Status Assessment of the Carolina Madtom

Final Report

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ABSTRACT

The Carolina madtom, *Noturus furiosus*, is a rare fish endemic to the Tar and Neuse River basins, North Carolina. It is listed as State Threatened and a Federal Species of Concern. Surveys over the last three decades suggest declines in distribution and abundance. We conducted 60 surveys at 30 sites with historical survey records during the spring and summer of 2007 to assess the current status of the Carolina madtom. Data were compared to historical records to detect any temporal change in occurrence. We also applied a new method to estimate the proportion of sites occupied (occupancy) and detection probabilities for a subset of sites with the computer software package PRESENCE using repeat detection/nondetection data. Additionally, we examined aspects of the general biology and population structure of the Carolina Madtom (e.g., spawning period, size structure, catch per unit effort). Results indicate a significant temporal change in occurrence in the Neuse River basin (X^2= 41.6, p<0.05). Frequencies of occurrence decreased from 0.80 to 0.13 between 1960's and 2007 data. A robust population was detected at only one site surveyed in the Neuse River basin. No significant temporal change in occurrence was seen in the Tar River basin (X^2= 0, p=1). Occupancy estimates generated from PRESENCE were similar to observed frequencies of occurrence due to high detection probabilities. Further investigations are needed to determine if estimated occupancy is an important statistic for long term, large scale monitoring programs. Spawning and nesting behaviors were observed from mid-May through early July. CPUE data and length frequencies suggest strong recruitment in most Tar River basin populations and in one Neuse River basin population. Conservation measures are needed throughout the range of the Carolina madtom, and especially in the Neuse River basin where there is a high risk of extirpation.

INTRODUCTION

The southeastern United States has one of the most diverse temperate fish assemblages in the world. However, many of these fishes are considered rare, threatened, or endangered (Warren et al. 1997). Many of the imperiled fishes in the southeast are endemic to relatively small areas, which make them extremely vulnerable to population declines with even very localized perturbations (Williams et al. 1989; Warren and Burr 1994). Unfortunately, despite much research over the past century on the southeastern fish fauna, regularly updated distribution and population trend data for many species are still lacking. Filling this data gap, especially for rare and narrowly endemic species, is paramount in the development of effective monitoring and management strategies (Lydeard and Mayden 1995; Benz and Collins 1997; Warren et al. 2000). Twenty-six percent of threatened or imperiled southeastern endemic fishes are in the family Ictaluridae, the majority of which are madtoms (*Noturus* spp.) (Warren and Burr 1994; Etnier 1997; Warren et al. 1997; Piller et al. 2004).

The Carolina madtom, *Noturus furiosus* (Jordan and Meek 1889), is endemic to the lower Piedmont and upper Coastal Plain physiographic provinces within the Neuse and Tar River basins in North Carolina (Burr et al. 1989; Page and Burr 1991; Menhinick and Braswell 1997). This fish historically occupied most of the subbasins within the Tar and Neuse River basins, preferring free-flowing, medium to large streams containing detritus, sand, gravel, and rubble substrata (Burr et al. 1989; Page and Burr 1991; Menhinick and Braswell 1997). Records over the past three decades suggest a decline in Carolina madtom populations.

In the early 1960s North Carolina Wildlife Resources Commission (NCWRC) biologists conducted basin-wide rotenone surveys and found the Carolina madtom to be common in the larger waterways in both the Tar and Neuse drainages (Bayless and Smith 1962; Smith and Bayless 1964). Burr et al. (1989) identified 36 historical occurrence localities within the Neuse and Tar River basins from museum voucher specimens and reports in the literature. Upon revisiting 26 of these sites in the mid 1980s, nine in the Neuse and six in the Tar River basins yielded no Carolina madtoms (Burr et al. 1989). Additional survey results from the 1990s and early 2000s suggest further declines in the Neuse River basin (NCWRC unpublished data); however, very few surveys that targeted the Carolina madtom were conducted during that time period. Sampling methodologies for the Carolina madtom varied among the aforementioned surveys making it difficult to compare results and determine population trends. Additionally, certain life history attributes (e.g., nocturnal foraging, spawning in cavities) make this fish difficult to capture.

Due to its limited distribution and presumed recent declines, the conservation status of the Carolina Madtom was recently elevated to Threatened in North Carolina and a Federal Species of Concern (LeGrand et al. 2008). The North Carolina Wildlife Action Plan (NCWRC 2005) also recognizes the Carolina madtom as a Priority Species. However, distribution, life history information, and assessment of threats to the Carolina madtom have not been updated in over fifteen years (see Burr et al. 1989 for the most recent assessment). Thus, a need existed to update their current status and range to determine the factors necessary for successful conservation of this species.

We analyzed historical collection data and conducted a series of surveys during the spring and summer of 2007 to assess the current distribution and conservation status of the Carolina madtom. We also tested our ability to detect this fish by estimating detection probabilities, and utilized those probabilities to estimate the proportion of sites occupied (occupancy) by the Carolina madtom. Specific objectives of this project were to:

1.) Compile all available Carolina madtom collection records into an ArcGIS™ database to assess their known distribution.
2.) Conduct surveys to estimate the occupied range of the Carolina madtom.
3.) Obtain size distributions and relative abundances of Carolina madtoms at each site surveyed.

4.) Compare contemporary presence-absence results to historical data (Bayless and Smith 1962, Smith and Bayless 1964, and Burr et al. 1989) to assess any changes in the Carolina madtom's distribution.

5.) Utilize a new technique to estimate occupancy and detection probabilities using the software package PRESENCE.

Methods

Assessment of survey sites

All known Carolina madtom collection records were gathered from available sources, including Bayless and Smith (1962), Smith and Bayless (1964), Burr et al. (1989), the NCWRC Aquatics Database, the North Carolina Division of Water Quality (NCDWQ) Fishes Community Database, North Carolina Museum of Natural Sciences (NCMNS) database, and other sources (e.g., Robert J. Goldstein & Associates, Inc., The Catena Group, Inc.). These records were incorporated into an ArcGIS™ database for spatial and temporal examination.

Twenty one historical occurrence locations were revisited to determine if Carolina madtom populations were still detectable (Figures 1 and 2; Table 1). Nine sites where the Carolina madtom had not been discovered were also surveyed to search for previously unknown populations (Figures 1 and 2; Table 1).

Fish sampling

Sixty surveys at 30 sites (15 in each of the two basins) were conducted to determine presence-absence, detection probability, relative abundances, size distributions, and any spawning/nesting behaviors of the Carolina madtom. Prior to sampling each site, surveyors measured a 150 m sample reach that included a variety of habitats. Each sample reach was marked with flagging tape at the up- and downstream boundaries. Visual detection while snorkeling was determined the most effective sampling method for Carolina madtoms during a short pilot study conducted prior to the surveys. Single-pass visual surveys were made at each site by 2-6 mask and snorkel-equipped personnel. Surveys were conducted between 0900 and 1800 h to maximize underwater visibility. Surveyors entered the stream at the downstream end of the survey site and snorkeled upstream slowly and deliberately in order to minimize disturbance. During surveys, snorkelers turned over cobble and logs, sifted through leaf packs and debris, and emptied any jars or bottles to detect any concealed Carolina madtoms. Dip nets were used to capture Carolina madtoms when possible. Captured fish were immediately placed in a collection bucket with an aerator.

Population Parameters and Life History Information

All Carolina madtoms captured were measured (total length, mm) and weighed (mg). Length frequencies were calculated and examined for each river basin. Survey time was recorded and the number of Carolina madtoms observed per person hour was calculated as catch per unit effort (CPUE). Fin clips were taken from all captured Carolina madtoms and preserved in 95% ethanol for future genetic analyses (e.g., inter/intra-basin comparison, parentage, microsatellite analysis). Observations of life history traits (i.e., spawning activity, nesting activity, etc.) were noted. Cover used by concealed fish was described (e.g., type of structure, direction the opening of a bottle was facing). Voucher specimens from new occurrence localities were preserved in 5% formalin and deposited at the NCMNS. All other fish were released.

Physical and chemical data

A qualitative assessment of the physical habitat and a quantitative assessment of certain water quality variables were completed at each site in accordance with the standardized NCWRC Aquatic Wildlife Diversity datasheet (Figure 13). Survey sites were georeferenced (NAD 1983) using a Garmin GPS 12XL™. Any potential threats to the Carolina madtom, including point-source discharges, habitat degradation, and exotic species seen during surveys were noted. All data were entered into the NCWRC Aquatics Database.

Temporal Comparisons

Contemporary presence/absence data were compared to historical data from Bayless and Smith (1962), Smith and Bayless (1964), and Burr et al. (1989) to temporally compare site occurrences. A chi square goodness to fit test was used to determine any significant changes in presence/absence data between the 1960s and 2007 sampling periods. Additionally, the Frequency of Occurrence (the number of sites the Carolina madtom was detected / the number of sites surveyed) was calculated for each basin and sampling period. These data were not statistically analyzed but used to assess any temporal occurrence trends.

Occupancy and Detection Probability Estimates

Nondetection of the Carolina madtom at a site does not guarantee absence (MacKenzie et al. 2002; MacKenzie, and Royle 2005). The ability (or inability) to detect a species of interest is a major source of variation in monitoring programs for rare species (Bailey et al. 2004). Species detection probability is defined as the probability of detecting at least one individual of a target species during a sampling event, given that individuals of the species are present in the area (MacKenzie et al. 2002). We expected the probability of detecting the Carolina madtom to be less than one. Naïve assumptions concerning site occupancy may be made when detection probabilities are not accounted for (MacKenzie et al. 2002). Thus, we estimated detection probabilities for the Carolina madtom in each basin (MacKenzie and Royle 2005). A random subset of 16 sites (eight sites per basin) was surveyed three times during the spring/summer of 2007. Presence/absence data from those repeat surveys were then used to estimate detection probabilities and occupancy using the program PRESENCE. The computer software package PRESENCE is available for download online and was used for all parameter estimates; available at http://www.mbr-pwrc.usgs.gov/software/bin/presence.zip (December 2006).

RESULTS

Collection Records

Sixty one historical occurrence localities were identified from 158 collections spanning 117 years. An ArcGIS™ project was constructed with all known historical occurrence locations and any associated data (e.g., collectors, collection techniques, etc.).

The Tar River basin has 36 historical occurrence locations and the Neuse River basin has 25 (Figure 1). The majority of these localities are at bridge crossings. Records from several bridge crossings in close proximity on the same waterway were regarded as one occurrence locality in this analysis. An ArcGIS™ database was constructed with all known historical occurrence locations and any associated data (e.g., collectors, collection techniques, etc.).

Survey Results

Sixty surveys at 30 sites (15 in each of the two basins) were conducted to determine presence-absence, relative abundances, size distributions, and any spawning/nesting behaviors of the Carolina madtom. Overall, 208 Carolina madtoms were captured between April and August, 2007: 173 from the Tar River basin and 35 from the Neuse River basin. Carolina madtoms were detected at 11 of the 30 sites surveyed: nine sites in the Tar River basin and two in the Neuse River basin (Figure 3; Table 2). Nine of the 2007 occurrence localities were at sites with historical capture records. One new occurrence locality was discovered in each basin during the 2007 surveys (Table 2).

Population parameters and life history information

CPUE varied among sites and temporally. Tar River basin sites averaged higher CPUE than Neuse River basin sites, with Fishing Creek in the Tar River basin showing the highest CPUE among all sites (Figure 8). In the Neuse River basin, Contentnea

Creek had the highest catch rates (Figure 9). The highest overall catch rates were in July and August.

Length frequency distributions show an early season bias towards individuals 60-85 mm. This size range represents the 2-3 year old age class (Burr et al. 1989). Later in the summer a greater proportion of the fish captured were juveniles and young of year (Figures10, 11, and 12). The mean size (total length) was 81.4mm, with the smallest and largest Carolina madtom captured being 9mm and 126mm, respectively.

Most Carolina madtoms were found concealed in cover, such as rocks, logs, mussel shells, leaf packs, and debris piles. Spawning behavior (i.e., paired individuals occupying a cavity nest) was observed from May through early July at six sites: five sites in the Tar River basin and one in the Neuse River basin. Eight large males guarding either egg clusters or juveniles were observed at seven separate sites (six sites in the Tar River basin and one in the Neuse River basin). No nest guarding was observed in July or August, but small juveniles were captured in typical Carolina madtom cover habitat (leaf packs, debris piles, under rocks or bark, under/inside mussel shells).

Temporal Comparisons

We found strong evidence that Carolina madtom occurrences across its range are much fewer today than in the 1960s (X^2= 15.9; $p<0.05$). There was a decrease in the Frequency of Occurrence from 0.70 to 0.37 between the 1960s and 2007 (Figure 4). There was a 57% decrease in occurrences at historical occurrence sites (Table 3). However, changes in Frequency of Occurrence overall were due solely to declines in the Neuse River basin. There was no significant change in occurrence in the Tar River basin

(X^2=0, p=1) (Figure 6; Table 3). The Carolina madtom was not detected at one historical site in the Tar River basin (11% decrease in occurrences at sites with historical records, Table 3), but one previously unknown occurrence was found.

Carolina madtom occurrences declined significantly in the Neuse River basin between the 1960s and 2007 (X^2= 41.6, $p<0.05$). The Frequency of Occurrence was 0.80 and 0.13 in the 1960s and 2007, respectively (Figure 5; Table 3). There was a 92% decrease in occurrences at sites with historical occurrence records (Figure 6; Table 3). A comparison of a subset of sites that were each surveyed in the 1960s, 1980s, and 2007 also showed a declining trend (Figure 7). Brooks et al. (1989) found the Carolina madtom at 60 % of sites surveyed in the 1960s (Smith and Bayless 1962; Bayless and Smith 1964). When we surveyed the same sites in 2007, the Carolina madtom was detected at only 13% of them. Only one site in the Neuse River basin on Contentnea Creek appeared to harbor a robust population. A sparse population was also verified in the Little River (Figure 3; Table 2).

Occupancy estimates

Surveys at eight sites in each basin were repeated three times to estimate detection probabilities and occupancy using the software package PRESENCE. Occupancy estimates were similar to observed data (i.e., the Frequencies of Occurrence) in each basin due to high detection probabilities. Except for one site in the mainstem Tar River, at each site where the Carolina madtom was detected, it was detected in all three surveys. This resulted in an estimated detection probability for the Carolina madtom of 0.94 (SE= 0.05) in the Tar River basin and 1.0 (SE=0) in the Neuse River basin. The estimated occupancy values were 0.75 (SE=0.15) for the Tar River basin and 0.25 (SE=.15) for the Neuse River basin (Table 4). Similarly, The Frequencies of Occurrence for those same eight sites were 0.75 and 0.25 for the Tar and Neuse River basins.

DISCUSSION

Temporal comparisons suggest a decrease in occurrences throughout the range of the Carolina madtom between the 1960s and 2007; however, when the data are analyzed for each basin separately, it is clear that most significant change has occurred in the Neuse River basin. There is often inadequate power and a large amount of error associated with such presence-absence data comparisons, and coming to a statistically sound conclusion is difficult (Strayer and Fetterman 1999). A power analysis on presence-absence designs shows that modest changes are difficult to detect with a feasible sample size (Strayer 1999). One obvious source of error is the lack of continuity between sampling periods. Survey methods and effort are often different. A less obvious source of error is in choice of survey sites. To avoid bias, researchers should choose sites that have both historical occurrence records and sites within the putative range of the species of interest where historical records are not available (Strayer 1999). For example, if researchers only sampled sites that have historical occurrence records only two conclusions are possible; either the target organism was discovered at all the historical sites and it is concluded stable, or it is not discovered at all sites and it is concluded to be declining. This approach ignores the possibilities of range expansions, previously undetected populations, and a spatially dynamic metapopulation model where localized populations may wax and wane over time. Also, researchers were not perfect at detecting populations, and resurveying sites with no historical occurrence records is necessary to qualitatively assess their efficacy. Therefore, surveys conducted only at sites with historical occurrence records may lead to a false conclusion of decline (Strayer and Fetterman 1999). We attempted to offset this source of error by specifically choosing a number of sites in each basin where the Carolina madtom was not discovered in the 1960s surveys, and by doing so, two new occurrence localities were identified (see Table 2). Lastly, there is a large amount of error associated with detectability (McKenzie et al 2002; McKenzie et al. 2005; Bailey et al. 2004).

Nondetection of a target organism at a site doesn't necessarily equal absence. Naïve assumptions may be made with observed presence-absence data for rare animals due to their low probabilities of detection. Surveys for rare, cryptic animals and/or in difficult field conditions (e.g., in turbid waters) can easily result in an erroneous conclusion of absence. We attempted to draw a more robust conclusion from our results by repeating surveys at some sites to estimate detection probabilities and occupancy. Biologists in the 1960s used rotenone (an ichthyocide) to sample fish, thus the probability of detecting even a cryptic fish like the Carolina madtom was high (i.e., close to one). Biologists in the 1980s used a combination of kick nets, seines, backpack shocking, and occasionally visually by snorkeling; thus, their efficacy at detecting the fish is unknown, but presumably lower than the 1960s surveys. We determined through a short pilot study prior to our investigations that snorkeling was the most effective manner to capture the Carolina madtom in the absence of rotenone. Since sampling methodologies differed among the three studies we felt that estimating our ability to detect the Carolina madtom would strengthen our comparisons to historical data. Detection probabilities for the 2007 surveys were almost one in both basins as determined by PRESENCE. This serves as a validation tool for our survey method. We are now confident that daytime snorkeling while lifting rocks/logs and sorting through detritus was indeed an efficient collection technique. Therefore, confidence is high that presence-absence survey results from the 2007 surveys are robust, and that comparisons to the 1960s surveys are valid, albeit statistically weak as mentioned above. No statistical comparison was made to the 1980s data due to their unknown detection probability. However, we are confident that the observed differences between the 1980s and 2007 data are factual since our sampling methods appear to be more effective than those used in the 1980s.

Even with the acknowledged error associated with temporal comparisons of presence-absence data, the comparison strengthens the anecdotal trend observed over the years: that the Carolina madtom is declining, and especially in the Neuse River basin. Future surveyors can utilize the estimates generated by PRESENCE for more robust comparisons with subsequent presence-absence surveys using similar methodologies (i.e., daytime snorkeling, repeat surveys). More research is needed to determine the true utility of estimating detection probabilities and occupancy in large scale monitoring programs for rare species. This project shows that if detection probabilities are high, repeat surveys may be unwarranted and a better use of survey time may be directed towards more sites instead of repeat surveys. However, to initially determine detection probabilities a pilot study may be necessary.

The Neuse River basin is experiencing a plethora of anthropogenic impacts due to tremendous human population growth. Construction of Falls Lake Dam on the Neuse River has fragmented habitat and hypolimnetic discharges have altered water temperature

(Burr et al. 1989; Menhinick and Braswell 1997). In addition, pollution associated with increasing human populations in the greater Raleigh area has degraded water quality (Burr et al. 1989; Menhinick and Braswell 1997). A water supply reservoir for the Raleigh area is proposed on the Little River, one of the two waterways in the Neuse River basin where Carolina madtom was found during the 2007 surveys. The planned reservoir would alter flow and temperature regimes in downstream reaches, and could negatively impact the sparse and vulnerable Carolina madtom population downstream. Burr et al. (1989) documented a strong population in the lower Little River; however, none were detected during our surveys. Sediments and stored nutrients released during a recent dam removal upstream may have impacted spawning and nesting habitat; however, we have no data to support this hypothesis. Also, Flathead catfish (*Pylodictus olivaris*) have invaded this system and were observed during the 2007 surveys well upstream of the confluence with the Neuse River. Flathead catfish are voracious predators and are known to consume bullhead catfish species (Pine et al. 2005). Thus, there is a high probability of predation where both species co-occur.

The population in Contentnea Creek may be the last viable population in the Neuse River basin. A short reach between the Buckhorn reservoir and Wiggins Mill Pond may serve as a refuge for this species. The Carolina madtom was not discovered in the lower stretches of Contentnea Creek below Wiggins Mill Pond, suggesting that this population is very localized and at a high risk of extirpation. Further surveys are needed in Contentnea Creek to delineate the up- and downstream boundaries of that population.

The Tar River basin appears less impacted, although habitat degradation has occurred downstream of Rocky Mount, NC, from municipal and industrial pollution

(Burr et al. 1989; Menhinick and Braswell 1997). The remaining populations in the Tar River basin appear to be healthy and robust. Both catch rates and length frequencies indicate high abundances and strong recruitment. Habitat is still available in the upper Tar River sub-basin (i.e., above Rocky Mount), the Fishing Creek subbasin, and to a lesser extent, the Swift Creek subbasin. The Fishing Creek subbasin currently harbors the most robust populations of the Carolina madtom throughout its known range. A diverse and rare assemblage of native aquatic fauna, including the federally endangered Tar River Spinymussel (*Elliptio steinstansana*) and Dwarf Wedgemussel (*Alasmidonta heterodon*), are still extant in the Fishing Creek subbasin.

Further surveys are needed in the lower mainstem Tar River. A few Carolina madtoms were captured in Town Creek, the most downstream tributary sampled in the Tar River basin. The Town Creek occurrence location was very close to the confluence with the Tar River, thus the individuals captured may represent a cohort of Carolina madtoms initially from the Tar proper.

The Carolina madtom only occurs in two river basins, one of which has experienced major habitat degradation. This fish requires clean waters and quality habitat to successfully spawn, nest, and survive. Occurrences throughout the Neuse River basin have declined and the remaining populations are in jeopardy. Isolated pockets in the Tar River basin presently maintain healthy populations. The current conservation status of the Carolina madtom is warranted due to its recent declines and limited distribution. Conservation efforts are needed in both basins to preserve the remaining extant Carolina madtom populations.

RECOMMENDATIONS

Neuse Basin

- Preserve intact riparian forests in both Contentnea Creek and the Little River to protect the remaining Neuse River basin populations.
- Maintain minimum flows from Buckhorn reservoir into Contentnea Creek to protect Carolina madtom populations in downstream reaches.
- Delineate the Contentnea Creek population boundaries.

Tar River Basin

- Acquire land in the Fishing Creek subbasin to promote conservation of unique communities.
- Conduct surveys in the lower Tar River proper to identify any extant populations.

Research Needs

- Identify the effects of siltation on Carolina madtom behavior and survival.
- Identify predatory impacts from Flathead catfish on Carolina madtom populations.
- Develop propagation techniques for potential future augmentation/reintroduction projects.
- Identify intra- and interbasin genetic differences/similarities. If the two basins prove to harbor genetically distinct populations, it is recommended to further elevate the conservation status of the Neuse River basin population to gain maximum protection.
- Continue monitoring Neuse River basin populations and selected populations in the Tar River basin every 4-5 years.

- Investigate the utility of estimating occupancy and detection probabilities on other animals with lower detection probabilities as identified through pilot studies.

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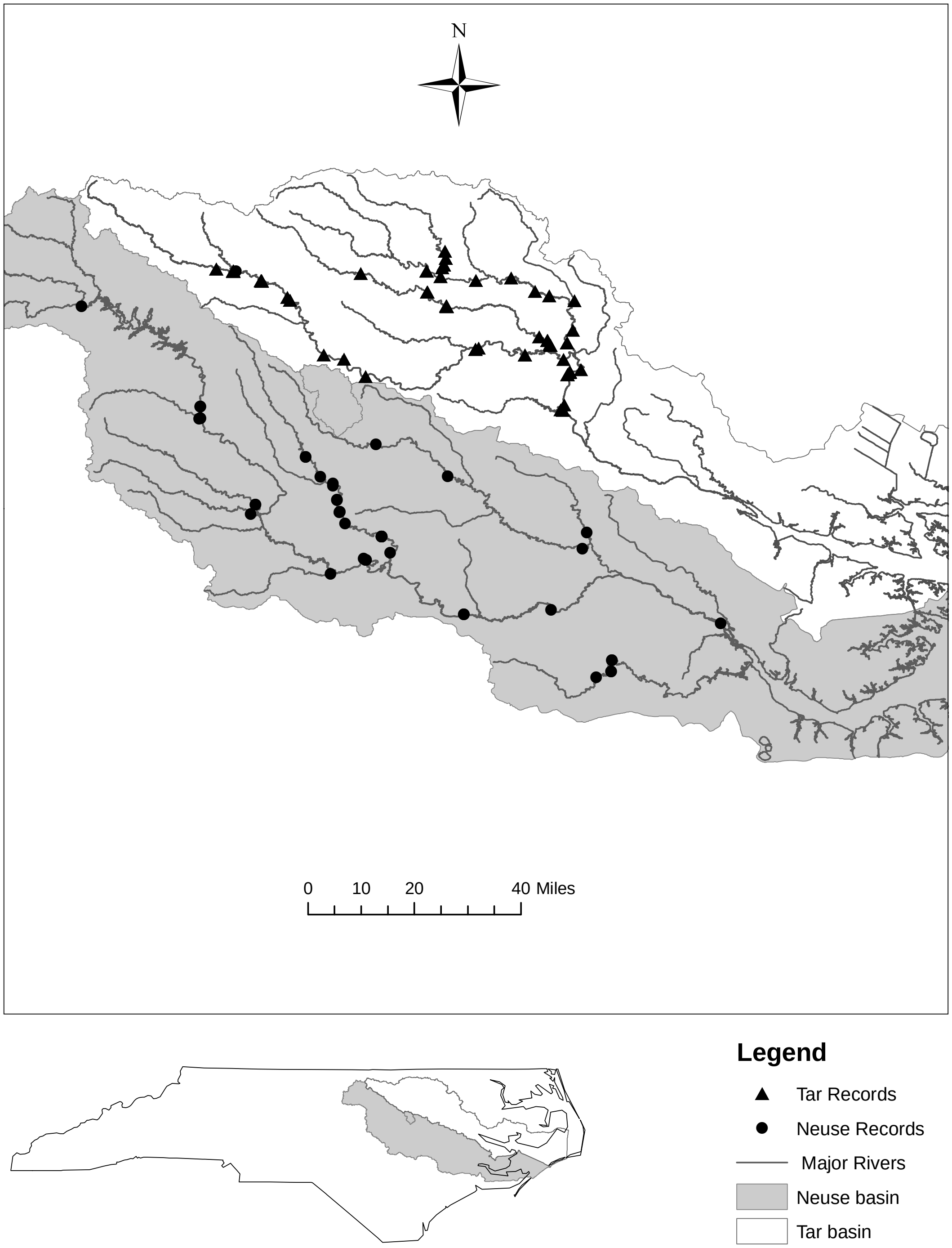

Figure 1: All known historical occurrences of the Carolina madtom.

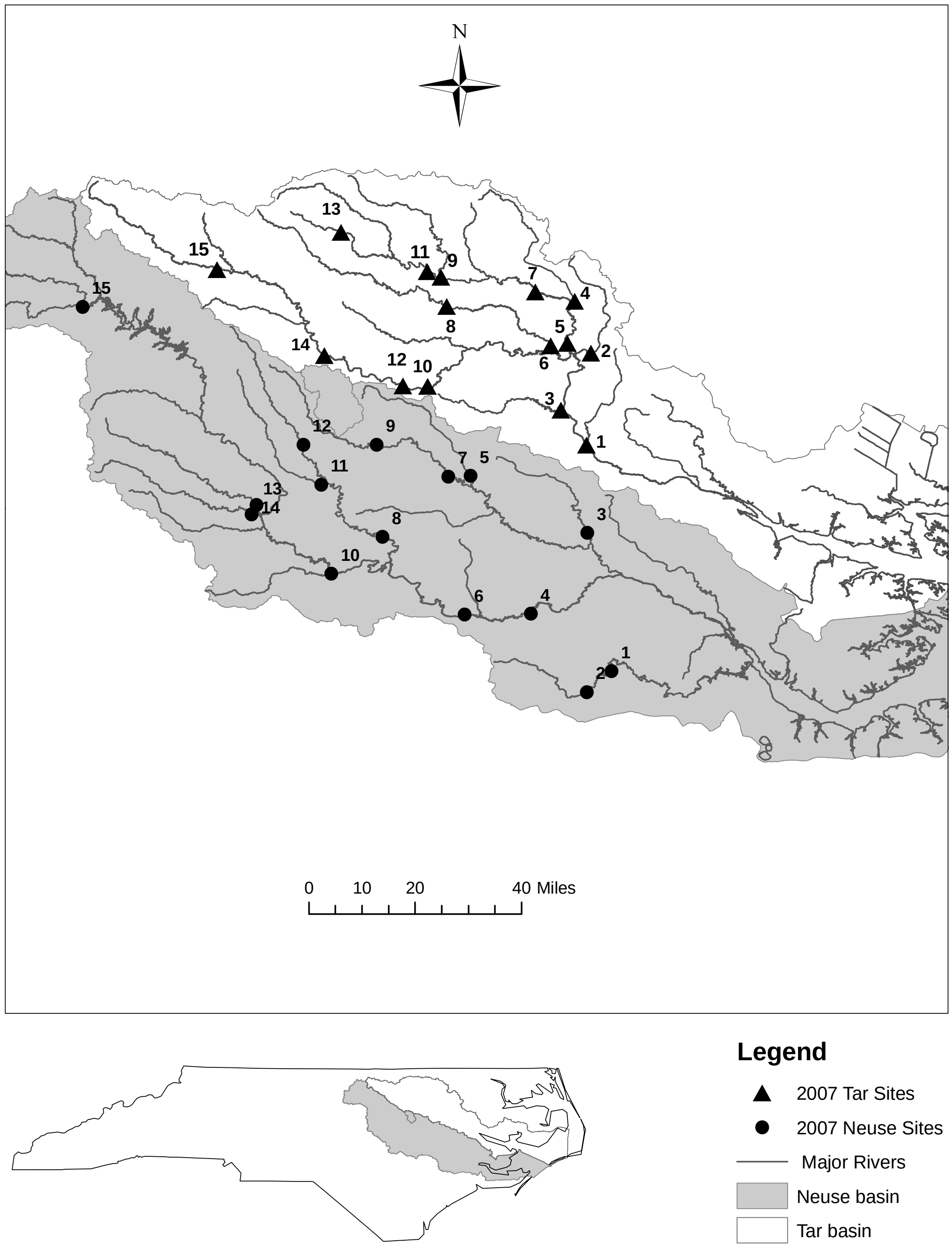

Figure 2: Survey sites for the 2007 Carolina madtom surveys.

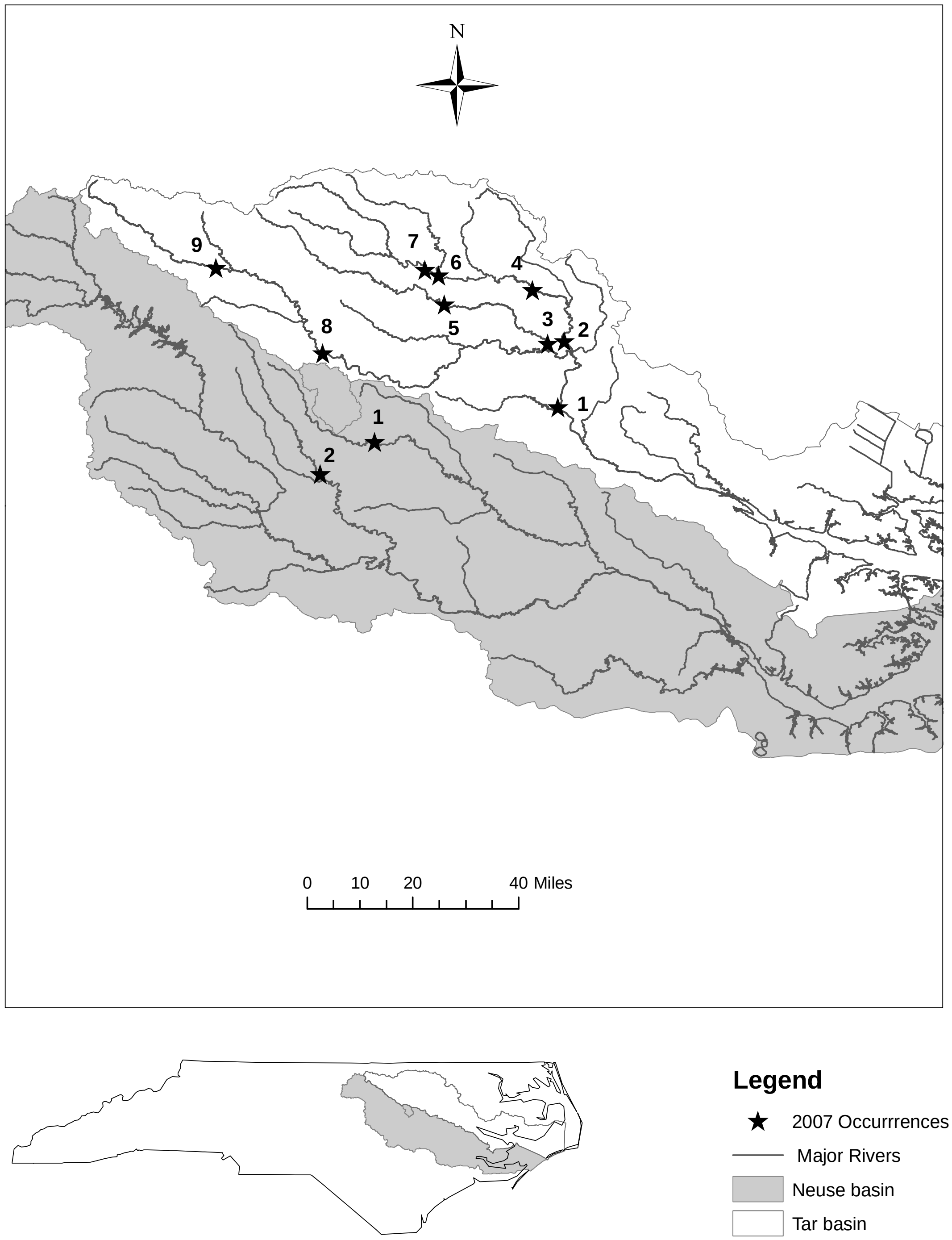

Figure 3: Occurrence sites from the 2007 Carolina madtom surveys.

Table 1: Location of Carolina Madtom survey sites within the Tar and Neuse River basins. Site numbers marked with an asterisk indicates localities with historical records.

Site Number	Stream	Rd. #	Lat/Long
	Tar Basin		
1	Conetoe Crk.	NC 222	35.6967 -77.4884
2	Deep Crk.	SR 1505	35.9475 -77.4758
3*	Town Crk.	SR 1601	35.7919 -77.5583
3*	Beech Swamp	SR 1100	36.0886 -77.5202
5*	Fishing Crk.	SR 1500	35.9739 -77.5404
6*	Swift Crk.	SR 1253	35.9666 -77.5855
7*	Fishing Crk.	SR 1418	36.1137 -77.6280
8*	Swift Crk.	SR 1003	36.0742 -77.8697
9*	Little Fishing Crk.	SR 1343	36.1541 -77.8849
10	Tar River	NC 64 A	35.9262 -78.1465
11*	Fishing Crk.	SR 1506	36.1695 -77.9230
12	Tar River	SR 1331	35.9354 -78.1477
13	Shocco Crk.	NC 58	36.2106 -78.1051
14*	Tar River	SR 1611	35.9411 -78.2032
15	Tar River	SR 1203	36.1752 -78.4964
	Neuse Basin		
1*	Trent River	NC 58	35.0789 -77.4194
2*	Trent River	SR 1300	35.1098 -77.4170
3*	Little Contentnea Crk.	NC 102	35.4568 -77.4857
4*	Neuse River	NC 581	35.31406 -77.9447
5	Toisnot Swamp	NC 222	35.6120 -77.8048
6*	Neuse River	NC 903	35.2330 -77.8209
7*	Contentnea Crk	SR 1628	35.6101 -77.8649
8*	Little River	NC 581	35.4457 -78.0451
9*	Contentnea Crk.	NC 42	35.6977 -78.0611
10*	Mill Crk.	SR 1200	35.3451 -78.1841
11	Buffalo Crk.	SR 2130	35.5883 -78.2117
12	Little River	SR 2130	-78.2136 -35.6103
13*	Swift Crk.	SR 1579	35.5322 -78.3888
14*	Middle Crk.	NC 210	35.5078 -78.4017
15*	Eno River	SR 1004	36.0728 -78.8628

Table2: Location of Carolina Madtom occurrences identified during the 2007 surveys. Site numbers marked with an asterisk indicates localities with historical records.

Site Number	Stream	Rd. #	Lat/Long
	Tar Basin		
1*	Town Crk.	SR 1601	35.7919 -77.5583
2*	Fishing Crk.	SR 1500	35.9739 -77.5404
3*	Swift Crk.	SR 1253	35.9666 -77.5855
4*	Fishing Crk.	SR 1418	36.1137 -77.6280
5*	Swift Crk.	SR 1003	36.0742 -77.8697
6*	Little Fishing Crk.	SR 1343	36.1541 -77.8849
7*	Fishing Crk.	SR 1506	36.1695 -77.9230
8*	Tar River	SR 1611	35.9411 -78.2032
9	Tar River	SR 1203	36.1752 -78.4964
	Neuse Basin		
1*	Contentnea Crk.	NC 42	35.6977 -78.0611
2	Little River	SR 2130	-78.2136 -35.6103

Table 3: Presence-Absence, Chi square values with associated p values, numbers of newly discovered occurrences, and % changes at historical occurrences for the Carolina madtom

Year	Present	Absent	X^2	p	New Occurrences	% Change in Historical Occurrences
			Tar and Neuse Basin Combined			
1960s	21	9				
2007	11	19	15.9	<0.05	2	57
			Tar Basin			
1960s	9	6				
2007	9	6	0	>0.05	1	11
			Neuse			
1960s	12	3				
2007	2	13	41.6	<0.05	1	92

Table 4: The Frequency of Occurrence (FOO), Occupancy estimates (Ψ), and detection probabilities (p) with associated standard errors for the Carolina madtom in the Tar and Neuse River basins at 16 sites that were surveyed three times each.

	FOO	Ψ (SE)	p(SE)
Tar	0.7500	0.7501(.1531)	0.9400 (.0543)
Neuse	0.2500	0.2500 (.1531)	1.0(0)

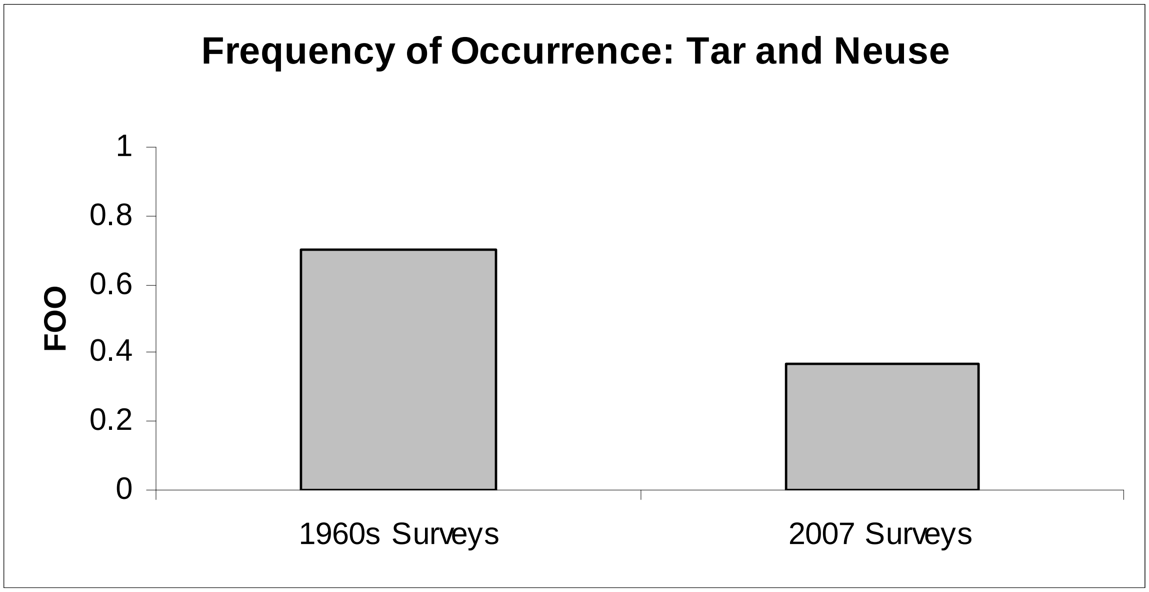

Figure 4: The Carolina madtom Frequency of Occurrence from all sites sampled in 2007.

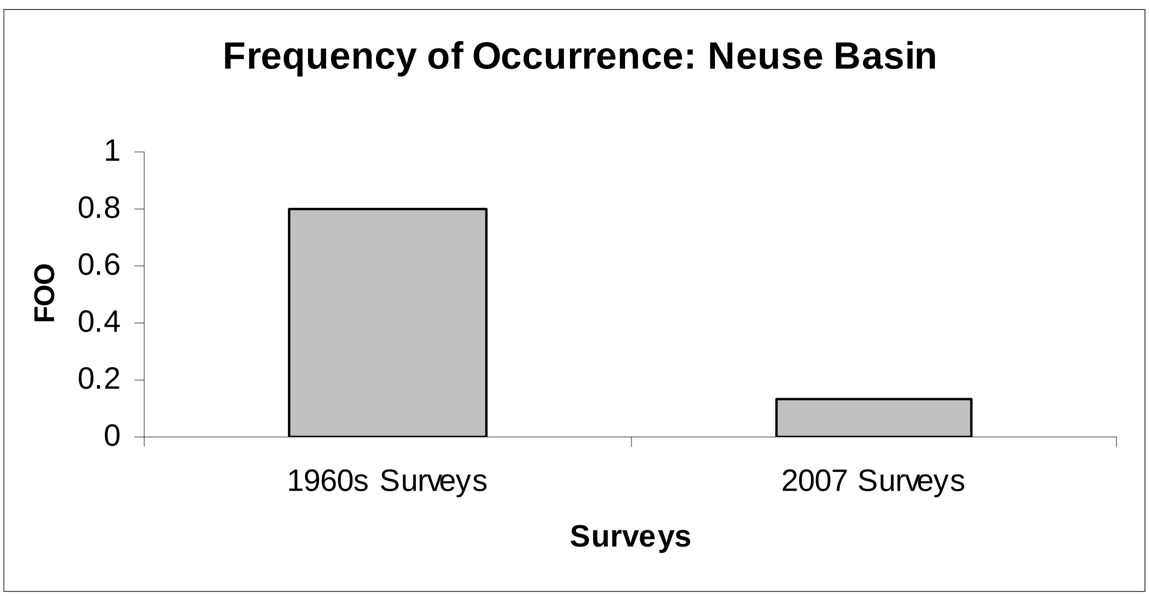

Figure 5: The Carolina madtom Frequency of Occurrence in the Neuse River basin.

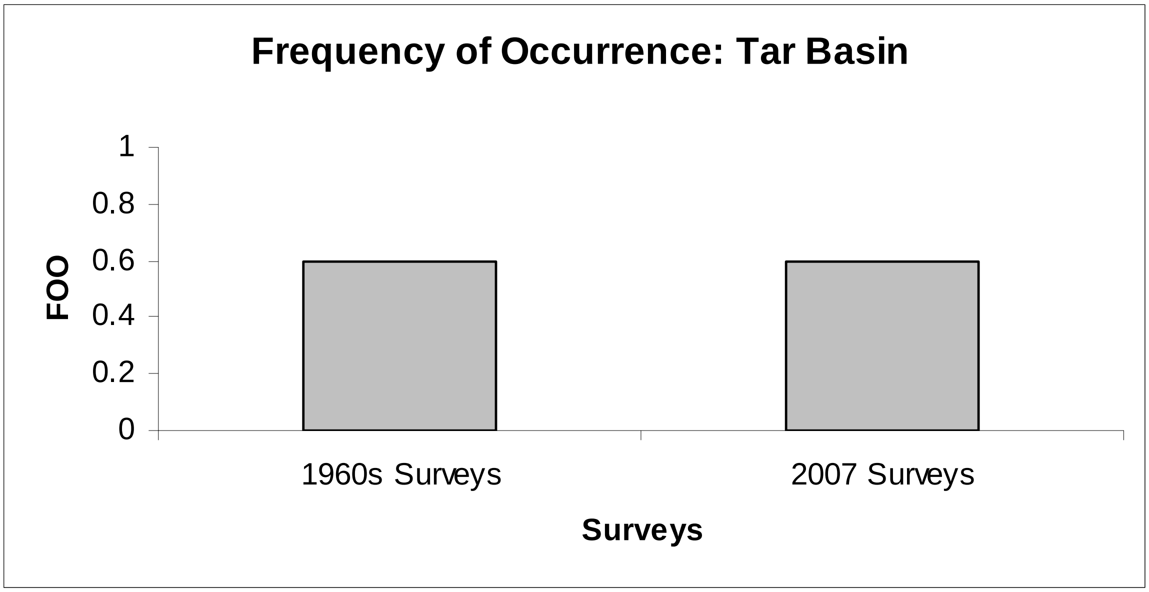

Figure 6: The Carolina madtom Frequency of Occurrence in the Tar River basin.

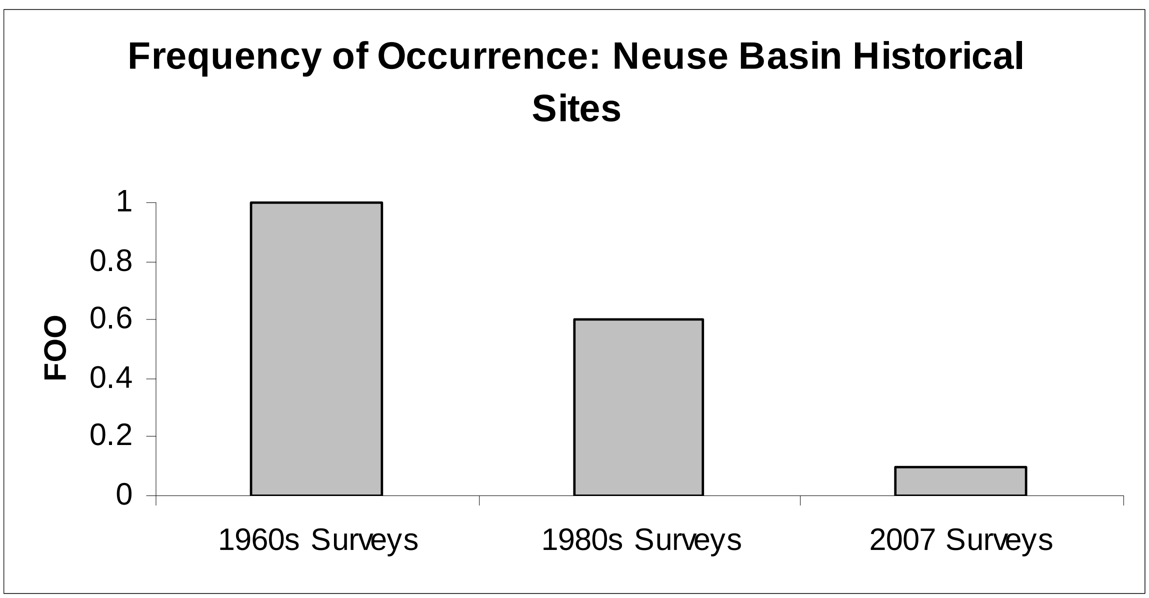

Figure 7: The Carolina madtom Frequency of Occurrence at occurrence sites from the 1960s (NCWRC) that were also surveyed in the 1980s (Burr et al. 1989) and 2007.

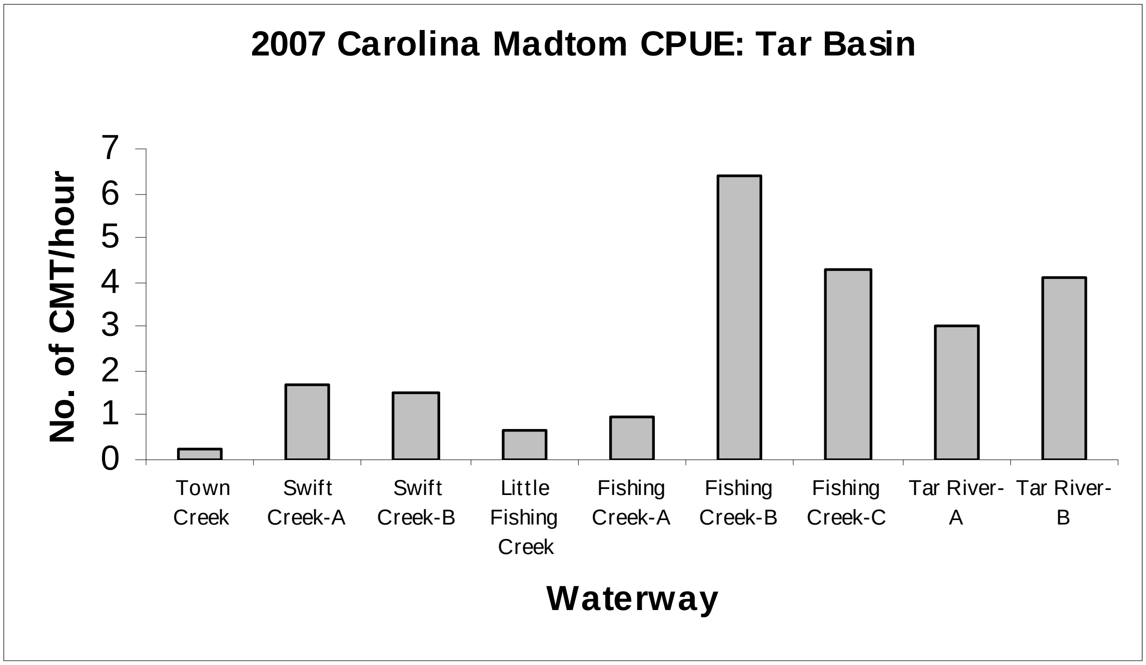

Figure 8: Carolina madtom CPUE at Tar River basin occurrence localities.

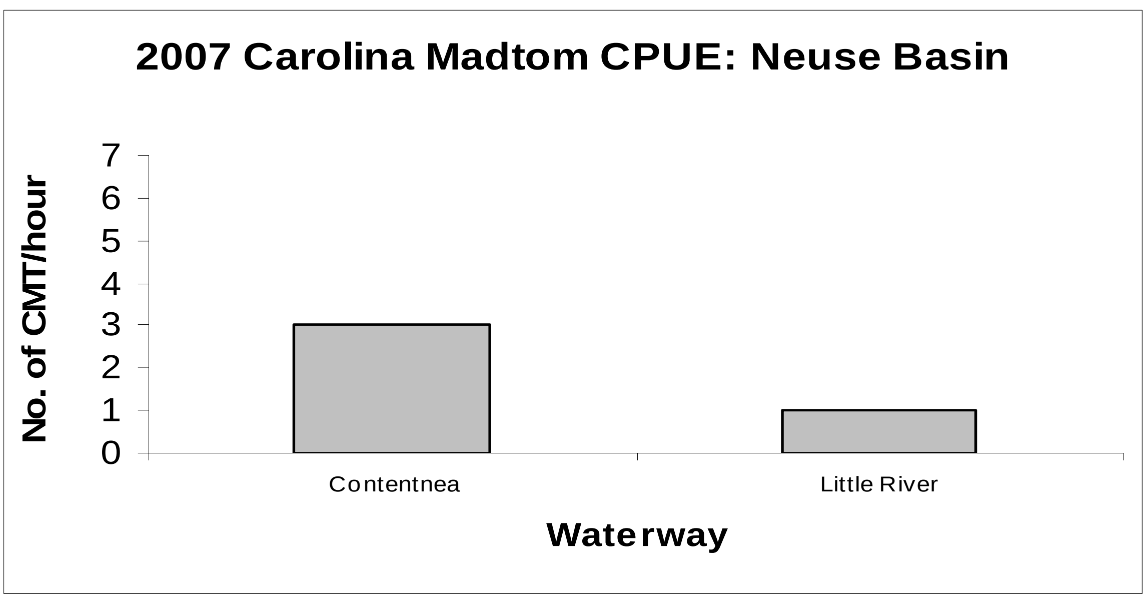

Figure 9: Carolina madtom CPUE at Neuse River basin occurrence localities.

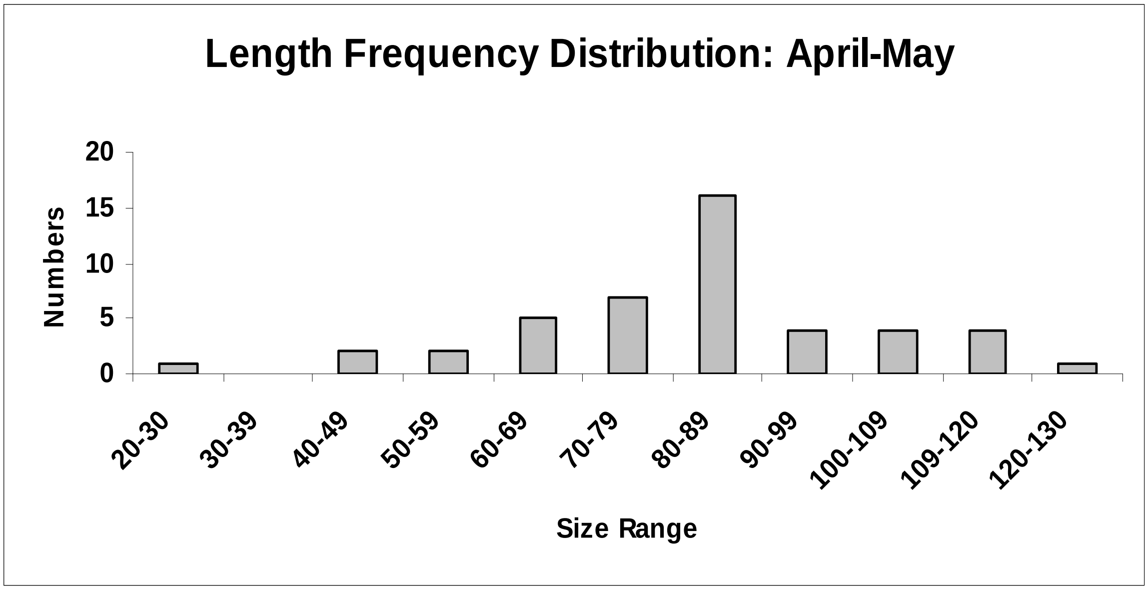

Figure 10: Pooled Carolina madtom Length Frequency distributions during April and May, 2007.

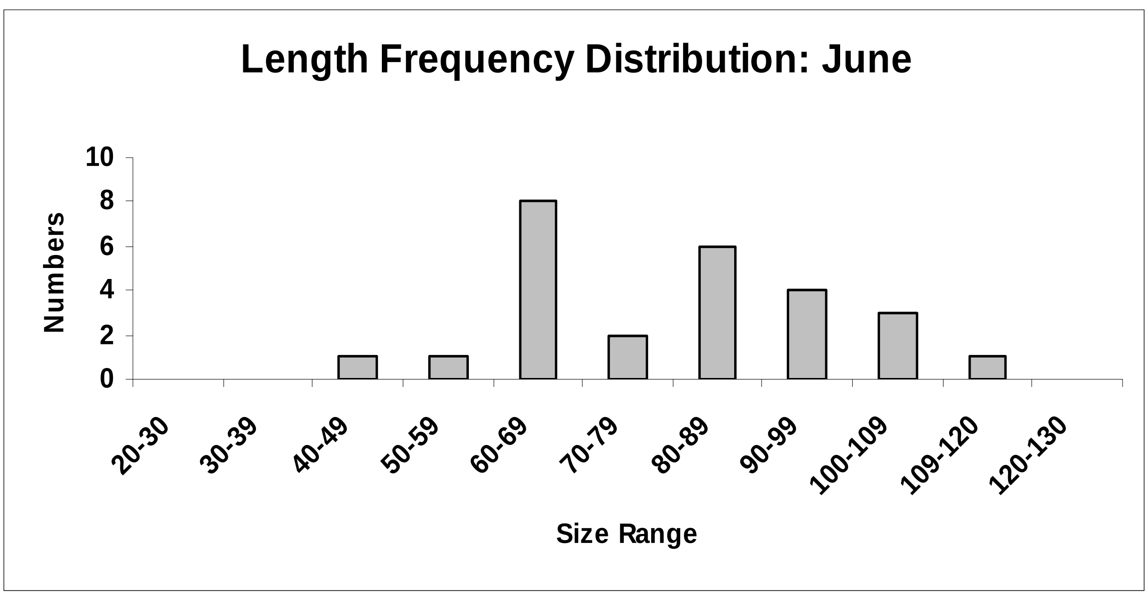

Figure 11: Pooled Carolina madtom Length Frequency distributions during June, 2007.

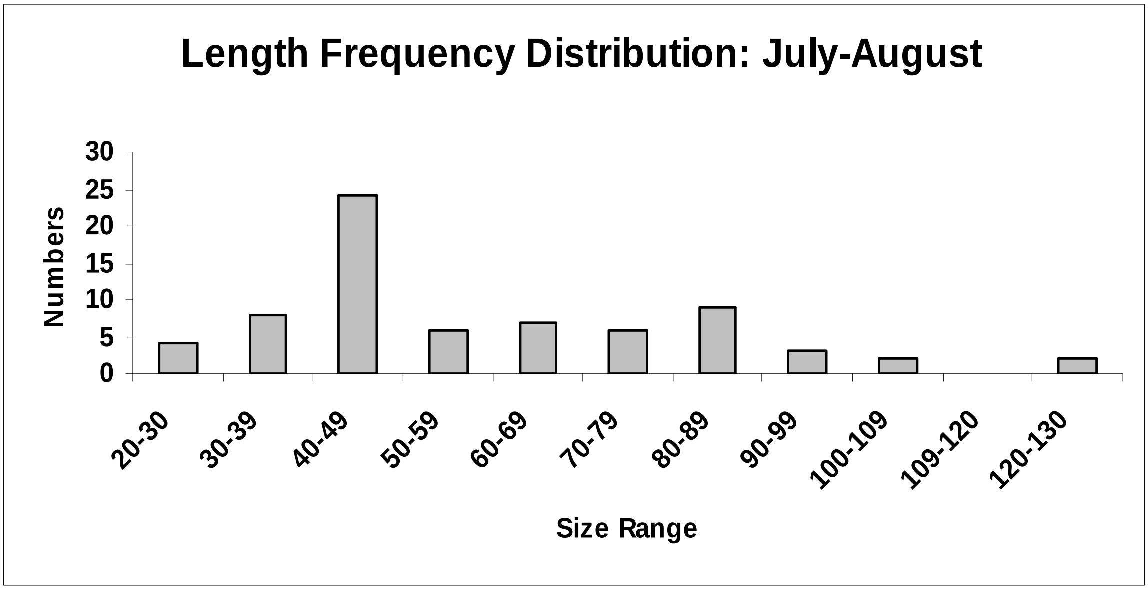

Figure 12: Pooled Carolina madtom Length Frequency distributions during July and August, 2007.

Site No.	County	Waterway	Road No.	GPS info
Date	**Project**	**Road Name**	**River Basin**	

Waterbody type River Stream Pond Lake Reservoir Channel Ditch Swamp Wetland

Flow Run Riffle Slack Pool

Average Depth

Dominant substrate S Sa C Co B Bo P G R V D M

Compactness

Sand/gravel bars

Woody debris

Beaver activity

Stream/channel width (m)

Bank stability
Very stable Some erosion/undercutting
Unstable Stabilization present n/a

Buffer width None Narrow Moderate Wide

Riparian vegetation
Wooded _______ Marsh _______
Grass _______ Other _______
Shrub-brush _______

Bank height (m)

Land use Natural Active crop Timber Active pasture Urban Rural Road

Percent cover

Water level Normal Low High Dry

Weather Sunny Rainy Cloudy Sun-Cloud Cold Cool Warm Hot

Visibility Clear Turbid Slightly turbid Light tannic Dark tannic

Site Comments

Figure 13: NCWRC Aquatic Wildlife Diversity datasheet