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Decline of the Frecklebelly Madtom in the Pearl River Based on Contemporary and Historical Surveys

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Abstract.—The Pearl River has experienced numerous human-caused disturbances since the 1950s, including completion of a navigation channel, reservoir construction, and channel modifications on the main stem of the river. These types of disturbances are known to negatively impact the biotic and abiotic components of riverine ecosystems. Since the 1960s, several fish species in the drainage have declined in abundance or have been extirpated from the drainage. We undertook this study to assess the current conservation status of the frecklebelly madtom *Noturus munitus* in the Pearl River drainage. A 1999 survey of 53 sites within the historic range of the frecklebelly madtom yielded only 13 specimens from eight localities. We also examined historical population trends for the frecklebelly madtom and other benthic fishes using archived museum material (1950–1988). After standardizing for variation in collection effort, analysis of long-term collection data indicated that frecklebelly madtom populations have declined significantly since the 1960s. Despite greater sampling effort in the postmodification period (1965–1988), frecklebelly madtoms were most abundant in samples during the modification period (1950–1964). Similar declines were observed for the brighteye darter *Etheostoma lynceum*, a gravel–riffle-dependent species. Other percid taxa (including the crystal darter *Crystallaria asprella* (formerly *Ammocrypta asprella*), the saddleback darter *Percina vigil*, the Gulf logperch *P. suttkusi*, and the dusky darter *P. sciera*) showed no significant changes between modification and postmodification periods. However, benthic taxa (including the naked sand darter *Ammocrypta beani*, longnose shiner *Notropis longirostris*, channel catfish *Ictalurus punctatus*, hogchoker *Trinectes maculatus*, gulf darter *E. swaini*, speckled chub *Macrhybopsis aestivalis*, and silver chub *M. storeriana*) increased in abundance between modification and postmodification study periods. We suggest that channel changes and the loss of gravel substrates are related and are contributing to the decline of the frecklebelly madtom in the Pearl River drainage.

Lotic habitats throughout the southeastern United States have been subjected to numerous human-caused modifications over the past 50 years (Craig and Kemper 1987; Brookes 1988; Benke 1990; Richter et al. 1997). Different groups of fishes have responded to these disturbances in different ways. Based on lists of imperiled species, fishes adapted to midwater or surface habitats, such as sunfishes (Centrarchidae) and topminnows (Fundulidae), appear to be little affected (Williams et al. 1989; Warren and Burr 1994; Etnier 1997). In contrast, benthic fishes, such as species in the families Percidae and Ictaluridae, have been most affected, with over one-quarter of the taxa in each of these groups currently classified as jeopardized (Warren and Burr 1994; Warren et al. 2000). In fact, ictalurid catfishes are the most imperiled group of fishes in the southeastern United States (Warren and Burr 1994) and most of these jeopardized taxa are madtoms (*Noturus* spp.), a species group (26 species) of small (50–230 mm TL), secretive catfishes that occur throughout eastern North America (Page and Burr 1991).

The frecklebelly madtom *Noturus munitus* has a broad but fragmented distribution, with populations in the Pearl, Upper Tombigbee, Alabama, Cahaba, Etowah, and Conasauga river systems (Suttkus and Taylor 1965). It primarily inhabits the main channels and larger tributaries of these river systems and typically occurs over firm gravel substrates in swift flowing water (Suttkus and Taylor 1965; Mettee et al. 1996). Due to its fragmented distribution and rarity, the frecklebelly madtom is jeopardized in each of the states that it inhabits: Mississippi (Mississippi Natural Heritage Program 2000; Ross 2001), Alabama (Pierson 1990), Georgia (Georgia Natural Heritage Program 2001), Tennessee (Redmond 1996; McCoy et al. 2001), and Louisiana (Louisiana Natural Heritage Program 1996).

Studies addressing the decline of freshwater aquatic biodiversity have focused on diverse up-

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land systems, such as the Tennessee River and Mobile Bay basins (Etnier 1994; Lydeard and Mayden 1995), whereas other regions (i.e., Coastal Plain streams) have been understudied. Recent research has suggested that human-induced disturbances in Gulf Coastal Plain drainages cause severe geomorphic instability in these easily eroded, alluvial streams (Box and Mossa 1999; Patrick et al. 1991; Ross et al. 2001), and disproportionately impact benthic organisms (Box and Mossa 1999; Hartfield 1993). In the Pearl River drainage, accelerated erosion and geomorphic instability have lead to distinct changes in the percid fish community, particularly in areas inhabited by the frecklebelly madtom (Tipton et al., in press).

Monitoring a population's response to environmental perturbation typically requires a prolonged period of observation (Reznick and Baxter 1994). Unfortunately, resource managers have neither the financial resources nor the personnel to implement such studies. Instead, intensive, short-duration field surveys are typically conducted to assess the population's current status and to establish conservation priorities. Alternatively, historic collection records from natural history museums, coupled with modern field surveys, provide a more comprehensive means of assessing population or community trends over longer periods of time (Walser and Bart 1999; Ponder et al. 2001). We used natural history museum data from two long-term fish monitoring surveys on the Pearl River system of Louisiana and Mississippi, and our own intensive 1-year study to assess the conservation status of the frecklebelly madtom and to examine long-term population trends for this species and other benthic fishes in the system.

Study Area

The Pearl River is a sand- and gravel-bottomed river that drains approximately 23,000 km^2 of bottomland forest and agricultural lands in south-central Mississippi and eastern Louisiana. It originates in Neshoba County in northern Mississippi and flows in a southwesterly direction to the Mississippi Sound. Principal tributaries of the system include the Yockanookcanay, Bogue Chitto, and Strong rivers.

The Pearl River has experienced three major physical changes since the 1950s. The first was the construction of the Pearl River Navigation Canal in 1956, which provided a shorter route for barge traffic from the Gulf of Mexico to just south of Bogalusa, Louisiana. Two sills and three locks were constructed to control water levels within the navigation channel. Channel maintenance and lock and dam operations were abandoned in the early 1970s due the lack of commercial usage, but the structures remain. A second major disturbance was the impoundment of the river in 1964 at Jackson, Mississippi, to form the Ross Barnett Reservoir. Finally, channel changes in the lower Pearl River caused the West Pearl River, historically a small distributary channel, to capture most of the river's flow and may be contributing to channel changes in more upstream reaches.

Methods

Contemporary survey.—We resurveyed historic collection sites of frecklebelly madtoms within the Pearl River Basin to assess the species' current conservation status. Several sites were reconnoitered only and were not sampled due to the lack of suitable gravel–riffle habitats. For other sites, we sampled in early spring through late fall 1999, sampling main channel and tributary sites and making day and night samples. We made collections with a standard minnow seine (2 × 3.3 m) or a backpack electrofisher (Smith-Root model 15A). We either electrofished and kicked fishes into a seine set below a riffle or swift run, or seined at sites with high turbidities. Localities with high water clarity were sampled with an electrofisher and dip nets. We sampled each site for least 30 min and targeted the preferred habitat (gravel riffles) of the frecklebelly madtom (Suttkus and Taylor 1965). We measured, photographed, and released most specimens. At selected sites, we retained one voucher specimen for deposition in the Royal D. Suttkus (RDS) Fish Collection at the Tulane University Museum of Natural History.

Historical population trends.—We extracted records of all Pearl River sites known to support frecklebelly madtoms from the RDS Fish Collection (main channel and tributary sites covering the period 1950–1988). Royal D. Suttkus has been conducting quarterly fish and water quality surveys in the Pearl River since 1963, working most of this time with his longtime colleague, the late Gerald E. Gunning. The general fish surveys involved sampling at numerous sites along the main stem of the Pearl River in Louisiana (Lower Pearl River Survey, 1963–present) and Mississippi (Upper Pearl River Survey, 1973–present). Sampling methodology and collecting gear (2 × 3.3-m seine) remained constant throughout most of this period. However, in 1988 the time (night to day) and duration (1 h to 15 min) of sampling was changed; therefore, we only used survey data from 1950 to

TABLE 1.—Ranking of the 25 most abundant species in the Pearl River (1950–1988). Taxonomic groupings follow (Nelson 1994); ecological groupings are based on experience of the authors and Ross (2001).

Rank	Species	Number of specimens	Taxonomic group	Ecological group
1	Blacktail shiner *Cyprinella venusta*	289,326	Cyprinidae	Nonbenthic, substrate generalist
2	Weed shiner *Notropis texanus*	61,773	Cyprinidae	Nonbenthic, substrate generalist
3	Speckled chub *Macrhybopsis aestivalis*	60,025	Cyprinidae	Benthic, sand–gravel specialist
4	Mississippi silvery minnow *Hybognathus nuchalis*	55,972	Cyprinidae	Nonbenthic, substrate generalist
5	Bullhead minnow *Primephales vigilax*	30,580	Cyprinidae	Nonbenthic, substrate generalist
6	Emerald shiner *N. atherinoides*	25,728	Cyprinidae	Nonbenthic, substrate generalist
7	Saddleback darter *Percina vigil*	22,270	Percidae	Benthic, gravel dependent
8	Longnose shiner *N. longirostris*	22,108	Cyprinidae	Benthic, sand–gravel specialist
9	Mimic shiner *N. volucellus*	19,751	Cyprinidae	Nonbenthic, substrate generalist
10	Silver chub *M. storeriana*	11,678	Cyprinidae	Benthic, substrate generalist
11	Longear sunfish *Lepomis megalotis*	6,574	Centrarchidae	Nonbenthic, substrate generalist
12	Clear chub *Hybopsis winchelli*	6,040	Cyprinidae	Nonbenthic, substrate generalist
13	Dusky darter *P. sciera*	5,859	Percidae	Benthic, substrate generalist
14	Naked sand darter *Ammocrypta beani*	5,607	Percidae	Benthic, sand specialist
15	Channel catfish *Ictalurus punctatus*	4,563	Ictaluridae	Benthic, substrate generalist
16	Gulf logperch *P. suttkusi*	3,883	Percidae	Benthic, substrate generalist
17	Cypress minnow *Hybognathus hayi*	3,775	Cyprinidae	Nonbenthic, substrate generalist
18	Frecklebelly madtom *Noturus munitus*	3,440	Ictaluridae	Benthic, gravel dependent
19	Brighteye darter *Etheostoma lynceum*	3,067	Percidae	Benthic, gravel dependent
20	Threadfin shad *Dorosoma petenense*	2,909	Clupeidae	Nonbenthic, substrate generalist
21	Gulf darter *E. swaini*	2,717	Percidae	Benthic, substrate generalist
22	Crystal darter *Crystallaria asprella*	2,649	Percidae	Benthic, sand–gravel specialist
23	Highfin carpsucker *Carpiodes velifer*	2,605	Catostomidae	Benthic, substrate generalist
24	Blackspotted topminnow *Fundulus olivaceus*	2,592	Fundulidae	Nonbenthic, substrate generalist
25	Hogchoker *Trinectes maculatus*	2,439	Archiridae	Benthic, sand specialist

1988 to examine historical trends in abundance. Also, specimens of the frecklebelly madtom and other protected fishes were sometimes released. As a result, samples since 1988 do not provide as accurate a picture of population trends. Our historical analysis is based only on specimens archived in the museum. Thus, the focus of the historical portion of the present study is population changes that occurred during 1950–1988 and is only based on archived specimens.

In analyzing long-term population trends of the frecklebelly madtom in the Pearl River survey data, we standardized collection effort by first pooling yearly data for all samples from localities known to support frecklebelly madtoms. We expressed abundance in individual years as the total number of frecklebelly madtoms divided by the total number of samples from frecklebelly madtom localities and herein refer to this metric as the Annualized Collection Effort Ratio (ACER), which measures the catch per unit effort of frecklebelly madtom in historical Pearl River collections. We also examined distributional change by comparing the total number of sites occupied by frecklebelly madtoms in a given year as a proportion of frecklebelly madtom samples taken from frecklebelly madtom localities in that year and refer to this metric as the Distributional Change Ratio (DCR). We ranked all species collected at these localities according to abundance (1950–1988) and compared abundance trends for these species. The 25 most common species are listed in Table 1. We based taxonomic classifications on fish families (Nelson 1994) and ecological groups (i.e., benthic or nonbenthic; gravel dependent, habitat generalist, sand–gravel specialist, or sand specialist) based on our field experience and Ross (2001).

We grouped the ACER metric into two time periods representing different river modification regimes: (1) a modification period (1950–1964) characterized by extensive channel modification and construction of the Ross Barnett Dam and the Pearl River Navigation Canal; and (2) a postmodification period (1965–1988).

We hypothesized that species with disparate habitat preferences would respond differently to the environmental changes in the Pearl River Basin. We expected benthic fishes, especially gravel–riffle-dependent species such as the frecklebelly madtom, brighteye darter, and saddleback darter to decline in abundance between time periods and habitat generalists (e.g., blacktail shiner, dusky darter, and channel catfish), sand specialists (e.g., naked sand darter *Ammocrypta beani*), and sand–

gravel specialists (e.g., longnose shiner and crystal darter) to show no change.

Statistical analyses.—Ratios, such as the ACER and DCR metrics used in this study, tend to be nonnormally distributed and have nonconstant variance (Atchley et al. 1976). Although no transformation produced normally distributed observations for all metrics, the log-transformation resulted in approximately symmetric distributions with more constant variance. Because there was still evidence of nonconstant variance following log-transformation, a version of the *t*-test that does not assume equal variances was used to test for abundance differences between modification and postmodification study periods (Satterthwaite 1946; Sokal and Rohlf 1995). Multiple comparisons were corrected using the sequential Bonferroni method (Rice 1989). All statistical analyses were performed using SAS (version 8.02; SAS Institute 2000).

Results

Contemporary Survey

Frecklebelly madtoms occurred in low numbers in a few Pearl River tributaries, but no individuals were found in the main river channel in our survey in 1999. Of the 53 surveyed sites, 13 frecklebelly madtom specimens were collected from only eight of these localities (Figure 1). All individuals occurred in swift flowing water over firm gravel substrates in medium–large-sized (third or fourth order) tributaries of the Pearl River (8/37 samples). No individuals were collected from 26 main channel localities.

Historical Population Trends

Our analysis of historical population trends is based on 989 samples made at frecklebelly madtom localities from 1950 to 1988, and comprised 701,866 total fish specimens. During this period the average number of samples and specimens of all species taken per year was 25.3 (SE = 2.07) and 17,996 (SE = 2,016), respectively. Two-hundred fifty lots of frecklebelly madtom, representing 3,440 specimens ($\bar{x}$ = 92.97/year, SE = 20.42) from 80 localities, were archived from the Pearl River drainage during this period (Figure 1). The frecklebelly madtom is not known to occur upstream of the Ross Barnett Reservoir.

The catch of frecklebelly madtoms has declined precipitously since the late 1960s. Comparisons of abundance between the modification and postmodification periods indicate that the frecklebelly madtom was significantly more common from 1950 to 1964 than after this time (Figure 2A; Table 2). This was true despite the fact that collection effort was higher during the postmodification period (number of samples per year: $\bar{x}_{1950–1964}$ = 15.00 and $\bar{x}_{1965–1988}$ = 31.83). In addition, frecklebelly madtoms occurred in a higher proportion of samples (DCR) in the modification period ($\bar{x}_{1950–1964}$ = 0.31 and $\bar{x}_{1965–1988}$ = 0.12, t = 4.37, $P < 0.001$; Figure 2B).

Abundances of several other species changed between modification and postmodification periods based on ACER metrics (Table 2). Brighteye darter was significantly less common in the postmodification period, whereas other percid species (including the saddleback darter, dusky darter, Gulf logperch, and crystal darter showed no change between periods. Other benthic taxa (including the longnose shiner, naked sand darter, highfin carpsucker, hogchoker, gulf darter *E. swaini*, channel catfish, speckled chub, and silver chub were significantly more abundant in the postmodification period.

Discussion

Frecklebelly madtoms still occur in the Pearl River drainage but are much less common today than in the past. Samples taken in the long-term surveys were general fish surveys that did not target particular species. Seines, which were the preferred sampling gear during these surveys, are most effective in areas with slow flow and smooth bottoms, and have been shown to be particularly efficient in the collection of cyprinids and other pelagic species (Onorato et al. 1998) and less efficient for demersal or benthic fishes in both lentic (Lyons 1986) and lotic habitats (Onorato et al. 1998). Historical samples taken during the modification period frequently contained large numbers of frecklebelly madtoms and other gravel–riffle species. In contrast, our contemporary samples, which focused on the preferred habitat of the frecklebelly madtom at many of the same localities and used gear (i.e., backpack electrofisher) that madtoms and other catfishes are more vulnerable to than seines (Reynolds 1996), rarely yielded more than a single of frecklebelly madtom specimen.

Evidence suggests that the Pearl River has undergone a dramatic change in substrate composition—from extensive patches of firm gravel to a predominance of loose, shifting sands at localities that historically yielded large numbers of frecklebelly madtoms (R. D. Suttkus, Tulane University, personal observation; Tipton et al., in press). These sites are now dominated by benthic species

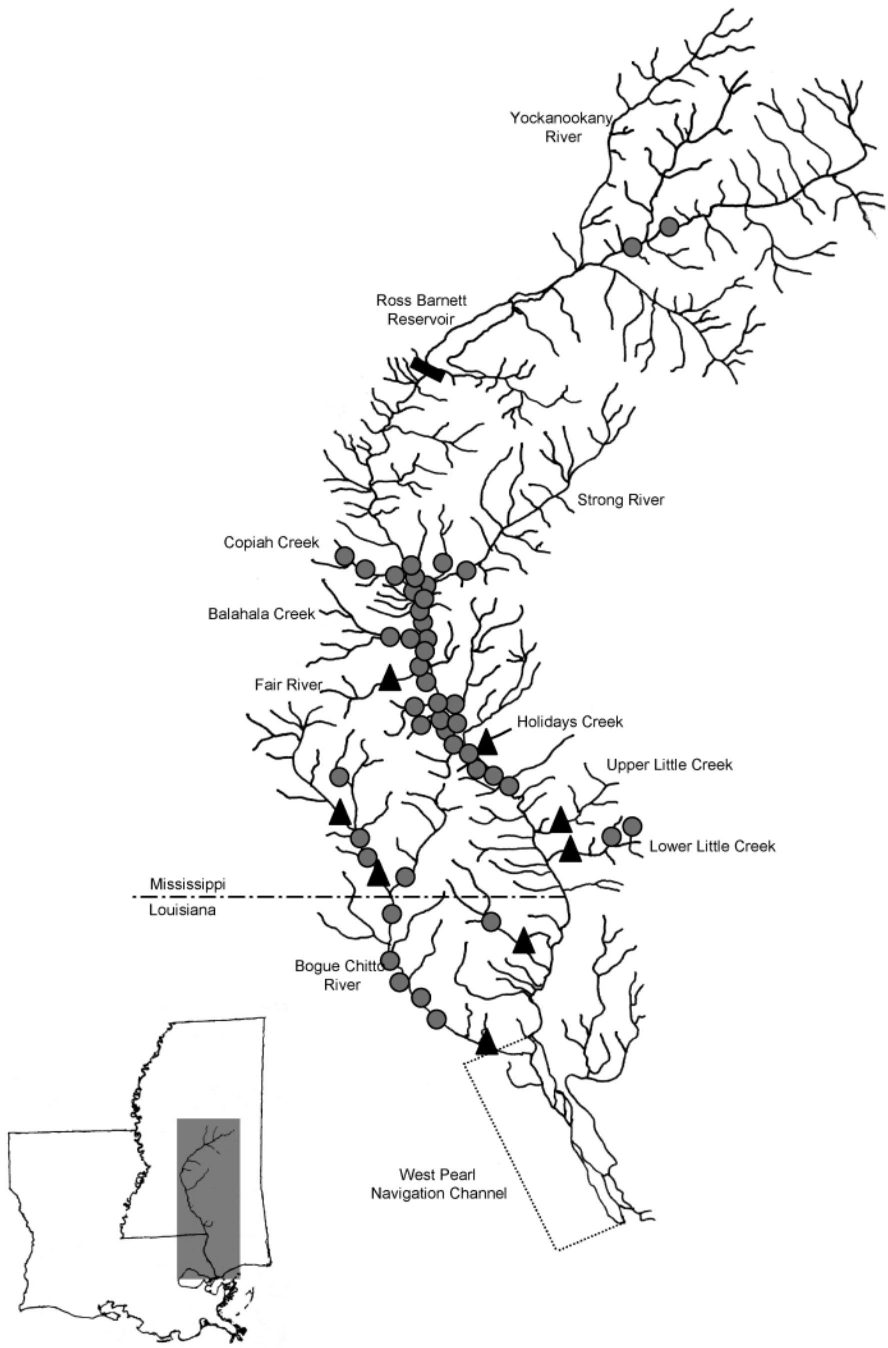

FIGURE 1.—Distribution of sampling locations and points of capture for frecklebelly madtoms in the Pearl River drainage, 1999. Triangles represent points of capture and circles represent sites sampled that failed to yield frecklebelly madtoms.

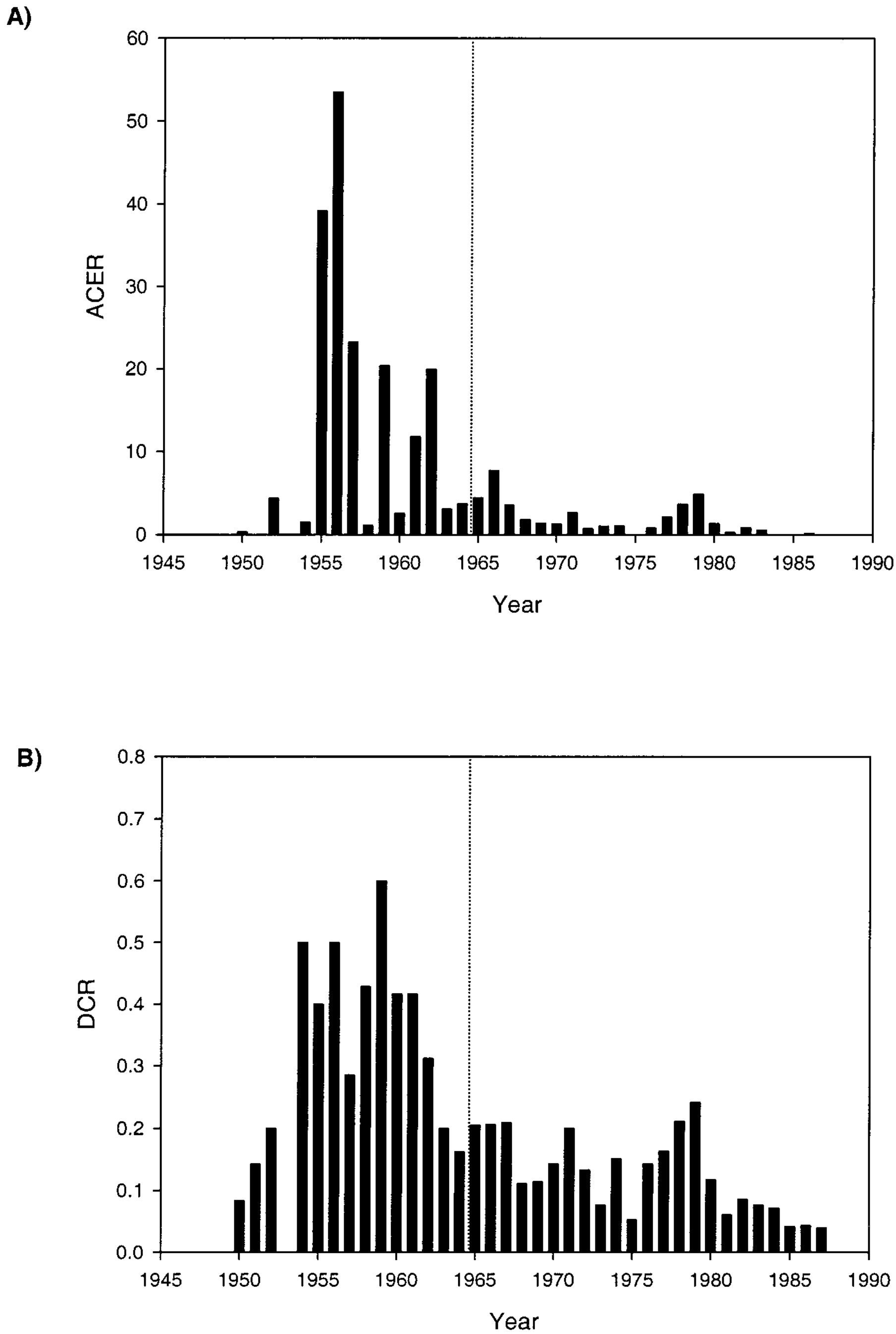

FIGURE 2.—Bar graphs depicting the number of frecklebelly madtoms (1950–1988) based on **(A)** the number of specimens expressed as a proportion of the total number of samples (Annualized Collection Effort Ratio [ACER]), and **(B)** the number of occupied sites expressed as a proportion of the total number of collections at frecklebelly madtom localities (Distributional Change Ratio [DCR]). The vertical dashed line is used to delineate modification and postmodification periods.

TABLE 2.—Summary of abundance changes of benthic taxa in the Pearl River between modification (1950–1964) and postmodification (1965–1988) periods based on annualized collection effort ratio (ACER) metrics. Mean scores are raw values and *P*-values with an asterisk are those found to be significant after sequential Bonferroni adjustment.

Species	1950–1964		1965–1988			
	Mean	SD	Mean	SD	*t*	*P*
Speckled chub	21.47	28.24	68.94	65.17	−3.87	0.0009*
Longnose shiner	9.10	10.63	27.93	21.20	−3.91	0.0004*
Saddleback darter	23.69	27.71	21.98	27.72	0.72	0.47
Silver chub	2.43	3.05	14.20	16.62	−4.44	0.0001*
Dusky darter	3.22	2.98	6.27	6.96	−1.96	0.06
Naked sand darter	3.08	1.97	6.39	2.30	−5.20	0.0001*
Channel catfish	1.57	2.39	5.17	3.70	−4.10	0.0002*
Gulf logperch	3.45	5.52	4.65	7.17	−0.93	0.36
Frecklebelly madtom	12.33	16.18	1.70	1.94	2.83	0.01*
Brighteye darter	5.39	4.65	1.71	3.06	4.08	0.0002*
Gulf darter	1.24	1.32	3.12	2.99	−2.91	0.0062*
Crystal darter	2.42	3.74	2.51	3.23	−0.55	0.58
Highfin carpsucter	0.87	0.96	3.49	5.66	−3.17	0.0031*
Hogchoker	1.11	2.34	4.19	4.85	−3.86	0.0004*

with preferences for sand or sand–gravel substrates including naked sand darter and longnose shiner, and nonbenthic generalist species such as blacktail shiner (Cyprinidae).

The presence or absence of coarse gravel substrate is an important indicator of the occurrence of certain madtom species. Simonson and Neves (1992) showed that the orangefin madtom *N. gilberti* occurred at localities with abundant gravel and cobble substrates, but was absent at sites dominated by silt or sand substrates. Gravel also is an important predictor for the occurrence of other madtoms, including the Ozark madtom *N. albater* (Mayden et al. 1980; Robison and Buchanan 1985), the mountain madtom *N. eleutherus* (Starnes and Starnes 1985), and the pygmy madtom *N. stanauli* (Etnier and Jenkins 1980).

Benthic taxa are often the first to become imperiled following human-induced modifications to streams (Reice and Wohlenberg 1993; Warren et al. 1997). The life histories of the frecklebelly madtom and brighteye darter, two species that declined in this study, are intimately associated with the stream bottom (Suttkus and Taylor 1965; Page 1983; Ross 2001). Loss of gravel substrates and increased levels of sedimentation due to poor agricultural practices are implicated in the extirpation of the Pearl River population of the Pearl darter *P. aurora*, which has not been collected in the Pearl River drainage since 1973 (Ross 2001). In contrast, species less dependent on gravel substrates (e.g., naked sand darter and longnose shiner) actually increased in abundance over the study period. These species most often occur over sandy substrates, or substrates of mixed sand and gravel (Heins and Clemmer 1975; Ross et al. 1987; Ross 2001).

Although we expected saddleback darter populations to show significant declines, abundance did not changes between periods. Gunning and Suttkus (1991) documented distinct declines for the saddleback darter at the Monticello, Mississippi, survey site, and the authors attributed the decline to changes in substrate composition at this particular locality. In addition, they noted that the saddleback darter was most abundant in the Lower Pearl River survey area. As a result, the saddleback darter may be less dependent on gravel substrates than previously believed. Unfortunately, no comprehensive study of the habitat of the saddleback darter has been conducted.

The Pearl River experienced numerous human-caused disturbances since the 1950s, and it is difficult to attribute the decline of the frecklebelly madtom to any one of these factors. Rather, it is likely that all of the disturbances contributed to the widespread problem of geomorphic instability in the river, and this in turn is depressing populations of gravel-dependent species such as the frecklebelly madtom. Previous studies have documented significant negative affects on aquatic faunas following human-induced impacts, such as those that have occurred in the Pearl River (Wildhaber et al. 2000; Quinn and Kwak 2003).

Ecological and geomorphological processes of fluvial environments are altered following the construction of dams (Vannote et al. 1980; Gup 1994; Shields et al. 2000). Adjustments in channel width and depth, reorganization of sediments, and bank collapse downstream of dams are a few of the telltale signs of geomorphic instability (Lignon et al. 1995). Each of these factors is evident in the areas of the Pearl River occupied by frecklebelly madtoms (Tipton et al., in press).

Channelization of the middle reaches of the Pearl River and the extreme physical restructuring of the lower portion of the watershed associated with the construction of the Pearl River navigation canal and the capture of flow from the East Pearl River by the West Pearl River have also likely contributed to the channel instability. Although it is well-known that these types of factors are impacting river systems across the southeastern United States (Benke 1990; Lydeard and Mayden 1995; Richter et al. 1997), additional research is needed to establish more direct connections between particular types of anthropogenic disturbances and geomorphic changes in alluvial rivers and the impacts these changes have on benthic fishes.

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References

Atchley, W. R., C. T. Gaskins, and D. Anderson. 1976. Statistical properties of ratios. I. Empirical results. Systematic Zoology 25:563–583.

Benke, A. C. 1990. A perspective on America's vanishing streams. Journal of the North American Benthological Society 9:77–88.

Box, J. B., and J. Mossa. 1999. Sediment, land use, and freshwater mussels: prospects and problems. Journal of the North American Benthological Society 18:99–117.

Brookes, A. 1988. Channelized rivers: perspectives for environmental management. Wiley, New York.

Craig, J. F. and J. B. Kemper. 1987. Regulated streams: advances in ecology. Plenum, New York.

Etnier, D. A. 1994. Our southeastern fishes: what have we lost and what are we likely to lose. Proceedings of the Southeastern Fishes Council 29:5–9.

Etnier, D. A. 1997. Jeopardized Southeastern freshwater fishes: a search for causes. Pages 87–104 *in* G. W. Benz and D. E. Collins, editors. Aquatic fauna in peril: the Southeastern perspective. Special Publication 1, Southeast Aquatic Research Institute, Lenz Design and Communications, Decatur, Georgia.

Etnier, D. A. and R. E. Jenkins. 1980. *Noturus stanauli*, a new madtom catfish from the Clinch and Duck rivers, Tennessee. Bulletin of the Alabama Museum of Natural History 5:17–22.

Georgia Natural Heritage Program. 2001. Special concern animals of Georgia. Georgia Department of Natural Resources, Social Circle.

Gunning, G. E., and R. D. Suttkus. 1991. Species dominance in the fish populations of the Pearl River at two study areas in Mississippi and Louisiana: 1966–1988. Proceedings of the Southeastern Fishes Council 23:7–15.

Gup, T. 1994. Dammed from here to eternity: dams and biological integrity. Trout 35:14–20.

Hartfield, P. 1993. Headcuts and their effects on freshwater mussels. Pages 131–141 *in* K. S. Cummings, A. C. Buchanan, and L. M. Loch, editors. Conservation and management of freshwater mussels. Proceedings of the Upper Mississippi River Conservation Committee. Rock Island, Illinois.

Heins, D. C., and G. H. Clemmer. 1975. Ecology, foods, and feeding of the longnose shiner, *Notropis longirostris* (Hay) in Mississippi. American Midland Naturalist 94:284–295.

Lignon, F. K., W. E. Dietrich, and W. J. Trush. 1995. Downstream ecological effects of dams: a geomorphic perspective. Bioscience 45:183–192.

Louisiana Natural Heritage Program. 1996. Rare, threatened, and endangered animals of Louisiana. Louisiana Department of Fish and Wildlife Resources, Baton Rouge.

Lydeard, C., and R. L. Mayden. 1995. A diverse and endangered aquatic ecosystem of the Southeastern United States. Conservation Biology 9:800–805.

Lyons, J. 1986. Capture efficiency of a beach seine for seven freshwater fish species in a north temperate lake. North American Journal of Fisheries Management 6:288–289.

Mayden, R. L., B. M. Burr, and S. L. Dewey. 1980. Aspects of the life-history of the Ozark madtom, *Noturus albater*, in southeastern Missouri (Pisces: Ictaluridae). American Midland Naturalist 104: 335–340.

McCoy, R. A., D. I. Withers, and C. Smoot. 2001. A guide to the rare vertebrates of the state of Tennessee for the new millennium. Tennessee Department of Environment and Conservation, Division of Natural History, Nashville.

Mettee, M. F., P. E. O'Neil, and J. M. Pierson. 1996. Fishes of Alabama and the Mobile Basin. Oxmoor House, Birmingham, Alabama.

Mississippi Natural Heritage Program, 2000. Special animals tracking list. Museum of Natural Science, Mississippi Department of Wildlife, Fisheries and Parks, Jackson.

Nelson, J. S. 1994. Fishes of the world. 3rd edition. Wiley, New York.

Onorato, D. P., P. A. Angus, and K. R. Marion. 1998. Comparison of a small-mesh seine and a backpack

electroshocker for evaluating fish populations in a north-central Alabama stream. North American Journal of Fisheries Management 18:361–373.
Page, L. M. 1983. The handbook of darters. TFH Publications, Neptune City, New Jersey.
Page, L. M. and B. M. Burr. 1991. A field guide to freshwater fishes of North America North of Mexico. Peterson Field Guide Series, Houghton Mifflin and Company, Boston.
Patrick, D. M., L. Mao, and S. T. Ross. 1991. Accelerated erosion of the Bayou Pierre Basin, southwest Mississippi: characterization and causes. Pages 36–44 *in* B. J. Daniel, editor. Proceedings of the Mississippi water resources conference. Mississippi State University, Starkville.
Pierson, J. M. 1990. Status of endangered, threatened, and special concerned freshwater fishes in Alabama. Journal of the Alabama Academy of Science 61: 106–116.
Ponder, W. F., G. A. Carter, P. Flemons, and R. R. Chapman. 2001. Evaluation of museum collection data for use in biodiversity assessment. Conservation Biology 15:648–657.
Quinn, J. W., and T. J. Kwak. 2003. Fish assemblage changes in an Ozark river after impoundment: a long-term perspective. Transactions of the American Fisheries Society 132:110–119.
Redmond, W. 1996. TVA: endangered and threatened Animals. Tennessee Valley Authority Regional Natural Heritage Project, Norris, Tennessee.
Reice, S. R. and M. Wohlenberg. 1993. Monitoring freshwater benthic macroinvertebrates and benthic processes: measure for assessment of ecosystem health. Pages 287–305 *in* D. M. Rosenberg and V. H. Resh, editors. Freshwater biomonitoring and benthic macroinvertebrates. Chapman and Hall, New York.
Reynolds, J. B. 1996. Electrofishing. Pages 221–253 *in*: B. R. Murphy and D. W. Willis editors. Fisheries techniques. 2nd edition. American Fisheries Society, Bethesda, Maryland.
Reznick, D., and R. J. Baxter. 1994. Long-term studies of tropical stream fish communities: the use of field notes and museum collections to reconstruct communities of the past. American Zoologist 34:452–462.
Rice, W. R. 1989. Analyzing tables of statistical tests. Evolution 43:223–225.
Richter, B. D., D. P. Braun, M. A. Mendelson, and L. L. Master. 1997. Threats to imperiled freshwater fauna. Conservation Biology 11:1081–1093.
Robison, H. W. and T. M. Buchanan. 1985. The fishes of Arkansas. University of Arkansas Press, Fayetteville.
Ross, S. T. 2001. Inland fishes of Mississippi. University Press of Mississippi, Jackson.
Ross, S. T., J. A. Baker, and K. E. Clark. 1987. Microhabitat partitioning of southeastern stream fishes: temporal and spatial predictability. Pages 42–51 *in* W. J. Matthews and D. C. Heins, editors. Evolutionary and community ecology of North American stream fishes. University of Oklahoma Press, Norman.
Ross, S. T., M. T. O'Connell, D. M. Patrick, C. A. Latorre, W. T. Slack, J. G. Knight, and S. D. Wilkins. 2001. Stream erosion and densities of *Etheostoma rubrum* (Percidae) and associated riffle-inhabiting fishes: biotic stability in a variable habitat. Copeia 2001:916–927.
SAS Institute. 2000. User's manual, version 8.02. SAS Institute, Cary, North Carolina.
Satterthwaite, F. W. 1946. An approximate distribution of estimates of variance components. Biometrics Bulletin 2:110–114.
Shields, F. D., A. Simon, and L. J. Steffen. 2000. Reservoir effects on downstream river channel migration. Environmental Conservation 27:54–66.
Simonson, T. D., and R. J. Neves. 1992. Habitat suitability and reproductive traits of the orangefin madtom *Noturus gilberti* (Pisces: Ictaluridae). American Midland Naturalist 127:115–124.
Sokal, R. R. and F. J. Rohlf. 1995. Biometry, 3rd editon. Freeman: New York.
Starnes, W. C., and L. B. Starnes. 1985. Ecology and life history of the mountain madtom, *Noturus eleutherus* (Pisces: Ictaluridae). American Midland Naturalist 114:331–341.
Suttkus, R. D., and W. R. Taylor. 1965. *Noturus munitus*, a new species of madtom, family Ictaluridae, from the southeastern United States. Proceedings of the Biological Society of Washington 78:169–178, 1965.
Tipton, J. A., H. L. Bart Jr., and K. R. Piller. In press. Geomorphic disturbance and its impact on darter distribution (Teleostomi: Percidae) and abundance in the Pearl River drainage, Mississippi, USA. Hydrobiologia.
Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37:130–137.
Walser, C. A. and H. L. Bart Jr. 1999. Influence of agriculture on in-stream habitat and fish community structure in Piedmont watersheds of the Chattahoochee River system. Ecology of Freshwater Fish 8: 237–246.
Warren, Jr., M. L., P. L. Angermeier, B. M. Burr, and W. R. Haag. 1997. Decline of a diverse fauna: patterns of imperilment and protection in the southeastern United States. Pages 105–164 *in* G. W. Benz and D. E. Collins editors. Aquatic fauna in peril: the Southeastern perspective. Special Publication 1, Southeast Aquatic Research Institute, Decatur, Georgia.
Warren Jr., M. J., and B. M. Burr. 1994. Status of freshwater fishes of the United States: overview of an imperiled fauna. Fisheries 19(1):6–18.
Warren, M. L., Jr., B. M. Burr, S. J. Walsh, H. L. Bart Jr., R. C. Cashner, D. A. Etnier, B. J. Freeman, B. R. Kuhajda, R. L. Mayden, H. W. Robison, S. T. Ross, W. C. Starnes. 2000. Diversity, distribution, and conservation status of the native freshwater

fishes of the southern United States. Fisheries 25(10):7–29.

Wildhaber, M. L., V. M. Tabor, J. E. Whitaker, A. L. Allert, D. W. Mulheren, P. J. Lamberson, and K. L. Powell. 2000. Ictalurid populations in relation to the presence of a main-stem reservoir in a midwestern warmwater stream with emphasis on the threatened Neosho madtom. Transactions of the American Fisheries Society 129:1264–1280.

Williams, J. E., J. E. Johnson, D. A. Hendrickson, S. Contreras-Balderas, J. D. Williams, M. Navarro-Mendoza, D. E. McAllister, and J. E. Deacon. 1989. Fishes of North America: endangered, threatened, or of special concern: 1989. Fisheries 14(6):6–23.