Mean	Standard Deviation	Standard Error	95 % Confidence Interval for Mean	Minimum	Maximum
This Study	234	0.2066	0.1695	0.0111	0.1848 - 0.2285	0.0075	0.6186
Hubbs (1953-1996)	10	0.4808	0.3864	0.1222	0.2044 - 0.7573	0.0675	1.4014
Mosier and Ray (1992)	26	0.3146	0.2461	0.0483	0.2152 - 0.414	0.0552	1.1613
Weighted Average	270	0.2272	0.1975	0.012	0.2035 - 0.2508	0.0075	1.4014

2. Creek chub—*Semotilus atromaculatus* (Mitchill)

Distribution: This species is found throughout the eastern U.S. In Texas, it is limited to the smaller streams of east Texas to the coastal waters of the Brazos basin (Lee and Platania 1980, Mahon and Ferguson 1981, Hubbs et al. 1991, Tumlison et al. 1992, Chenoweth et al. 1995).

Habitat Occupation: Creek chubs typically inhabit small, clear streams and only occasionally are found in clear lakes. Oftentimes, this species inhabits the smallest, clear, gravel-bottomed headwater streams. These headwater creeks often have few other fishes. These are often intermittent streams where creek chubs inhabit the pools containing some sort of cover for escapes from other predators including birds (Fraser and Gilliam 1986). They are commonly associated with *Campostoma anomalum* in these small creek habitats. Creek chubs apparently avoid larger streams having continuous strong flows and a variety of competing fishes (Zaroban 1987, Robison and Buchanan 1988, Kirker 1989, Moody 1989, Stork and Momot 1989, Hubert and Rahel 1990, Harvey and Stewart 1991, Peterson and Gale 1991).

The species requires gravel bottoms for spawning, thus limiting its abundance in some areas. The species is often opportunistic; creek chubs are often among the first species to recolonize recently perturbed areas such as streams in forest clear-cutting zones (Garman 1987, Garman and Moring 1993) and can tolerate substantial turbidities, especially after episodic rains.

Table 5. Habitats occupied by *Semotilus atromaculatus*. Values are percent occupation at sites selected for current speed measurements. Mean velocities for each habitat type are shown.

	N	Slow Moving Pools	Moving Pools
Mean Velocity (m/sec)		**0.0675**	**0.2912**
Semotilus atromaculatus	**22**	**36.4**	**63.6**

Feeding: Creek chubs eat mostly invertebrates and plant material; however, large adults can also eat other fish. The species is a generalized feeder and prey selection tends to be a density-dependent function of prey availability (Garman and Moring 1993). The rather catholic feeding habits of this species have been cited as an important factor in determining resource partitioning between creek chubs and other fishes (Magnan and FitzGerald 1982, 1984a, 1984b). When competing with similar food competitors, creek chubs often choose benthic prey while the competitor often must rely on planktonic prey items (Magnan and FitzGerald 1984a). In general, the species is diurnal and feeds by sight mostly in the early evening and least in the morning (Barber and Minckley 1971). The young feed heavily on small aquatic invertebrates. Adult creek chubs have been found to consume small fish and large invertebrates, including crayfish. They also eat terrestrial insects floating on the water's surface and some vascular plants (Reighard, 1910; Dinsmore, 1962; Moshenko and Gee, 1973; Shemske, 1974, Copes, 1978). Felley and Hill (1983) reported that creek chubs fed almost entirely on flying insects during the summer and fall in Oklahoma, a finding largely substantiated by McNeely (1987).

Reproduction: The presence of specimens in research museums ranging from 16 to 18 mm in July and individuals ranging in size from 38 to 44 mm SL in March suggests that breeding activities begin in Texas during the summer from about June and continue through about November.

Spawning generally occurs over gravel bottoms in flowing water. The males make a shallow depression into the stream bottom with their tails and then remove the smaller remaining stones with their mouths. Pebbles are moved upstream with their snouts and the end result is a strip (or ridge) of gravel aligned with the current flow. When the redd is finished, there is usually a small ledge of stones at the head of the pit. There is apparent evidence that spawning activities begin at night (Maurakis et al. 1995). Females deposit about 50 eggs per spawning act at the upstream end of the pit; the male elongates the pit downstream, mounding the newly excavated stones over the freshly laid eggs at the head of the "trench" (Etnier and Starnes 1993). At the end of this process, a long low ridge indicates the filled in trench. (Johnston 1989, Tomelleri and Eberle, 1990). Some individuals, rather than building their own nest, appropriate constructed nests of stonerollers after first driving the males away (Becker 1983).

Creek chub fecundities have been estimated to be approximately 1100 to 7500 eggs/female (Etnier and Starnes 1993).

Growth: Creek chubs can reach a relatively large size, the maximum size record is over 300 mm TL (almost 12 inches long), but normally they only reach about half that size (typically a large creek chub would be about 125 to 150 mm TL, although the largest specimen found in research museums from Texas is only 97 mm SL)(Trautman 1957, Robison and Buchanan 1988). The species is unusual in that the largest specimens are males (Trautman 1981). In Tennessee, the young reach 50 to 90 mm during their first year, and average approximately 120 mm after two years and about 150 mm by three years with a maximum lifespan of up to 6 years (Etnier and Starnes 1993). In Texas growth rates are probably similar with a maximum lifespan of about three years.

Velocity Profile:

Table 6. Mean current velocities (in meters/second) and associated descriptive statistics for all *Semotilus atromaculatus* habitats in which current speed information is known from localities in Texas. See text for explanation of data sets used and localities sampled.

Semotilus atromaculatus	N	Mean	Standard Deviation	Standard Error	95 % Confidence Interval for Mean	Minimum	Maximum
This Study	21	0.1007	0.0601	0.0131	0.0734 - 0.1281	0.026	0.1467
Hubbs (1953-1996)	1	0.2912	0	0	0 - 0	0.2912	0.2912
Weighted Average	22	0.1094	0.0713	0.0152	0.0778 - 0.141	0.026	0.2912

3. Speckled chub—*Macrhybopsis aestivalis* (Girard)

Distribution: This species is found in most Gulf of Mexico drainages from the Rio Grande to the Apalachicola River and northward to the Great Lakes. In Texas, the speckled chub occurs in streams from the Rio Grande to the Red River (Wallace 1980, Miller 1983, Hubbs et al. 1991, Platania 1991, Winston et al. 1991, Wenke et al. 1993, Hesse 1994). Two subspecies are found in the state, *M. a. aestivalis* is the typical speckled chub found throughout most of the state while *M. a. tetranemus* is found in the Red and Canadian River drainages (Miller 1983).

Habitat Occupation: All species of *Macrhybopsis* prefer a clean bottom of sand or gravel. Speckled chubs inhabit swift flowing waters in large rivers over sandy and gravelly substrates (Robison and Buchanan 1988, Etnier and Starnes 1993). It is often the most characteristic fish inhabiting shallow rivers and streams with rapid, turbulent, or laminar flows (Sublette et al. 1990). These streams often have sand or gravel substrates; are often somewhat turbid with high levels of dissolved solids (Cross and Moss 1987). Trautman (1981) noted a preference for deeper water during the day and shallower water at night. Where found, speckled chubs often are taken either singly or in small (about 10 to 20 individuals) schools. Rarely are large schools found.

Table 7. Habitats occupied by *Macrhybopsis aestivalis*. Values are percent occupation at sites selected for current speed measurements. Mean velocities for each habitat type are shown.

	N	Isolated Pools	Slow Moving Pools	Edge	Moving Pools	Above Riffle	Below Riffle	In Riffle	Run/ Glides	Rapids
Mean Velocity (m/sec)		**0.0000**	**0.0675**	**0.0829**	**0.2912**	**0.4001**	**0.4405**	**0.5896**	**0.7847**	**1.2211**
Macrhybopsis aestivalis	**51**	**2.0**	**3.9**	**2.0**	**35.3**	**13.7**	**5.9**	**23.5**	**5.9**	**7.8**

Feeding: Speckled chubs feed on a diet of aquatic insect larvae, especially midges (Chironomidae). Juveniles tend to be solitary, feeding actively from the bottom, or on items falling toward the bottom while larger individuals are more likely to only feed on the bottom and are easily frightened into seeking cover when disturbed (Tomelleri and Eberle, 1990, Etnier and Starnes 1993).

Reproduction: Individuals less than approximately 20 mm SL are found in research museum collections throughout the year except the late winter months. This suggests that, in Texas, speckled chubs have a protracted spawning season beginning in late spring and continuing until about November or early December. This is much longer than the summer (May through August) breeding season in Arkansas and Tennessee where spawning begins when temperatures exceed 21.1C (Robison and Buchanan 1988, Etnier and Starnes 1993). Bottrell et al. (1964) reported spawning occurs near midday in flowing water, and eggs drift for the approximate day or so until hatching. Eggs generally are deposited in deeper waters with swift current at midday and the eggs develop as they drift in the current. Eggs are clear, nonadhesive, semibuoyant, pelagic, and about 0.7 to 0.9 mm in diameter (Coburn 1986).

Growth: The young grow to about 40 mm by their first spring-time and they live maximally for about 1.5 years. The largest specimen in museum collections is 59 mm SL. Similarly, in Arkansas, speckled chubs seldom live more than 1.5 years and reproduction is by 1-year old fish (Robison and Buchanan 1988).

Velocity Profile:

Table 8. Mean current velocities (in meters/second) and associated descriptive statistics for all *Macrhybopsis aestivalis* habitats in which current speed information is known from localities in Texas. See text for explanation of data sets used and localities sampled.

Macrhybopsis aestivalis	N	Mean	Standard Deviation	Standard Error	95 % Confidence Interval for Mean	Minimum	Maximum
This Study	39	0.4087	0.3002	0.0481	0.3114 - 0.506	0.026	0.82
Hubbs (1953-1996)	11	0.7601	0.4147	0.125	0.4815 - 1.0388	0.0675	1.4014
Mosier and Ray (1992)	1000	0.583	0.1835	0.0058	0.5716 - 0.5944	0	1.7343
Weighted Average	1050	0.5784	0.196	0.006	0.5665 - 0.5902	0	1.7343

4. Mimic shiner—*Notropis volucellus* (Cope)

Distribution: The mimic shiner is found throughout the eastern half of the state from the Nueces basin northward, but apparently not found in the Red River in Texas. Elsewhere its distribution includes the Gulf of Mexico states eastward to Mobile Bay (Gilbert and Burgess 1980, Hubbs et al. 1991Morrison and Cincotta 1992). One unusual anomaly is that the species is apparently absent from much of Tennessee, especially in coastal plain tributaries where it would seem to have suitable conditions (Etnier and Starnes, 1993).

Habitat Occupation: This species is a schooling minnow living in midwater or at the surface. Mimic shiners are generally found in medium to large streams and rivers in current over gravel or hard substrates. In the larger rivers, it commonly occurs over sandy bottoms and is very abundant near creek mouths (Robison and Buchanan 1988, Kinsolving and Bain 1990). They tend to be rarely encountered in the smaller creeks as well as in marshy or swampy areas. Elsewhere in their range they tend to be commomly found in glacial lakes in midwestern U.S. and also in clear small rivers and streams in this geographic region. They possess considerable tolerance for reservoirs and even the Mississippi River. Diurnal migrations to and from inshore areas have been noted (away from shore at night) (Black, 1945; Moyle, 1973).

Table 9. Habitats occupied by *Notropis volucellus*. Values are percent occupation at sites selected for current speed measurements. Mean velocities for each habitat type are shown.

	N	Isolated Pools	Back-water	Slow Moving Pools	Edge	Shallow Shelf	Channel	Moving Pools
Mean Velocity (m/sec)		**0.0000**	**0.0164**	**0.0675**	**0.0829**	**0.0882**	**0.2405**	**0.2912**
Notropis volucellus	**343**	**0.3**	**5.8**	**11.1**	**0.3**	**0.3**	**0.3**	**50.1**

		Above Riffle	Below Riffle	In Riffle	Run/ Glide	Rapids
Mean Velocity (m/sec)		**0.4001**	**0.4405**	**0.5896**	**0.7847**	**1.2211**
Notropis volucellus		**14.3**	**7.6**	**9.3**	**0.3**	**0.3**

Feeding: The diets of *N. volucellus* include microcrustacea, midge larvae and pupae, and some terrestrial insects (Johnson and Dropkin 1991, Etnier and Starnes 1993, Johnson and Dropkin 1993, 1995,). Foods consumed tend to be small but can even include larval fishes such as the larval American shad in the Susquehanna River in Pennsylvania (Johnson and Dropkin 1992, Rottiers and Johnson 1993).

Reproduction: Small mimic shiners (less than 16 mm SL) are present in research museum collections as early as the end of March and as late in the year as mid-December suggesting that spawning probably occurs in late spring and early summer although the exact breeding sites and spawning habits of the species are largely unknown. Spawning likely reaches a peak in mid-summer as many small specimens are present in the various museum collections during this time. Black (1945) suggested that the species is a nocturnal spawner using deep water areas among dense weed beds as spawning sites. Males produce nuptial tubercles from late May to early October in Tennessee, also suggesting a relatively long breeding season peaking in the summer (Etnier and Starnes 1993).

Growth: The maximum record size of mimic shiners is 65 mm TL (in Tennessee) but they reportedly can get larger elsewhere, for example in Ohio where the largest individual taken is 76 mm TL (Black 1945, Trautman 1981, Etnier and Starnes 1993). Individuals reach sexual maturity at approximately one year of age and likely have a maximum lifespan of no more than two years. In Texas, the largest individuals in museum collections are 51 mm SL which corresponds to approximately 66 mm TL.

Velocity Profile:

Table 10. Mean current velocities (in meters/second) and associated descriptive statistics for all *Notropis volucellus* habitats in which current speed information is known from localities in Texas. See text for explanation of data sets used and localities sampled.

Notropis volucellus	N	Mean	Standard Deviation	Standard Error	95 % Confidence Interval for Mean	Minimum	Maximum
This Study	331	0.3899	0.2226	0.0122	0.3658 - 0.4139	0.005	0.82
Hubbs (1953-1996)	12	0.4051	0.4412	0.1274	0.1248 - 0.6854	0.0164	1.2211
Mosier and Ray (1992)	24	0.1776	0.1442	0.0294	0.1167 - 0.2385	0.0061	0.3536
Weighted Average	367	0.3765	0.2337	0.0122	0.3525 - 0.4005	0.005	1.2211

5. Red shiner—*Cyprinella lutrensis* (Baird and Girard)

Distribution: Red shiners can be found throughout the southern Great Plains of the U.S. into Mexico. This plains species occurs widely throughout the state. One subspecies, the Maravillas red shiner (*C. lutrensis blairi*), was found only in a very limited area of the Big Bend region in west Texas and is thought to be extinct (Miller et al. 1989), although attempts to document this form in the region are limited (Burr et al. 1980, Matthews 1980, Matthews 1987, Hubbs et al. 1991)

Habitat Occupation: This species occupies small streams and large rivers over a variety of bottom substrates, including sand and mixed sand, silt, and gravel (Callam and Peters 1981, Robison and Buchanan 1988, Callam 1989, Meador et al. 1990, O'Shea et al. 1990, Braaten 1993). Red shiners are very tolerant of altered or drastically fluctuating habitats and introduced populations often thrive in these localities (Cross, 1967, Williams 1977, Bestgen and Propst 1987, Bramblett 1989, Haines and Tyus 1990, Bramblett and Fausch 1991, Fausch and Bramblett 1991, Rinne 1991, Douglas et al. 1994). They are most often found in quiet waters, but they have also been found in water with significant currents, especially during the summer months when water temperatures are elevated (Jakle and Barrett 1988, Robison and Buchanan 1988, Brown and Coon 1994, pers. observ.). In Arkansas, the species appears to be replaced in clear lowland tributaries of the large silty rivers by blacktail shiners, *C. venusta* (Robison and Buchanan 1988).

Brues (1928) collected red shiners in New Mexico at water temperatures of 39.5C. This is the highest thermal tolerance known for a cyprinid. Matthews and Hill (1977) found extremely high tolerances to rapidly changing temperatures, dissolved oxygen, pH, and a variety of salinity regimes. Tolerances for pH was between 5 and 10, salinity up to 10 ppt, and thermal shock of T+10 to T-21 C. The species' extreme tolerance for low dissolved oxygen levels of approximately 1.5 ppm was attributed to the red shiner's ability to obtain oxygen from water surface film. Further evidence for extreme tolerances to low dissolved oxygen levels and elevated temperatures was provided by Rutledge and Beitinger (1989). However, it has also been shown that a variety of pollutants, including heavy metals and industrial and agricultural contaminants can reduce the tolerance of red shiners to environmental stressors (Roxie 1987, Carrier and Beitinger 1988, Abukhalaf et al. 1994)

Table 11. Habitats occupied by *Cyprinella lutrensis*. Values are percent occupation at sites selected for current speed measurements. Mean velocities for each habitat type are shown.

	N	Isolated Pools	Back-water	Slow Moving Pools	Edge	Shallow Shelf	Moving Pools	In Riffle
Mean Velocity (m/sec)		**0.0000**	**0.0164**	**0.0675**	**0.0829**	**0.0882**	**0.2912**	**0.5896**
Cyprinella lutrensis	**1499**	**5.4**	**6.0**	**72.0**	**3.5**	**0.5**	**2.6**	**10.0**

Feeding: The diet of red shiners includes both terrestrial and aquatic insects, and algae (Sublette 1975, Hummer 1978, Peck 1984, Deacon and Greger 1987, Greger and Deacon 1988, Ruppert et al. 1993). They are generally unspecialized in taking suitable foods and appear to be feeding generalists consuming foods in the proportion in which they occur.

Reproduction: Red shiners have an extended spawning season in Texas and small individuals have been taken in all but the coldest winter months. This suggests a spawning season from about mid- to late-February until mid-November depending upon water temperatures. The species spawns over beds of submerged vegetation, well oxygenated stream gravels or other objects, including the nests of a variety of sunfishes (Altenbach 1993, pers. observ.). Cross

(1967) reported a spawning aggregation associated with a submerged stump that had been "polished" by the cleaning activities of approximately 50 nuptial males. Eggs are adherent and settle to the bottom where they cling to the substrate. Females have a fecundity of about 485 to 684 eggs (Becker 1983). Extensive hybridization with *C. venusta* is common throughout the western portion of these two species' ranges.

Growth: Individuals grow to approximately 35 to 45 mm SL in their first year and grow slowly afterwards. The maximum adult size present in museum collections of Texas specimens is 73 mm SL although slightly larger individuals are known. The maximum lifespan is probably two years.

Velocity Profile:

Table 12. Mean current velocities (in meters/second) and associated descriptive statistics for all *Cyprinella lutrensis* habitats in which current speed information is known from localities in Texas. See text for explanation of data sets used and localities sampled.

Cyprinella lutrensis	N	Mean	Standard Deviation	Standard Error	95 % Confidence Interval for Mean	Minimum	Maximum
This Study	1499	0.086	0.1764	0.0046	0.077 - 0.0949	0	0.6011
Mosier and Ray (1992)	1471	0.2959	0.1647	0.0043	0.2875 - 0.3044	0	1.1247
Weighted Average	2970	0.19	0.2004	0.0037	0.1827 - 0.1972	0	1.1247

6. Blacktail shiner—*Cyprinella venusta* Girard

Distribution: Blacktail shiners range primarily in the Gulf Coastal Plain from the Suwannee drainage in Florida to Texas. In Texas, the species ranges in most streams as far west as the Edwards Plateau. A population has been introduced into the Pecos River near Pandale (Gilbert and Burgess 1980, Cicerello and Warren 1984, Hubbs et al. 1991, Bart et al. 1994).

Habitat Occupation: This is a schooling species inhabiting medium to large streams and rivers, sluggish ditches over sand bottoms and occasionally oxbow lakes which are sparsely vegetated (Robison and Buchanan 1988). Blacktail shiners usually prefer waters with some currents, although the species is not uncommon in reservoirs. Where they are sympatric with red shiners (*Cyprinella lutrensis*), blacktail shiners more often inhabit larger streams with greater currents while red shiners inhabit the quieter waters of the smaller streams and tributary creeks. Within these tributary creeks, red shiners are found in the more upstream areas while blacktail shiners inhabit the downstream stretches. They are often found in clear to very turbid waters; however, they tend to be in reduced abundance from constant temperature spring runs. When largescale perturbations occur, such as aquatic vegetation control in reservoirs, blacktail shiners are moderately slow in recovering from such events compared with a number of other sympatric species (Bettoli 1988).

Table 13. Habitats occupied by *Cyprinella lutrensis*. Values are percent occupation at sites selected for current speed measurements. Mean velocities for each habitat type are shown.

	N	Isolated Pools	Back-water	Slow Moving Pools	Slow Narrows	Channel	Moving Pools	Below Dam
Mean Velocity (m/sec)		**0.0000**	**0.0164**	**0.0675**	**0.1300**	**0.2405**	**0.2912**	**0.3500**
Cyprinella venusta	**4803**	**5.8**	**1.9**	**25.2**	**0.2**	**0.4**	**62.0**	**3.6**

	Above Riffle	In Riffle	Run/ Glide	Rapids
Mean Velocity (m/sec)	**0.4001**	**0.5896**	**0.7847**	**1.2211**
Cyprinella venusta	**0.3**	**0.4**	**0.2**	**0.02**

Feeding: Foods are primarily terrestrial insects and plant material (Hambrick and Hibbs 1977, Baker and Foster 1994).

Reproduction: Specimens less than approximately 18 mm SL are present in research museum collections from Texas from all except the coldest winter months suggesting a protracted spawning season similar to that found in *Cyprinella lutrensis*. Like red shiners, spawning activities begin as early as mid-February and continue until the latter part of November or early December. For comparison, in Missouri spawning begins in about late March and continues to

September (Pflieger 1975). Eggs are apparently deposited in crevices of submerged objects (Pflieger 1975) and are adhesive. Clutch sizes range from about 139 to 459 eggs (Heins and Dorsett 1986). Low current speeds are apparently avoided for egg deposition sites. In their study of the influence of different current speeds on egg deposition sites, Baker et al. (1994) found that blacktail shiners deposited eggs in areas with current speeds of 0 to 52.5 cm/sec (mean = 30 cm/sec). A considerable amount of variation was found, however, for different populations of this species (Baker et al. 1994) with, in general, populations from areas with quieter waters (for example, lakes and reservoirs) selecting relatively slower current areas for their egg deposition sites than blacktail shiners from swifter water areas.

Growth: Blacktail shiners reach approximately 45 to 60 mm SL in their first year although stochastic events such as flooding can influence (downwards) the growth of this species (Cone et al. 1986). The largest individual from Texas present in museum collections is 105 mm SL. The maximum lifespan for the species is probably two years.

Velocity Profile:

Table 14. Mean current velocities (in meters/second) and associated descriptive statistics for all *Cyprinella venusta* habitats in which current speed information is known from localities in Texas. See text for explanation of data sets used and localities sampled.

Cyprinella venusta	N	Mean	Standard Deviation	Standard Error	95 % Confidence Interval for Mean	Minimum	Maximum
This Study	4798	0.2027	0.1739	0.0025	0.1977 - 0.2076	0	0.5219
Hubbs (1953-1996)	5	0.5769	0.529	0.2366	-0.08 - 1.2337	0.15	1.4014
Mosier and Ray (1992)	225	0.315	0.2601	0.0173	0.2808 - 0.3491	0	1.1613
Weighted Average	5028	0.2081	0.181	0.0026	0.203 - 0.2131	0	1.4014

7. Texas shiner—*Notropis amabilis* (Girard)

Distribution: The Texas shiner ranges primarily within the Edwards Plateau streams (including portions of the San Gabriel River on the northeast) and to the Pecos River in the west. The species is also found in Rio Grande tributaries in Mexico, including the Rio Salado and Rio San Juan (Gilbert 1980, Hubbs et al. 1991).

There have been no published studies on the ecology of this species (Gilbert 1980).

Habitat Occupation: Texas shiners are often found in moderately large schools in midwater in streams with moderately fast currents. Oftentimes, this species can be found in the upstream ends of pools below riffle areas, in the swiftly moving waters along gravel bars and in moderately flowing pools. It is also commonly encountered in areas below lower water dams and road crossings where there are turbulent water flows. Where sympatric with *Cyprinella lutrensis* and *C. venusta*, *Notropis amabilis* generally selects areas with a greater current velocity than the previous two species and also tends to maintain its school integrity to a greater extent than the previous species. The species is rarely found in the upstream portions of tributary creeks and is common in streams with significant spring flow components.

Table 15. Habitats occupied by *Notropis amabilis*. Values are percent occupation at sites selected for current speed measurements. Mean velocities for each habitat type are shown.

	N	Isolated Pools	Back-water	Slow Moving Pools	Channel	Moving Pools	Below Dam	Above Riffle
Mean Velocity (m/sec)		**0.0000**	**0.0164**	**0.0675**	**0.2405**	**0.2912**	**0.3500**	**0.4001**
Notropis amabilis	**682**	**7.6**	**6.6**	**7.2**	**0.6**	**40.2**	**3.5**	**20.4**

	Below Riffle	In Riffle	Run/ Glide	Rapids
Mean Velocity (m/sec)	**0.4405**	**0.5896**	**0.7847**	**1.2211**
Notropis amabilis	**8.8**	**1.5**	**3.2**	**0.4**

Feeding: The few *Notropis amabilis* stomachs (all adults) that have been examined contained terrestrial insects during the summer. No other information about the food habits or variation among different populations is known.

Reproduction: Specimens from Texas that are less than 20 mm SL are present in research museums which were collected from mid-April to mid-December suggesting that Texas shiners spawn beginning in about late March and continuing through about mid-November. Other aspects of the reproduction of this species are unknown.

Growth: The maximum size of Texas shiners found in research museums is 62 mm SL. Although no studies have been conducted, it is likely that individuals grow to about 50 mm SL in their first year and have a maximum lifespan of no more than two years.

Velocity Profile:

Table 16. Mean current velocities (in meters/second) and associated descriptive statistics for all *Notropis amabilis* habitats in which current speed information is known from localities in Texas. See text for explanation of data sets used and localities sampled.

Notropis amabilis	N	Mean	Standard Deviation	Standard Error	95 % Confidence Interval for Mean	Minimum	Maximum
This Study	676	0.3287	0.237	0.0091	0.3108 - 0.3466	0	1.4014
Hubbs (1953-1996)	6	0.5156	0.3843	0.1569	0.1123 - 0.9189	0.3587	1.3
Weighted Average	682	0.3303	0.2389	0.0091	0.3124 - 0.3483	0	1.4014

8. Silverband shiner—*Notropis shumardi* (Girard)

Distribution: The silverband shiner is primarily large river species inhabiting the Mississippi-Missouri River systems. In Texas, this species is abundant in the Brazos basin and is found in limited numbers in the Red River and other coastal plain streams as far south as the Lavaca drainage (Gilbert 1980, Hubbs et al. 1991).

Habitat Occupation: *Notropis shumardi* is a schooling species found primarily in areas of moderate to swift currents in the main channels of large rivers along sand or gravel bars

(Robison and Buchanan 1988). The species is known for its tolerance of great turbidities (Gilbert and Bailey 1962).

Feeding: Little is known about the food habits of this species.

Reproduction: Reproductive habits are likewise little known but inferences from a variety of sources suggest that reproduction takes place in the summer from late May to early September in Missouri and Louisiana localities (Pflieger 1975, Suttkus 1980) where breeding aggregations have been observed over hard sand to fine gravel substrates in swiftly moving water at depths of one to two meters. An analysis of the sizes of specimens taken from Texas in the various research museums suggests a slightly longer breeding season occurs in Texas than reported from Missouri and Louisiana. Small specimens (31 mm SL) taken in late February were most likely hatched two months or so earlier indicating a breeding season lasting from probably late-April or early-May until the mid-fall in Texas. Individuals in nuptial coloration have been taken from the Red River on 23 April, also suggesting a late-spring initiation to the spawning season (Robison and Buchanan 1988).

Growth: Little information is available, however, the largest Texas specimen from museum collections is 60 mm SL. As with many minnows, individuals reach adulthood by the end of their first year and have a maximum lifespan of approximately two years.

Velocity Profile: No Information Available

9. Pugnose minnow—*Notropis (Opsopoeodus) emiliae* Hay

Distribution: The range of the pugnose minnow in Texas is primarily in streams of the Coastal Plain. There is a record of this species in the Trinity River near the Dallas area. Elsewhere, it is found throughout the Mississippi Valley, usually in slow moving rivers and streams (Gilbert 1980, Dimmick 1987, Hubbs et al. 1991).

Habitat Occupation: Pugnose minnows are found primarily inhabiting streams of the Coastal Plain in Texas where they inhabit slow moving rivers and streams. Elsewhere in their range, the species inhabits tannin-stained, vegetated, quiet regions of sluggish streams, oxbow lakes, borrow pits, and sloughs over mud and sand or debris substrates in or near vegetation (Robison and Buchanan 1988, Sadler 1989). The species has also been collected in clear water environments, for example, in the Colorado River between Austin and Bastrop in the stream edges next to a slow moving pool.

Table 17. Habitats occupied by *Notropis emiliae*. Values are percent occupation at sites selected for current speed measurements. Mean velocities for each habitat type are shown.

	N	Slow Moving Pools	Slow Narrows	Moving Pools	Run/ Glide
Mean Velocity (m/sec)		**0.0675**	**0.1300**	**0.2912**	**0.7847**
Notropis emiliae	**11**	**54.5**	**9.1**	**27.3**	**9.1**

Feeding: Foods include chironomids, copepods, filamentous algae, fish eggs and miscellaneous microcrustaceans (Gilbert and Bailey 1972).

Reproduction: Spawning probably occurs in the summer, but little is known about their reproduction (Robison and Buchanan 1988). Small specimens (less than 16 mm SL) housed in various research museums are present from March through July suggesting a spawning season in Texas beginning in late February and extending through at least the summer. It would not be unexpected to find this species' spawning season to continue into the fall months, once more extensive collections of the species are available.

Growth: Individuals reach approximately 35 mm SL after their first year of growth and probably have a maximum lifespan of two years. The largest individual found in the research collections is 55 mm SL.

Velocity Profile:

Table 18. Mean current velocities (in meters/second) and associated descriptive statistics for all *Notropis emiliae* habitats in which current speed information is known from localities in Texas. See text for explanation of data sets used and localities sampled.

Notropis emiliae	N	Mean	Standard Deviation	Standard Error	95 % Confidence Interval for Mean	Minimum	Maximum
This Study	1	0	0	0	0 - 0	0	0
Hubbs (1953-1996)	11	0.1626	0.1571	0.0474	0.0571 - 0.2682	0	0.3587
Weighted Average	12	0.1491	0.157	0.0453	0.0493 - 0.2488	0	0.3587

10. Ghost shiner—*Notropis buchanani* Meek

Distribution: The ghost shiner ranges from the lower Rio Grande and its Mexican tributaries northward to the Great Lakes where it becomes extremely rare. It inhabits large silt-laden streams (Gilbert 1980, Hubbs et al. 1991, Holm and Houston, 1993).

Habitat Occupation: The species inhabits warm sluggish streams throughout its range. Ghost shiners are often found in schools in often turbid rivers and sometimes are found abundantly in reservoirs. This midwater species often seeks out protected backwaters and large pools away from strong currents. Other aspects of the ecological requirements of this species are little known (Gilbert 1980).

Table 19. Habitats occupied by *Notropis buchanani*. Values are percent occupation at sites selected for current speed measurements. Mean velocities for each habitat type are shown.

	N	Isolated Pools	Back-water	Slow Moving Pools	Moving Pools	In Riffle
Mean Velocity (m/sec)		**0.0000**	**0.0164**	**0.0675**	**0.2912**	**0.5896**
Notropis buchanani	**11**	**9.1**	**54.5**	**9.1**	**18.2**	**9.1**

Reproduction: Spawning in Oklahoma occurs from late spring through August generally over sluggish riffles composed of sand and fine gravels (Miller and Robison 1973, Pflieger 1975. Robison and Buchanan 1988). Spawning in Texas is likely protracted beginning in about early February and continuing through September or maybe October based on the presence of small individuals in the various research museum collections.

Growth: Little is known about the growth of this species in Texas; however, the largest individual found in the research museum collections is 38 mm SL indicating that this species does not reach relatively large sizes. It is likely that the maximum lifespan for ghost shiners is about two years.

Velocity Profile:

Table 20. Mean current velocities (in meters/second) and associated descriptive statistics for all *Notropis buchanani* habitats in which current speed information is known from localities in Texas. See text for explanation of data sets used and localities sampled.

Notropis buchanani	N	Mean	Standard Deviation	Standard Error	95 % Confidence Interval for Mean	Minimum	Maximum
This Study	4	0.0075	0	0	0.0075 - 0.0075	0.0075	0.0075
Hubbs (1953-1996)	7	0.1867	0.2315	0.0875	-0.0274 - 0.4008	0	0.5896
Weighted Average	11	0.1215	0.2008	0.0606	-0.0134 - 0.2565	0	0.5896

Suckers (Family Catastomidae)

11. Gray redhorse sucker—*Moxostoma congestum* (Baird and Girard)

Distribution: This species is restricted in Texas to the streams within the Edwards Plateau including the Brazos, Colorado, Guadalupe, San Antonio, Nueces and Rio Grande drainages. Elsewhere, its range includes Gulf of Mexico coastal streams as far south as the Rio Soto la Marina in Mexico and the Rio Grande tributaries in New Mexico, although it appears to be declining in distribution in New Mexico (Jenkins 1980, Sublette et al. 1990, Hubbs et al. 1991).

Habitat Occupation: Gray redhorse suckers are found in rock, sand, or gravel bottomed pools and deep runs of creeks and rivers. The species also inhabits some reservoirs. The young and subadults form loose schools and inhabit riffles and gravelly runs. Adult redhorse suckers are generally found inhabiting stream pools with firm bottoms of sand or silt, sometimes with moderate turbidity (Hubbs et al. 1953). These pools are often rather deep with slow-moving currents and little vegetation. Adults and subadults can often be observed moving both up- and downstream between large pools and will often spend considerable time slowly foraging while moving across runs and other shallow water environments before settling into the new pool habitats (Cowley and Sublette 1987, pers. observ.).

Table 21. Habitats occupied by *Moxostoma congestum*. Values are percent occupation at sites selected for current speed measurements. Mean velocities for each habitat type are shown.

	N	Isolated Pools	Back-water	Slow Moving Pools	Channel	Moving Pools	Above Riffle	In Riffle	Run/ Glide
Mean Velocity (m/sec)		**0.0000**	**0.0164**	**0.0675**	**0.2405**	**0.2912**	**0.4001**	**0.5896**	**0.7847**
Moxostoma congestum	**173**	**2.3**	**39.9**	**1.2**	**0.6**	**15.0**	**14.5**	**11.0**	**15.6**

Feeding: Foods include algae, crayfish, snails, small clams, larval insects and other food organisms associated with firm substrates. Feeding seems non-selective and individuals pick up foods in the abundances in which they occur in their environment. It has been noted that the species feeds at least part of the time over riffles, since the caddisflies found in their stomachs are generally restricted to riffle habitats (Cowley and Sublette 1987, Tomelleri and Eberle 1990).

Reproduction: Gray redhorse suckers move upstream and into smaller creeks to spawn in the spring. (Martin 1986, Tomelleri and Eberle, 1990). Spawning occurs in early spring (March to April) in clear creeks where the adults have migrated. Adults school in aggregates of between 9 and about 15 adults. Spawning activities begin when water temperatures reach approximately 16.5 C and spawning has been observed at temperatures as high as 21.5 C. Spawning took place over coarse gravel and pebbles as opposed to more cobble-type environments (Martin 1986) below large riffles with swift water currents. Small specimens (less than 36 mm SL) are found in research collections during the months of May through July suggesting a spring spawning season. One individual, taken in early March from Salado Creek, a stream with abundant spring influences, was only 43 mm SL. It may be that this individual was born late in the previous year or very early in the present year.

Growth: Gray redhorse suckers can reach relatively large sizes. The largest specimen contained in the research museum collections is 300 mm SL; however, larger sizes are well known. The species is relatively long-lived; the oldest individual I have observed was five years old, although it is likely that the maximum lifespan of the species in Texas is somewhat older than that.

Velocity Profile:

Table 22. Mean current velocities (in meters/second) and associated descriptive statistics for all *Moxostoma congestum* habitats in which current speed information is known from localities in Texas. See text for explanation of data sets used and localities sampled.

Moxostoma congestum	N	Mean	Standard Deviation	Standard Error	95 % Confidence Interval for Mean	Minimum	Maximum
This Study	167	0.1769	0.2293	0.0177	0.1418 - 0.2119	0	0.6186
Hubbs (1953-1996)	6	0.3587	0	0	0.3587 - 0.3587	0.3587	0.3587
Mosier and Ray (1992)	56	0.3302	0.2554	0.0341	0.2618 - 0.3986	0	0.7132
Weighted Average	229	0.2191	0.2426	0.016	0.1875 - 0.2507	0	0.7132

12. Spotted Sucker—*Minytrema melanops* (Rafinesque)

Distribution: Spotted suckers range widely in the eastern U.S. from the Great Plains westward to the Great Lakes, and southward from western Pennsylvania to Florida. The species is absent from much of the area east of the Appalachian mountain range. In Texas it is found primarily in east Texas streams from the Red to the Brazos basins. A disjunct population occurs in the Llano River (Colorado River basin) near Junction downstream to about Mason (Gilbert and Burgess 1980, Hubbs et al. 1991, Cofer and Watkins 1993).

Habitat Occupation: Spotted suckers are usually found living in sluggish, turbid, low-gradient streams with soft bottoms of silt, organic debris, or sand, often with submerged vegetation. These areas include lowland ditches, oxbows and borrow pits and quiet backwater areas away from strong currents. In clear, hard substrate streams, such as the Llano River where they are also found, they are often found in backwaters without much current near patchy beds of vegetation or other cover which can be used as refuges. Their abundances have been noted to change markedly and negatively following artificial increases in streamflows in the southeastern U.S. (Paller et al. 1992).

Table 23. Habitats occupied by *Minytrema melanops*. Values are percent occupation at sites selected for current speed measurements. Mean velocities for each habitat type are shown.

	N	Back-water
Mean Velocity (m/sec)		**0.0164**
Minytrema melanops	**1**	**100.0**

Feeding: The species feeds off the bottom and consumes predominately zooplankton and detritus along with occasional benthic invertebrates (White and Haag 1977).

Reproduction: Spawning occurs in the spring, and male spotted suckers establish territories in large riffles Adults spawn in these riffles above pools over coarse substrates during midday. One or more males will often accompany a female in the spawning act, and the fertilized demersal and adhesive eggs then drift downstream and sink to the bottom. The eggs are eventually covered by sand and debris that are stirred up by the spawning fish (Tomelleri and Eberle, 1990). After hatching, the larvae form dense schools and then slowly lose the school integrity over a several week interval when individuals move to areas with much less current flows (Robison and Buchanan 1988). Small specimens (less than about 40 mm SL) are present in research museum collections from April through July suggesting an approximately March through June spawning season in Texas waters. Spawning occurs from March to May elsewhere in the spotted sucker's range (McSwain and Gennings 1972, Hogue and Buchanan 1977).

Growth: This species reaches a relatively large size, but apparently not as large as *Moxostoma congestum*. The largest individual present in the research museum collections is 270 mm SL. Although information is lacking about the growth of the species in Texas, a maximum lifespan of approximately five years would not be unexpected.

Velocity Profile:

Table 24. Mean current velocities (in meters/second) and associated descriptive statistics for all *Minytrema melanops* habitats in which current speed information is known from localities in Texas. See text for explanation of data sets used and localities sampled.

Minytrema melanops	N	Mean	Standard Deviation	Standard Error	95 % Confidence Interval for Mean	Minimum	Maximum
This Study	1	0	0	0	0 - 0	0	0

Catfish (Family Ictaluridae)

13. Tadpole madtom—*Noturus gyrinus* (Mitchill)

Distribution: The tadpole madtom occurs widely throughout eastern Texas from the Red River to the Nueces basin. There is also a report of this species from the Rio Grande in Webb County that may be a result of an introduction. Elsewhere, this species ranges widely east of the Rocky Mountains, except in upland streams draining the Appalachian mountain chain (Rohde 1980, Shipley and Moss 1982, Hubbs et al. 1991, Gutowski and Raesly 1993, Haynes and Weekly 1993).

Habitat Occupation: Throughout most of it's range, the tadpole madtom lives in relatively clear perennial streams in shallow riffles where it hides by day in crevices beneath stones or in leaf litter and detritus (Tomelleri and Eberle, 1990). The species appears to prefer clear to moderately turbid quiet water areas of small streams, oxbow lakes, and sluggish rivers where significant amounts of detritus has accumulated (Parmley and Hall 1993). They can also be found in areas with thick growths of aquatic vegetation over mud and gravel substrates such as are found below the headsprings of the San Marcos River. This species can also be found in some reservoirs, especially in Arkansas; however, they appear to be much less common in Texas reservoirs. Individuals can be found hiding in leaf litter and detritus during the day and they apparently move from these areas to forage at night on the bottom among plants and in shallow riffle areas.

Table 25. Habitats occupied by *Noturus gyrinus*. Values are percent occupation at sites selected for current speed measurements. Mean velocities for each habitat type are shown.

	N	Isolated Pools	Back-water	Slow Moving Pools	Edge	Moving Pools	Above Riffle	In Riffle	Rapids
Mean Velocity (m/sec)		**0.0000**	**0.0164**	**0.0675**	**0.0829**	**0.2912**	**0.4001**	**0.5896**	**1.2211**
Noturus gyrinus	**27**	**3.7**	**14.8**	**14.8**	**11.1**	**14.8**	**3.7**	**22.2**	**14.8**

Feeding: Tadpole madtoms feed primarily at night on a variety of foods including, amphipods, ostracods, copepods, isopods, aquatic insects, especially dipterans, oligochaetes, algae, small fishes and miscellaneous vascular plants (Becker 1983, Whiteside and Burr 1986).

Reproduction: Individuals less than approximately 15 mm SL have been taken by various researchers in Texas waters from mid-April through July indicating a probable spawning season from about March to late July or early August. Egg masses are guarded by one of the parents until they hatch (Adams and Hankinson 1928). Spawning habitats of tadpole madtoms include crevices in boulders and even discarded soft drink and beer cans (Robison and Buchanan 1988).

Growth: Tadpole madtoms are reasonably small catfish. The maximum size of an individual from Texas in the research museum collections is 127 mm SL, although most adult individuals are about half that length. No published studies on the growth or lifespan of this species in Texas exist.

Velocity Profile:

Table 26. Mean current velocities (in meters/second) and associated descriptive statistics for all *Noturus gyrinus* habitats in which current speed information is known from localities in Texas. See text for explanation of data sets used and localities sampled.

Noturus gyrinus	N	Mean	Standard Deviation	Standard Error	95 % Confidence Interval for Mean	Minimum	Maximum
This Study	2	0.1738	0.2351	0.1663	-1.9387 - 2.2862	0.0075	0.34
Hubbs (1953-1996)	25	0.3937	0.4828	0.0966	0.1944 - 0.593	0	1.4014
Mosier and Ray (1992)	2	0.1509	0.0798	0.0564	-0.5657 - 0.8675	0.0945	0.2073
Weighted Average	29	0.3618	0.4567	0.0848	0.1881 - 0.5355	0	1.4014

Bass/Sunfish (Family Centrarchidae)

14. Guadalupe bass—*Micropterus treculi* (Vaillant and Bocourt)

Distribution: The Guadalupe bass is endemic to the streams of the northern and eastern Edwards Plateau including portions of the Brazos, Colorado, Guadalupe and San Antonio basins. This species is also found outside of the Edwards Plateau streams in decreased abundance primarily in the lower Colorado River. Two introduced populations have been established in the Nueces River system. The Guadalupe bass is the official state fish of Texas (Edwards 1980, Guillory 1980, Garrett 1991, Hubbs et al. 1991).

Habitat Occupation: Guadalupe bass inhabit the flowing waters of streams within their native range and use large rocks, cypress knees, stumps and similar types of cover for refugia (Edwards 1980, Tomelleri and Eberle, 1990, Garrett 1991). The species is usually found in waters with annual thermal fluctuations of 4 to 35 C, but are generally absent from upper spring-runs with relatively constant water temperatures or below reservoirs with hypolimnion releases such as Canyon Reservoir (Edwards 1978, 1980). Guadalupe bass spawn in relatively slow moving pool areas close to a source of current. The young, after leaving the nest, move into gradually faster and deeper moving waters during their first summer and fall. They can be often found, during this time, inhabiting the swiftly moving areas above and below riffles and in moving pools. The adults, following spawning, return to the deeper, moving pool environments and are often found associated with brush, logs, large rocks and cypress knees and stumps. During winter, the young-of-the-year move into deeper pool habitats that maintain moderate currents.

Table 27. Habitats occupied by Guadalupe Bass (*Micropterus treculi*) by season. Shown also are habitats occupied by season for sympatric largemouth bass (*M. salmoides*) and allopatric spotted bass (*M. punctulatus*) for comparison. Values are percent occupation. Mean velocities for each habitat type are shown. Adapted in part from Edwards (1980).

	N	Isolated Pools	Back-waters	Slow Moving Pools	Moving Pools	Above Riffles	Below Riffles	In Riffles
Mean Velocity (m/sec)		**0.0000**	**0.0164**	**0.0675**	**0.2912**	**0.4001**	**0.4405**	**0.5896**
Micropterus treculi								
Spring	**186**	**13.4**	**34.9**	**3.8**	**25.3**	**7.5**	**6.5**	**8.6**
Summer	**757**	**---**	**55.4**	**0.9**	**22**	**4.4**	**15.5**	**1.7**
Fall	**248**	**8.1**	**6**	**3.6**	**58.5**	**5.6**	**15.3**	**2.8**
Winter	**43**	**---**	**2.3**	**9.1**	**61.4**	**---**	**25**	**2.3**
Micropterus salmoides								
Spring	**66**	**10.6**	**53**	**28.8**	**7.6**	**---**	**---**	**---**
Summer	**565**	**0.4**	**60.2**	**32**	**5.5**	**0.4**	**1.2**	**0.4**
Fall	**198**	**4.5**	**44.4**	**36.9**	**9.1**	**1**	**3.5**	**0.5**
Winter	**14**	**---**	**---**	**92.9**	**7.1**	**---**	**---**	**---**
Micropterus punctulatus								
Spring	**56**	**---**	**7.1**	**1.8**	**83.9**	**---**	**7.1**	**---**
Summer	**63**	**---**	**36.5**	**---**	**60.3**	**---**	**3.2**	**---**
Fall	**148**	**2.7**	**11.5**	**10.1**	**48.6**	**---**	**19.6**	**---**
Winter	**2**	**---**	**---**	**100.0**	**---**	**---**	**---**	**---**

Feeding: Young Guadalupe bass feed extensively on larval emphemeropterans (mayflies). Other important foods are fishes, aquatic dipteran larvae and terrestrial hymenopterans (bees and wasps). The species appears to increase the taxonomic variety of foods until they reach approximately 60 to 90 mm SL at which point the diversity of food items decreases (Edwards 1980, Garrett 1991). Seasonally, the variety of food items is greatest during the warmer months and least during winter. Adults feed mostly on larval megalopterans (hellgrammites), crayfish, insects and fishes which are selected in proportion to the abundances in which they are found (Hurst et al. 1975, Edwards 1980, Tomelleri and Eberle 1990, Garrett 1991).

Reproduction: The Guadalupe bass, similar to other members of the genus *Micropterus* is primarily a spring-time spawner with nesting beginning in early March and continuing through

May or June (Hurst et al. 1975, Boyer et al. 1977, Edwards 1980, Garrett 1991). There is also, apparently a secondary spawning period in the late summer and fall (Edwards 1980). Spawning sites are usually located near slow to moderately flowing water in water greater than one meter in depth. This spawning habitat is typical of all of the *Micropterus* species found in Texas, except the largemouth bass (*Micropterus salmoides*), which utilizes more quiet waters for nesting locations. This similarity in spawning sites has resulted in massive introgressive hybridization with the introduced smallmouth bass (*M. dolomieu*), especially throughout the Guadalupe River basin (Edwards 1979, Garrett 1988, Whitmore and Bulter 1982, Whitmore 1983, Morizot et al. 1991). Edwards (1980) found significant variation in ova sizes among different populations of Guadalupe bass; with females from the Guadalupe River basin having larger eggs (mean = 2.17 mm diameter, range = 1.85 to 2.25 mm diameter) than females from the Colorado River basin (mean = 1.63 mm diameter, range = 1.5 to 1.81 mm diameter). Boyer (1977) found similar sizes of ova from one *M. treculi* nest from a Guadalupe River site (mean = 2.058 mm diameter).

Growth: Growth of the Guadalupe bass is similar to its sympatric congeners during the first several years of life (Edwards 1980, Carmichael and Williamson 1986, Garrett 1991). However, among older bass, largemouth bass maintain a higher growth rate, in part due to lessened metabolic demands from living in a more lentic habitat. On average, the species reaches from 65 to 84 mm SL after one year, 121 to 154 mm SL after two years, 136 to 189 mm SL after 3 years and grows about 30 mm per year afterwards. The oldest Guadalupe bass are six years old and females (Edwards 1980). Guadalupe bass living in reservoirs appear to become significantly larger than similar aged fish living in stream habitats. The largest specimen held in research museums is 220 mm SL and largest known specimen is the state record, a specimen 18.25 inches (approximately 380 mm SL) captured in Lake Travis in 1983.

Velocity Profile:

Table 28. Mean current velocities (in meters/second) and associated descriptive statistics for all *Micropterus treculi* habitats in which current speed information is known from localities in Texas. See text for explanation of data sets used and localities sampled.

Micropterus treculi	N	Mean	Standard Deviation	Standard Error	95 % Confidence Interval for Mean	Minimum	Maximum
Edwards (1980)	1233	0.2001	0.1817	0.0052	0.1900 - 0.2103	0	0.5896
Mosier and Ray (1992)	105	0.1896	0.2512	0.0245	0.1410 - 0.2383	0	1.2558
Weighted Average	1338	.1993	0.1880	0.0051	0.1892 - 0.2094	0	1.2558

15. Warmouth—*Lepomis gulosus* (Cuvier)

Distribution: This species is widely distributed throughout much of the eastern U.S. It may be found statewide with the exception of the plains streams in the Texas panhandle area (Lee 1980, Hubbs et al. 1991).

Habitat Occupation: The warmouth is generally a solitary sunfish that is most commonly found inhabiting the sluggish waters of swamps, bayous, borrow ditches, and oxbow lakes where there are considerable muddy substrates, detritus, and often, dense beds of vegetation. These habitats contain many sources of cover for this species, including brushpiles, stumps, cypress knees and even discarded tires and barrels. Although warmouth may be found occasionally in somewhat turbid waters, they seem to prefer clear water with thick growths of aquatic vegetation (Gatz and Adams 1994). They can sometimes be found in impoundments, generally in backwater areas with extensive brushpiles or stumps. It is absent from much of the Great Plains, primarily because of the lack of suitable backwaters, and other flooded lowland-type habitats (Tomelleri and Eberle, 1990). In contrast to its ecological equivalent, the green sunfish (*Lepomis cyanellus*), warmouth inhabit larger streams, bayous, and rivers with suitable habitats while green sunfish inhabit the smaller creeks and tributaries (Layzer and Clady 1991).

Table 29. Habitats occupied by *Lepomis gulosus*. Values are percent occupation at sites selected for current speed measurements. Mean velocities for each habitat type are shown.

	N	Slow Moving Pools	Edge
Mean Velocity (m/sec)		**0.0675**	**0.0829**
Lepomis gulosus	**3**	**33.3**	**66.7**

Feeding: The food habits of warmouth are similar to the green sunfish, *Lepomis cyanellus*, and they feed on small fishes, crayfish, larval aquatic insects, and isopods (Larimore 1957, Carlander 1977, Clary 1985, Layzer and Clady 1991). They are "sit and wait" predators which often ambush their prey by darting quickly out from cover and attacking the unsuspecting prey.

Reproduction: Small warmouth individuals (less than 16 mm SL) have been taken from late March through July suggesting that the spawning season for this species takes place from about early March through July, similar to other sunfishes in the state. Males build redds near stumps, rocks, vegetation or other objects. Males guard emergent fry for about a week after the fry are free-swimming (Robison and Buchanan 1988). Potential fecundities (all ova, not only "ripe" ova) have been estimated to range from 4,500 to 63,200 eggs (Larimore 1957). In general, however, warmouth have a reasonably low reproductive potential (Tomelleri and Eberle 1990).

Growth: Warmouths attain a relatively large size for sunfishes. The largest individual found in the research museums is 170 mm SL; however, individuals as large as 284 mm TL (approximately 189 mm SL) are known (Trautman 1957, Carlander 1977). Larimore (1957) noted that individuals generally reach adulthood in their second year at a size of 75 to 100 mm TL (about 50 to 67 mm SL) with maximum lifespans of about three years in most Texas aquatic environments.

Velocity Profile:

Table 30. Mean current velocities (in meters/second) and associated descriptive statistics for all *Lepomis gulosus* habitats in which current speed information is known from localities in Texas. See text for explanation of data sets used and localities sampled.

Lepomis gulosus	N	Mean	Standard Deviation	Standard Error	95 % Confidence Interval for Mean		Minimum	Maximum
This Study	3	0.0552	0.0956	0.0552	-0.1822 - 0.2925	0	0.1655	
Mosier and Ray (1992)	4	0.0114	0.019	0.0095	-0.0188 - 0.0417	0	0.0396	
Weighted Average	7	0.0302	0.0614	0.0232	-0.0266 - 0.087	0	0.1655	

16. Longear sunfish—*Lepomis megalotis* (Rafinesque)

Distribution: This species is wide ranging throughout much of the central U.S. southward to northeastern Mexico. Longear sunfish may be found statewide in Texas except in the headwaters of the Canadian and Brazos Rivers. A number of populations have been introduced throughout the state (Bauer 1980, Hubbs et al. 1991, Jennings and Philipp, 1992, Bart et al. 1994).

Habitat Occupation: Longear sunfish are the predominant sunfish inhabiting clean, gravel-bottomed creeks and small rivers. They are most commonly found in and about shallow pools or slow runs with very slow-moving flows. The species is usually very abundant in clear, small upland streams with rocky bottoms and permanent or semi-permanent flows such as are found in Edwards Plateau and Ozark streams (Robison and Buchanan 1988). It is also found inhabiting reservoirs and farm ponds (Bettoli 1988). In smaller first and second order creeks in Texas, longear sunfish are often found with only green sunfish (*L. cyanellus*) and are typical of such headwater systems without large sources of springflows. In medium to larger streams, and in those with significant springflow sources, longear sunfish are often found syntopically with a variety of other sunfish, including bluegills (*L. macrochirus*), spotted sunfish (*L. punctatus*), redear sunfish (*L. microlophus*), orangespotted sunfish (*L. humilis*), and the introduced redbreast sunfish (*L. auritus*). Mixed, loosely aggregated schools of two or more of these species, along with longear sunfish, can often be found (Bietz 1981, Layzer and Clady 1991, Rabeni 1990, Rabeni and Jacobson 1991, Dibble 1993, Annett and Knight 1994, Jennings and Philipp 1994). One feature of the habitat of longear sunfish is the presence of cover. This can be underneath banks, in rocky rubble areas, under logs and other brush or any other relatively large or extensive hiding place. Typically longear sunfish will forage within their relatively small home ranges (estimated at approximately 1 km^2), yet are easily "spooked" and nearly always seek the protective cover nearby (pers. observ.). The young, after leaving their nest, first seek quiet backwater environments and gradually move into deeper, slow-moving pools during their first summer. Adults overwinter in the deepest pools, and can often be found lethargically in areas of dense cover. Old discarded automobile tires, thrown in the deeper pools of rivers, can also serve as winter refuges, often for a half-dozen or so adults (pers. observ.).

Table 31. Habitats occupied by *Lepomis megalotis*. Values are percent occupation at sites selected for current speed measurements. Mean velocities for each habitat type are shown.

	N	Isolated Pools	Back-water	Slow Moving Pools	Edge	Shallow Shelf	Slow Narrows	Channel	Moving Pools	Below Dam
Mean Velocity (m/sec)		**0.0000**	**0.0164**	**0.0675**	**0.0829**	**0.0882**	**0.1300**	**0.2405**	**0.2912**	**0.3500**
Lepomis megalotis	**535**	**7.5**	**3.4**	**46.7**	**0.2**	**4.1**	**0.6**	**1.1**	**34.4**	**2.1**

Feeding:. Longear sunfish eat mainly aquatic and terrestrial insects but other invertebrates, filamentous algae and small fish and fish eggs (including eggs of other longear sunfish) have been found in their stomachs (Applegate et al. 1967, Swann et al. 1991, Short and Holomuzki 1992, Holomuzki and Hatchett 1994). When available, longear sunfish diets also include small crayfish, mayflies, amphipods, isopods, and an occasional snail (Minckley 1963).

Reproduction: *Lepomis megalotis* nests in colonies beginning in early spring and continuing through the summer. An analysis of individuals less than 18 mm SL from research museums and personal observations indicate that males build nests in colonies during the early spring (February) through the early autumn (about late September) breeding season, although the greatest densities of longear sunfish redds are usually found between April and mid-June (various research museums, Edwards 1976). Nests are often constructed only a few inches from other nests and males defend fry against predators (Tomelleri and Eberle 1990). Nesting usually occurs at depths between 0.2 and 3.5 m and females usually sequentially spawn with more than one male. Nesting males are known to produce “grunt”-like sounds as a female attractive device (Herald 1971).

Precocious “sneaker” males are known in this species. Jennings and Philipp (1992) found that the “sneakers” tended to be dull-colored, resembling the females, and about 40 to 85 mm TL. They also had significantly higher GSIs than typical “parental” males who were brightly colored and at least 85 to 100 mm TL. In a study in Jordan Creek in Illinois, longear sunfish brood losses during low, relatively stable flow years appeared to be due to biotic interactions as opposed to variable flow years when brood losses came primarily from flood events (Jennings and Philipp 1994). These authors also noted that nests occurred in water depths from 12 to 50 cm deep (mean = 26.8 ± 0.8 cm, N = 123) and in areas with little or no current (mean = 2.9 ± 0.1 cm/sec (0.029 m/sec), N = 50). In Texas, large brood losses have also been observed following severe flood events associated with episodic late spring and summer rainshowers. Fecundities ranged from approximately 177 to 717 (mean = 414) for females 55 to 65 mm SL in an Arkansas reservoir (Boyer 1969). However, this same study found that the number of ova in individual nests ranged from 608 to 2756 eggs/nest, indicating that more than one female spawned in each redd.

Growth: The maximum size of a longear sunfish in the various research museum collections is 117 mm SL. The largest individuals known are 201 mm TL (approximately 145 mm SL), although the state angling record for Texas is an individual of just over 100 mm SL captured in 1995 (Carlander 1977, Texas Parks and Wildlife Dept. records). Individuals generally reach adulthood at the age of one-year and rarely live past three years of age in Texas stream environments.

Velocity Profile:

Table 32. Mean current velocities (in meters/second) and associated descriptive statistics for all *Lepomis megalotis* habitats in which current speed information is known from localities in Texas. See text for explanation of data sets used and localities sampled.

Lepomis megalotis	N	Mean	Standard Deviation	Standard Error	95 % Confidence Interval for Mean	Minimum	Maximum
This Study	529	0.0906	0.1067	0.0046	0.0815 - 0.0997	0	0.5219
Hubbs (1953-1996)	5	0.043	0.0349	0.0156	-0.0003 - 0.0863	0	0.07
Mosier and Ray (1992)	234	0.0773	0.1581	0.0103	0.057 - 0.0977	0	0.6706
Weighted Average	768	0.0863	0.1244	0.0045	0.0774 - 0.0951	0	0.6706

Darters (Family Percidae)

17. Orangethroat darter—*Etheostoma spectabile* (Agassiz)--orangethroat darter

Distribution: The orangethroat darter is found through much of the central U.S., especially in the Ozarks and central lowlands, this species occurs in Texas primarily in the Edwards Plateau from the San Antonio River north and east to the Red River. It is absent from the portions of streams flowing through the Coastal Plain (Bruner 1980, Hubbs et al. 1991).

Habitat Occupation: Orangethroat darters inhabit slow to swift riffles of headwater streams with sand, gravel, rubble, or bedrock substrates. They are less often found in raceways and pools, although they can sometimes be abundant in the gravelly areas along the sides of pools with moderate flows (Layher et al. 1981, Layher and Maughan 1987, Robison and Buchanan 1988, Wenke et al. 1993). Occasionally they may be found in spring runs, although species such as greenthroat darters (*E. lepidum*) seem to outcompete orangethroat darters in these areas. Where sympatric with the goldstripe darter (*E. parvipinne*) in east Texas, orangethroat darters are found in moderate-size streams while goldstripe darters are much more abundant in the smallest headwater creeks and first order streams. In other parts of the range, this species is often found in spring-fed first order streams and limestone bedded second-order streams (Trautman 1957, Pflieger 1975, Kuehne and Barbour 1983). One factor which seems consistent throughout the range of orangethroat darters is their apparent avoidance of larger rivers with powerful currents. They appear also to be moderately sensitive to pollution and have been used as an indicator organism for determining non-point pollution effects on aquatic communities (Feminella and Matthews 1984, Greenberg 1990, Gammon and Gammon 1993, Hoyt et al. 1994). The subspecies we have in Texas is *E. s. pulchellum*.

Figure 1. Ranges in current speeds, depths and substrates occupied by darter subgenera *Hadropterus*, *Oligocephalus* and *Imostoma*. Adapted from Page (1983).

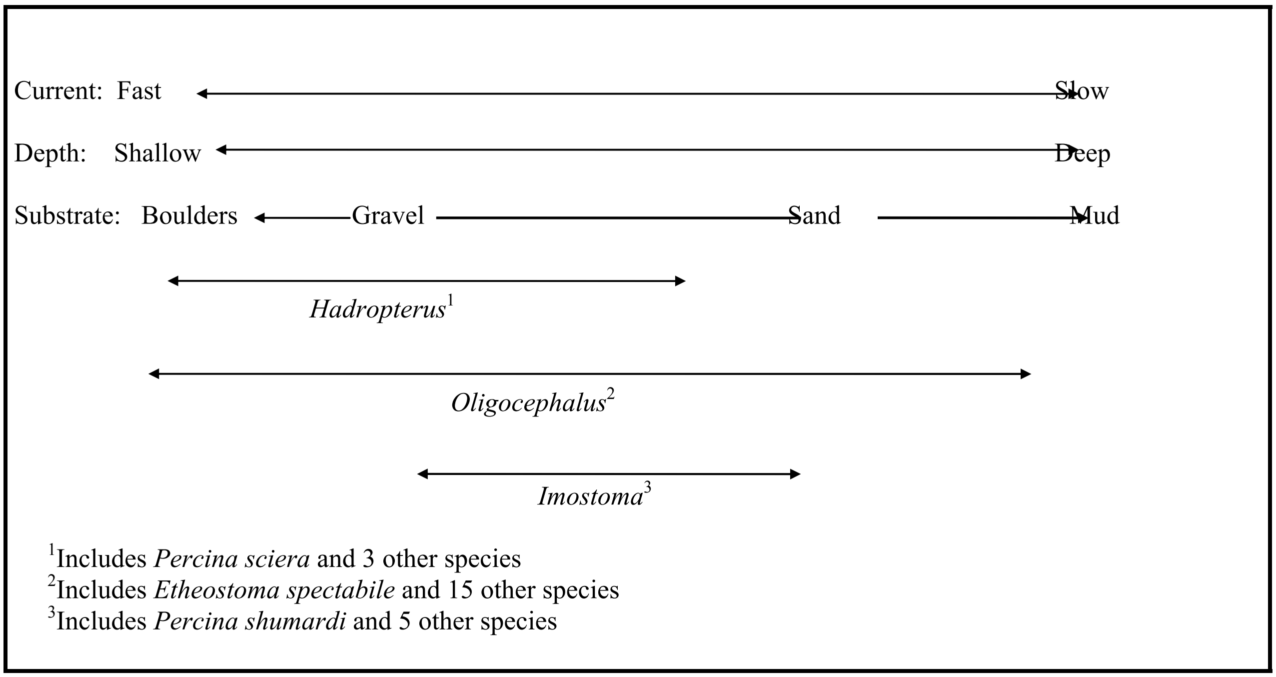

Table 33. Habitats occupied by *Etheostoma spectabile*. Values are percent occupation at sites selected for current speed measurements. Mean velocities for each habitat type are shown.

		Isolated Pools	Slow Moving Pools	Edge	Moving Pools	Below Dam	Below Riffle	In Riffle	Rapids
Mean Velocity (m/sec)		**0.0000**	**0.0675**	**0.0829**	**0.2912**	**0.3500**	**0.4405**	**0.5896**	**1.2211**
Etheostoma spectabile	**383**	**0.8**	**0.5**	**0.3**	**22.2**	**0.3**	**1.3**	**74.2**	**0.5**

Feeding: After hatching, the fry drift downstream into quiet, shallow pools and feed on small insects and crustaceans. The subadults and adults feed on larger foods including larval dipterans, caddisflies, amphipods, terrestrial insects, and fish eggs. Where several species of darters are found together, there appears to be considerable partitioning of food resources, in part because of differential resource availabilities in the particular microhabitats selected.(Milstead 1983, Martin 1984, Todd 1985, Vogt 1987, Dewey 1988, Hoover 1988, Vogt and Coon 1990, Strange 1993).

Reproduction: Spawning in Texas occurs from mid-October through July (Hubbs and Armstrong 1962, Marsh 1980, Hubbs 1985) within and below shallow gravel riffles with moderate flows and the eggs are buried in the substrate. Hatching is usually within 9 to 10 days depending upon water temperatures. Prior to spawning, males establish territories around females and become relatively aggressive at this time. The precise spawning times at different localities in Texas varies (Hubbs 1985) and occurs from mid-October (in the North Guadalupe River) through May (in the Lampasas River). The artificial temperature regime below Canyon Dam on the Guadalupe River extends the breeding season of the species in that area through about July (Marsh 1980, Hubbs 1985). It would not be unexpected that newly hatched young move into nests of Guadalupe bass (*Micropterus treculi*) or spotted bass (*M. punctulatus*) for the protection afforded them by the male bass and for the abundant microorganismal food supply as Pflieger (1975) noted for *E. spectabile* in Missouri which used smallmouth bass (*M. dolomieu*) nests. Females produce from less than 50 to about 200 eggs per season, generally with multiple clutches (Hubbs 1958). Variation in egg size (mass) has been noted geographically, seasonally and among females captured at the same place and time (Marsh 1984).

Growth: The largest individual found in the museum collections is 46 mm SL. Individuals become adults after one-year and rarely live longer than two years. Most die following their first breeding season as adults.

Velocity Profile:

Table 34. Mean current velocities (in meters/second) and associated descriptive statistics for all *Etheostoma spectabile* habitats in which current speed information is known from localities in Texas. See text for explanation of data sets used and localities sampled.

Etheostoma spectabile	N	Mean	Standard Deviation	Standard Error	95 % Confidence Interval for Mean	Minimum	Maximum
This Study	373	0.501	0.138	0.0071	0.487 - 0.5151	0	0.98
Hubbs (1953-1996)	10	0.7013	0.4014	0.1269	0.4142 - 0.9884	0.0829	1.4014
Mosier and Ray (1992)	113	0.4006	0.3831	0.036	0.3292 - 0.472	0.003	1.6977
Weighted Average	496	0.4822	0.2307	0.0104	0.4619 - 0.5026	0	1.6977

18. River darter—*Percina shumardi* (Girard)

Distribution: The range of this species includes drainages from parts of the Hudson Bay system in Canada southward in the Mississippi and Ohio river basins to its southern and western edge of its range in Texas. It is apparently absent in the Missouri River basin, however. In Texas, this species is limited to east Texas streams including the Red southward to the Neches and a disjunct population occurs in the Guadalupe and San Antonio River systems east of the Balcones escarpment (Gilbert 1980, Dalton 1990, Hubbs et al. 1991).

Habitat Occupation: River darters inhabit the very largest rivers and the lower reaches of medium-size lowland rivers throughout their range. They are generally found in the deeper, lower ends of riffles and raceways over a gravel and rubble substrate often at depths of 0.6 m or more. Other substrates include large rocks and gouged and eroded bedrock. They are the most abundant darter in the main channel of the Mississippi River and are found rather abundantly downstream from some large mainstem reservoirs (Sanders and Yoder 1989). In Arkansas, it can also be found over sand substrates in very swift currents (Robison and Buchanan 1988). Young specimens sometimes enter slower moving water shallower than 0.5 meters while adults are nearly always found in water greater than 1 m in depth with swift flows (Thomas 1970). Pflieger (1975) and Trautman (1957) both stress that *P. shumardi* does well in waters that are too turbid for other darters. Because of its preference for deep waters and its tolerance for murkiness, if it is found with other darters, these are almost always *Percina* species, and only rarely would an *Ammocrypta* or *Etheostoma* be syntopic. The species apparently migrates inshore during the evening and night and returns to deeper waters during the day (Robison and Buchanan 1988). A population in the Guadalupe River near Gonzalez has been stable for more than 30 years, and inhabits the fast, deep riffles among strewn boulders which occur at that site.

Table 35. Habitats occupied by *Percina shumardi*. Values are percent occupation at sites selected for current speed measurements. Mean velocities for each habitat type are shown.

		Slow Moving Pools	Below Riffle	In Riffle
Mean Velocity (m/sec)		**0.0675**	**0.4405**	**0.5896**
Percina shumardi	**47**	**4.3**	**83.0**	**12.8**

Feeding: River darters feed on midge and caddisfly larvae, and also on other small invertebrates inhabiting swift, deep riffle areas. Some populations are also known to consume considerable numbers of snails (Kuehne and Barbour 1983, Sanders and Yoder 1989).

Reproduction: Little is known about its reproductive habits, in part because their deep water habitats make collection of large numbers of specimens difficult. In the Guadalupe River, near Gonzalez, river darters have been found to be reproductive from mid-January through April (Hubbs 1985). Based upon the presence of small individuals in various research museum collections and from field investigations, the likely spawning season for this species in Texas is from about mid-January through late-April (Hubbs 1985) which is a longer spawning season than in any other geographic area. Spawning occurs in waters greater than 0.5 meters in depth in areas with strong current, scattered rubble, and associated clean gravel. A number of investigators have noted that adults migrate upstream to spawn in the spring and move downstream in the fall to reach their overwintering habitats (Cross 1967, Trautman 1957).

Growth: Individuals grow approximately 40 to 45 mm during their first year. The largest individual found in the research museum collections is 52 mm SL. It is likely that the maximum lifespan is less than about three years.

Velocity Profile:

Table 36. Mean current velocities (in meters/second) and associated descriptive statistics for all *Percina shumardi* habitats in which current speed information is known from localities in Texas. See text for explanation of data sets used and localities sampled.

Percina shumardi	N	Mean	Standard Deviation	Standard Error	95 % Confidence Interval for Mean	Minimum	Maximum
This Study	2	0.4655	0	0	0.4655 - 0.4655	0.4655	0.4655
Hubbs (1953-1996)	47	0.4437	0.0945	0.0138	0.4159 - 0.4714	0.0675	0.5896
Weighted Average	49	0.4446	0.0927	0.0132	0.4179 - 0.4712	0.0675	0.5896

19. Dusky darter—*Percina sciera* (Swain)

Distribution: The range of this species extends from the Guadalupe River system north and eastward through the states of Texas and Oklahoma to Indiana, Ohio and West Virginia (Page 1980, Hubbs et al. 1991, Lemmons et al. 1991). The Guadalupe basin stocks of this species differ morphologically from those elsewhere, including the rest of the state of Texas and are designated as *P. s. apristis* (Hubbs 1954, Kuehne and Barbour 1983). This subspecies is restricted to the Guadalupe River and its tributaries, the San Marcos and Blanco rivers although it is apparently absent from the headwaters of the Blanco and the entirety of the San Antonio River.

Habitat Occupation: Dusky darters live in medium to large streams of moderate to low gradients as long as they are not highly turbid. During spring and early summer they are most often found in riffles over coarse clean gravel at depths of 20 cm or more. Some live in or adjacent to aquatic vegetation, if it happens to be present. During hot weather, they may retreat to quieter, deeper pools, especially where debris or vegetation affords protection. Winter is spent in deeper moderately flowing pools and specimens are not as commonly found in riffles or shallows from November through March (Page 1983). An exception to this are the populations in the San Marcos River where spring-influenced water moderates cold winter water temperatures and dusky darters can be found in rather swift flowing riffles throughout the year.

Associates include other *Percina* (such as *P. caprodes*) and *Etheostoma* (such as *E. spectabile, E. lepidum and E. fonticola*) in addition to Guadalupe bass (*M. treculi*) or spotted bass (*M. punctulatus*) which may be predators (Kuehne and Barbour 1983, Rakocinski 1988, 1991, pers. observ). Page (1983) discussed *P. sciera* as among "the best examples" of a species restricted as adults to gravel raceways in midwater (=midstream) habitats. The young, in contrast to the adults, can often be found along the shallow gravel edges of pools with moderate currents and sometimes enter tributaries not visited by the adults (Page and Smith 1970).

Table 37. Habitats occupied by *Percina sciera*. Values are percent occupation at sites selected for current speed measurements. Mean velocities for each habitat type are shown.

		Slow Moving Pools	Edge	Other	Moving Pools	Below Riffle	In Riffle	Rapids
Mean Velocity (m/sec)		**0.0675**	**0.0829**	**0.1954**	**0.2912**	**0.4405**	**0.5896**	**1.2211**
Percina sciera	**188**	**5.9**	**0.5**	**0.5**	**1.6**	**21.3**	**68.1**	**2.1**

Feeding: Foods consist of larval insects that are found in the riffles, particularly midges, blackflies, mayflies and caddisflies. In Illinois, Page and Smith (1970) found that midge and blackfly larvae comprised nearly 70 to 90% of individual food items in all months but the summer when almost 80% of the individual items were caddisflies. These authors concluded that the foods taken were in same approximate abundance as they occurred in the riffle habitats. Where sympatric darters occur, ecological partitioning by selecting different sized prey items due to different gape sizes among the darters seems common and occurs not only between different species but also between males and females within a species (Miller 1983, Rakocinski 1991). The heaviest feeding in this species apparently occurs just before spawning (Page and Smith 1970). Young dusky darters consumed relatively more midge larvae and less caddisfly larvae than did the adults (Page and Smith 1970).

Reproduction: Dusky darters less than 20 mm SL are present in museum collections from the months of March through the end of July suggesting a breeding season for the species beginning in about January and extending through early June. This is in accordance with the spawning season listed by Hubbs (1985) based upon his field observations. In the Colorado River, Hubbs (1985) found that the species spawns from February through mid-June and tolerated a comparatively narrow range of developmental temperatures (Hubbs 1961). In the San Marcos River, this reproductive period is extended somewhat, beginning in mid-January and extending to mid-June (Hubbs 1985). Breeding males sometimes develop a bluish sheen on their backs and a little yellow on their bodies; all of their fins but their pectorals are variably dark. Males of the subspecies *apristis* may develop a submarginal orange band in their spinous dorsal fin (Kuehne and Barbour 1983, Page 1983). Spawning in Illinois occurs in gravel riffles 30 to 90 cm deep and females produce between about 80 and 200 eggs which hatch in about four days at 25 C (Page 1983). The parents provide no parental care and apparently abandon the eggs once they have been laid in the gravel. Laboratory spawning of the Guadalupe River subspecies, *P. s. apristis*, has been accomplished (Labay 1992).

Growth: In Illinois males breed at one year of age and a few individuals are known to live about three years (the oldest known is four years old). In Texas, the largest individual known from museum specimens is 95 mm SL. Individuals grow to about 40 to 50 mm in their first year and likely breed at one-year of age. Leeches are common parasites of the adults (Page and Smith 1970).

Velocity Profile:

Table 38. Mean current velocities (in meters/second) and associated descriptive statistics for all *Percina sciera* habitats in which current speed information is known from localities in Texas. See text for explanation of data sets used and localities sampled.

Percina sciera	N	Mean	Standard Deviation	Standard Error	95 % Confidence Interval for Mean		Minimum	Maximum
This Study	168	0.5673	0.2007	0.0155	0.5367 -	0.5978	0.026	0.82
Hubbs (1953-1996)	20	0.7456	0.3944	0.0882	0.5611 -	0.9302	0.0675	1.4014
Mosier and Ray (1992)	296	0.5096	0.3075	0.0179	0.4745 -	0.5448	0	1.7343
Weighted Average	484	0.5394	0.2835	0.0129	0.5141 -	0.5647	0	1.7343

Conclusions and Recommendations

The species covered in this document 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. Because of this, 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.

During low flow periods, the following generalizations appear to apply:

a) Density-dependent interactions become greater among and within species as water volumes are decreased. This temporarily puts a larger number of individuals/volume of water to compete for fewer overall resources. This concentrating effect can cause increased mortalities of all life stages by making it easier to deplete food supplies and by interfering with reproductive and other activities.

b) As flows decrease, the amount of overall suitable habitat is decreased and in most cases, the amount of suitable "preferred" habitat is similarly impacted. As examples, during January 1996 in the Llano River immediately downstream from the dam in the town of Llano and in June 1996 at the Bosque River site, the extensive riffles at these two locations were found to be visibly smaller, (covering much less area and approximately two-thirds as deep) than they were during previous investigations at the same sites during the late 1970s when higher streamflow rates were recorded. Pools were also less deep and the water judged to flow more slowly in 1996 than in the 1970s, although current velocities were not quantitatively measured in the earlier study. For species which inhabit deeper riffles or prefer to utilize deeper pool habitats such as members of *Percina* or *Micropterus*, respectively, there were clearly less available suitable habitats for these species to occupy during the low water conditions of 1996 and their numbers during this time were likely depressed. From the habitat and current velocity profiles, it was found that none of the species occupied the entire range of environments available. During low water conditions, an individual species tended to contract the number of different habitat types they occupied, in part because there were fewer habitat types available and in part because they concentrated in their most favorable habitats. There are exceptions. One impact of decreased flow in the summer is increased stream temperatures. Some species will move into unusual habitats in order to take advantage of either food resources or physical characteristics of this different habitat. The peculiar movement of red shiners (*C. lutrensis*) into the swiftest waters during the summer of 1996 in the Bosque River may well be in response to increased temperatures. Presumably the swifter turbulent waters in which they were found either contained more oxygen, food, or some unknown factor needed by the species.

c) In typically freshwater environments closer to the coast, drought effects include the upstream extension of species with more estuarine and marine affinities. While this phenomenon has long been recognized from southern Texas (Edwards and Contreras 1991), east Texas streams such as the Neches showed similar upstream penetrations of several estuarine and marine forms which normally would not be found in such environments.

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.

A number of species with very limited ranges are found throughout the state. For the most part, they exhibit a similar range of life history traits as were developed in this document. However, these species are also exposed to the impacts of drought conditions and usually have fewer populations from which recovery from periodic water reductions would be possible. These species also tend to have a greater reliance on springflows than many of the species covered in this current document, adding another factor which should be taken into consideration in water development scenarios.

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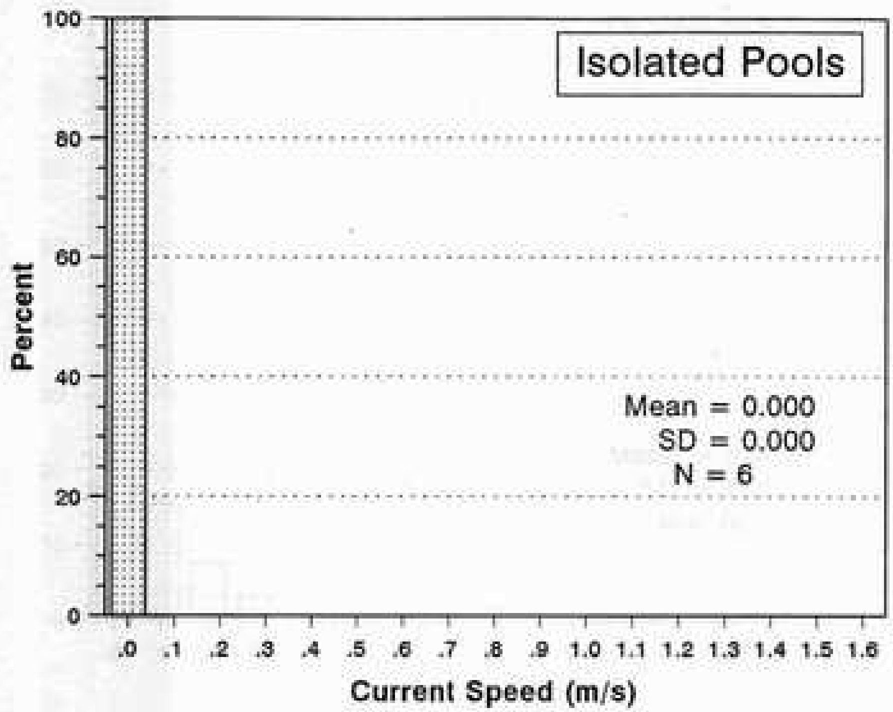
Appendix A

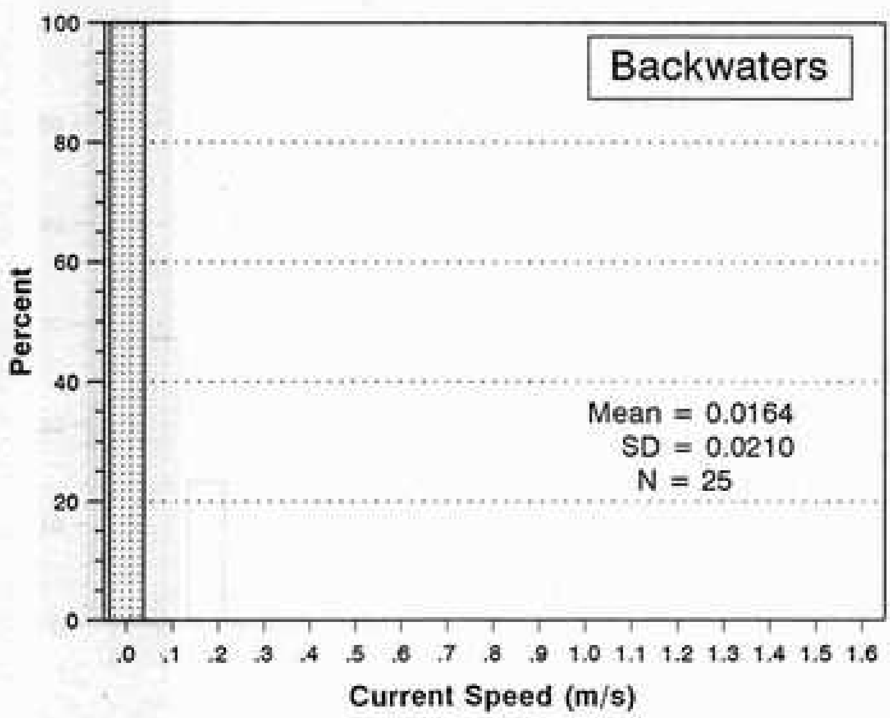
Summary of occupation of various habitat types by selected stream-dwelling fishes. Shown are the percent frequency of each species occupying specific habitats arranged in order of current velocity. Mean velocities of each habitat are shown.

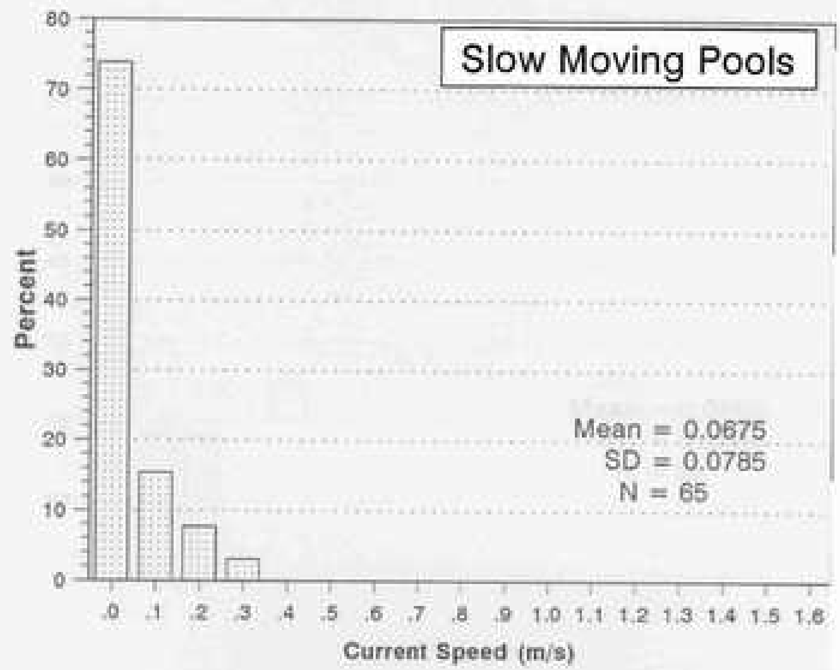
		Isolated Pools	Back-water	Slow Moving Pools	Edge	Shallow Shelf	Slow Narrows	Other	Channel	Moving Pools	Below Dam	Above Riffle	Below Riffle	In Riffle	Run/ Glide	Rapids
Mean Velocity		**0.0000**	**0.0164**	**0.0675**	**0.0829**	**0.0882**	**0.1300**	**0.1954**	**0.2405**	**0.2912**	**0.3500**	**0.4001**	**0.4405**	**0.5896**	**0.7847**	**1.2211**
Minnows	**N**															
Campostoma anomalum	244	---	10.7	---	---	1.2	---	---	---	54.9	1.2	6.1	---	9.0	16.4	0.4
Semotilus atromaculatus	22	---	---	36.4	---	---	---	---	---	63.6	---	---	---	---	---	---
Macrhybopsis aestivalis	51	2.0	---	3.9	2.0	---	---	---	---	35.3	---	13.7	5.9	23.5	5.9	7.8
Notropis volucellus	343	0.3	5.8	11.1	0.3	0.3	---	---	0.3	50.1	---	14.3	7.6	9.3	0.3	0.3
Cyprinella lutrensis	1499	5.4	6.0	72.0	3.5	0.5	---	---	---	2.6	---	---	---	10.0	---	---
Cyprinella venusta	4803	5.8	1.9	25.2	---	---	0.2	---	0.4	62.0	3.6	0.3	---	0.4	0.2	0.02
Notropis amabilis	682	7.6	6.6	7.2	---	---	---	---	0.6	40.2	3.5	20.4	8.8	1.5	3.2	0.4
Notropis emiliae	11	---	---	54.5	---	---	9.1	---	---	27.3	---	---	---	---	9.1	---
Notropis buchanani	11	9.1	54.5	9.1	---	---	---	---	---	18.2	---	---	---	9.1	---	---
Suckers																
Moxostoma congestum	173	2.3	39.9	1.2	---	---	---	---	0.6	15.0	---	14.5	---	11.0	15.6	---
Minytrema melanops	1	---	100.0	---	---	---	---	---	---	---	---	---	---	---	---	---
Catfish																
Noturus gyrinus	27	3.7	14.8	14.8	11.1	---	---	---	---	14.8	---	3.7	---	22.2	---	14.8
Sunfish																
Micropterus treculi	1233	3.6	40.6	2.2	---	---	---	---	---	31.2	---	4.9	14.4	3.0	---	---
Lepomis gulosus	3	---	---	33.3	66.7	---	---	---	---	---	---	---	---	---	---	---
Lepomis megalotis	535	7.5	3.4	46.7	0.2	4.1	0.6	---	1.1	34.4	2.1	---	---	---	---	---
Darters																
Etheostoma spectabile	383	0.8	---	0.5	0.3	---	---	---	---	22.2	0.3	---	1.3	74.2	---	0.5
Percina shumardi	47	---	---	4.3	---	---	---	---	---	---	---	---	83.0	12.8	---	---
Percina sciera	188	---	---	5.9	0.5		---	0.5	---	1.6	---	---	21.3	68.1	---	2.1

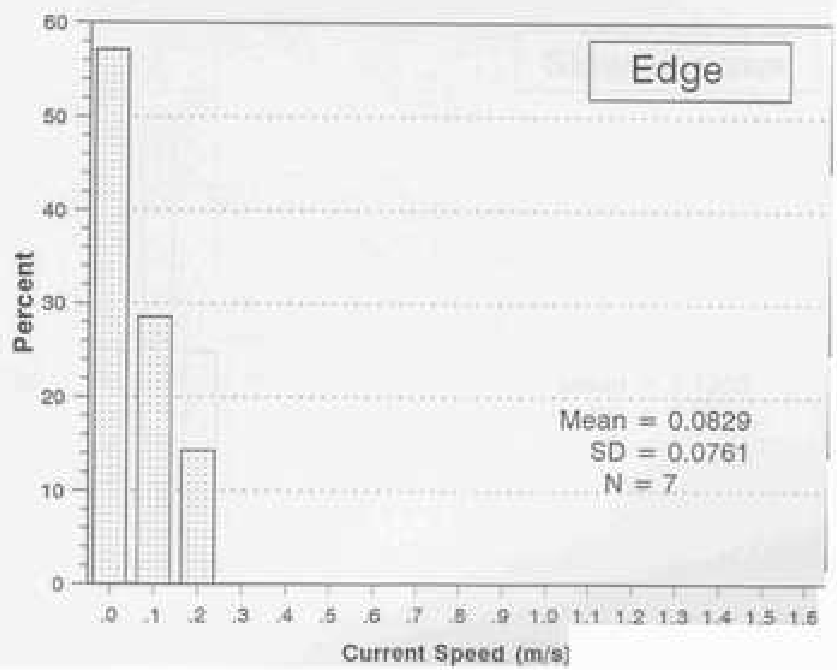
Appendix B

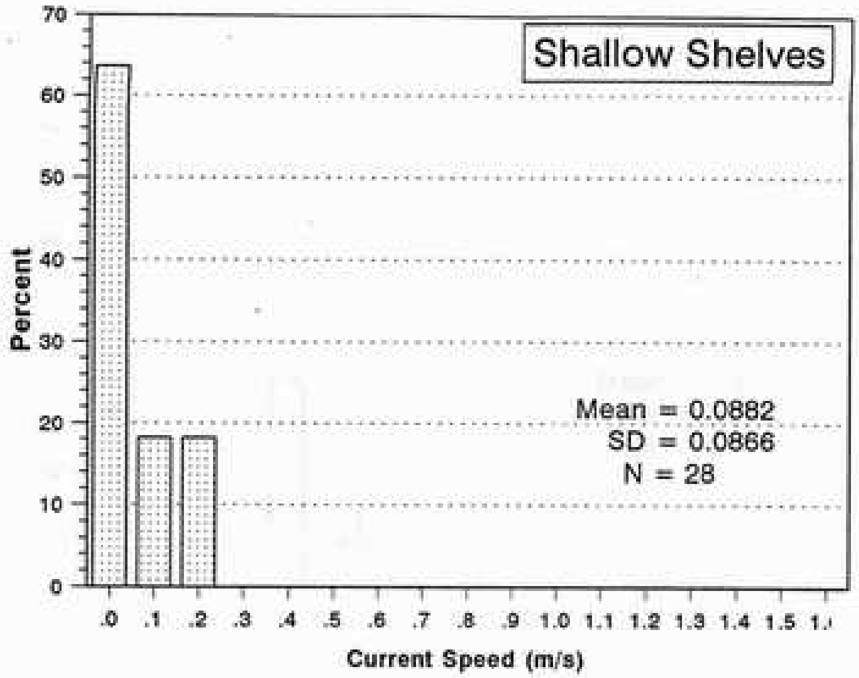
Current velocity frequency distributions of different aquatic microhabitats in Texas.

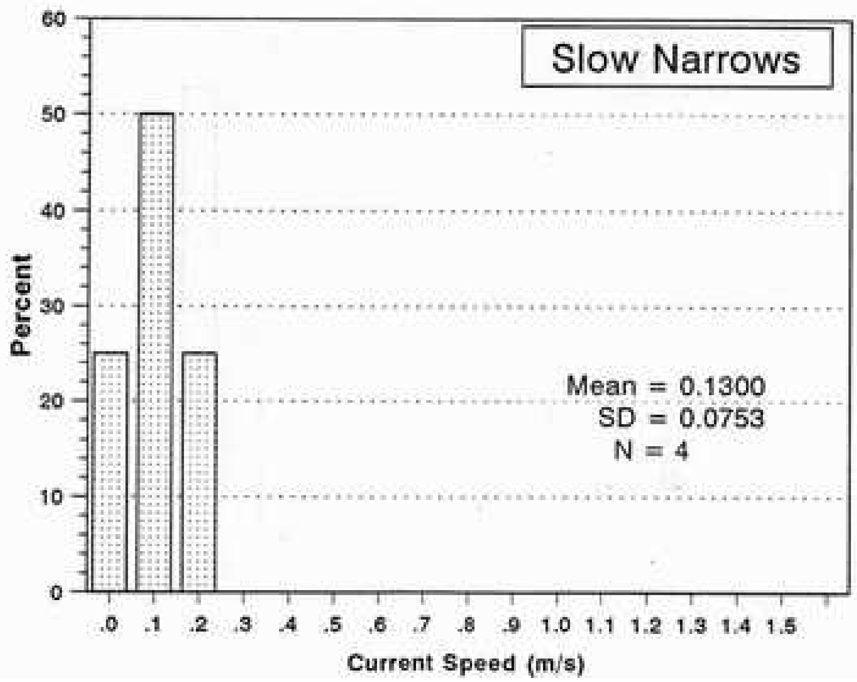

Isolated Pools
Mean = 0.000
SD = 0.000
N = 6
Percent
0
20
40
60
80
100
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6
Current Speed (m/s)

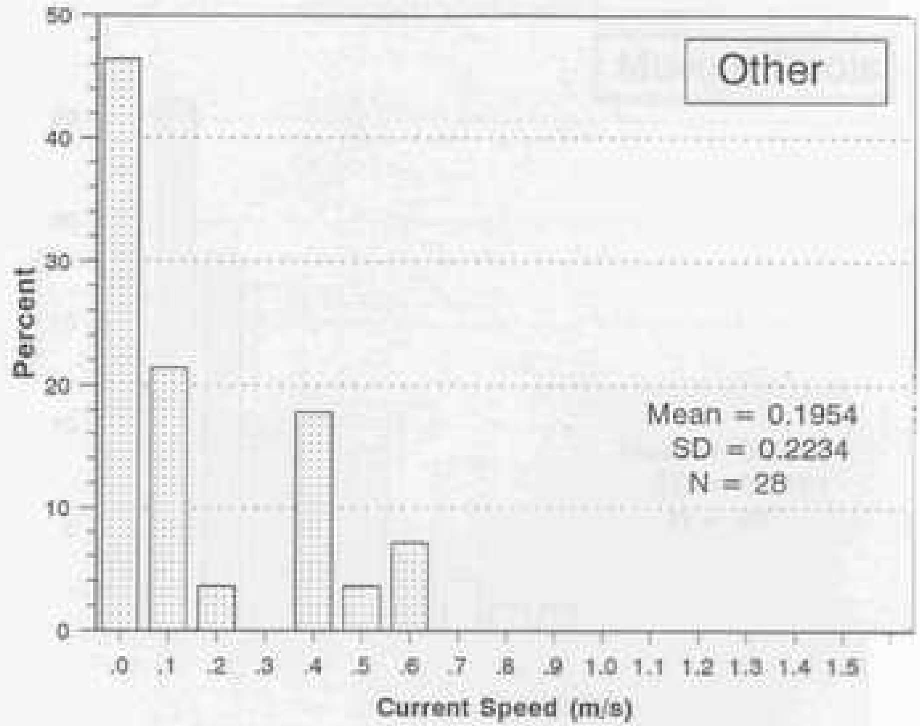

Backwaters
Mean = 0.0164
SD = 0.0210
N = 25
Percent
0
20
40
60
80
100
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6
Current Speed (m/s)

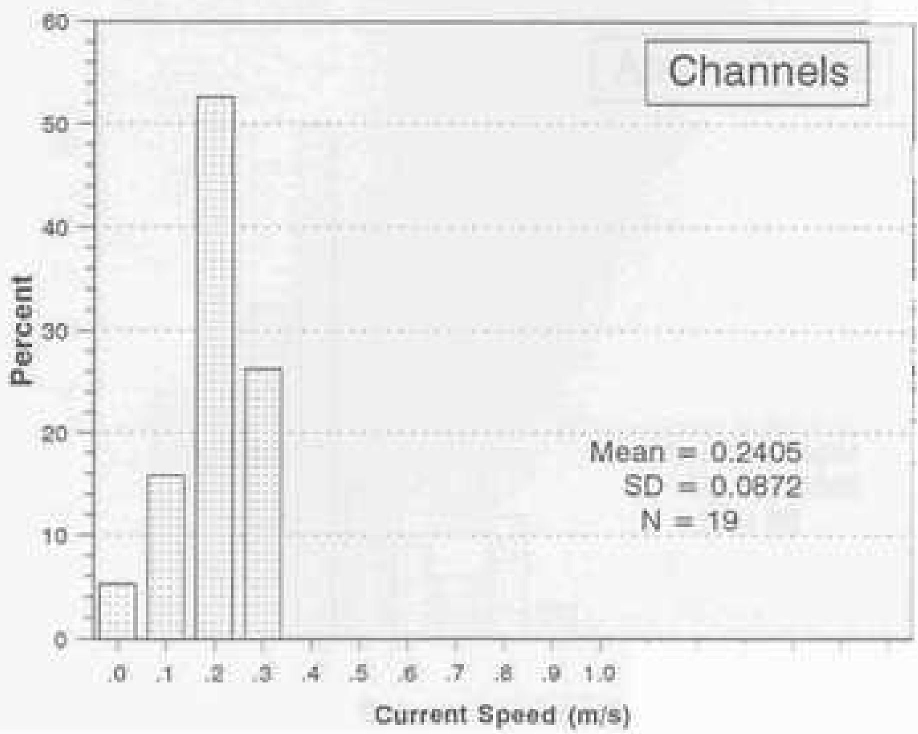

Slow Moving Pools
Percent
Current Speed (m/s)
Mean = 0.0675
SD = 0.0785
N = 65
0
10
20
30
40
50
60
70
80
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6

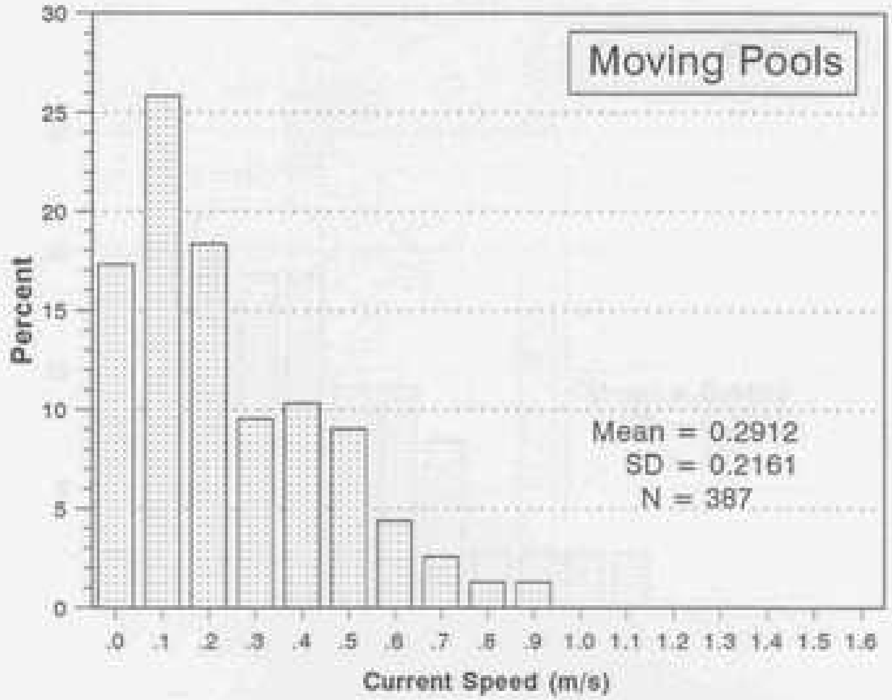

Edge
Percent
Current Speed (m/s)
Mean = 0.0829
SD = 0.0761
N = 7
0
10
20
30
40
50
60
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6


Shallow Shelves
Mean = 0.0882
SD = 0.0866
N = 28
Percent
0
10
20
30
40
50
60
70
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5
Current Speed (m/s)

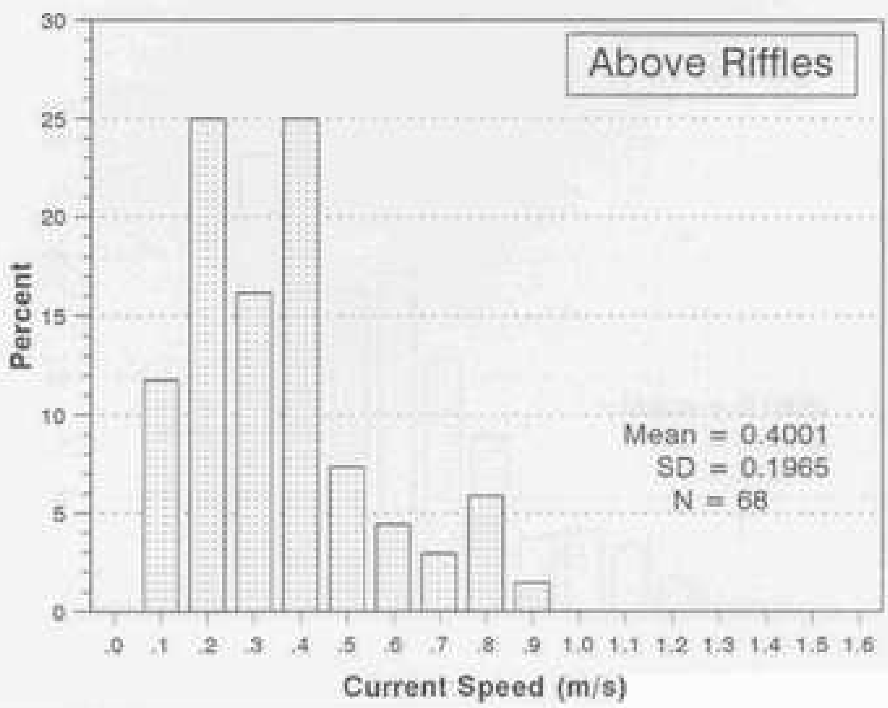

Slow Narrows
Mean = 0.1300
SD = 0.0753
N = 4
Percent
0
10
20
30
40
50
60
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5
Current Speed (m/s)


Other
Percent
0
10
20
30
40
50
Mean = 0.1954
SD = 0.2234
N = 28
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5
Current Speed (m/s)

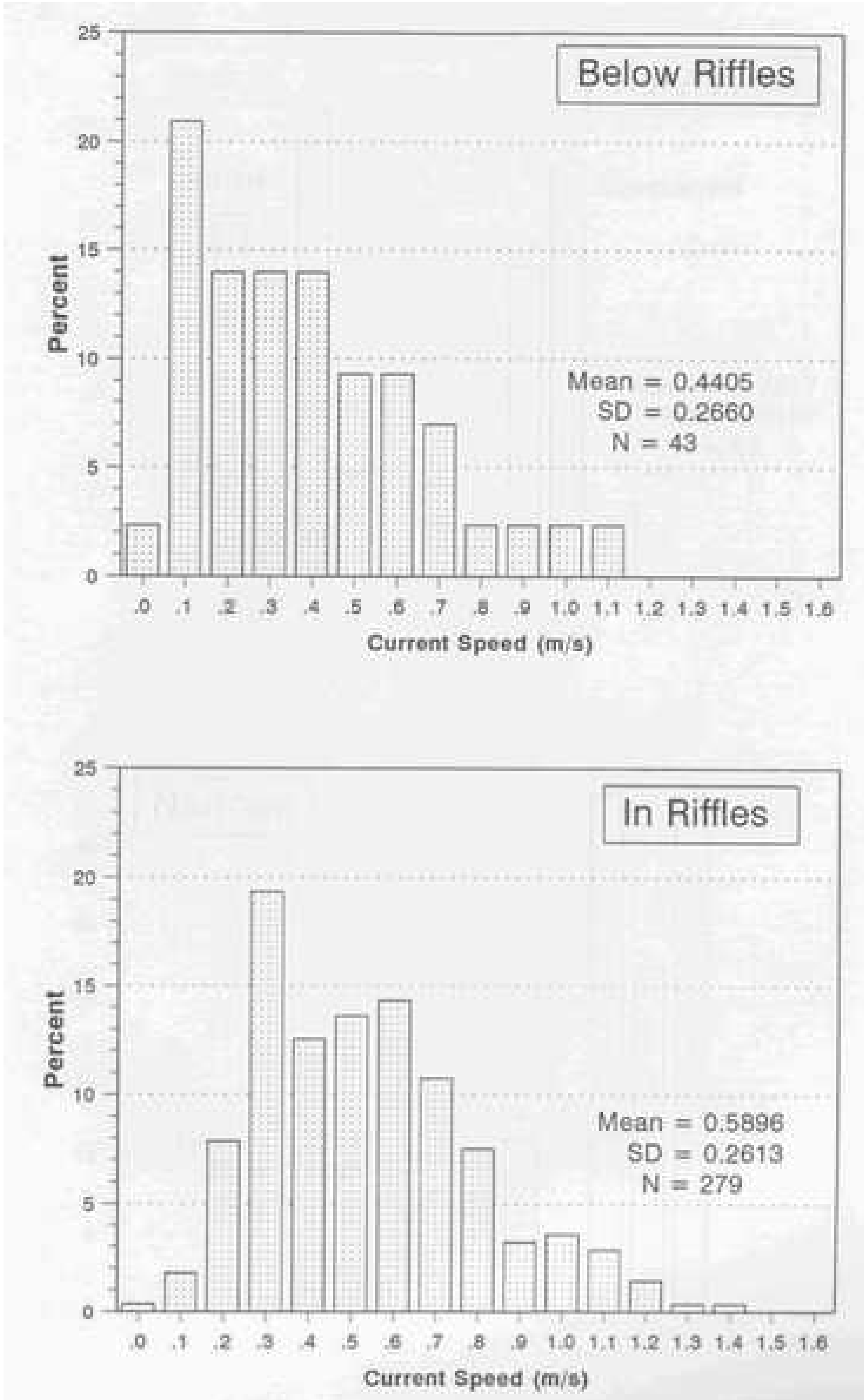

Channels
Percent
0
10
20
30
40
50
60
Mean = 0.2405
SD = 0.0872
N = 19
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0
Current Speed (m/s)

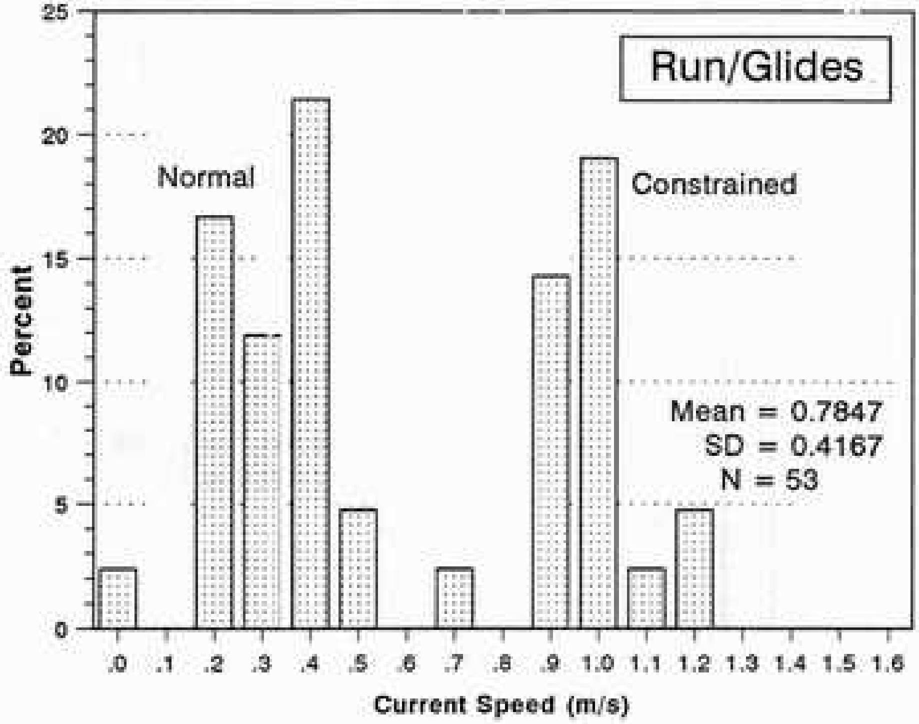


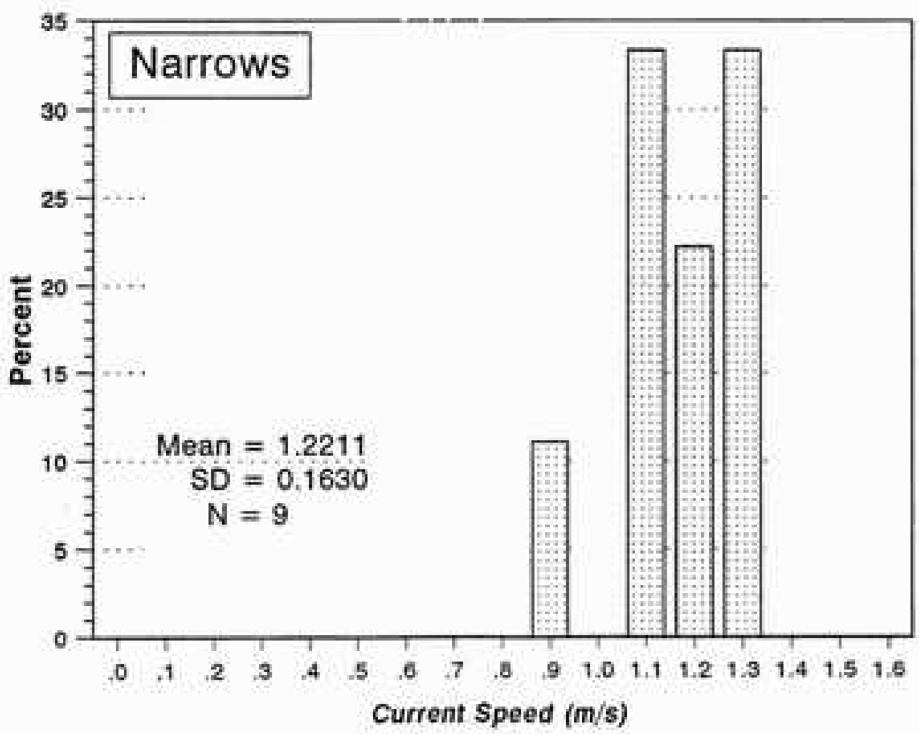
Moving Pools
Percent
0
5
10
15
20
25
30
Mean = 0.2912
SD = 0.2161
N = 387
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6
Current Speed (m/s)

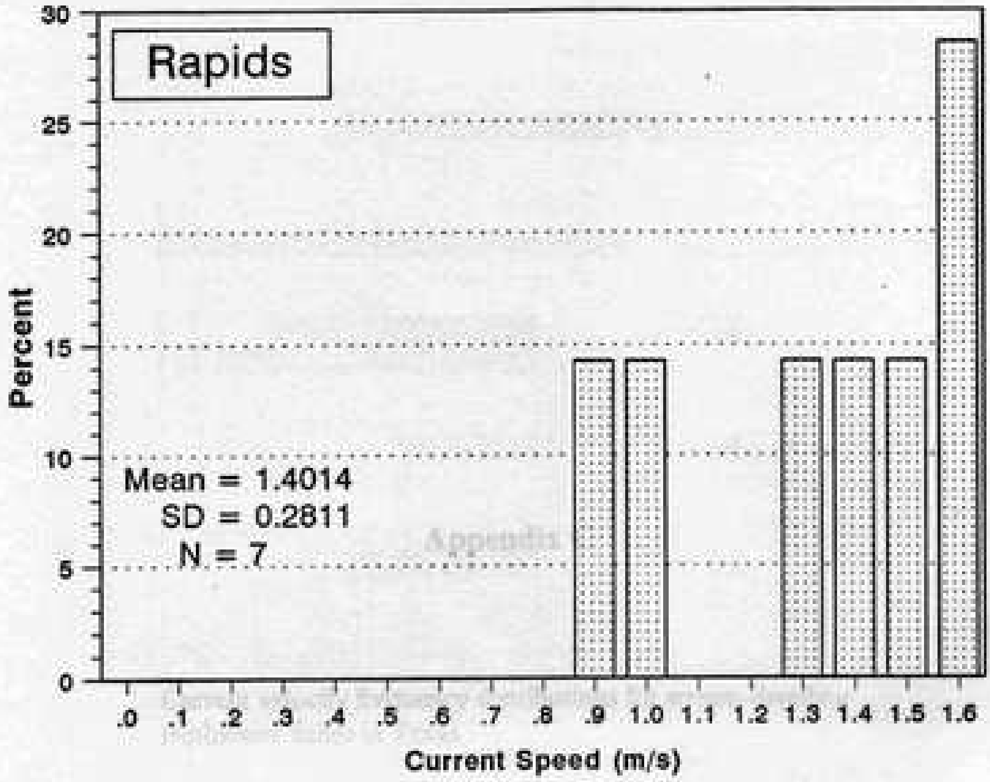


Above Riffles
Percent
0
5
10
15
20
25
30
Mean = 0.4001
SD = 0.1965
N = 68
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6
Current Speed (m/s)


Below Riffles
Mean = 0.4405
SD = 0.2660
N = 43
Percent
Current Speed (m/s)
In Riffles
Mean = 0.5896
SD = 0.2613
N = 279
Percent
Current Speed (m/s)


Run/Glides
Normal
Constrained
Percent
Mean = 0.7847
SD = 0.4167
N = 53
0
5
10
15
20
25
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6
Current Speed (m/s)

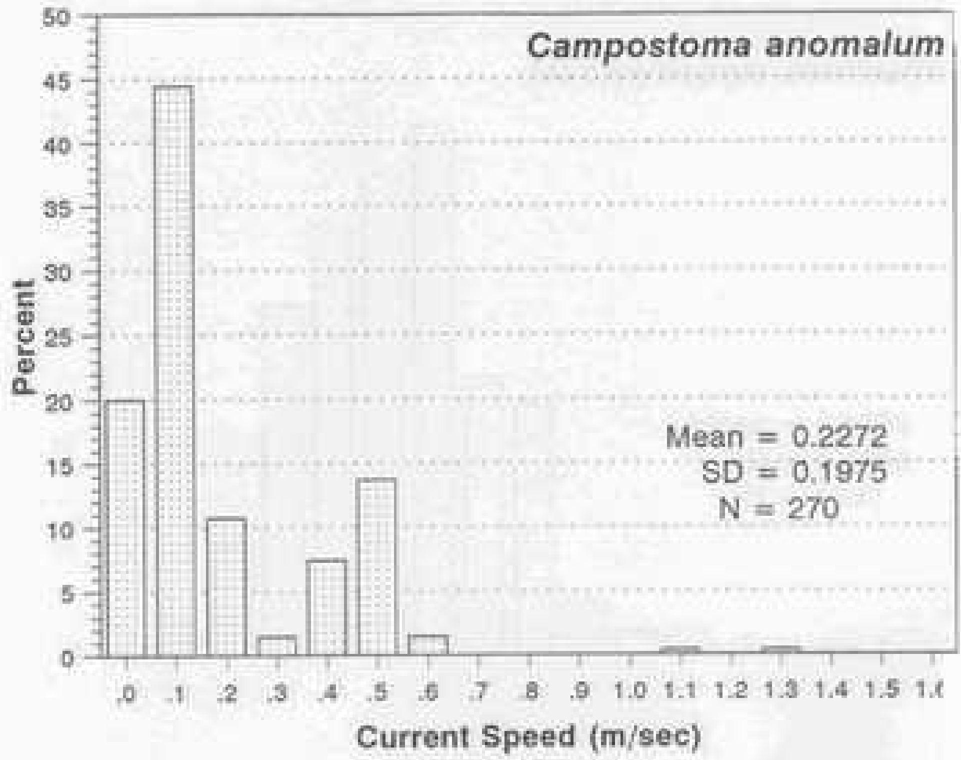

Narrows
Percent
Mean = 1.2211
SD = 0.1630
N = 9
0
5
10
15
20
25
30
35
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6
Current Speed (m/s)

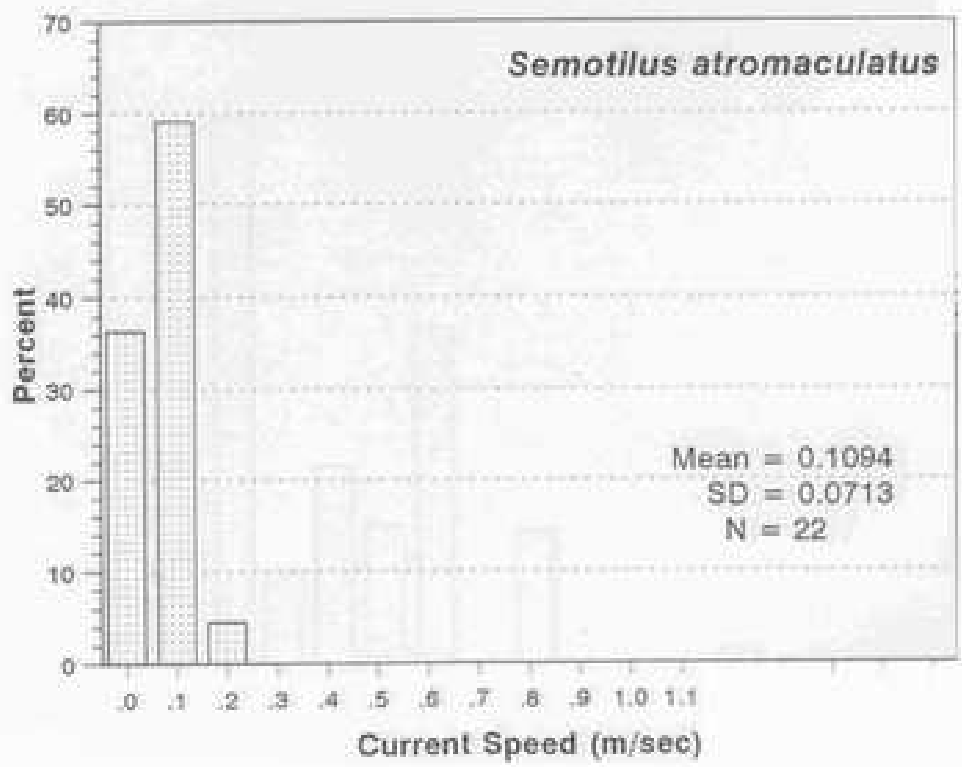


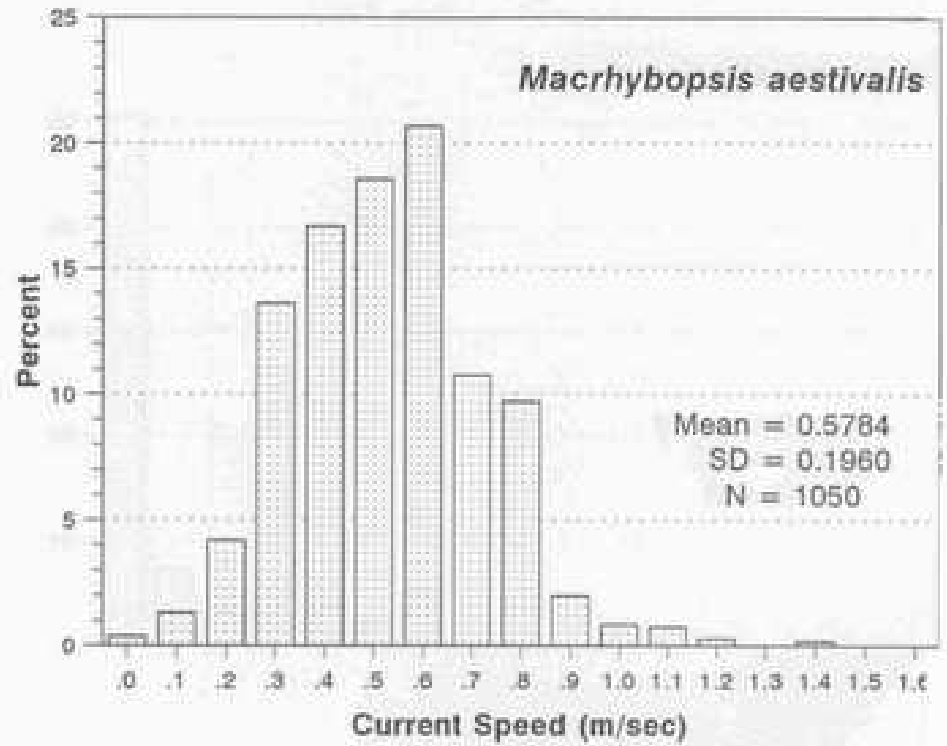
Rapids
Mean = 1.4014
SD = 0.2811
N = 7
Percent
30
25
20
15
10
5
0
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6
Current Speed (m/s)

Appendix C

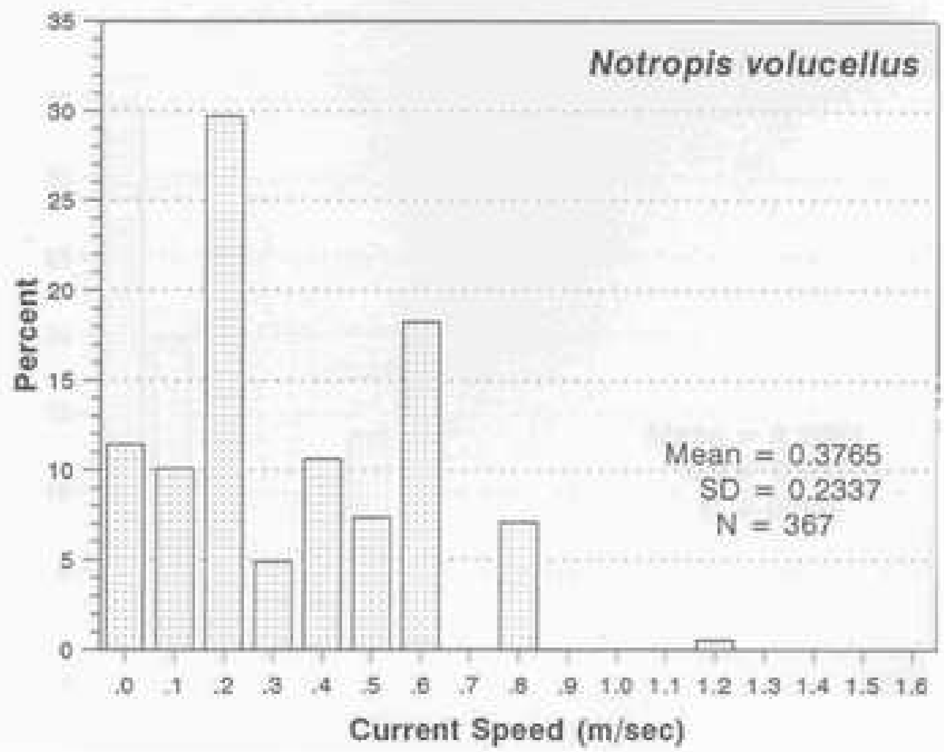
Current velocity frequency distributions for stream-dwelling freshwater fishes in Texas.


Campostoma anomalum
Percent
Mean = 0.2272
SD = 0.1975
N = 270
Current Speed (m/sec)

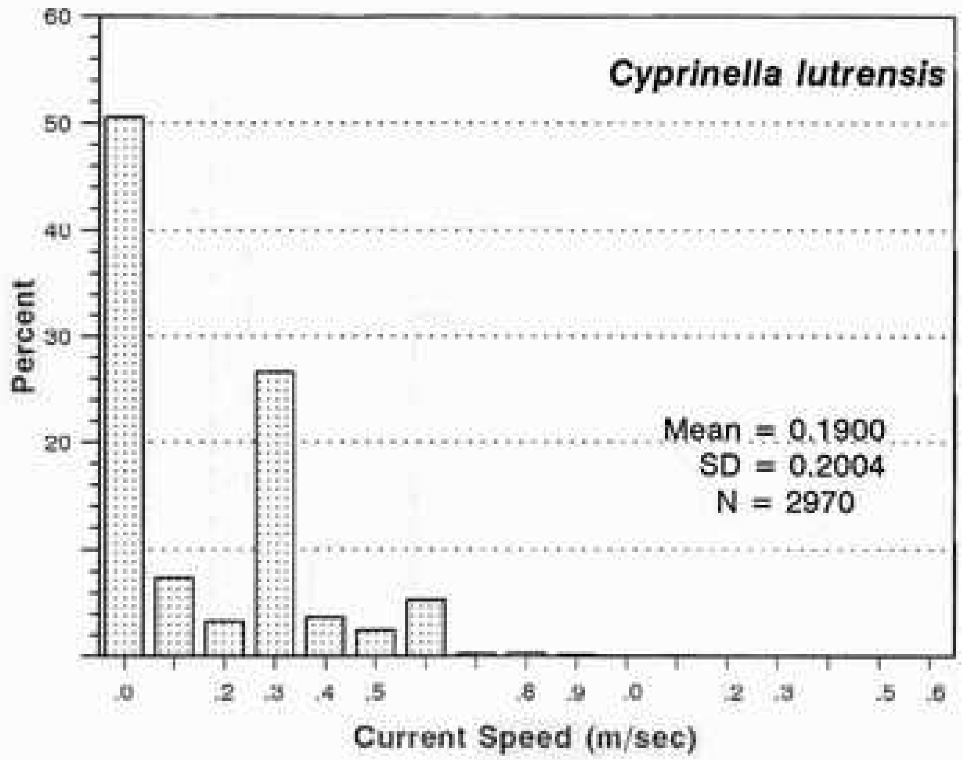

Semotilus atromaculatus
Percent
Mean = 0.1094
SD = 0.0713
N = 22
Current Speed (m/sec)

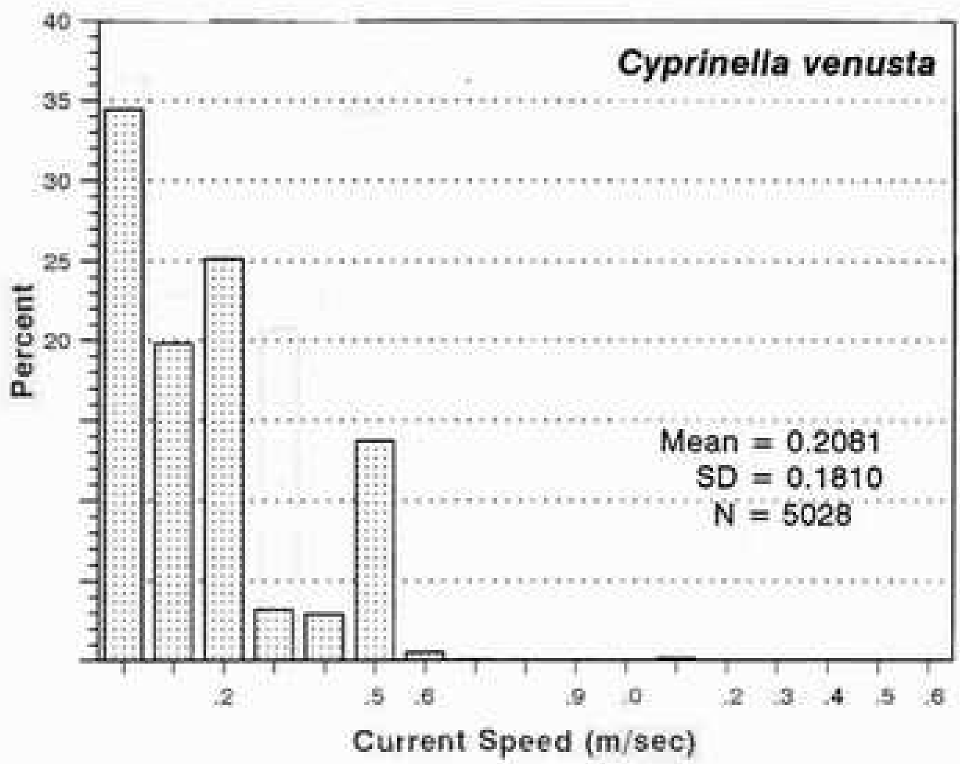


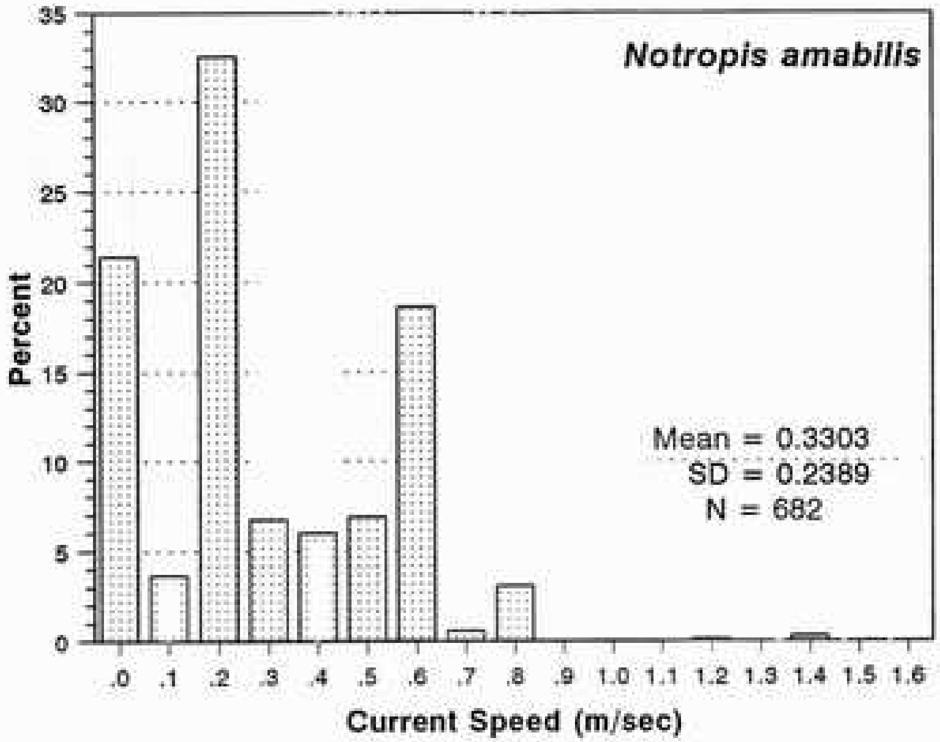
Macrhybopsis aestivalis
Percent
Mean = 0.5784
SD = 0.1960
N = 1050
Current Speed (m/sec)

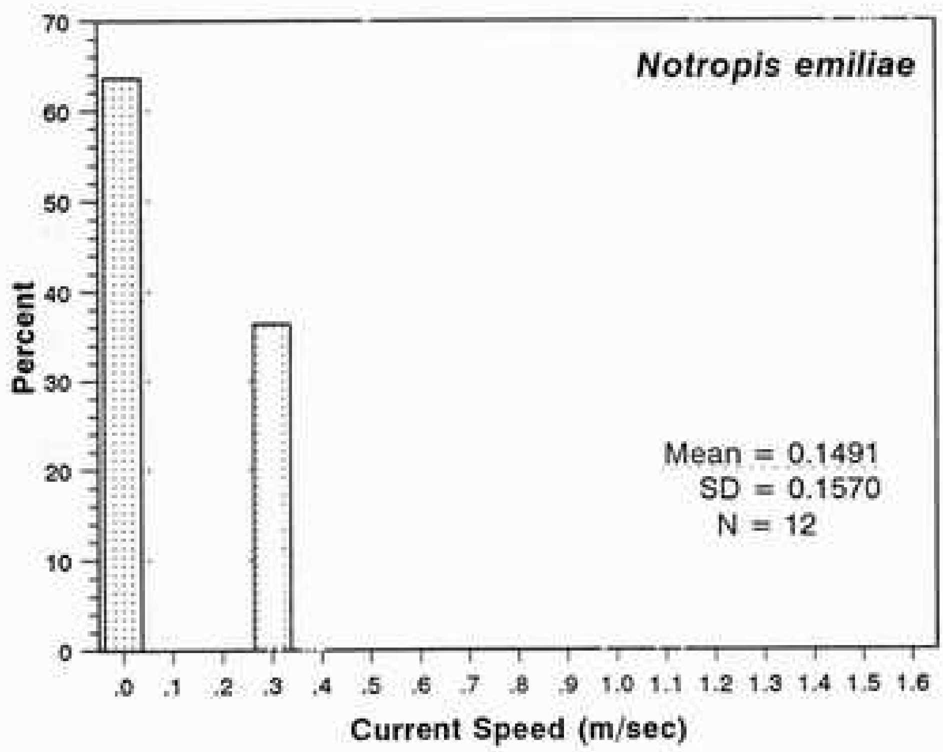


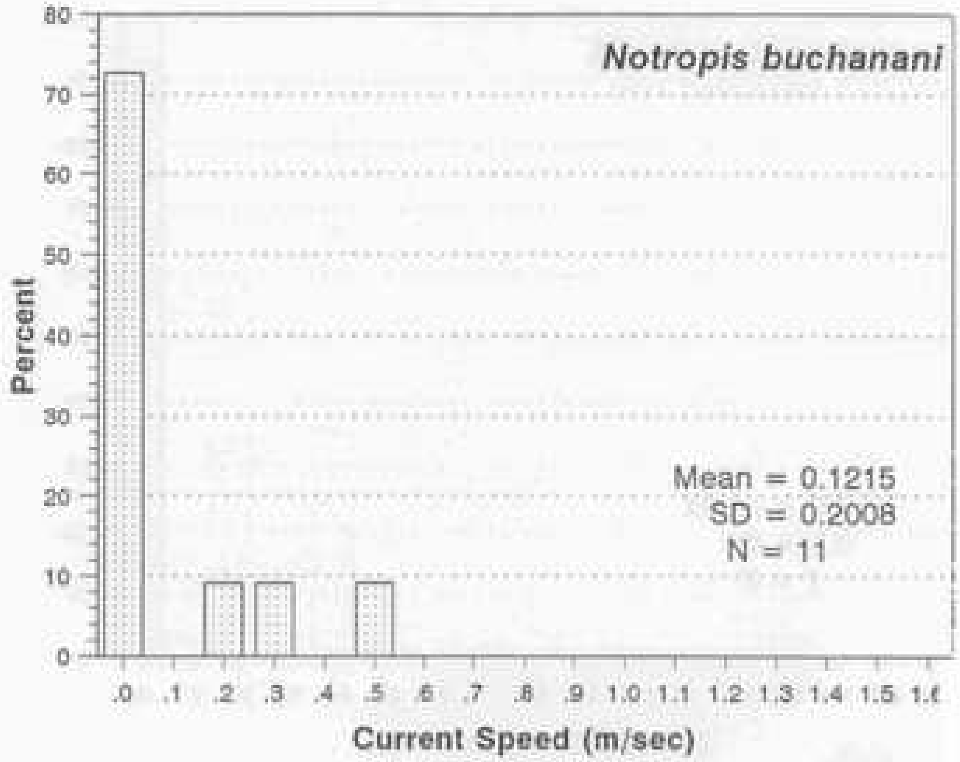
Notropis volucellus
Percent
Mean = 0.3765
SD = 0.2337
N = 367
Current Speed (m/sec)

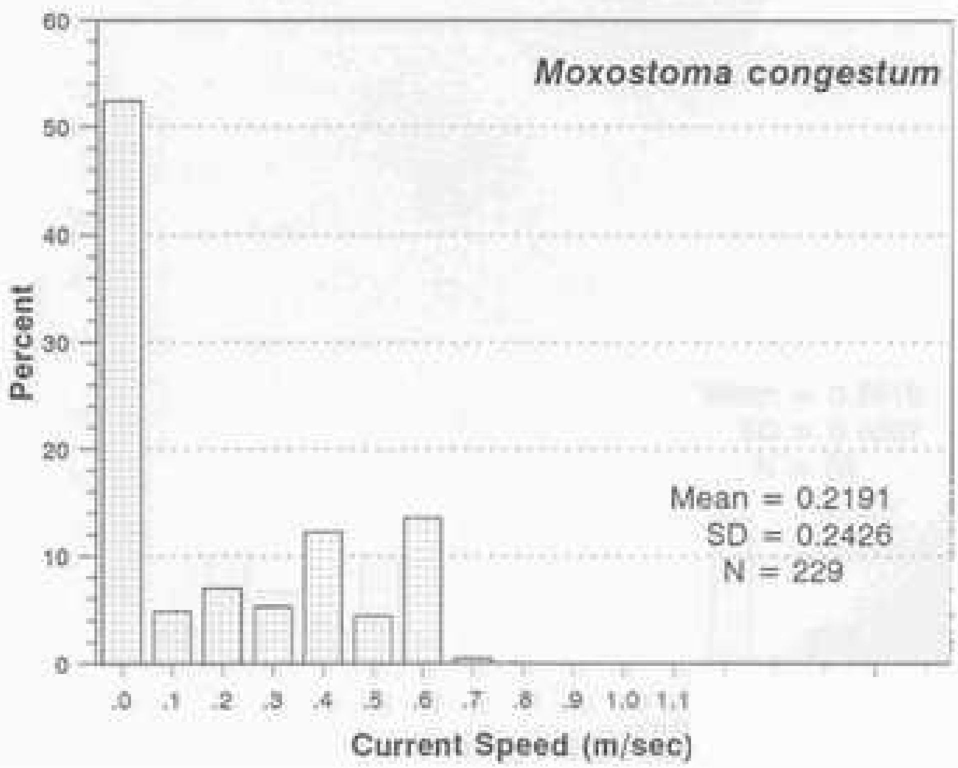

Cyprinella lutrensis
Percent
60
50
40
30
20
Mean = 0.1900
SD = 0.2004
N = 2970
.0
.2
.3
.4
.5
.6
.9
.0
.2
.3
.5
.6
Current Speed (m/sec)

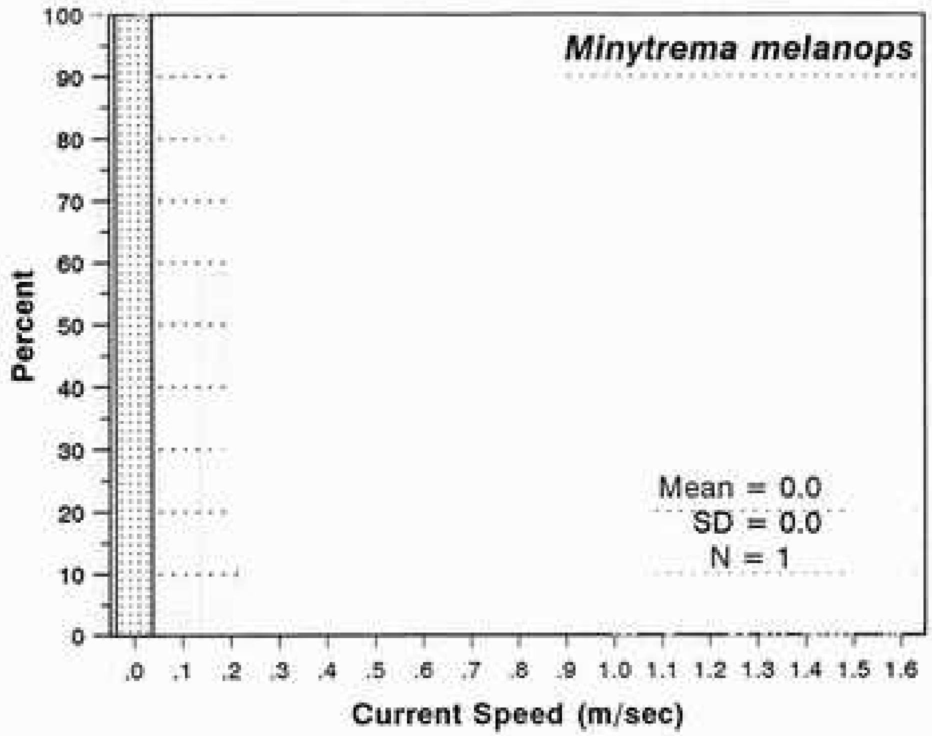

Cyprinella venusta
Percent
40
35
30
25
20
Mean = 0.2081
SD = 0.1810
N = 5028
.2
.5
.6
.9
.0
.2
.3
.4
.5
.6
Current Speed (m/sec)

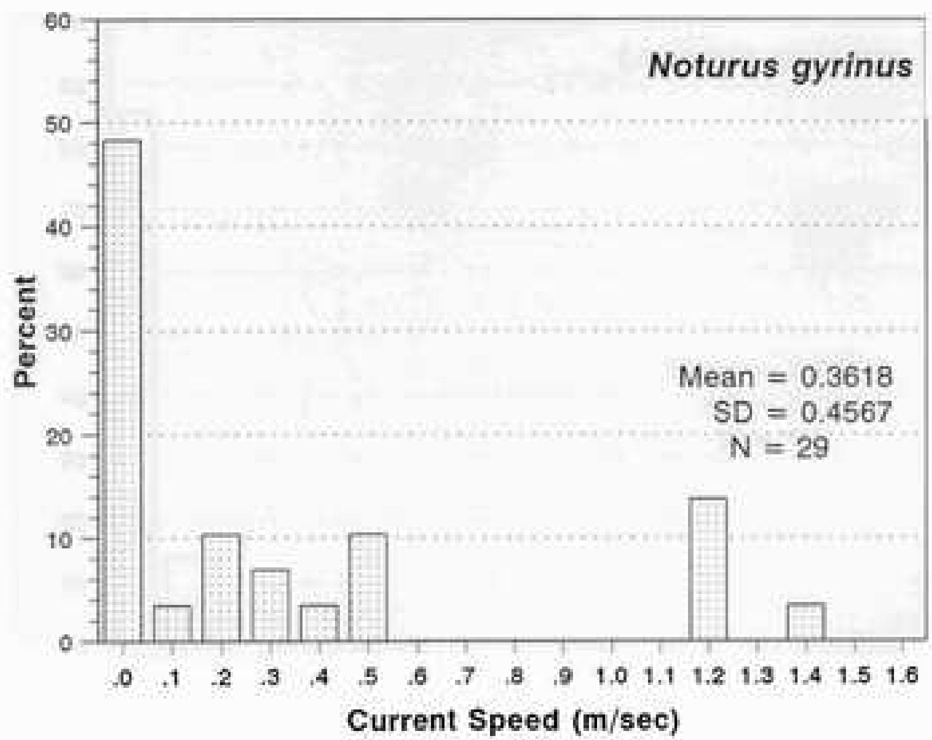

Notropis amabilis
Percent
35
30
25
20
15
10
5
0
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6
Current Speed (m/sec)
Mean = 0.3303
SD = 0.2389
N = 682

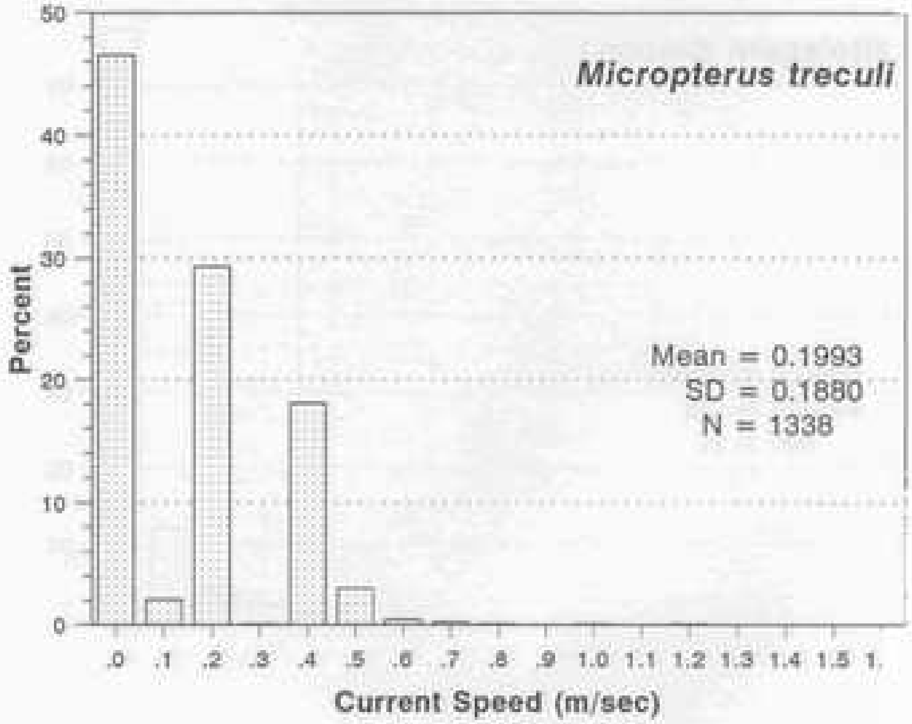

Notropis emiliae
Percent
70
60
50
40
30
20
10
0
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6
Current Speed (m/sec)
Mean = 0.1491
SD = 0.1570
N = 12

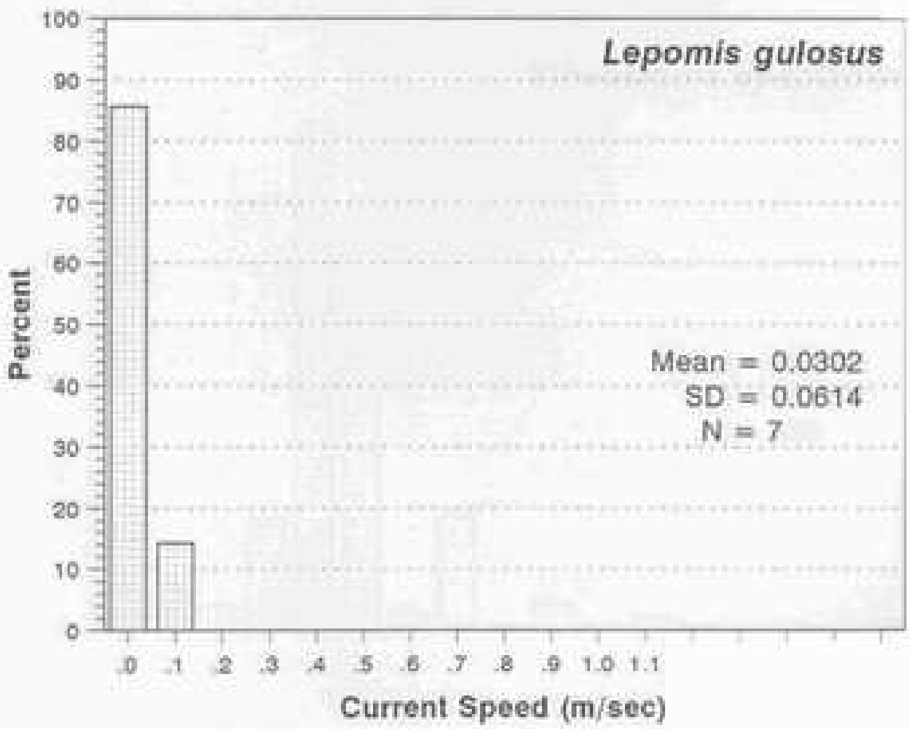

Notropis buchanani
Percent
Current Speed (m/sec)
Mean = 0.1215
SD = 0.2008
N = 11
0
10
20
30
40
50
60
70
80
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5

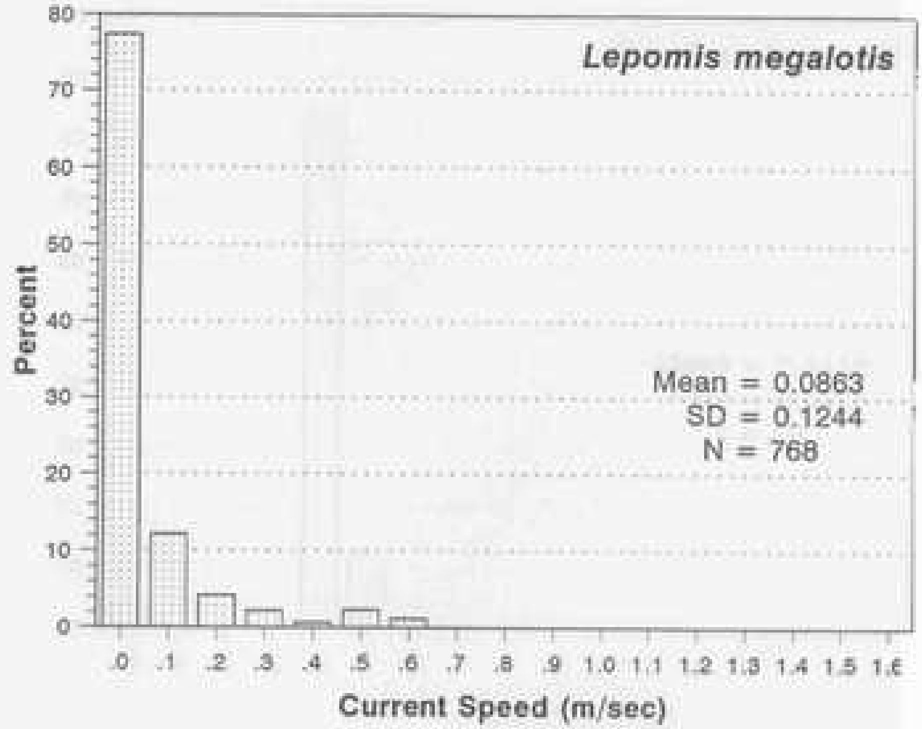

Moxostoma congestum
Percent
Current Speed (m/sec)
Mean = 0.2191
SD = 0.2426
N = 229
0
10
20
30
40
50
60
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1

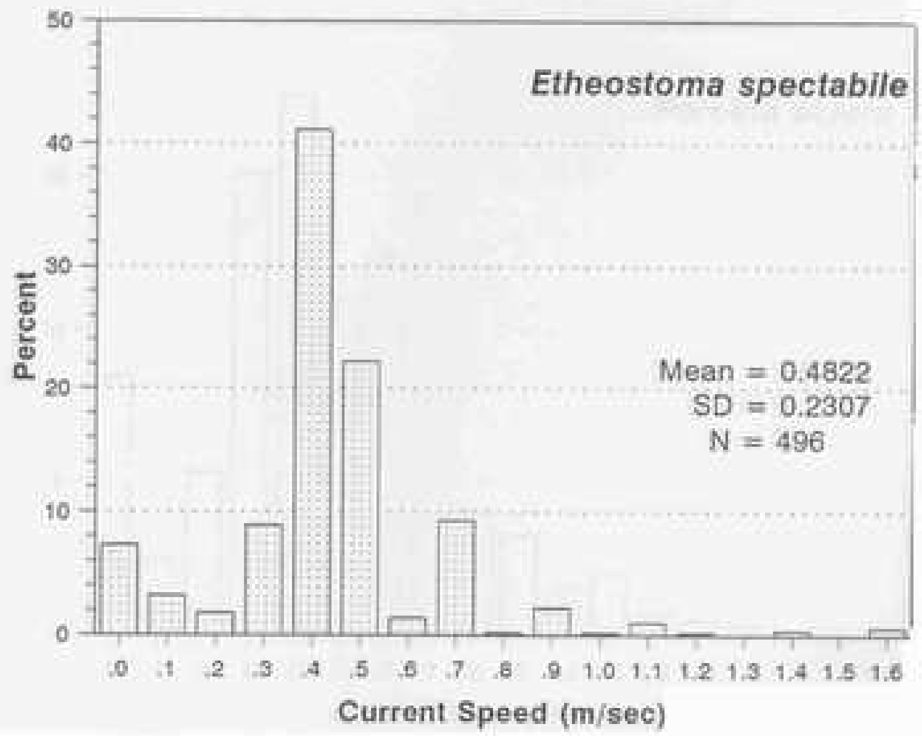

Minytrema melanops
Percent
Mean = 0.0
SD = 0.0
N = 1
Current Speed (m/sec)

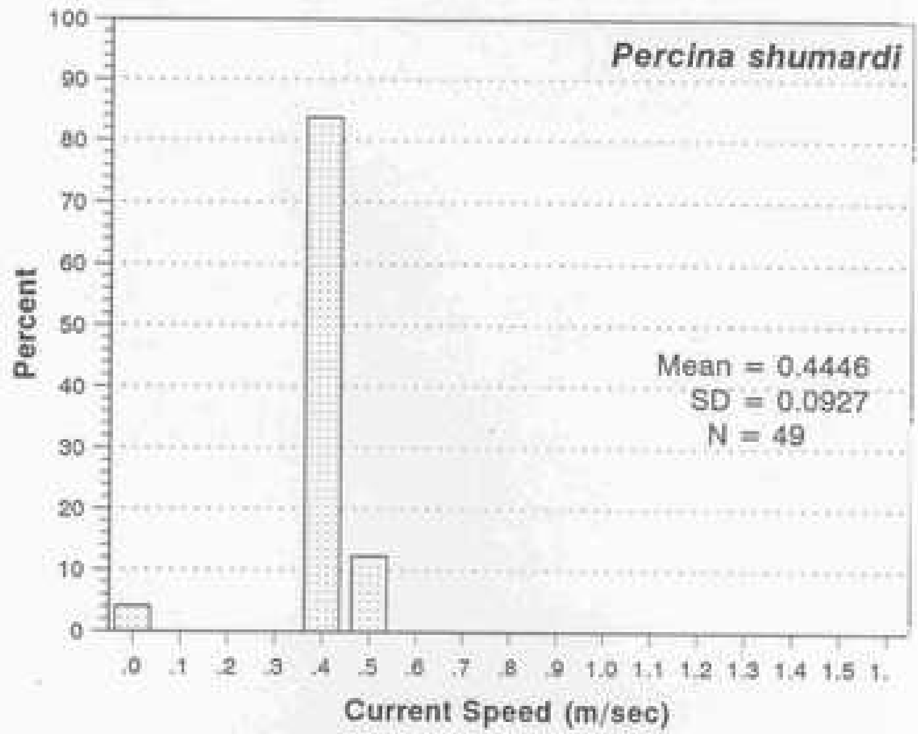

Noturus gyrinus
Percent
Mean = 0.3618
SD = 0.4567
N = 29
Current Speed (m/sec)

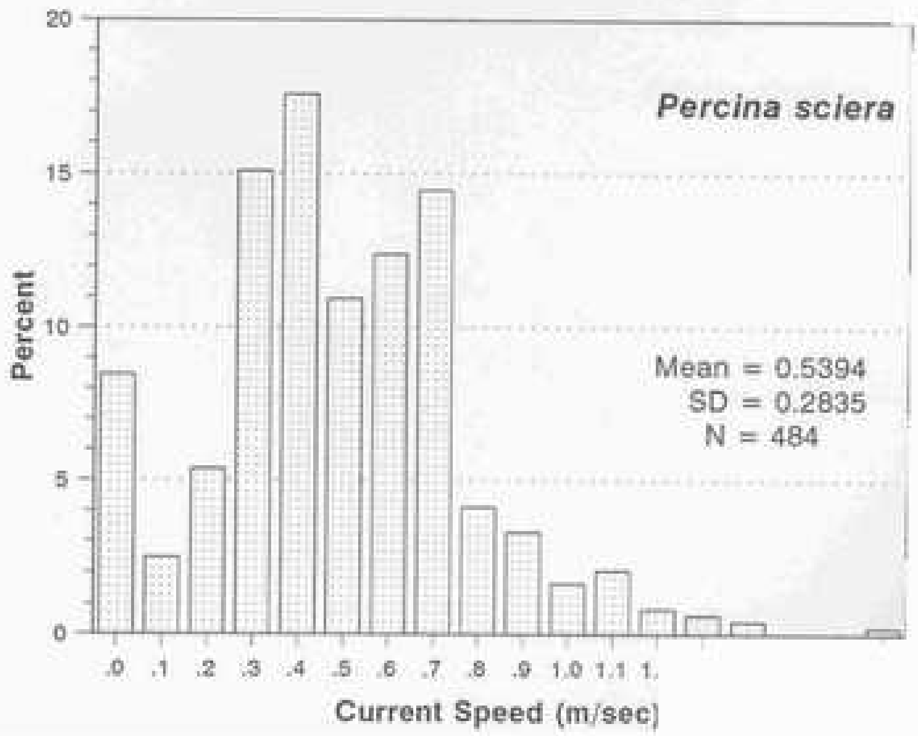

Micropterus treculi
Percent
Mean = 0.1993
SD = 0.1880
N = 1338
Current Speed (m/sec)


Lepomis gulosus
Percent
Mean = 0.0302
SD = 0.0614
N = 7
Current Speed (m/sec)


Lepomis megalotis
Percent
80
70
60
50
40
30
20
10
0
Mean = 0.0863
SD = 0.1244
N = 768
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6
Current Speed (m/sec)


Etheostoma spectabile
Percent
50
40
30
20
10
0
Mean = 0.4822
SD = 0.2307
N = 496
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6
Current Speed (m/sec)


Percina shumardi
Mean = 0.4446
SD = 0.0927
N = 49
Percent
100
90
80
70
60
50
40
30
20
10
0
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.
Current Speed (m/sec)


Percina sciera
Mean = 0.5394
SD = 0.2835
N = 484
Percent
20
15
10
5
0
.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.
Current Speed (m/sec)