Final Project Report to the
USGS Greater Everglades Priority Ecosystems Science Program

# Inventory of Freshwater Fishes of the Big Cypress National Preserve

Greg Ellis[1], Marcus Zokan[1], William F. Loftus[2], Jerome Lorenz[1]

[1]National Audubon Society Tavernier Science Center,
115 Indian Mound Trail, Tavernier, FL 33070, 305-852-5318

[2]USGS FISC-WRS, Everglades National Park Field Station,
40001 State Road 9336, Homestead, FL 33034, 305-242-7835

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## EXECUTIVE SUMMARY

During the past two years, we have conducted field sampling to inventory the freshwater fishes of the Big Cypress National Preserve (BCNP), in accordance with the National Park Service's Inventory and Monitoring (I&M) Program. We sampled 456 sites in BCNP between October 2002 and June 2004. Samples were collected across a range of forested and herbaceous wetland habitats, including cypress forests, mixed-hardwood swamp forests, cypress prairies, herbaceous prairies, freshwater and coastal marshes, and canals. Samples were taken using a variety of methods, including traps, gill nets, cast nets, dip nets, angling, and electrofishing. Trapping and electrofishing proved to be the most effective techniques, and we used them most widely.

Nine of the 64 fish species we documented in freshwater habitats in BCNP were non-indigenous: oscar (*Astronotus ocellatus*), pike killifish (*Belonesox belizanus*), black acara (*Cichlasoma bimaculatum*), Mayan cichlid (*Cichlasoma urophthalmus*), walking catfish (*Clarias batrachus*), jewel cichlid (*Hemichromis letourneauxi*), brown hoplo (*Hoplosternum littorale*), blue tilapia (*Oreochromis aureus*), and spotted tilapia (*Tilapia mariae*). This study is the first to document *Hemichromis* and *Hoplosternum* in the preserve.

Canals supported the greatest diversity of species, with 62 of the 64 species taken from this habitat. Many of the canal dwellers were either euryhaline species moving inland from the Gulf of Mexico, or were large, freshwater species ill-suited to seasonal wetland habitats. Because of their connections to the estuaries, coastal marshes also supported a number of euryhaline fishes. The freshwater wetland habitats shared similar

fish fauna; nearly half of the 33 species found in these wetland habitats were found in all of them.

Based on data from our sampling, in combination with literature records for fish species in BCNP, we estimate that we surpassed the NPS I&M goal of documenting 90 percent of the freshwater fish species in the preserve. Our estimate of 67 species includes records for several species reported from Big Cypress by previous researchers. These include diamond killifish (*Adinia xenica*), chain pickerel (*Esox niger*), naked goby (*Gobiosoma bosc*), and channel catfish (*Ictalurus punctatus*). These were not captured in this project, however, because of their rarity within BCNP. Maps of the sampling sites and the distributions of the fish species are provided in the report appendixes.

NPS funding for the inventory work ceased at the end of FY 04. This project is now being funded through the CERP MAP (Monitoring and Assessment Program) to the National Audubon Society and USGS, which will jointly conduct sampling five times per year. We present preliminary results of the inventory in this report.

In May 2004, we began a long-term research project on fish populations in three areas of BCNP to acquire baseline information to evaluate hydrologic modifications proposed as part of the Comprehensive Everglades Restoration Plan (CERP). The work commenced after delays in funding, and was supported by the USGS Greater Everglades Priority Ecosystems Science (PES) Program. We began by testing a variety of sampling methods intended for use in the sampling study, and set up a network of quantitative sampling devices in three regions of BCNP. (We present results from sampling conducted in July 2004 in this report.) By FY 05, PES funding for the work was redirected to a new study of BCNP fishes.

## INTRODUCTION

The Big Cypress National Preserve (BCNP) is a low relief, seasonally inundated subtropical wetland that was established in 1974 to protect a large segment of the Big Cypress Swamp ecosystem, which covers an extensive portion of southwestern Florida (Duever et al., 1986). The establishment of this 295,245-ha preserve also helped to protect freshwater flow into the western portions of Everglades National Park (ENP) that lie downstream from BCNP. The preserve comprises a heterogeneous array of shallowly flooded forested and herbaceous wetlands, interspersed with upland pine forests and deep-water ponds and sloughs (Figure 1). The BCNP landscape is now crossed by an extensive system of canals that provide dry-season refuge and travel corridors for aquatic species, many of which are non-indigenous or euryhaline.

### Previous Studies

Prior to our inventory, few studies had systematically documented the fish-community composition of the entire BCNP ecosystem. Kushlan (1974) observed and reported the effects a seasonal dry-down had on the fish within an alligator pond along Loop Road. Carlson and Duever (1979) monitored fish populations through an annual wet-season-dry-season cycle in a Corkscrew Swamp cypress strand north of BCNP. Fish sampling was also conducted during construction of the Jetport (now the Dade-Collier Transition and Training Airport), and during baseline studies of the BCNP Addition Lands administrative unit (Evans, 1970, Dalrymple, 1995). The Conservancy of Southwest Florida is currently conducting a fish-monitoring program in Fakahatchee Strand and the Golden Gate Estates (both west of BCNP), but results have not been published (David Ceilley, Conservancy of Southwest Florida, oral. comm. 2003). The

most extensive BCNP fish sampling effort conducted in the region to date was by Loftus and Kushlan (1987), but was limited to the area south of U.S. Highway 41.

**Objectives**

This project was intended to fulfill the needs of the NPS I&M program for freshwater fishes in BCNP, and to begin a long-term research study of aquatic-animal dynamics in the preserve. The I&M program is a national initiative that is attempting to document 90% of the vertebrate and vascular plant species found on NPS properties. The data we collected also were intended to serve as a background for establishing a long-term study of fish and crustacean populations for eventual incorporation into CERP monitoring and assessment efforts. Specifically, our objectives were to:

1. Inventory the freshwater fishes of BCNP to provide geo-referenced information about fish composition, richness, and distribution in aquatic habitats within preserve boundaries.
2. Conduct methods testing to establish which sampling techniques are appropriate for long-term quantitative monitoring of fish populations across the range of varied aquatic habitat types found in BCNP.

In FY 05, the redirection of USGS funding into a new set of fish studies in BCNP ended the sampling study prematurely, but the effort has subsequently been funded by the CERP Monitoring and Assessment Program (CERP-MAP), and continues to collect data.

**METHODS**

We conducted the inventory using a stratified sampling design based on habitat type. To simplify access, most sites were located within 250 m of roads or trails passable by truck. Sites were also reached by boat, all-terrain vehicle, helicopter, and airboat

when these means of transportation were available. Habitat heterogeneity made random selection of sites difficult, particularly during the dry season, because no spatially explicit hydrologic data were available to help us determine whether our randomly pre-selected sites were inundated. In such cases, we selected sampling sites arbitrarily to insure the presence of standing surface water.

**Habitat Classification**

The habitat type classification scheme we used is based on the seasonally inundated habitats identified by Duever et al. (1986). Eight broad categories based on dominant vegetation and hydroperiod were used. Six of these are subject to seasonal dry-down and are ranked by hydroperiod as follows:

- Cypress forest—The dominant trees of the Big Cypress Swamp, the bald cypress *Taxodium distichum* and pond cypress *T. ascendens,* are characteristic of this habitat, which includes both cypress domes and cypress strands. Hydroperiods in these areas are in excess of 240 days per year, and may be over 290 (National Park Service, 1991).
- Mixed swamp forest—These forested wetlands are dominated by hardwoods such as *Acer rubrum*, *Fraxinus caroliniana*, and *Annona glabra. Taxodium* is frequently present, but it is not dominant in these areas. The hydroperiods average about 270 days per year (Duever et al., 1986).
- Freshwater marshes—Vegetation is dominated by *Pontederia* spp*, Sagittaria* spp*, Typha* spp and a variety of grasses and sedges (National Park Service, 1991). Hydroperiods in this habitat range from 150-250 days per year.

- Coastal marshes—Located in southwestern areas of BCNP, these herbaceous wetlands vary seasonally between fresh- and brackish-water salinities. Dominant forms of vegetation include *Spartina spartinae, Distichilis spicata,* and *Eleocharis cellulosa* (National Park Service, 1991). Hydroperiods are similar to those of freshwater marshes.
- Cypress prairie—This community is characterized by an open canopy of sparse, dwarf pond cypress. It often flanks and intergrades with cypress forests. Hydroperiods average approximately 120 days per year (National Park Service, 1991).
- Herbaceous prairie—A variety of grasses dominates these areas, including *Muhlenbergia capillaris*, *Spartina bakeri*, *Cladium jamaicense, Panicum hemitomon,* and *Rhynchospora* spp. (Duever et al., 1986). This habitat has the shortest hydroperiod of all habitat types, with a maximum of 70 days per year (National Park Service, 1991).

Two additional habitats hold water year-round:

- Canals—Man-made, deep-water channels in or bordering BCNP include Barron Collier Canal, L-28 Interceptor Canal, L-28 Canal, Loop Road Canal, and Tamiami Canal. They provide refuges for aquatic species during the dry season, and allow for rapid dispersal by fishes, assisting in the spread of exotic species.
- Sloughs/ponds/rivers—These are naturally occurring, persistent, and relatively deep-water bodies in the preserve. They cover only a small geographic area, but include such important features as Deep Lake, Mud Lake, and Turner River.

## Sampling Techniques

The diversity of habitat types in BCNP presented a considerable challenge to the development of a comprehensive sampling regime, because the effectiveness of any given methodology varied among habitats. To compensate for this, we used numerous techniques during the inventory portion of this study. These methods included a variety of fish traps, as well as electrofishing gear, gill nets, cast nets, dip nets, and angling.

**Traps:** Traps provide a means of sampling with a standardized unit of effort and are suitable for use in virtually all BCNP habitats. They are also relatively portable and, therefore, suitable for work in remote locations. They have the disadvantage of inherent selection biases, based both on trap construction, and the size and behavior of targeted species. To attempt to minimize these biases, we deployed a variety of small-fish traps simultaneously. These included Gee-type minnow traps, box traps, collapsible mesh traps, and Breder traps (Table 1). Soak times were generally 24 hours, although 1-hour sets were also performed. Small-fish traps were consistently fished unbaited and relied on passive encounters to generate captures.

Hoop nets were used to sample larger fishes in deeper water. They were fished unbaited, with or without leads, but were occasionally baited with cheese to selectively target catfish species that proved difficult to capture otherwise. The hoop nets used here were 1.4 m in overall length and were constructed from four 50-cm diameter fiberglass hoops and tar-coated twine with a 2.5-cm mesh size. The nets had two throats and an approximately 15-cm-diameter aperture. Typically, hoop nets were deployed for 24-hour intervals.

**Electrofishing:** Electrofishing was conducted in locations where habitat composition permitted. Two electrofishing setups were used; the first consisted of a boat-mounted Smith-Root Type-6A electrofisher with a maximum current output of either 1,008 volts DC at 120 pulses per second, or 720 volts AC at 60 hertz. The electrofisher was used extensively for sampling in canals but was too large to operate in other habitats. Effort was generally standardized by sampling 100-m transects, although opportunistic sampling around structures such as bridge pilings was conducted as well.

Forested habitats and marshes were sampled using a second setup, which consisted of a small barge carrying a Smith-Root Type-2.5 GPP electrofisher with a maximum current of 1,000 volts at either 120 pulses per second DC, or at 60 hertz AC. The barge drew only several centimeters of water and was a meter wide, but it was still too large to be used in heavily vegetated habitats. Samples were standardized to 300 seconds of total shock time.

**Nets:** We used experimental gill nets to sample fishes in canals. Two nets were fished in tandem, and each was composed of four 242-cm deep x 180-cm wide panels,. The first net had mesh sizes of 1.2, 2.5, 3.7, and 5 cm; the second had mesh sizes of 6.2, 7.6, 8.8, and 11 cm. Nets were typically set from 1 to 4 hours. Reptile predation on entrapped fishes was a problem when using these nets, and encounters with alligators were particularly damaging, precluding longer sets.

Although cast nets do not provide quantitative data, we used them extensively in an opportunistic fashion to capture species sighted in canals. The cast nets had a radius of 180 cm, with a 1.2-cm mesh. In dense vegetation, we used dip nets with fine mesh (<1

mm) for collecting juvenile fishes and small-bodied species, such as the least killifish (*Heterandria formosa)* and Everglades pygmy sunfish (*Elassoma evergladei*).

**Other:** We conducted opportunistic sampling using light tackle, hook-and-line fishing with a variety of lures and live or dead baits. Lines of baited hooks were also occasionally deployed in canals in attempts to catch catfish, although hoop nets proved much more effective. Finally, we recorded those species observed and positively identified in the field when we could not capture the specimens.

We recorded the location of each sampling site in Universal Transverse Mercator (UTM) coordinates using a Garmin Etrex Vista GPS unit. For each sample, we identified all specimens to species, and recorded the total catch per species. We measured the total lengths of the first 20 randomly selected individuals of each species to obtain a representative size distribution. Water temperature, pH, salinity, and dissolved oxygen were measured at each site whenever possible; however, instrumentation problems prevented the collection of these data during much of the year. We subsequently borrowed a Hydrolab 4a minisonde and datalogger from the BCNP hydrology department. For electrofishing expeditions, water conductivity was determined using a YSI-33 conductivity meter.

All field data were recorded on paper datasheets or, during poor weather, in waterproof-paper notebooks. Datasheets were transcribed into an MS Access database, with linked tables for site location, physical parameters, and catch information. Each sample was given a unique numeric identifier to allow the automated generation of reports for each sampling expedition. We proofed geographical information by exporting Access data to Arcview GIS software and comparing the map location of a sample with

its known physical location. Once the field data were entered, we compared Access site reports to field notes to ensure quality control.

**Voucher Specimens**

We collected and saved representative voucher specimens of all captured species whenever practical. Specimens too large to preserve effectively were photographed. Vouchers were collected independently for each habitat type sampled, and to ensure complete spatial coverage of the preserve, vouchers of each species were collected from the north, central, and southern regions of BCNP (Figure 2). Voucher information was entered into the project Access database, and each voucher was assigned a unique identifier to link with related sampling information. The final status of the voucher collection for the inventory work is shown in Table 2. Upon completion of the inventory work, all vouchers were transferred to the NPS regional museum at ENP for curation. Inquiries regarding the voucher collection may be directed to NPS museum coordinator Nancy Russell.

**Community-Dynamics Research Methods**

We commenced long-term quantitative fish research in three regions of BCNP in May 2004 (Figure 3). The objective was to collect baseline information on seasonal patterns of fish abundance and community composition prior to the implementation of hydrologic changes planned as part of CERP. In addition to placing three sampling plots at the site that will be affected by these changes, we also selected two sampling sites that will not be affected by CERP to serve as reference sites.

Three identical sampling plots were constructed within each of the three sampling regions. All plots were located in forested wetland areas adjacent to long-hydroperiod

ponds or sloughs. A pair of 4-$m^2$ drop traps was constructed within each plot to sample short- and long-hydroperiod areas. The drop-trap design is analogous to that described by Lorenz et al. (1997); however, the high density of tree trunks in the sampling area required that we reduce the area of the trap from 9 $m^2$ to 4 $m^2$.

We also constructed a single drift-fence minnow-trap array at each plot. Each array consisted of four 15-m wings built with construction-debris fencing in an "X" pattern aligned so that the apex of each faced a cardinal direction. The wings direct animals into the center where four Gee-8 type minnow traps constructed of 1/8-in. (3.2 mm) steel mesh were positioned. This design has been used extensively in ENP and the Water Conservation Areas, and can provide data that are directly comparable to those regions (Loftus et al., 2001). We planned to sample large fishes in deep-water areas at each plot using either electrofishing or gill nets, depending on which of these methods exhibited greater efficiency after the first year of data collection. Small fish sampling was conducted as described in the next section.

We originally planned to sample five times per year (June/July, October, December, February, and April/May) to detect changes across the annual hydrologic cycle. However, only the June/July 2004 sampling was conducted before funding for this project was redirected to another study at the end of FY 04.

We conducted drop-trap sampling over a three-day period. On the first day, nets were transported to the sampling site and attached to the frames installed permanently at the site. The trap frames were then secured at the top of the supports and rigged to cable releases positioned several meters away. A Gee-type minnow trap was deployed in proximity to each drop trap to collect fish for efficiency measurements.

Drop traps were triggered on the second day of sampling when we arrived at the plot. Fishes from the associated minnow trap were counted and marked by fin clipping, then released into each trap, but efficiency was measured only if 10 or more individuals were caught in the minnow trap. Once this was completed for all traps within the plot, powdered rotenone was added to each trap at a dosage sufficient to kill the fish in the minnow traps. Traps were treated with rotenone in the same order they were triggered to attempt to normalize the sampling time for individuals inside. Physical parameters, including water temperature, conductivity, dissolved oxygen, and pH, were recorded from areas near the traps using a Hydrolab datasonde. After allowing enough time for the toxicant to act, we collected all fishes from each trap and preserved them for lab processing. Potassium permanganate was added to oxidize the rotenone to avoid incidental mortality outside of the traps. On the third day of sampling, fishes that had floated to the surface overnight were collected from each trap and preserved. The nets were then removed from the drop-trap frames and returned to the lab. Minnow-trap arrays were sampled during the first two days of this work. Minnow traps were placed at the center of each array on the first day and emptied 24 hours later. All fishes collected were recorded and returned to the lab for processing.

**Statistical Analysis - Inventory**

The extensive use of small-fish traps during this study provided a large amount of data for analysis. Although the traps used in this study have inherent selective biases, samples collected using identical methodology should be comparable to one another in this regard and permit an examination of variability among habitat types.

A total of 180 sampling expeditions were performed during this study using 24-hour, small-fish trap sets. For analytical purposes, the wet season was defined as June 1-November 30, and the dry season December 1 – May 31. Although this is a generalization of conditions that vary annually, it provides a uniform basis for analysis. Samples are not evenly distributed temporally because habitats were sampled when conditions were most favorable. For example, it was only possible to collect a few herbaceous prairie samples during the dry season because the habitat dries very soon after the rains cease. Although the uneven temporal distribution limited the statistical rigor of our analyses, acquiring information on seasonality was secondary to obtaining a complete inventory of BCNP fishes during this project.

Data for each sampling expedition were pooled to determine per-trap catch per unit effort (CPUE) values for each species at each site. No differentiation was made among different traps because all were used routinely for the trap sets. The correction to CPUE from absolute abundances was made to account for differences in the number of replicates of the various traps used, which varied for a number of logistical reasons. For each sample, the total number of species (S), total CPUE, and Shannon-Weiner Diversity were calculated.

## RESULTS AND DISCUSSION

During the Big Cypress inventory work, we sampled 456 sites throughout the preserve (Figure 4). The distribution of those sites among habitats is shown in Table 3. Canals were the most widely sampled habitat, but the effort involved in many of those samples was lower than for natural habitats, because sampling in canals often consisted of a single hoop-net set or electrofishing transect.

Frequency of sampling in each habitat type was based roughly upon a combination of geographic extent within BCNP and hydroperiod. Coastal marshes and tidally influenced canals were sampled only when salinities were less than one part per thousand. Those conditions prevailed in most locations from June to October of each year.

We documented 64 fish species from freshwater habitats within BCNP (Table 4). Appendix 1 contains distribution maps for each of these species

### Distribution by Habitat Type

Table 5 shows the occurrence or absence of each species from samples collected in each of the major habitats previously described. Canals held by far the most diverse assemblage; 62 of the 64 species documented in the preserve occurred within this habitat. Although this result is partly an artifact of the greater sampling effort in canals relative to other habitats, it also reflects the presence of euryhaline species penetrating inland from the Gulf of Mexico. Many of these fishes are probably temporary residents and do not appear to enter wetland habitats other than by swimming in channels in coastal marshes. Species in this category included the various needlefish (*Strongylura* spp.), mojarras (*Eugerres and Eucinostomus*), and gobies (*Bathygobius, Lophogobius, and Microgobius*),

as well as hardhead catfish (*Arius felis*), sheepshead (*Archosargus probatocephalus*), crevalle jack (*Caranx hippos*), snook (*Centropomus undecimalis*), sharksucker (*Echeneis naucrates*), pinfish (*Lagodon rhomboides*), gray snapper (*Lutjanus griseus*) and tarpon (*Megalops atlanticus*). Also, several fishes found in canal samples were freshwater species that prefer deep-water habitats and were also unlikely to be taken in the shallow wetlands. Those fishes included brown bullhead (*Ameiurus nebulosus*), gizzard shad (*Dorosoma cepedianum*), and black crappie (*Pomoxis nigromaculatus*).

Sloughs, ponds, and rivers are the only naturally occurring habitats in the preserve that retain water throughout the seasonal dry period. There are very few natural rivers draining BCNP, although Turner River drains the southwestern portion and allows passage inland to euryhaline wanderers in the same manner as canals. Lakes are also uncommon within BCNP; however, they provide refuge to large euryhaline species if they have a hydrologic connection to the canal system. The best examples of this are the substantial populations of tarpon (*Megalops atlanticus*) and snook (*Centropomus undecimalis*) inhabiting Deep Lake, a flooded sinkhole adjacent to the Barron Collier Canal. It appears that individuals of both species permanently reside in the lake, but it is unclear how long they have resided there, or how much interchange there is with populations along the coast.

We collected a variety of euryhaline fish species in the coastal marshes, although these were mainly small species or juveniles. Euryhaline species present in that habitat included clown goby (*Microgobius gulosus*), gulf killifish (*Fundulus grandis*), rainwater killifish (*Lucania parva*), and striped mullet (*Mugil cephalus*). During the wet season, many of the freshwater species found in the preserve moved into these marshes.

The remaining wetland habitats shared very similar fish faunas. Of the 34 species found in these habitats, 19 species were common to all. It is likely that several other species were present in all habitats as well, but we did not capture them. There seemed to be a general pattern among small fish species to utilize shallow-water areas, such as herbaceous prairies and cypress prairies when those habitats were inundated.

**Methods Testing**

The heterogeneity of aquatic habitat structure meant that no single sampling method was suitable for providing a complete picture of the fish-community in a given habitat. During the inventory work, we were not permitted by BCNP to use toxicants such as rotenone in enclosed areas to establish baseline-community profiles. This hampered efforts to determine the efficiency of each method in sampling fish populations within each habitat. The use of drop traps to explicitly determine fish population densities during future community-dynamics research will provide much-needed information in this regard. However, the data collected during the inventory work may be used to draw some general conclusions about the effectiveness of various techniques. Also, the efficiency tests performed for methods such as throw traps and drop traps, done in Everglades habitats structured similarly to the preserve habitats, are probably similarly effective in trapping fish and invertebrates in BCNP.

Minnow and Breder traps for small fishes were used most extensively in wetland environments; we took 37 species using them (Table 6). Of the 40 species taken from wetland habitats (Table 5), 35 were obtained in trap sets. The only documented wetland species not taken by these traps were the brook silverside (*Labidesthes sicculus*), brown hoplo (*Hoplosternum littorale*), clown goby (*Microgobius gulosus*), golden shiner

(*Notemigonus crysoleucas*), and striped mullet (*Mugil cephalus*). These were taken using a combination of dip netting, gill nets, and electrofishing. Table 7 shows the distribution of traps set by habitat and season. Although trap data may not necessarily provide good estimates of relative or absolute abundances, the ability of the traps to capture such a broad cross-section of species, combined with their ease of transportation and use, suggest they are the best available method for providing presence/absence data on fish species in BCNP wetlands, especially if supplemented with opportunistic dip netting.

Electrofishing proved to be the most effective method for surveying fishes in open-water areas. Forty-four species were taken during electrofishing surveys (Table 8). Demersal species such as catfish were difficult to obtain using this technique, thus any future canal sampling should also include the use of baited hoop nets. Gill nets were also useful in canals and other deep-water areas, but the large population of alligators in BCNP made entanglements a serious problem.

**Seasonal and Habitat Patterns**

For each sample, the total number of species (S), total CPUE, and Shannon-Weiner Diversity were calculated. The values of these parameters, averaged by habitat type and season, are shown in Table 9. Comparisons were then made for each of these parameters between seasons within each habitat type using a two-tailed *t*-test for between samples of unequal variance. The results of these tests are shown in Table 10.

Average aggregate CPUEs were greatest for the dry season in all habitats except natural deep-water areas. Insufficient numbers of wet-season trap sets were performed in that habitat to allow meaningful comparisons between seasons. Increased catch most likely reflected the concentration of fishes in remaining wetted areas during the seasonal

dry-down. This effect was statistically significant in cypress forest (dry season mean CPUE =14.4, wet season mean CPUE =2.56, $P = 1.905 \times 10^{-6}$) and freshwater marsh (dry season mean CPUE =23.47, wet season mean CPUE =7.67, P = 0.033) habitats, both of which were adjacent to shorter-hydroperiod habitats, such as herbaceous or cypress prairies. Cypress-forest samples also showed a significant increase in the number of species captured during the dry season (mean total dry season species =7.68, mean total wet season species =3.91, P = 0.0002). These results reflect the movement of fishes from short-hydroperiod areas to long-hydroperiod refuges during the dry season. This is similar to information reported by Carlson and Duever (1978) for flagfish (*Jordanella floridae*) and least killifish (*Heterandria formosa*) populations during the annual dry-down of Corkscrew Swamp. However, swamp-forest samples showed no significant differences between seasons. This may be due to the relatively small number of samples taken from this habitat and the large variability among these samples throughout the year. Additionally, swamp-forest habitats typically occurred within areas of cypress forest and, therefore, were less likely to be directly adjacent to short-hydroperiod wetlands, the likely source of the increased number of fishes seen in cypress and freshwater-marsh habitats.

To examine differences in community composition among habitat types, the per-species CPUE data for all samples were compared using the ANOSIM routine of PRIMER-E nonparametric statistical analysis software. ANOSIM examines a dataset to determine the similarity between samples within predefined strata (in this case, within habitats) and then uses a randomization procedure to compare between strata (Clarke and Warwick, 2001). The resultant statistic is a probability value indicating the likelihood that observed differences between strata could occur by chance. Table 11 shows the

ANOSIM results for comparisons between BCNP habitats. We made no distinction between wet and dry seasons in these calculations.

The assemblage of fish sampled with small-fish traps in canals was significantly different from that found in all other habitats except for naturally occurring deep-water areas. This probably reflects the presence of euryhaline species in the canal dataset, because those species also occurred in the natural deep-water areas (specifically in samples from Turner River). Euryhaline species also occurred in coastal marsh samples, which was the next most similar habitat. The canal fish assemblage also was likely influenced by the relatively high abundance of exotic species taken there.

Coastal marsh samples were most similar to those from canals (as mentioned previously). The coastal marsh, however, exhibited significant differences in fish-community structure from all other habitats, and reflects the influence of estuarine species. Naturally occurring deep-water areas (sloughs/ponds/rivers) intergrade between canals and long-hydroperiod freshwater wetlands. We found no significant differences in community structure between this habitat and the canal, cypress forest, or swamp forest habitats. There were significant differences in structure, however, between this and other habitats.

No significant differences in community structure were found between cypress-forest and the other freshwater-wetland habitats except herbaceous prairies. Cypress prairies and swamp forest both routinely intergrade with this habitat, so the lack of differences in community structure is not surprising. Cypress forest and freshwater-marsh habitats have similar hydroperiods, but we cannot provide a simple explanation for their observed similarity in community structure.

Swamp-forest results showed a very distinct separation from short-hydroperiod wetlands. This community was most similar to cypress forest, with which it commonly intergrades. Freshwater-marsh samples were difficult to interpret. The community was significantly different from herbaceous prairies, despite the fact that they commonly border each other. Marsh samples were not significantly different from cypress or swamp forest samples, perhaps owing to the similar hydroperiods of the habitats, but they were also not significantly different from shorter-hydroperiod cypress forest.

Cypress prairie fish-community structure was not significantly different from those of cypress forest or herbaceous prairie habitats. Cypress prairie often forms a continuum between these habitats, so this result is not surprising. As noted earlier, there was also no significant difference between this habitat and freshwater marsh. The herbaceous prairie community was distinct from all others except for cypress prairie, which operates under a similar hydrologic regime and is often adjacent to this habitat. The differences observed between this habitat and freshwater marshes were unexpected, as noted earlier.

Overall, communities with similar hydrology tended to have similar community composition, as did those that were contiguous. In general, geographic separation between habitats, as well as hydroperiod differences, were reflected by differences in community structure.

**Community-Dynamics Research Results**

Site selection was made during extensive reconnaissance trips. The first scheduled sampling for this monitoring program occurred during April-May 2004, but the sites were completely dry due to a strong and prolonged dry period. Therefore, sampling

of the fish monitoring stations occurred for the first time in July 2004. All stations had been completely dry until two weeks prior to sampling because wet season conditions were delayed. Therefore, the results represent very early recolonization of recently inundated habitats. Water levels were sufficient to allow sampling at the L-28 and Raccoon Point sites. The Bear Island sites were dry through the end of July and, therefore, could not be sampled.

Total catch from the monitoring sites is reported in Table 12. The minnow trap arrays are designed to concentrate catch from a large area and, therefore, were more effective given the low densities present at that point in the annual hydrologic cycle. *Gambusia holbrooki* and *Jordanella floridae* were the most commonly captured species.

The L-28 sampling stations are located in a large, semi-continuous slough habitat in relatively close proximity to several canals. It is likely that there were small, inundated refuge areas within this habitat in which fishes survived. Although the L-28 canal has levees on both sides that hydrologically isolate it from the surrounding wetlands, the canal bordering Interstate 75 is close to the third replicate plot and may have represented a potential refuge area.

Raccoon Point is an area of large cypress domes that are hydrologically separated during times of low water. There were no discernable refuge areas nearby, and sampling plots were still separated by areas of dry land at the time of sampling. It is therefore not surprising that the fish catch at Raccoon Point was lower than at the L-28 site.

Depending on hydrologic conditions, fish population levels can vary greatly from one July to the next. Therefore, it is possible that future sampling expeditions will find a greater number and diversity of species than were found during this particularly dry year.

The drop traps, in particular, should produce more meaningful results at higher population levels.

**Non-Indigenous Species**

We took nine species of introduced fishes in the preserve, most in the family Cichlidae (the cichlids). These included the oscar (*Astronotus ocellatus*), black acara (*Cichlasoma bimaculatum*), Mayan cichlid (*Cichlasoma urophthalmus*), jewel cichlid (*Hemichromis letourneauxi*), blue tilapia (*Oreochromis aureus*), and spotted tilapia (*Tilapia mariae*). Other families were represented by only one species, including the labyrinth catfishes (Clariidae: *Clarias batrachus*), livebearers (Poeciliidae: *Belonesox belizanus*) and the armoured catfish (Callichthyidae: *Hoplosternum littorale*). *Hemichromis* and *Hoplosternum* had not been previously recorded in BCNP and appear to be in the process of colonizing much of southern Florida. *Hoplosternum* was rarely taken during the inventory sampling, although several juveniles appeared during the July 2004 monitoring. *Hemichromis* were encountered much more frequently during the 2004 inventory than during previous efforts. In the cypress forest near Pinecrest (in the southeast part of the preserve), *Hemichromis* were a numerically dominant segment of the wet-season fish catch in 2004. This rapid spike in population has been seen in other species that have recently become established in south Florida wetlands, and is typically followed by a decline to some lower population level (Trexler et al., 2001).

Overall, the most widely distributed exotic species in the preserve were pike killifish, Mayan cichlids, black acara, and spotted tilapia. Oscar, walking catfish, and blue tilapia were captured almost exclusively in or adjacent to canals or other deep-water habitats, although their distribution in the preserve may be more widespread. Oscars,

Mayan cichlids, black acaras, and walking catfish were locally abundant in canals during the dry season.

## TOPICS OF CONCERN

### Undocumented Species

Several species have been documented by previous researchers in the preserve, but we were unable to take them in our sampling. Loftus and Kushlan (1987) reported diamond killifish (*Adinia xenica*) and naked goby (*Gobiosoma bosc*) in the southern portion of BCNP. The survey of the Addition Lands administrative area by Dalyrymple (1995) included reports of chain pickerel (*Esox niger*) and channel catfish (*Ictalurus punctatus*) in the L-28 Canal. We repeatedly sampled for all of these species in likely habitats, but were unsuccessful. We conclude that these species are localized or rare in the preserve.

Based on their presence in nearby areas, it is also possible that threadfin shad (*Dorosoma petenense*), pirate perch (*Aphredoderus sayanus*), jaguar guapote (*Cichlasoma managuense*), and sailfin catfish (*Pterygoplichthys* spp.) may be found in the future in the preserve. A complete list of species likely to be found in BCNP is given in Appendix 2.

Based on our records and on previously documented species from the preserve, and compared with all potential species likely to be found there in the future, we estimate that we have documented 92 percent of the ichthyofauna of the preserve.

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Table 1. Comparisons of small-fish traps used in BCNP sampling.

| Trap type | Material | Mesh size | Min. depth | Aperture | Dimensions |
|---|---|---|---|---|---|
| box trap | wire | 6 mm | 12 cm | 3cm | 20 cm x 40 cm x 46 cm rectangular |
| Breder trap | acrylic | n/a | 1 cm | 1cm | 30 cm x 15 cm x 15 cm rectangular, 2 30cm wings |
| mesh trap | nylon | 2 mm | 13 cm | 6 cm | 44 cm x 25 cm x 25 cm rectangular |
| minnow trap | wire | 6 mm | 12 cm | 2.5 cm | 43 cm x 22 cm diameter cylindrical |

Table 2. Current status of BCNP vouchers collection.

| | north | | | | | | | central | | | | | | | | south | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | cypress forest | mixed swamp forest | cypress prairie | herbaceous prairie | sloughs/ponds/rivers | canals | freshwater marsh | cypress forest | mixed swamp forest | cypress prairie | herbaceous prairie | sloughs/ponds/rivers | coastal marshes | canals | freshwater marsh | cypress forest | mixed swamp forest | cypress prairie | herbaceous prairie | sloughs/ponds/rivers | coastal marshes | canals | freshwater marsh |
| American Eel | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - |
| Atlantic Needlefish | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - |
| Black Acara | - | X | - | - | - | - | X | X | - | X | - | - | - | X | X | X | X | - | X | - | X | X | X |
| Black Crappie | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Blue Tilapia | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | X | - | X | - | X | X | X | - |
| Bluefin Killifish | X | X | - | - | - | X | X | X | X | X | X | - | - | X | X | X | X | X | X | - | - | - | X |
| Bluegill | - | X | - | - | - | X | - | X | - | - | - | - | - | X | - | X | - | - | - | - | - | - | - |
| Blue spotted Sunfish | X | X | - | - | - | - | X | - | - | - | - | X | - | X | - | X | X | - | X | X | - | X | X |
| Bowfin | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Brook Silverside | X | X | - | - | - | - | - | X | - | - | - | X | - | X | - | - | X | - | X | - | - | X | - |
| Brown Bullhead | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - |
| Brown Hoplo | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - |
| Clown Goby | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | X | - | - |
| Coastal Shiner | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | X | - |
| Crested Goby | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | X | - |
| Crevalle Jack | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Dollar Sunfish | X | X | - | X | - | X | X | X | - | X | X | - | - | X | X | X | X | X | X | X | - | X | X |
| Everglades Pygmy Sunfish | - | - | - | - | - | X | - | - | X | X | X | - | - | X | X | X | X | - | - | - | - | X | X |
| Flagfish | X | X | - | X | - | - | X | - | - | X | X | - | - | X | X | X | X | X | X | - | X | X | - |
| Florida Gar | - | - | - | - | - | X | - | - | X | - | - | - | - | - | - | - | - | X | - | - | - | X | - |
| Frillfin Goby | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - |
| Gizzard Shad | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Golden Shiner | - | X | - | - | - | X | - | - | - | - | - | X | - | X | - | - | - | - | - | - | - | X | - |
| Golden Topminnow | X | - | - | X | - | X | X | X | - | X | X | - | - | X | X | X | - | X | X | - | - | X | - |
| Gray Snapper | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - |
| Gulf Killifish | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - |
| Hardhead Catfish | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Hogchoker | - | - | - | - | - | - | - | - | - | - | - | X | - | X | - | - | - | - | - | X | - | X | - |
| Inland Silverside | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | X | X | - |
| Jewel Cichlid | - | - | - | - | - | - | - | - | - | - | - | - | - | X | X | X | - | X | X | - | - | - | - |
| Ladyfish | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - |
| Lake Chubsucker | - | - | - | - | - | X | - | X | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - |
| Largemouth Bass | - | - | - | - | - | X | - | - | - | - | - | - | - | X | - | X | - | - | - | - | - | X | - |

Table 2. continued.

| | north | | | | | | | central | | | | | | | | south | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | cypress forest | mixed swamp forest | cypress prairie | herbaceous prairie | sloughs/ponds/rivers | canals | freshwater marsh | cypress forest | mixed swamp forest | cypress prairie | herbaceous prairie | sloughs/ponds/rivers | coastal marshes | canals | freshwater marsh | cypress forest | mixed swamp forest | cypress prairie | herbaceous prairie | sloughs/ponds/rivers | coastal marshes | canals | freshwater marsh |
| Least Killifish | X | X | - | - | - | X | X | - | - | - | - | - | - | X | X | X | X | X | - | - | - | X | - |
| Marsh Killifish | X | - | - | X | - | - | X | X | - | X | X | - | - | X | X | X | X | X | X | X | X | - | - |
| Mayan Cichlid | - | - | - | - | - | - | X | X | - | X | X | X | - | X | X | X | X | X | X | X | X | X | X |
| Mosquitofish, Eastern | X | X | - | X | - | X | X | X | - | X | X | X | - | X | X | X | X | X | X | - | X | X | X |
| Oscar | - | - | - | - | - | - | - | - | - | - | X | - | - | X | - | - | - | - | - | - | - | - | - |
| Pike Killifish | - | - | - | X | - | X | X | X | - | X | X | - | - | X | - | X | X | X | - | - | - | X | X |
| Pinfish | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - |
| Rainwater Killifish | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | X | X | X | - |
| Red Drum | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - |
| Redear | - | - | - | - | - | X | - | X | - | - | - | - | - | X | - | X | - | X | - | - | - | X | X |
| Redfin Needlefish | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - |
| Redfin Pickerel | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Sailfin Molly | X | X | - | X | - | X | X | - | - | X | - | - | - | X | X | X | X | X | X | X | X | X | X |
| Seminole Killifish | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | X | X |
| Sharksucker | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Sheepshead | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - |
| Sheepshead Minnow | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | X | - | X | X | - |
| Snook | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | X | - |
| Spotted Sunfish | X | X | - | - | - | X | X | X | - | - | - | - | - | - | - | X | X | X | X | X | - | X | X |
| Spotted Tilapia | - | - | - | - | - | - | - | X | - | - | - | X | - | X | - | X | X | - | X | - | - | X | X |
| Striped Mojarra | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | X | - |
| Striped Mullet | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - |
| Swamp Darter | - | - | - | - | - | X | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | - | - |
| Tadpole Madtom | - | - | - | - | - | - | - | - | X | - | - | - | - | - | X | X | - | X | - | - | - | - | - |
| Taillight Shiner | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - |
| Tarpon | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Tidewater Mojarra | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | - | X | - |
| Timucu | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - |
| Walking Catfish | - | - | - | - | - | - | - | - | - | - | - | - | - | X | - | - | - | - | - | - | X | X | - |
| Warmouth | X | X | - | X | - | X | X | X | - | X | X | - | - | X | X | X | X | X | X | X | X | X | X |
| Yellow Bullhead | - | - | - | - | - | - | - | X | - | - | X | - | - | X | X | - | - | - | - | - | - | - | - |

Table 3. Sampling locations by habitat type.

| Habitat | # of samples |
|---|---|
| canals | 174 |
| cypress forest | 88 |
| freshwater marsh | 60 |
| herbaceous prairie | 38 |
| mixed swamp forest | 34 |
| sloughs/ponds/rivers | 28 |
| cypress prairie | 23 |
| coastal marshes | 11 |
| Total | 456 |

Table 4. BCNP freshwater fish species captured during the report period.

| Species Name | Common Name |
|---|---|
| *Ameiurus natalis* | Yellow Bullhead |
| *Ameiurus nebulosus* | Brown Bullhead |
| *Amia calva* | Bowfin |
| *Anguilla rostrata* | American Eel |
| *Archosargus probatocephalus* | Sheepshead |
| *Arius felis* | Hardhead Catfish |
| *Astronotus ocellatus* | Oscar |
| *Bathygobius soporator* | Frillfin Goby |
| *Belonesox belizanus* | Pike Killifish |
| *Caranx hippos* | Crevalle Jack |
| *Centropomus undecimalis* | Snook |
| *Cichlasoma bimaculatum* | Black Acara |
| *Cichlasoma urophthalmus* | Mayan Cichlid |
| *Clarias batrachus* | Walking Catfish |
| *Cyprinodon variegatus* | Sheepshead Minnow |
| *Dorsoma cepedianum* | Gizzard Shad |
| *Echeneis naucrates* | Sharksucker |
| *Elassoma evergladei* | Everglades Pygmy Sunfish |
| *Elops saurus* | Ladyfish |
| *Enneacanthus gloriosus* | Bluespotted Sunfish |
| *Erimyzon sucetta* | Lake Chubsucker |
| *Esox americanus* | Redfin Pickerel |
| *Etheostoma fusiforme* | Swamp Darter |
| *Eucinostomus harengulus* | Tidewater Mojarra |
| *Eugerres plumieri* | Striped Mojarra |
| *Fundulus chrysotus* | Golden Topminnow |
| *Fundulus confluentus* | Marsh Killifish |
| *Fundulus grandis* | Gulf Killifish |
| *Fundulus seminolis* | Seminole Killifish |
| *Gambusia holbrooki* | Eastern Mosquitofish |
| *Hemichromis letourneauxi* | Jewel Cichlid |
| *Heterandria formosa* | Least Killifish |
| *Hoplosternum littorale* | Brown Hoplo |
| *Jordanella floridae* | Flagfish |
| *Labidesthes sicculus* | Brook Silverside |
| *Lagodon rhomboides* | Pinfish |
| *Lepisosteus platyrhincus* | Florida Gar |
| *Lepomis gulosus* | Warmouth |
| *Lepomis macrochirus* | Bluegill |
| *Lepomis marginatus* | Dollar Sunfish |
| *Lepomis microlophus* | Redear |
| *Lepomis punctatus* | Spotted Sunfish |

Table 4. continued.

| Species Name | Common Name |
|---|---|
| *Lophogobius cyprinoides* | Crested Goby |
| *Lucania goodei* | Bluefin Killifish |
| *Lucania parva* | Rainwater Killifish |
| *Lutjanus griseus* | Gray Snapper |
| *Megalops atlanticus* | Tarpon |
| *Menidia beryllina* | Inland Silverside |
| *Microgobius gulosus* | Clown Goby |
| *Micropterus salmoides* | Largemouth Bass |
| *Mugil cephalus* | Striped Mullet |
| *Notemigonus crysoleucas* | Golden Shiner |
| *Notropis maculatus* | Taillight Shiner |
| *Notropis petersoni* | Coastal Shiner |
| *Noturus gyrinus* | Tadpole Madtom |
| *Oreochromis aureus* | Blue Tilapia |
| *Poecilia latipinna* | Sailfin Molly |
| *Pomoxis nigromaculatus* | Black Crappie |
| *Sciaenops ocellatus* | Red Drum |
| *Strongylura marina* | Atlantic Needlefish |
| *Strongylura notata* | Redfin Needlefish |
| *Strongylura timucu* | Timucu |
| *Tilapia mariae* | Spotted Tilapia |
| *Trinectes maculatus* | Hogchoker |

Table 5. Species distribution by habitat type.

| Species | Canals | Sloughs, ponds, and rivers | Mixed swamp forest | Freshwater marsh | Cypress forest | Cypress prairie | Herbaceous prairie | Coastal marshes | | All wetlands | Freshwater wetlands | Deep-water habitats only |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| American Eel | X | X | - | - | - | - | - | - | | - | - | X |
| Atlantic Needlefish | X | - | - | - | - | - | - | - | | - | - | X |
| Black Acara | X | X | X | X | X | X | X | X | | X | X | - |
| Black Crappie | X | - | - | - | - | - | - | - | | - | - | X |
| Blue Tilapia | X | X | - | X | X | X | - | X | | X | X | - |
| Bluefin Killifish | X | X | X | X | X | X | X | X | | X | X | - |
| Bluegill | X | X | X | X | X | - | - | X | | X | X | - |
| Bluespotted Sunfish | X | X | X | X | X | X | X | X | | X | X | - |
| Bowfin | X | X | - | - | X | - | - | - | | X | X | - |
| Brook Silverside | X | X | X | X | X | X | X | - | | X | X | - |
| Brown Bullhead | X | - | - | - | - | - | - | - | | - | - | X |
| Brown Hoplo | X | - | - | - | - | X | - | - | | X | X | - |
| Clown Goby | X | - | - | - | - | - | - | X | | X | - | - |
| Coastal Shiner | X | - | - | - | - | - | - | - | | - | - | X |
| Crested Goby | X | - | - | - | - | - | - | - | | - | - | X |
| Crevalle Jack | X | - | - | - | - | - | - | - | | - | - | X |
| Dollar Sunfish | X | X | X | X | X | X | X | X | | X | X | - |
| Everglades Pygmy Sunfish | X | X | X | X | X | X | X | - | | X | X | - |
| Flagfish | X | X | X | X | X | X | X | X | | X | X | - |
| Florida Gar | X | X | X | X | X | X | X | - | | X | X | - |
| Frillfin Goby | X | - | - | - | - | - | - | - | | - | - | X |
| Gizzard Shad | X | - | - | - | - | - | - | - | | - | - | X |
| Golden Shiner | X | X | X | X | - | - | - | - | | X | X | - |
| Golden Topminnow | X | X | X | X | X | X | X | X | | X | X | - |
| Gray Snapper | X | - | - | - | - | - | - | - | | - | - | X |
| Gulf Killifish | X | - | - | - | - | - | - | X | | X | - | - |
| Hardhead Catfish | X | - | - | - | - | - | - | - | | - | - | X |
| Hogchoker | X | X | - | - | - | - | - | X | | X | - | - |
| Inland Silverside | X | - | - | - | - | - | - | X | | X | - | - |
| Jewel Cichlid | X | - | - | X | X | X | X | - | | X | X | - |
| Ladyfish | X | - | - | - | - | - | - | - | | - | - | X |
| Lake Chubsucker | X | X | - | - | X | - | - | - | | X | X | - |
| Largemouth Bass | X | X | X | X | X | X | X | X | | X | X | - |
| Least Killifish | X | X | X | X | X | X | X | X | | X | X | - |
| Marsh Killifish | X | X | X | X | X | X | X | X | | X | X | - |

Table 5. continued.

| Species | Canals | Sloughs, ponds, and rivers | Mixed swamp forest | Freshwater marsh | Cypress forest | Cypress prairie | Herbaceous prairie | Coastal marshes | All wetlands | Freshwater wetlands | Deep-water habitats only |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mayan Cichlid | X | X | X | X | X | X | X | X | X | X | - |
| Mosquitofish, Eastern | X | X | X | X | X | X | X | X | X | X | - |
| Oscar | X | X | - | - | X | - | X | - | X | X | - |
| Pike Killifish | X | X | X | X | X | X | X | X | X | X | - |
| Pinfish | X | - | - | - | - | - | - | - | - | - | X |
| Rainwater Killifish | X | X | - | - | - | - | - | X | X | - | - |
| Red Drum | X | - | - | - | - | - | - | - | - | - | X |
| Redear | X | X | X | X | X | X | - | X | X | X | - |
| Redfin Needlefish | X | - | - | - | - | - | - | - | - | - | X |
| Redfin Pickerel | - | - | - | - | X | - | - | - | X | X | - |
| Sailfin Molly | X | X | X | X | X | X | X | X | X | X | - |
| Seminole Killifish | X | X | - | X | - | - | - | - | X | X | - |
| Sharksucker | X | - | - | - | - | - | - | - | - | - | X |
| Sheepshead | X | - | - | - | - | - | - | - | - | - | X |
| Sheepshead Minnow | X | - | - | X | - | - | X | X | X | X | - |
| Snook | X | X | - | - | - | - | - | - | - | - | X |
| Spotted Sunfish | X | X | X | X | X | X | X | - | X | X | - |
| Spotted Tilapia | X | X | X | X | X | X | X | X | X | X | - |
| Striped Mojarra | X | X | - | - | - | - | - | - | - | - | X |
| Striped Mullet | X | X | - | - | - | - | - | X | X | - | - |
| Swamp Darter | X | - | - | - | X | - | - | - | - | - | X |
| Tadpole Madtom | - | - | X | X | X | X | - | - | X | X | - |
| Taillight Shiner | X | - | - | - | - | - | - | - | - | - | X |
| Tarpon | X | X | - | - | - | - | - | - | - | - | X |
| Tidewater Mojarra | X | - | - | - | - | - | - | - | - | - | X |
| Timucu | X | - | - | - | - | - | - | - | - | - | X |
| Walking Catfish | X | X | X | - | - | - | - | X | X | X | - |
| Warmouth | X | X | X | X | X | X | X | X | X | X | - |
| Yellow Bullhead | X | X | - | X | X | X | X | - | X | X | - |
| Total | 62 | 36 | 24 | 28 | 30 | 25 | 23 | 26 | 40 | 34 | 24 |

Table 6. Species captured by small-fish traps.

| Species Name | Common Name | Trap Type box | Breder | minnow | mesh |
|---|---|---|---|---|---|
| *Ameiurus natalis* | Yellow Bullhead | X | - | X | - |
| *Amia calva* | Bowfin | X | - | - | - |
| *Astronotus ocellatus* | Oscar | X | X | X | - |
| *Bathygobius soporator* | Frillfin Goby | X | - | - | - |
| *Belonesox belizanus* | Pike Killifish | X | X | X | X |
| *Cichlasoma bimaculatum* | Black Acara | X | X | X | X |
| *Cichlasoma urophthalmus* | Mayan Cichlid | X | X | X | X |
| *Clarias batrachus* | Walking Catfish | X | - | - | - |
| *Cyprinodon variegatus* | Sheepshead Minnow | X | X | X | X |
| *Elassoma evergladei* | Everglades Pygmy Sunfish | - | X | - | X |
| *Enneacanthus gloriosus* | Bluespotted Sunfish | X | X | X | X |
| *Esox americanus* | Redfin Pickerel | X | - | - | - |
| *Eucinostomus harengulus* | Tidewater Mojarra | X | - | - | - |
| *Eugerres plumieri* | Striped Mojarra | X | - | - | - |
| *Fundulus chrysotus* | Golden Topminnow | X | X | X | X |
| *Fundulus confluentus* | Marsh Killifish | X | X | X | X |
| *Fundulus grandis* | Gulf Killifish | X | X | - | - |
| *Gambusia holbrooki* | Eastern Mosquitofish | X | X | X | X |
| *Hemichromis letourneauxi* | Jewel Cichlid | X | X | X | X |
| *Heterandria formosa* | Least Killifish | - | X | - | X |
| *Jordanella floridae* | Flagfish | X | X | X | X |
| *Lepisosteus platyrhincus* | Florida Gar | X | - | X | - |
| *Lepomis gulosus* | Warmouth | X | X | X | X |
| *Lepomis macrochirus* | Bluegill | X | X | - | - |
| *Lepomis marginatus* | Dollar Sunfish | X | X | X | X |
| *Lepomis microlophus* | Redear | X | X | X | - |
| *Lepomis punctatus* | Spotted Sunfish | X | X | X | X |
| *Lophogobius cyprinoides* | Crested Goby | X | - | X | - |
| *Lucania goodei* | Bluefin Killifish | X | X | - | X |
| *Lucania parva* | Rainwater Killifish | X | X | X | X |
| *Menidia beryllina* | Inland Silverside | - | X | - | X |
| *Micropterus salmoides* | Largemouth Bass | X | X | - | X |
| *Noturus gyrinus* | Tadpole Madtom | X | - | X | - |
| *Oreochromis aureus* | Blue Tilapia | X | - | X | X |
| *Poecilia latipinna* | Sailfin Molly | X | X | X | X |
| *Tilapia mariae* | Spotted Tilapia | X | X | X | X |
| *Trinectes maculatus* | Hogchoker | X | - | - | - |
| Total: | | 34 | 25 | 23 | 22 |

Table 7. Distribution of comparable small-fish trap sets by habitat type and season.

| | Season | | |
|---|---|---|---|
| Habitat | wet | dry | total |
| cypress forest | 11 | 40 | 51 |
| freshwater marsh | 12 | 25 | 37 |
| herbaceous prairie | 24 | 5 | 29 |
| swamp forest | 13 | 7 | 20 |
| cypress prairie | 7 | 10 | 17 |
| canals | 3 | 8 | 11 |
| sloughs/ponds/rivers | 1 | 7 | 8 |
| coastal marsh | 4 | 3 | 7 |
| **Total** | **75** | **105** | **180** |

Table 8. Species captured by electrofishing.

| Species Name | Common Name |
|---|---|
| *Ameiurus natalis* | Yellow bullhead |
| *Amia calva* | Bowfin |
| *Anguilla rostrata* | American eel |
| *Archosargus probatocephalus* | Sheepshead |
| *Astronotus ocellatus* | Oscar |
| *Belonesox belizanus* | Pike killifish |
| *Centropomus undecimalis* | Snook |
| *Cichlasoma bimaculatum* | Black acara |
| *Cichlasoma urophthalmus* | Mayan cichlid |
| *Clarias batrachus* | Walking catfish |
| *Cyprinodon variegatus* | Sheepshead minnow |
| *Dorsoma cepedianum* | Gizzard shad |
| *Elassoma evergladei* | Everglades pygmy sunfish |
| *Enneacanthus gloriosus* | Bluespotted sunfish |
| *Erimyzon sucetta* | Lake chubsucker |
| *Etheostoma fusiforme* | Swamp darter |
| *Eugerres plumieri* | Striped mojarra |
| *Fundulus chrysotus* | Golden topminnow |
| *Fundulus confluentus* | Marsh killifish |
| *Fundulus seminolis* | Seminole killifish |
| *Gambusia holbrooki* | Eastern mosquitofish |
| *Hemichromis letourneauxi* | Jewel cichlid |
| *Heterandria formosa* | Least killifish |
| *Jordanella floridae* | Flagfish |
| *Labidesthes sicculus* | Brook silverside |
| *Lepisosteus platyrhincus* | Florida gar |
| *Lepomis gulosus* | Warmouth |
| *Lepomis macrochirus* | Bluegill |
| *Lepomis marginatus* | Dollar sunfish |
| *Lepomis microlophus* | Redear |
| *Lepomis punctatus* | Spotted sunfish |
| *Lophogobius cyprinoides* | Crested goby |
| *Lucania goodei* | Bluefin killifish |
| *Lutjanus griseus* | Gray snapper |
| *Menidia beryllina* | Inland silverside |
| *Micropterus salmoides* | Largemouth bass |
| *Mugil cephalus* | Striped Mullet |
| *Notemigonus crysoleucas* | Golden shiner |
| *Notropis maculatus* | Taillight shiner |
| *Notropis petersoni* | Coastal shiner |
| *Oreochromis aureus* | Blue tilapia |
| *Poecilia latipinna* | Sailfin molly |
| *Tilapia mariae* | Spotted tilapia |
| *Trinectes maculatus* | Hogchoker |

Table 9. Mean statistical data for small-fish trap samples by habitat and season.

| Habitat | Season | # of samples (N) | Species(S) | Average CPUE | Shannon-Weiner Diversity |
|---|---|---|---|---|---|
| canals | dry | 8 | 5.00 | 9.94 | 1.19 |
| canals | wet | 3 | 4.33 | 2.39 | 1.20 |
| coastal marshes | dry | 3 | 6.33 | 19.17 | 1.19 |
| coastal marshes | wet | 4 | 7.50 | 9.94 | 1.11 |
| cypress forest | dry | 40 | 7.68 | 14.40 | 1.35 |
| cypress forest | wet | 11 | 3.91 | 2.56 | 0.99 |
| freshwater marsh | dry | 25 | 7.52 | 23.47 | 1.34 |
| freshwater marsh | wet | 12 | 7.08 | 7.67 | 1.47 |
| herbaceous prairie | dry | 5 | 5.00 | 10.35 | 1.22 |
| herbaceous prairie | wet | 24 | 6.67 | 4.69 | 1.41 |
| swamp forest | dry | 7 | 7.71 | 13.09 | 1.44 |
| swamp forest | wet | 13 | 5.85 | 9.27 | 1.28 |
| cypress prairie | dry | 10 | 8.71 | 22.37 | 1.38 |
| cypress prairie | wet | 7 | 6.80 | 6.29 | 1.50 |
| sloughs/ponds/rivers | dry | 7 | 5.86 | 4.28 | 1.23 |
| sloughs/ponds/rivers | wet | 1 | 5.00 | 8.50 | 0.64 |

Table 10. Results of *t*-tests (P values) comparing parameters between wet and dry seasons within habitats. Significant results ($P < 0.05$) in bold type.

| Habitat | Species(S) | Aggregate CPUE | Shannon-Weiner Diversity |
|---|---|---|---|
| canals | 0.7231 | 0.0712 | 0.9764 |
| coastal marshes | 0.6365 | 0.6186 | 0.8538 |
| cypress forest | **0.0002** | **$1.905 \times 10^{-6}$** | 0.0559 |
| freshwater marsh | 0.6270 | **0.0330** | 0.3258 |
| herbaceous prairie | 0.2290 | 0.3679 | 0.1492 |
| swamp forest | 0.2477 | 0.6471 | 0.5118 |
| cypress prairie | 0.1874 | 0.0957 | 0.3998 |
| sloughs/ponds/rivers | N/A | N/A | N/A |

Table 11. ANOSIM comparisons of fish communities among habitats ($P < 0.05$ in boldface type, $P < 0.01$).

| Habitat | # of samples | Sloughs/ponds/rivers | Cypress forest | Mixed swamp forest | Freshwater marsh | Cypress prairie | Herbaceous prairie | Canals | Coastal marsh |
|---|---|---|---|---|---|---|---|---|---|
| canals | 11 | 0.713 | **0.002** | **0.002** | **0.001** | **0.001** | **0.001** | - | **0.042** |
| sloughs/ponds/rivers | 20 | - | 0.082 | 0.074 | **0.019** | **0.001** | **0.004** | 0.713 | **0.026** |
| cypress forest | 51 | 0.082 | - | 0.148 | 0.421 | 0.751 | **0.027** | **0.002** | **0.005** |
| mixed swamp forest | 20 | 0.074 | 0.148 | - | 0.051 | **0.001** | **0.001** | **0.002** | **0.001** |
| freshwater marsh | 37 | **0.019** | 0.421 | 0.051 | - | 0.766 | **0.013** | **0.001** | **0.001** |
| cypress prairie | 17 | **0.001** | 0.751 | **0.001** | 0.766 | - | 0.494 | **0.001** | **0.001** |
| herbaceous prairie | 29 | **0.004** | **0.027** | **0.001** | **0.013** | 0.494 | - | **0.001** | **0.006** |
| coastal marsh | 7 | **0.026** | **0.005** | **0.001** | **0.001** | **0.001** | **0.006** | **0.042** | - |

Table 12. Counts of fish by species taken during the July 2004 monitoring work.

Raccoon Point station

| | Array | | | Deep drop trap | | | Shallow drop trap | | |
|---|---|---|---|---|---|---|---|---|---|
| Species | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| *G. holbrooki* | - | - | 3 | - | - | - | - | - | - |
| *J. floridae* | - | 3 | - | - | - | - | - | - | - |

L-28 station

| | Array | | | Deep drop trap | | | Shallow drop trap | | |
|---|---|---|---|---|---|---|---|---|---|
| Species | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| *C. bimaculatum* | - | - | 4 | - | - | - | - | - | - |
| *E. evergladei* | - | - | 2 | - | - | - | - | - | - |
| *E. gloriosus* | 1 | 2 | 2 | - | - | - | - | - | - |
| *F. confluentus* | - | 1 | - | - | - | - | - | - | - |
| *G. holbrooki* | - | 1 | 24 | - | - | 2 | - | - | - |
| *H. formosa* | - | - | - | - | - | - | - | - | 1 |
| *H. littorale* | 1 | 2 | - | - | - | - | - | - | - |
| *J. floridae* | 3 | 10 | 4 | - | - | - | - | - | - |
| *L. goodei* | - | 3 | - | - | - | - | - | - | - |
| *L. gulosus* | - | - | 1 | - | - | - | - | - | - |
| *P. latipinna* | 1 | 1 | - | - | - | - | - | - | - |

Bear Island station
was dry- not sampled

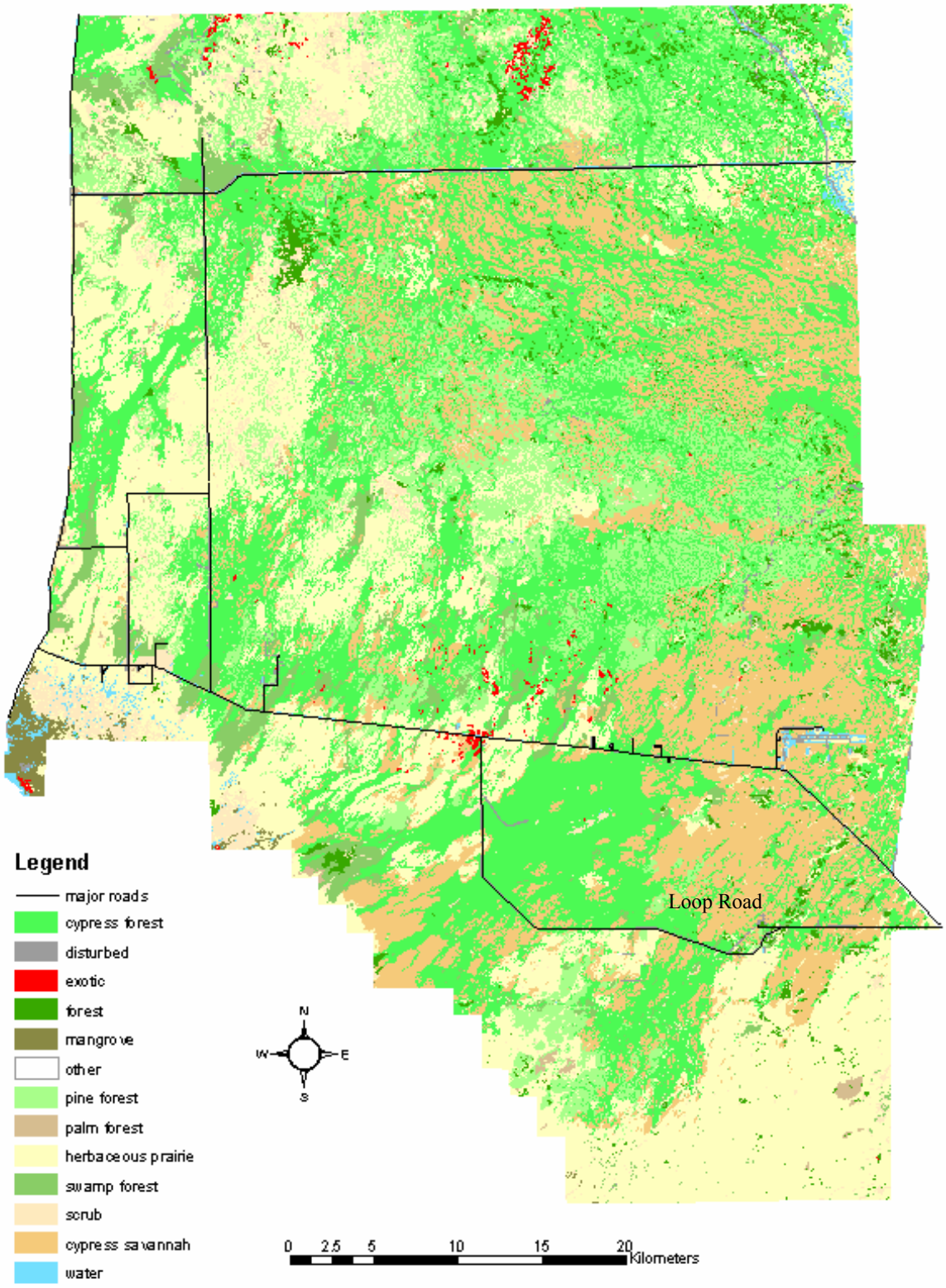



Figure 1: Principal habitats of BCNP.

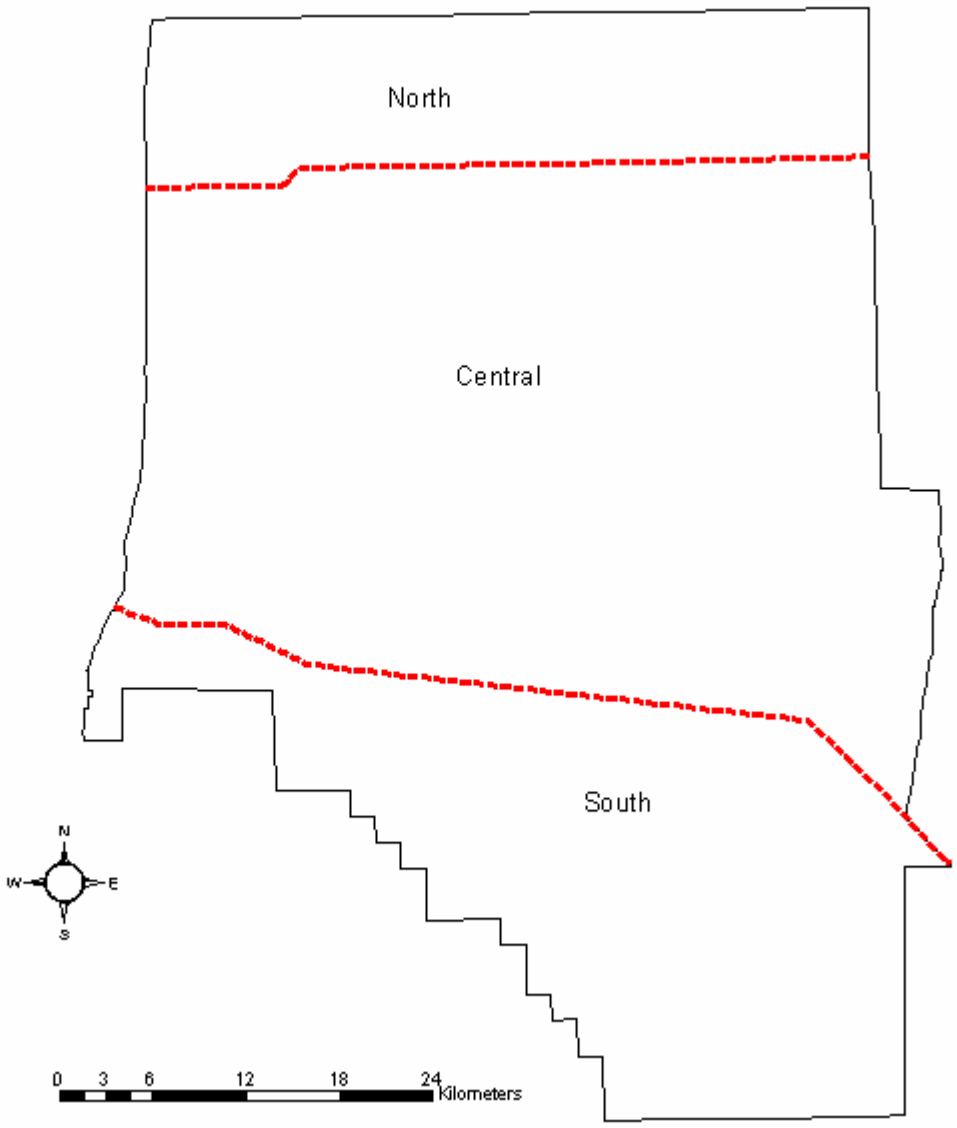



Figure 2: BCNP voucher collection regions.

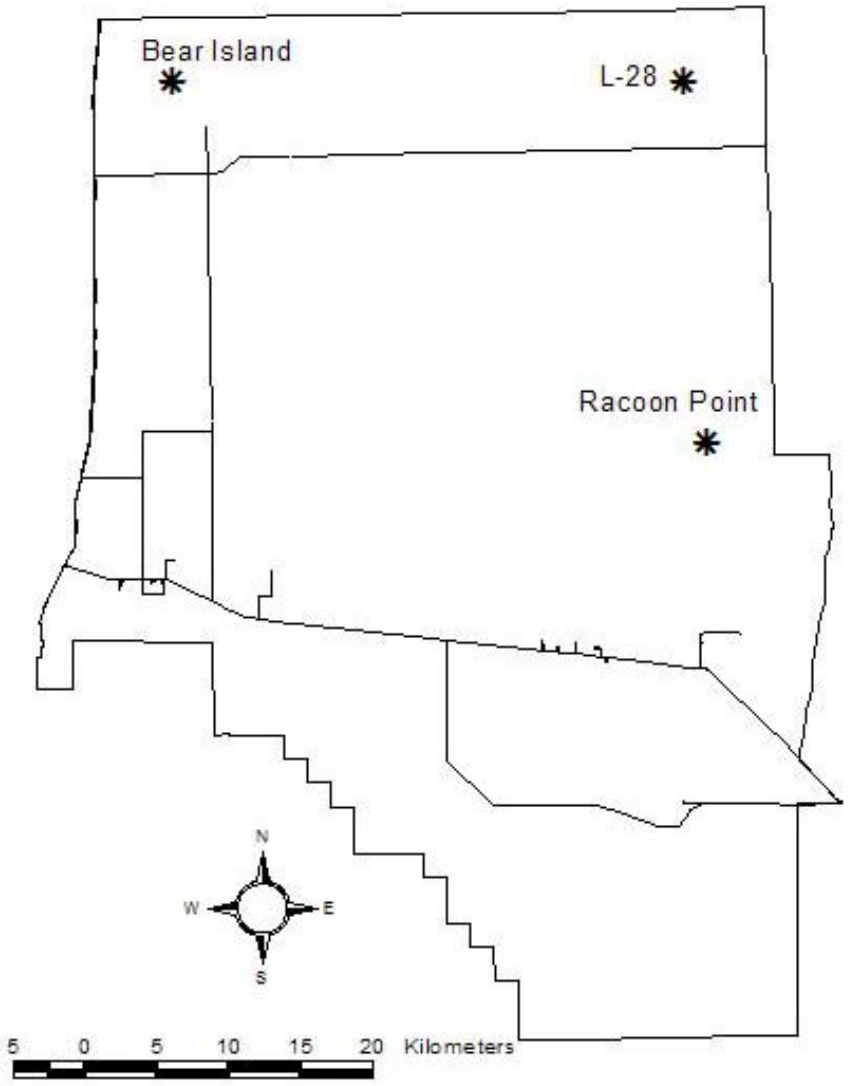



Figure 3: BCNP long-term fish research locations.

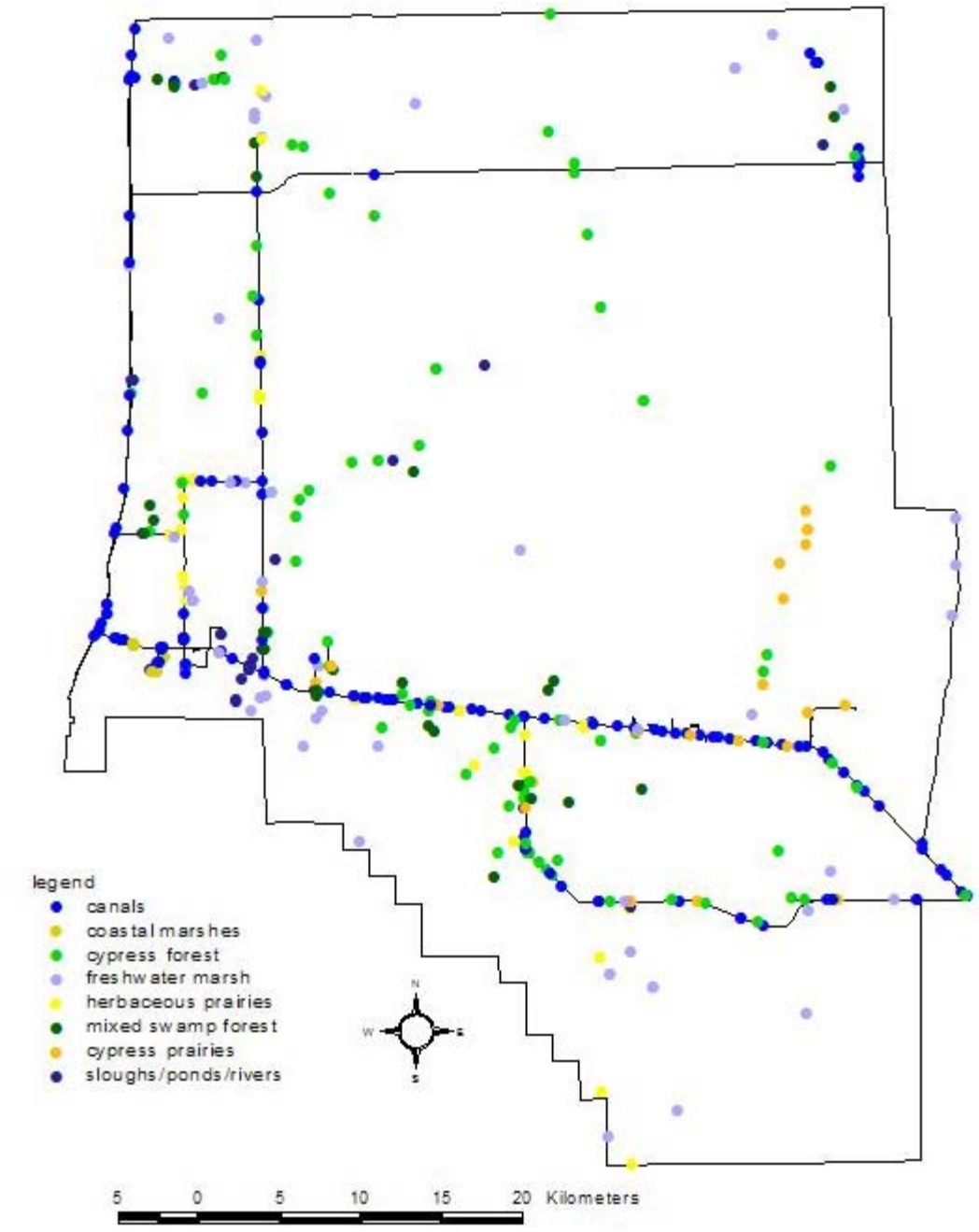
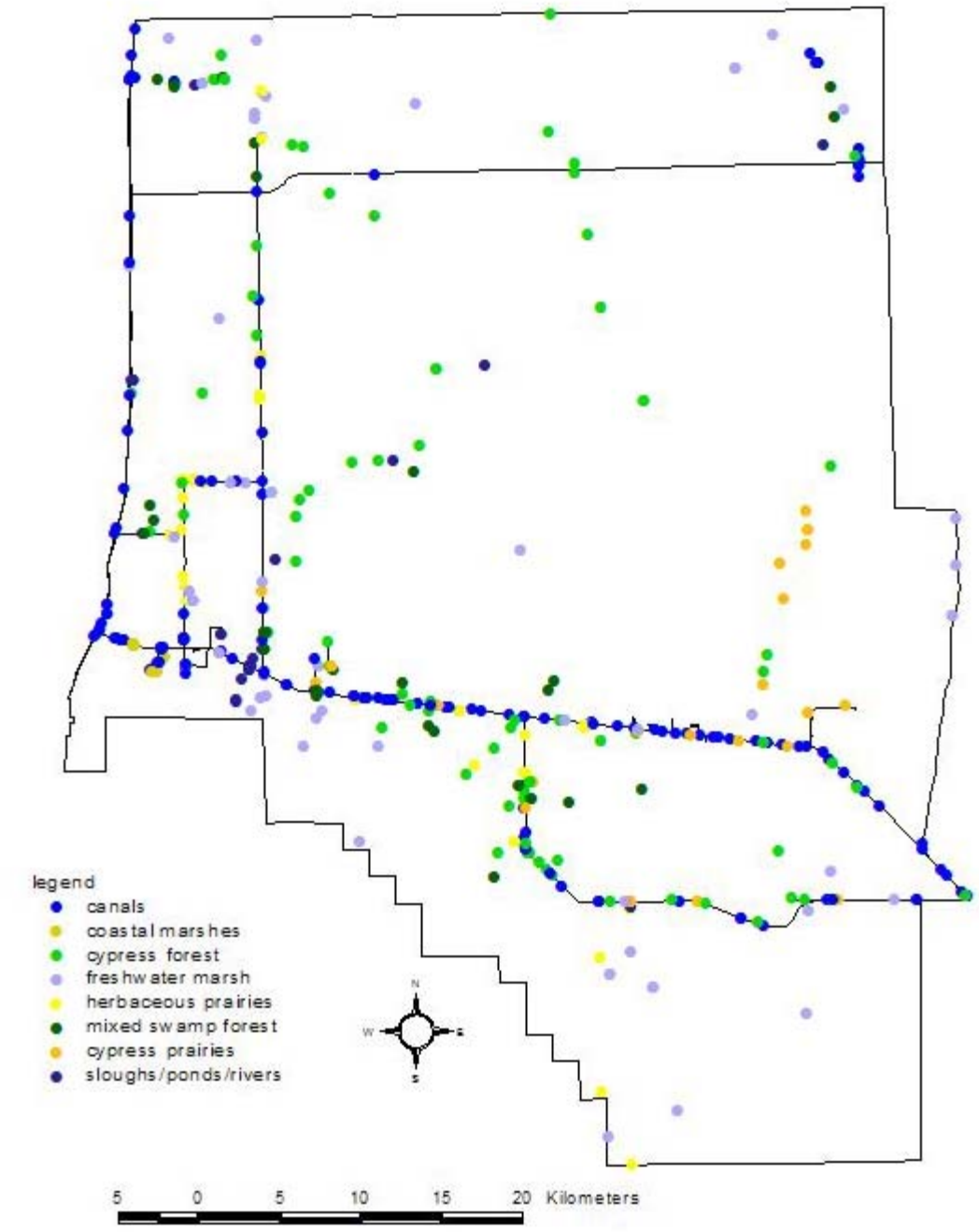


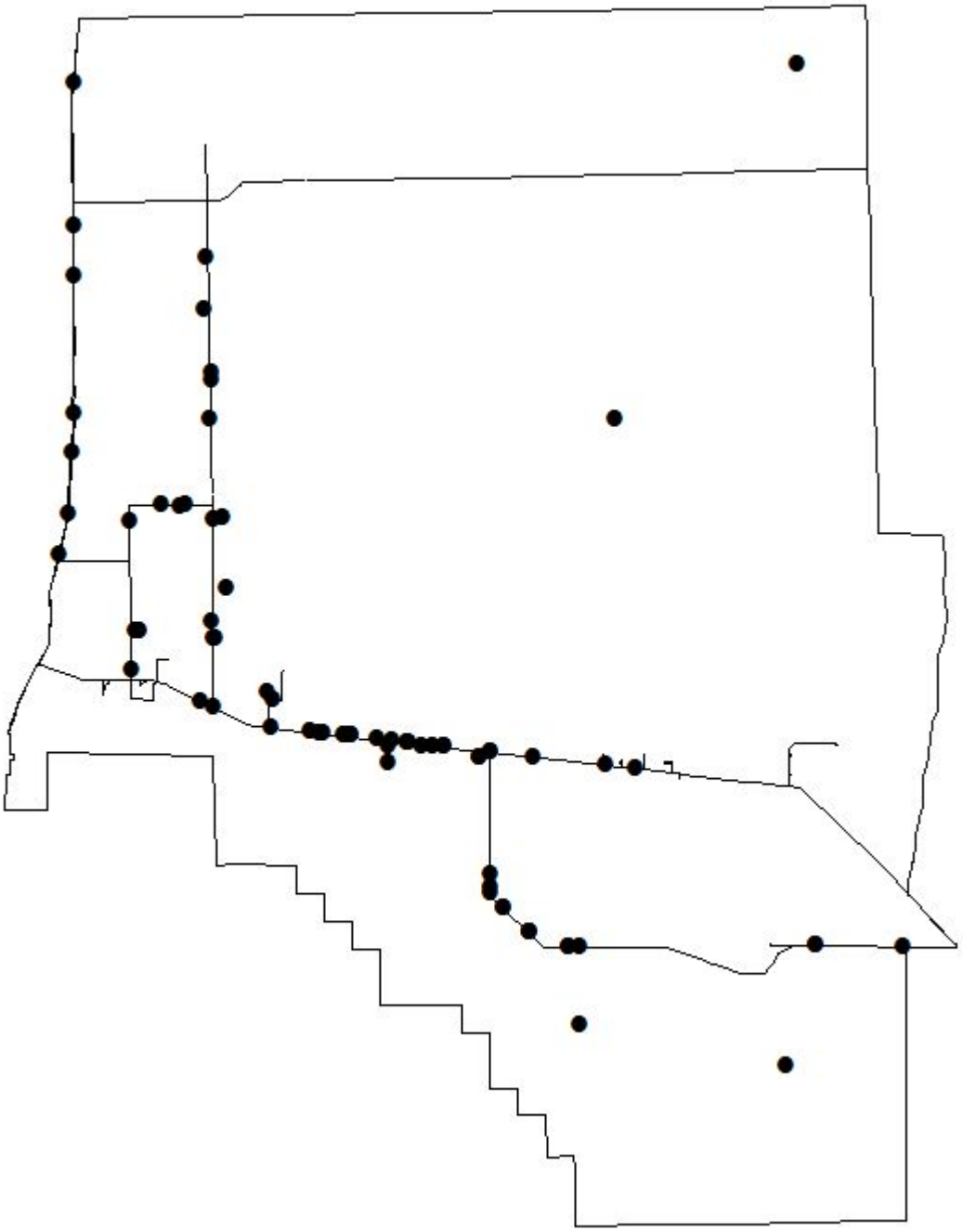

Figure 4: BCNP fish I & M sampling locations, 10/02-10/03, by habitat type.

## APPENDIX 1: SPECIES DISTRIBUTION MAPS, BCNP FISH I & M PROJECT, 2002-2004

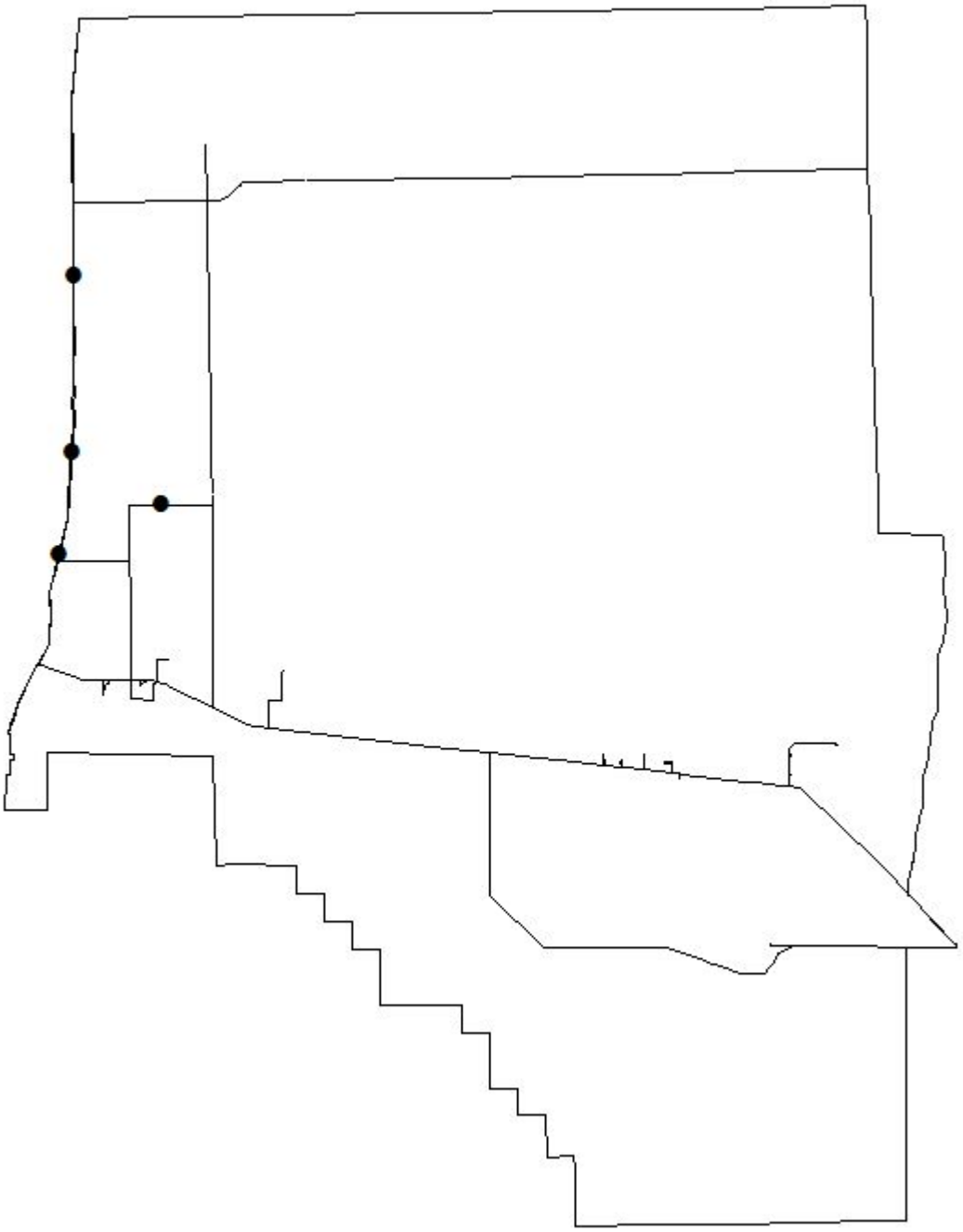
This appendix contains maps showing locations where individuals of each species were recorded during the 2002-2004 sampling work. Since some sampling methods may have missed individuals of certain species, absence from a sample at a given location does not guarantee absence from that location. The first map shows a complete list of BCNP sampling sites. Subsequent maps are presented alphabetically by species name. The page number by common name for each species is as follows:



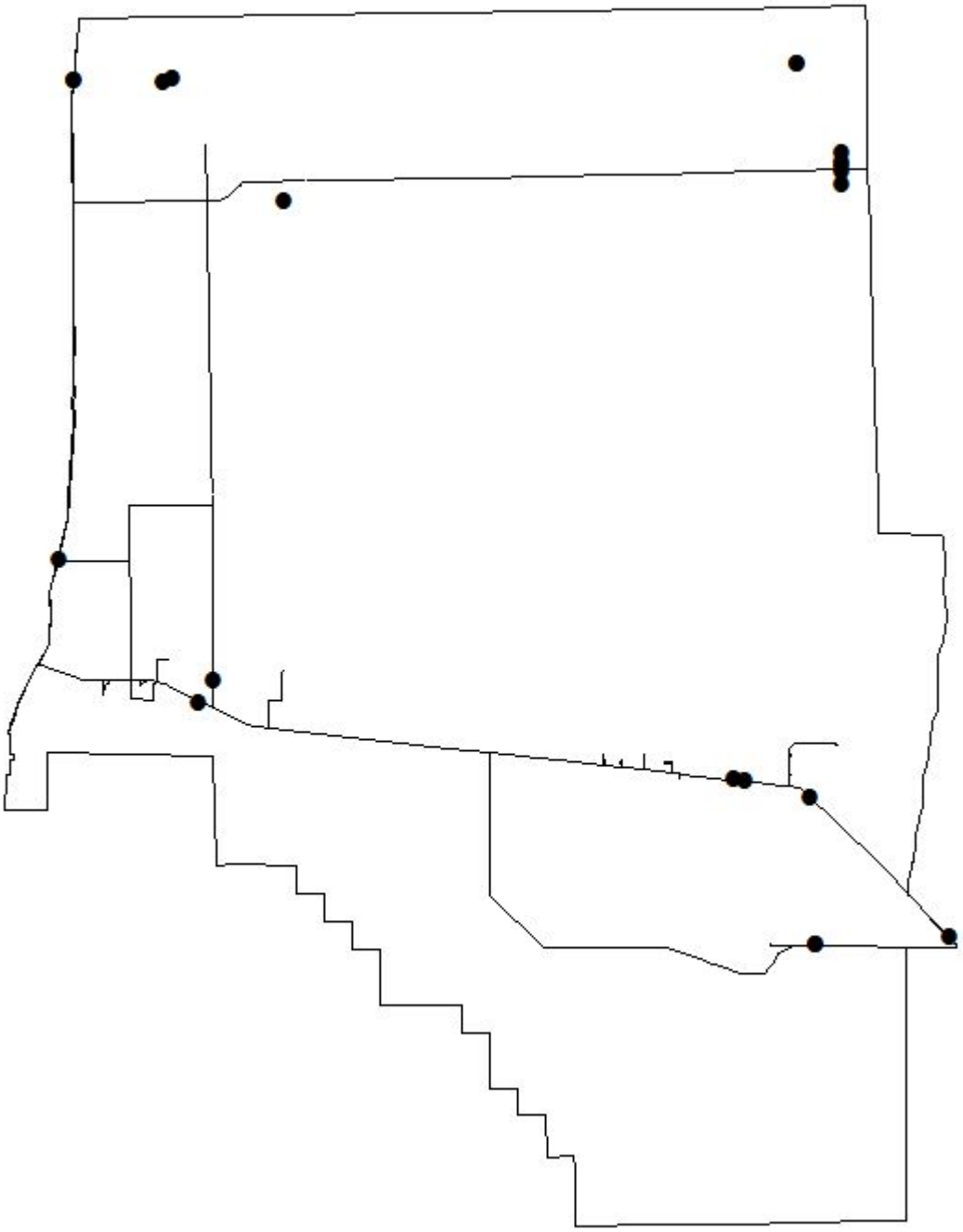

BCNP fish I & M sampling locations, by habitat type (Figure 4 from text).



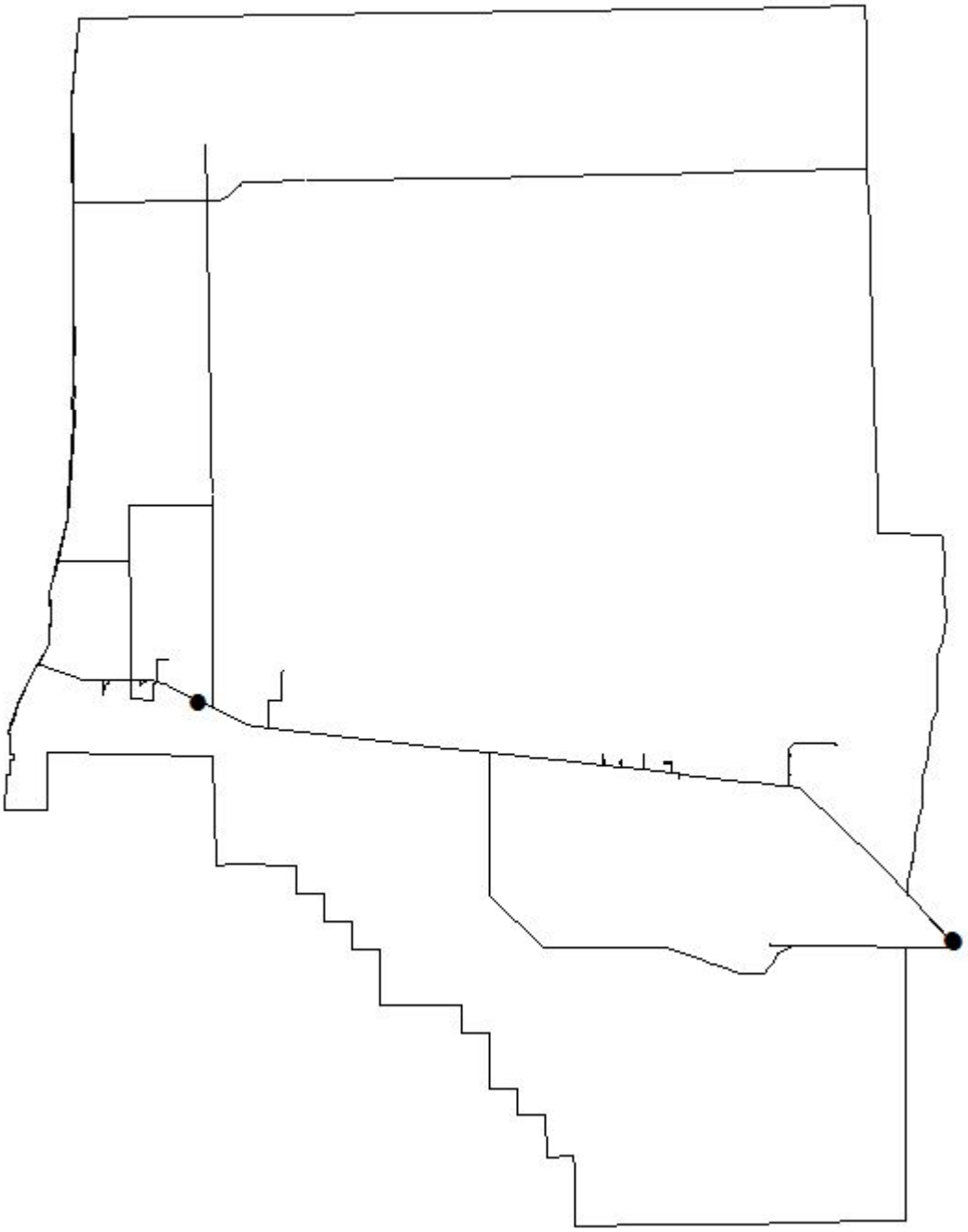
Distribution of Yellow Bullhead, *Ameiurus natalis.*



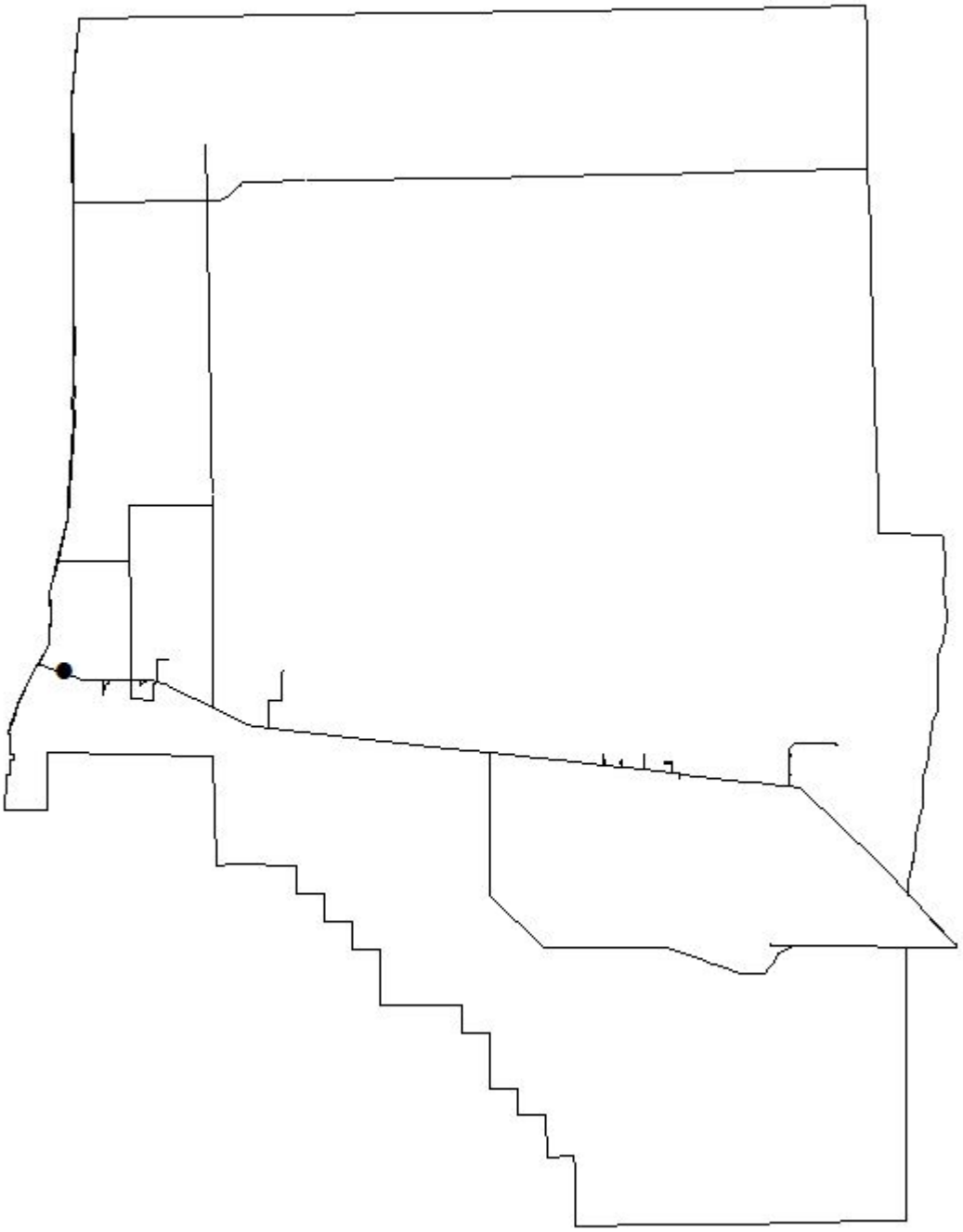
Distribution of Brown Bullhead, *Ameiurus nebulosus.*



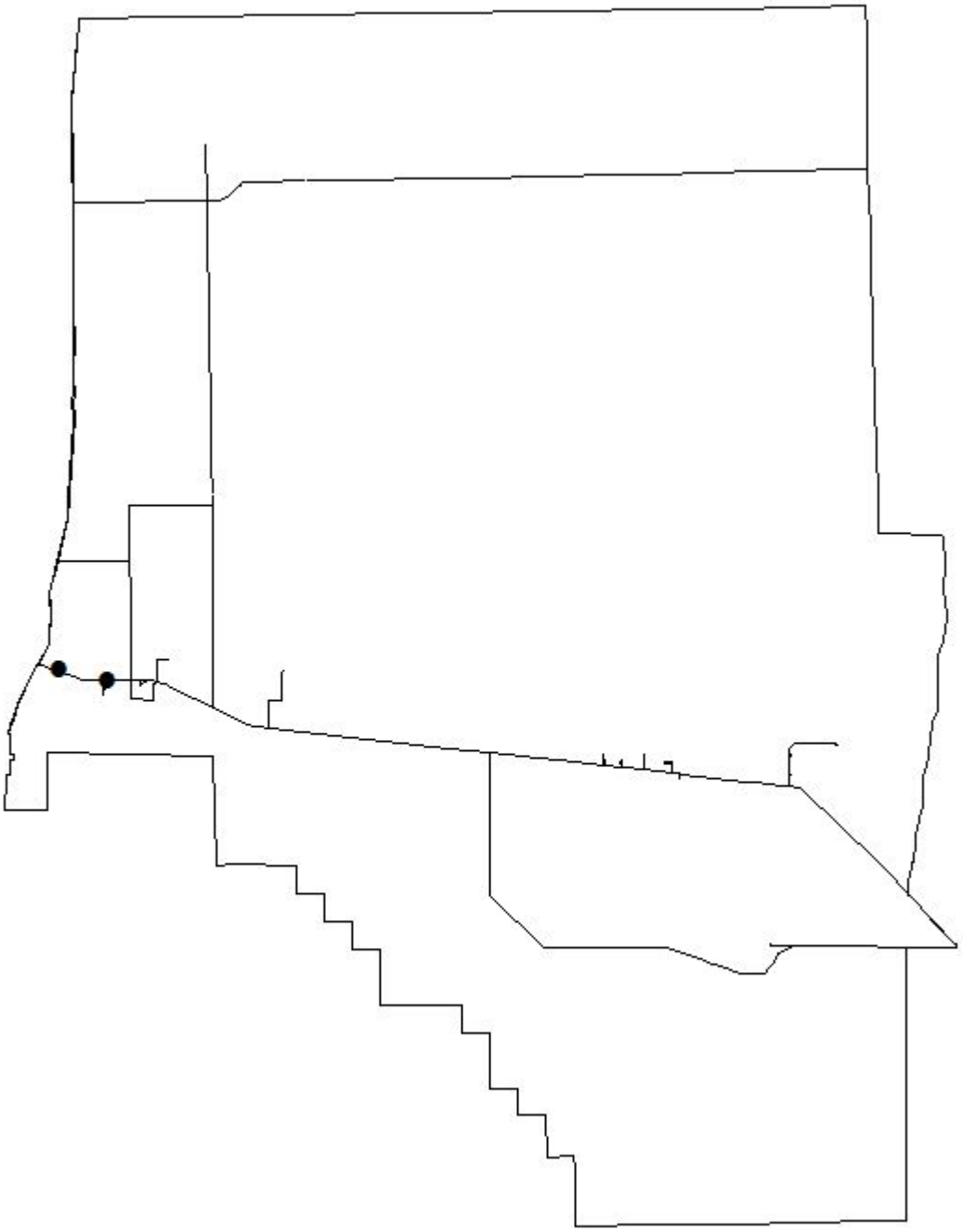
Distribution of Bowfin, *Amia calva.*



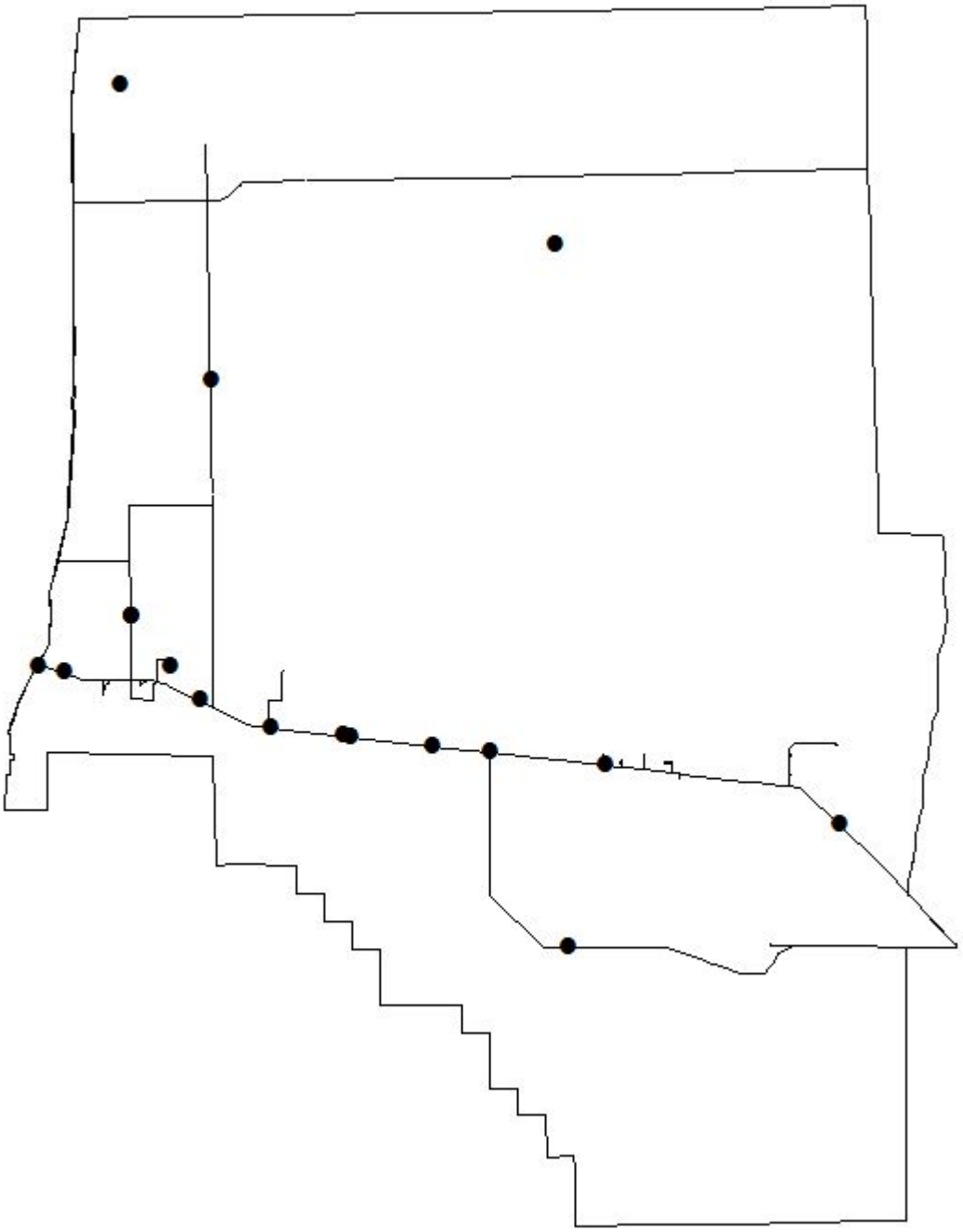
Distribution of American Eel, *Anguilla rostrata*.



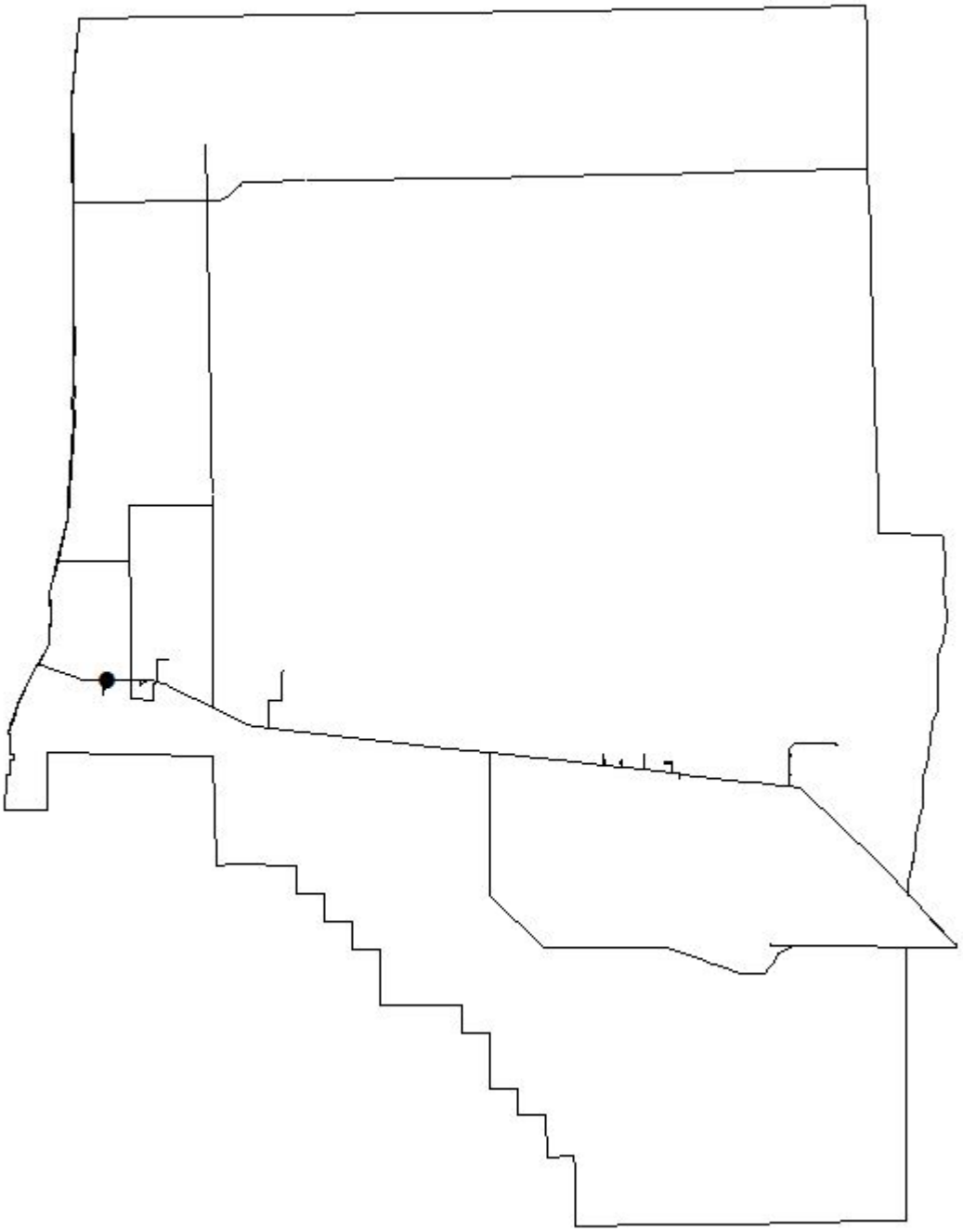
Distribution of Sheepshead, *Archosargus probatocephalus.*



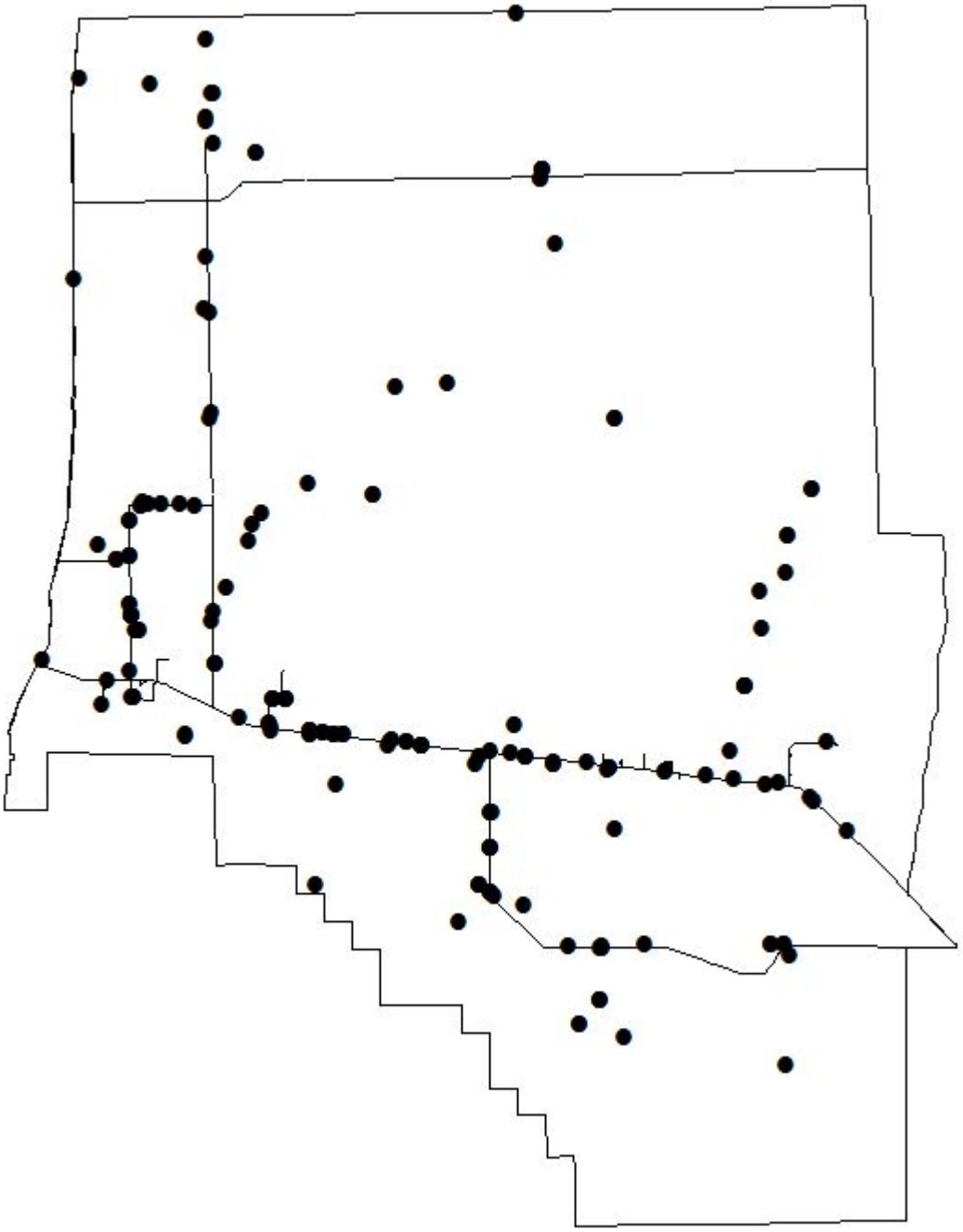
Distribution of Hardhead Catfish, *Arius felis.*



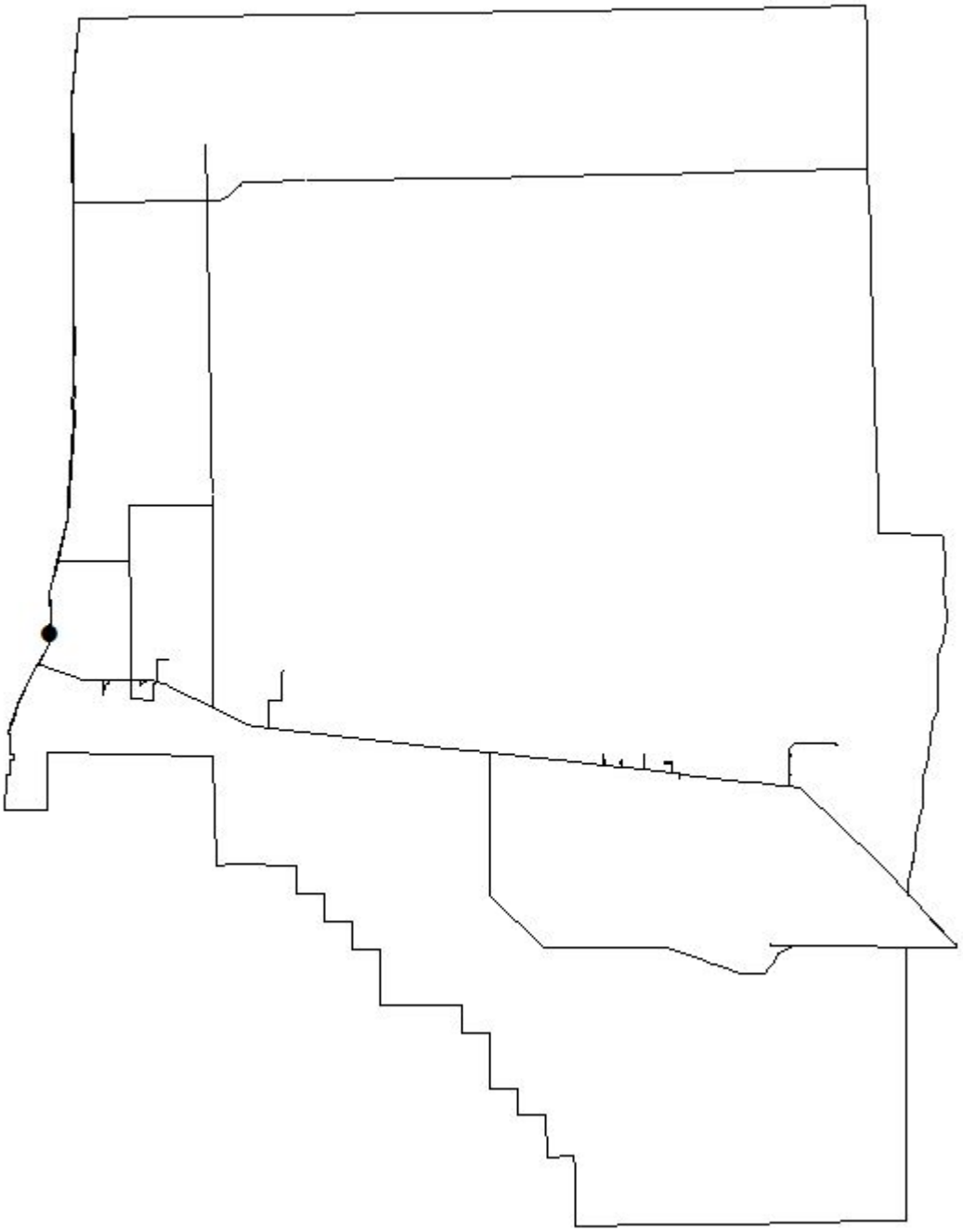
Distribution of Oscar, *Astronotus ocellatus.*



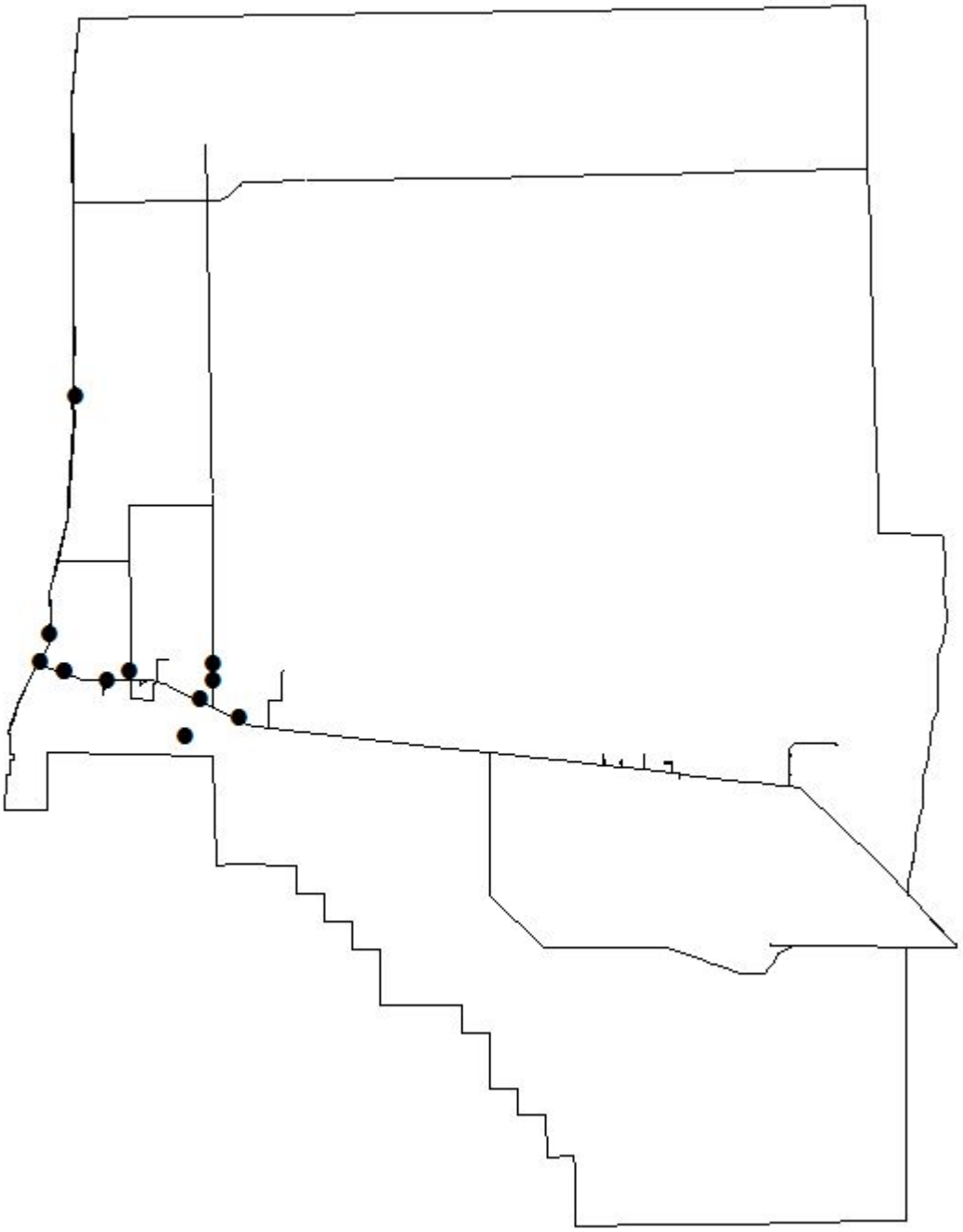
Distribution of Frillfinned Goby, *Bathygobius soporator*.



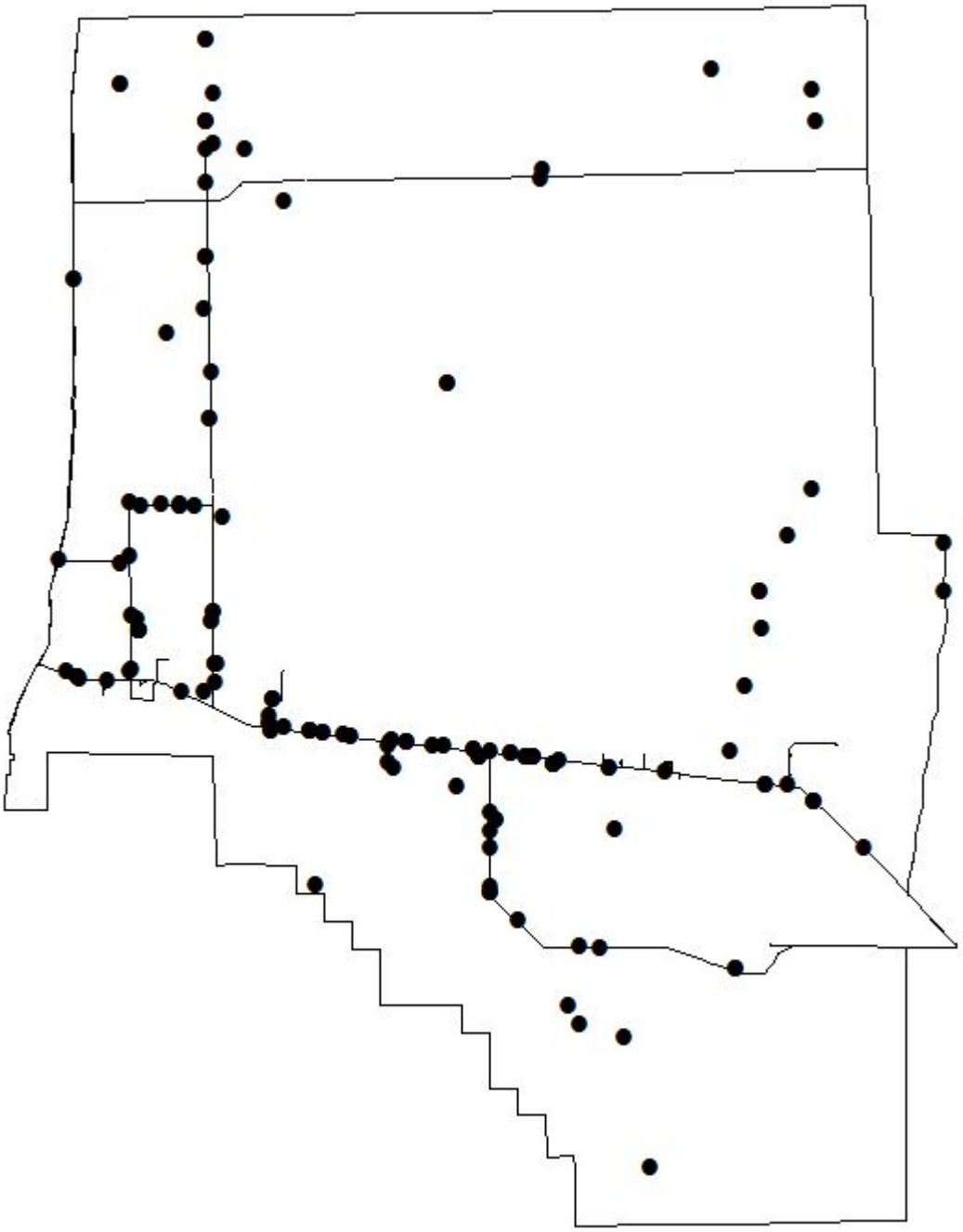
Distribution of Pike Killifish, *Belonesox belizanus.*



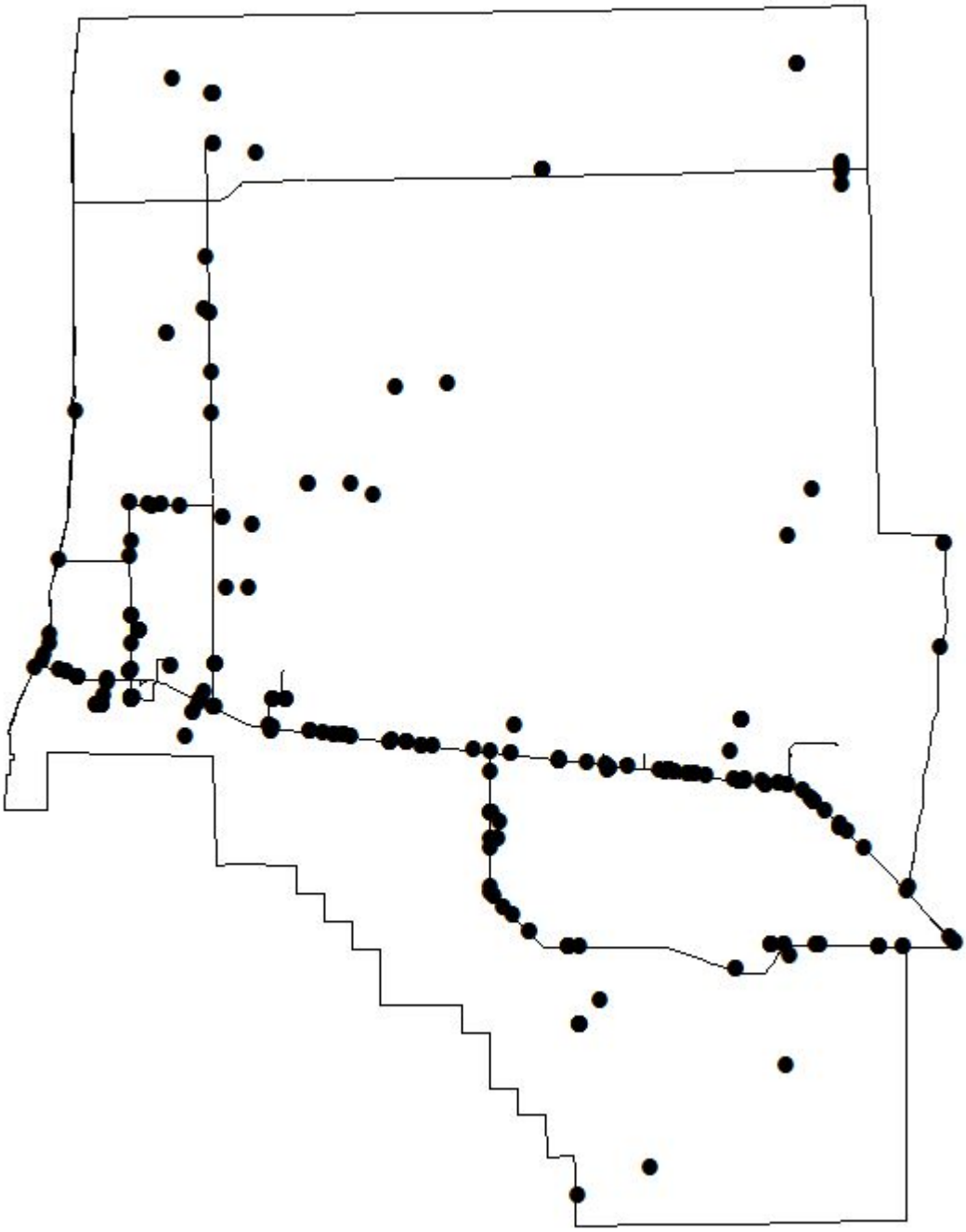
Distribution of Crevalle Jack, *Caranx hippos.*



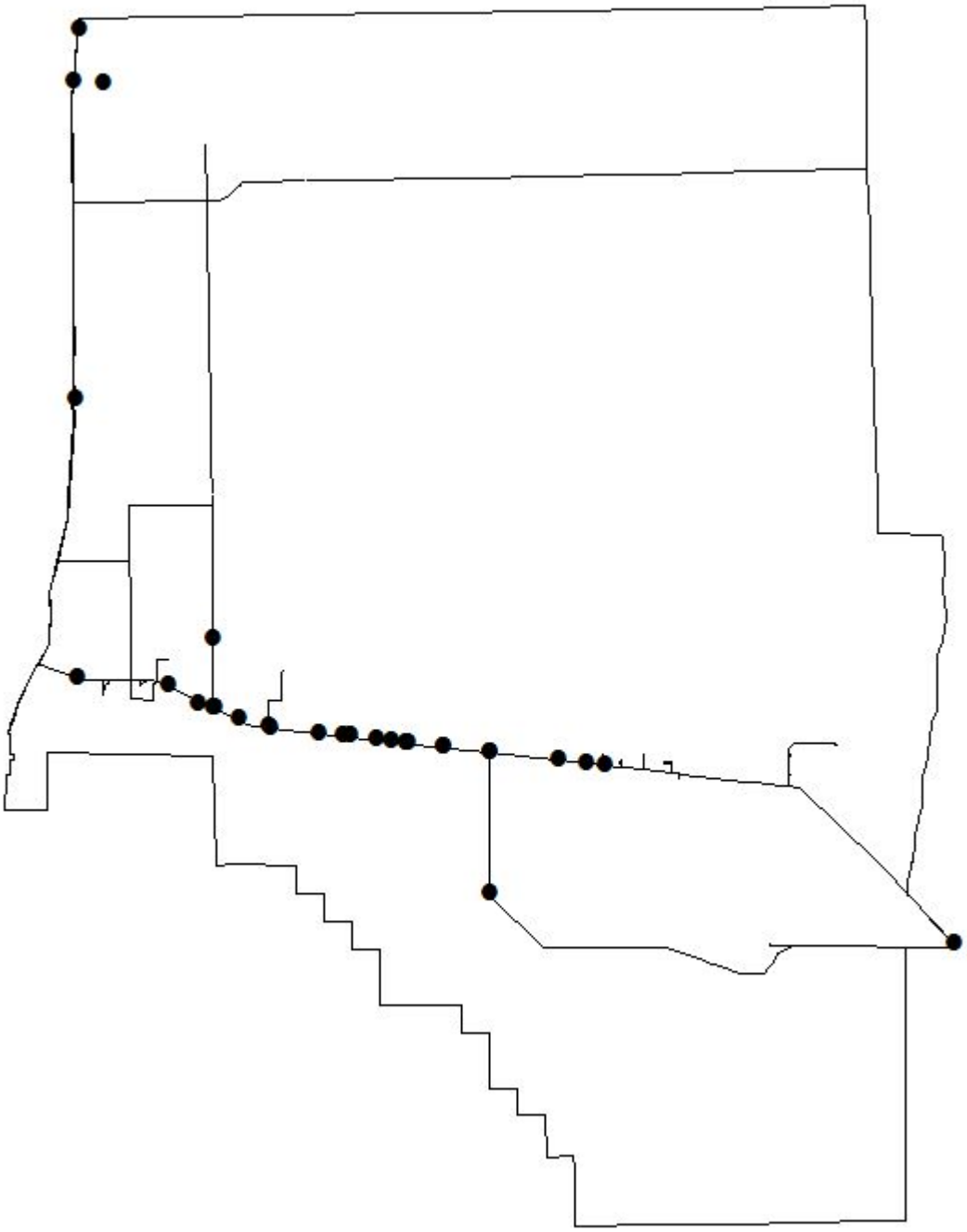
Distribution of Common Snook, *Centropomus undecimalis.*



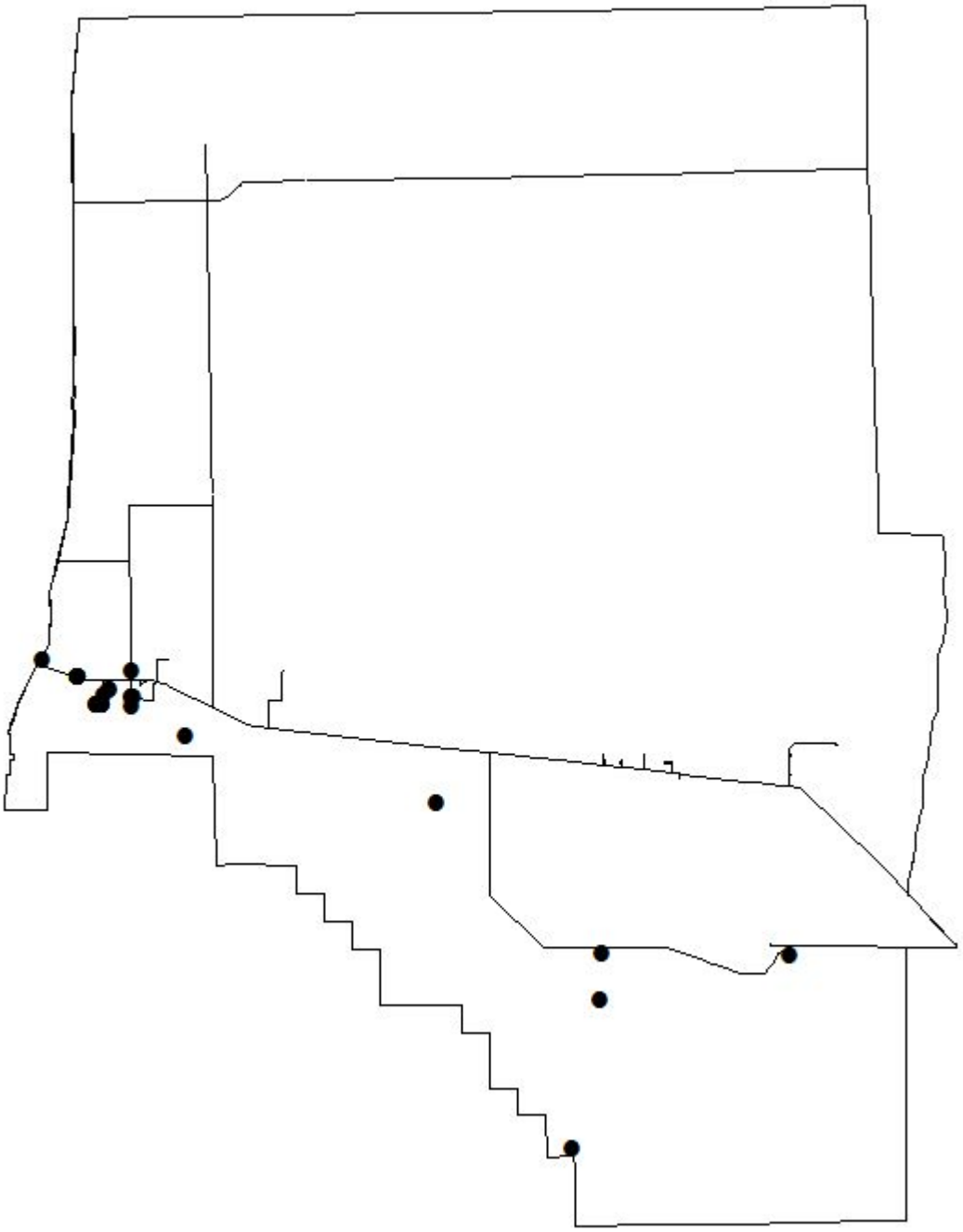
Distribution of Black Acara, *Cichlasoma bimaculatum.*



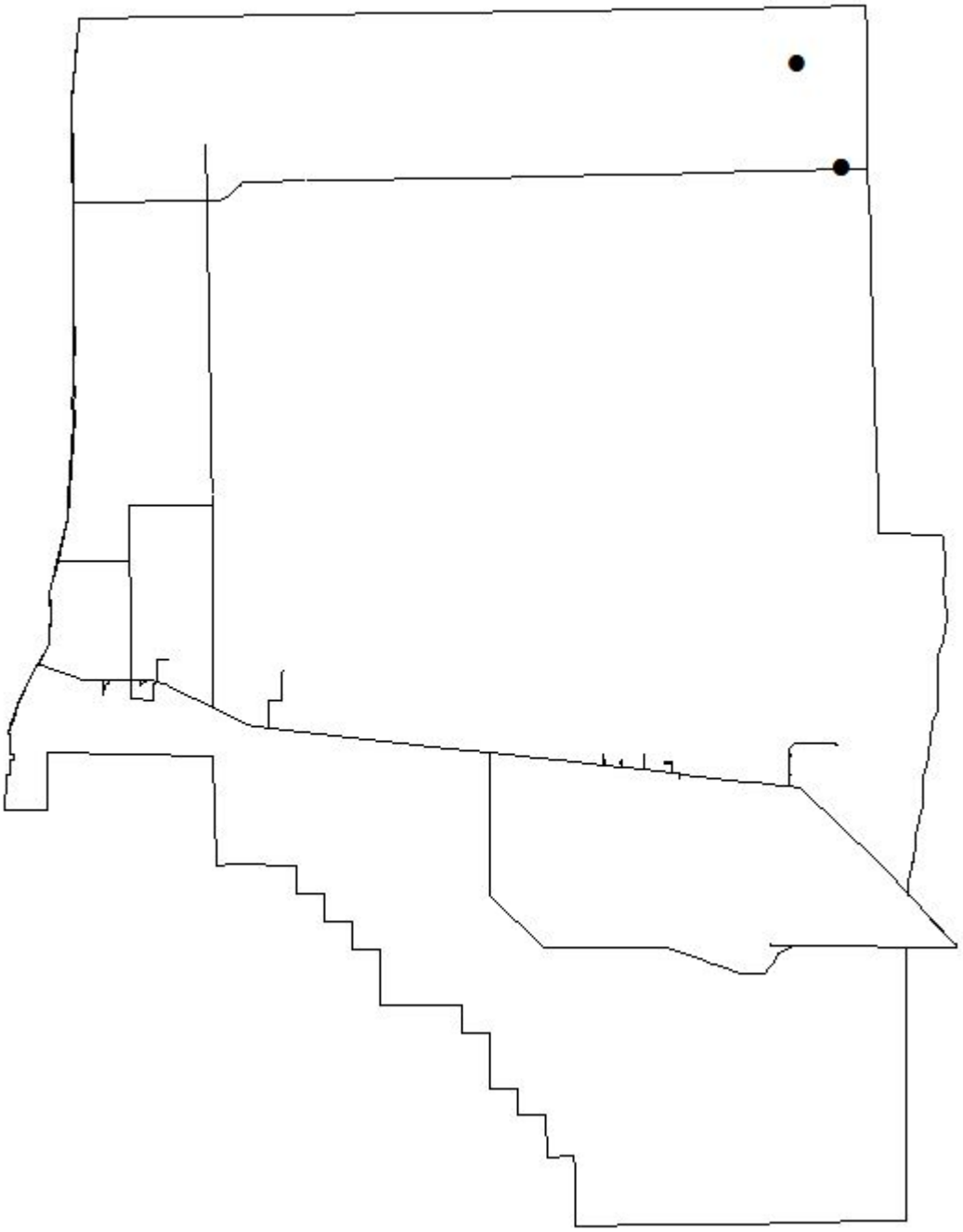
Distribution of Mayan Cichlid, *Cichlasoma urophthalmus.*



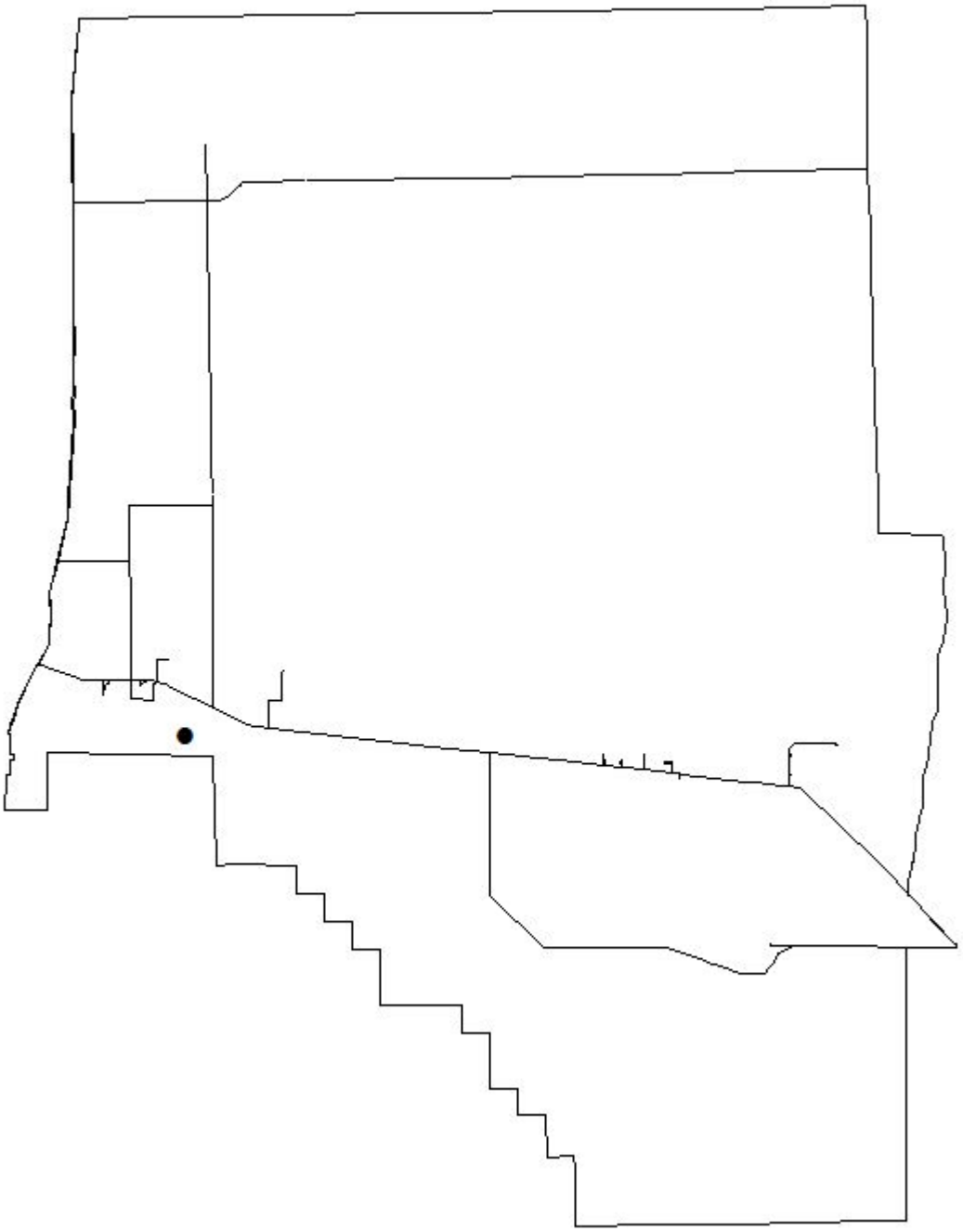
Distribution of Walking Catfish, *Clarias batrachus.*



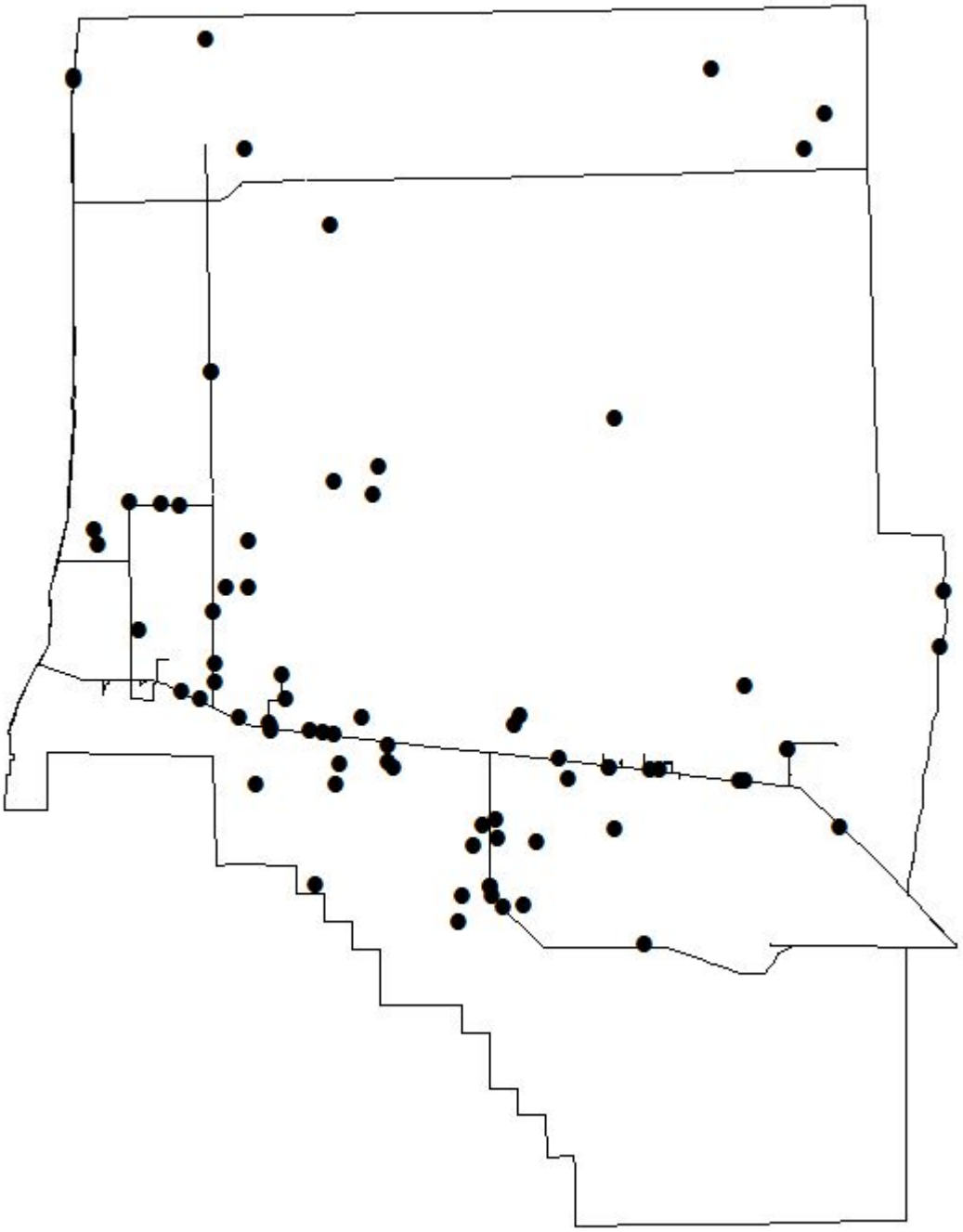
Distribution of Sheepshead Minnow, *Cyprinodon variegates.*



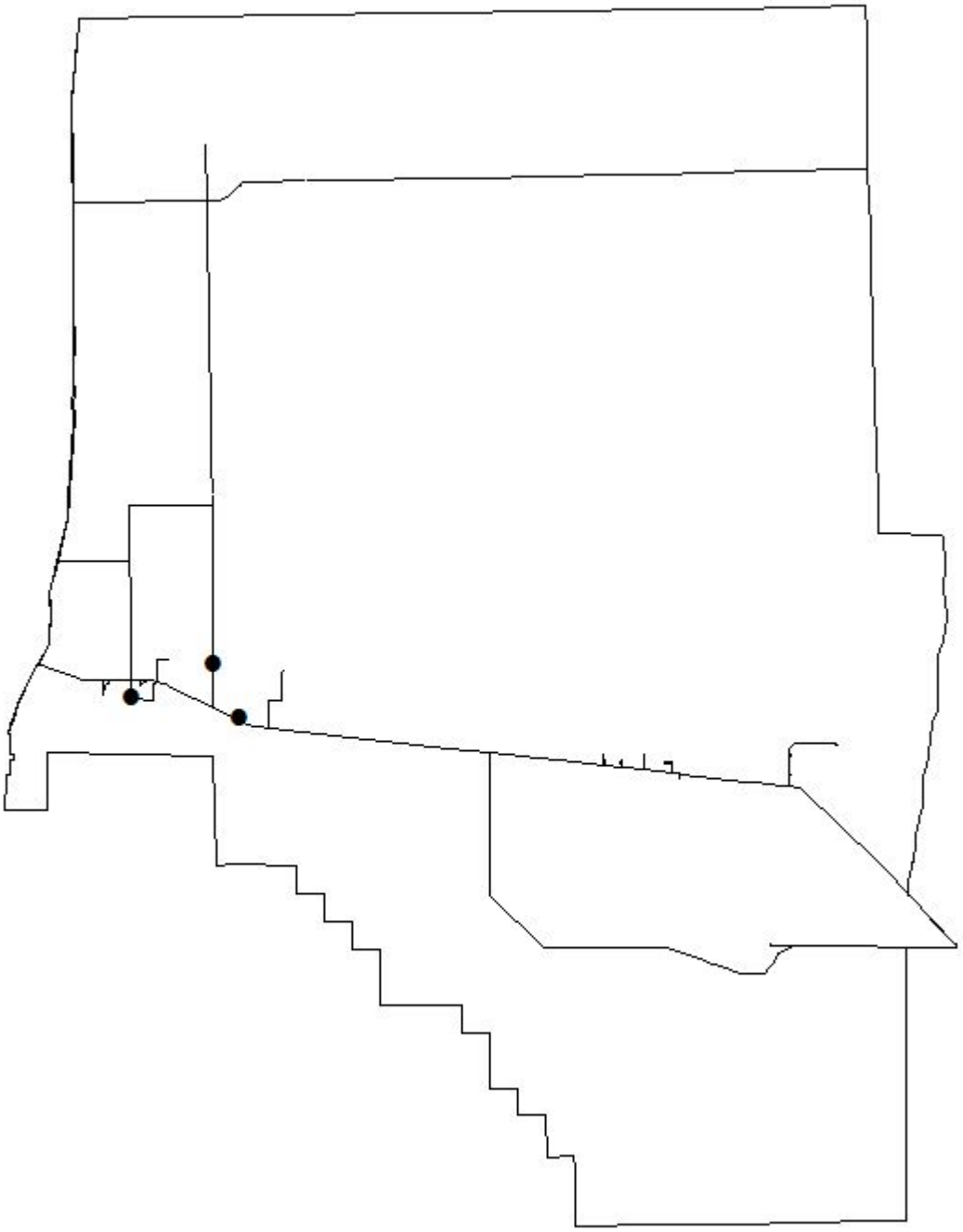
Distribution of American Gizzard Shad, *Dorosoma cepedianum.*



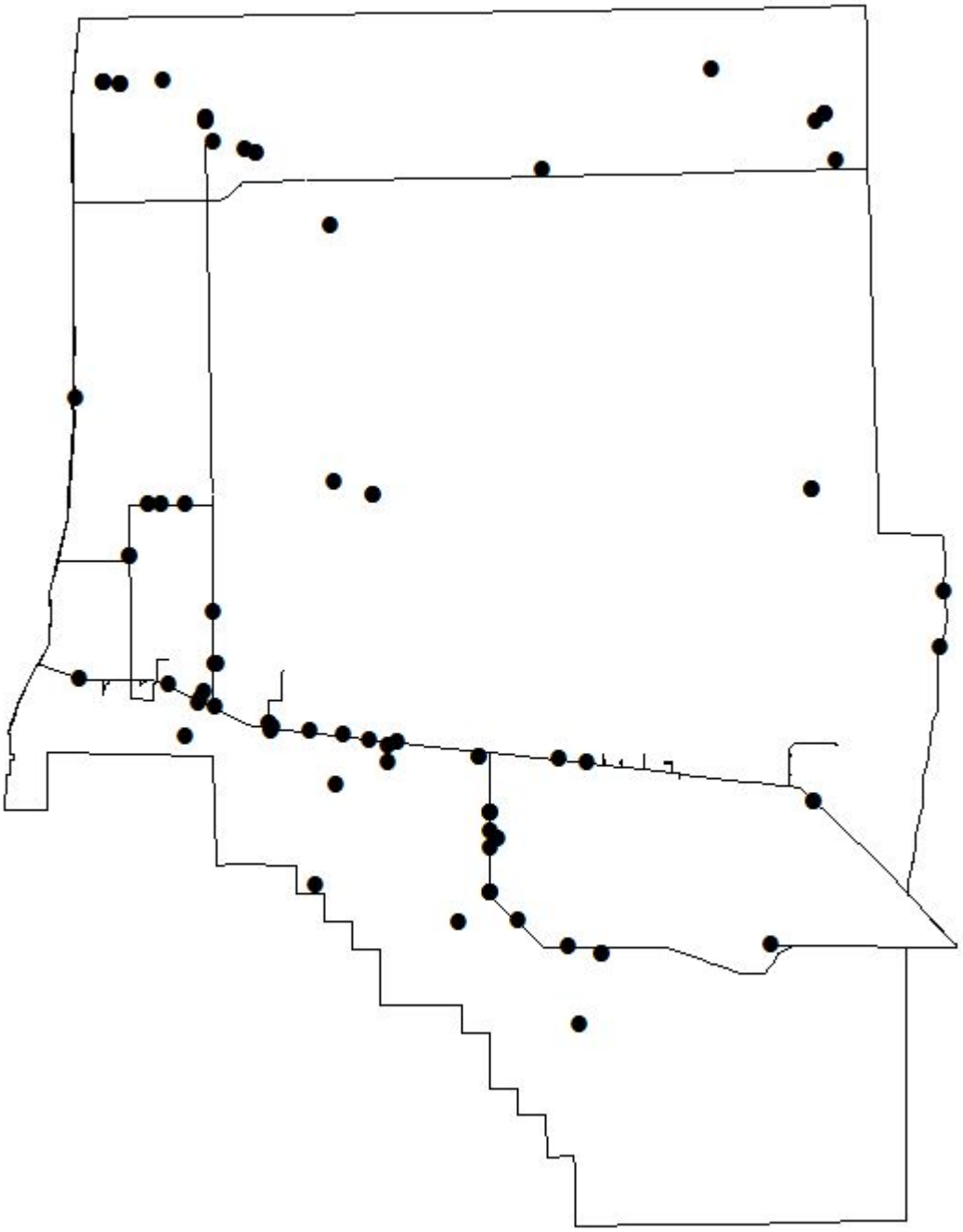
Distribution of Sharksucker, *Echeneis naucrates.*



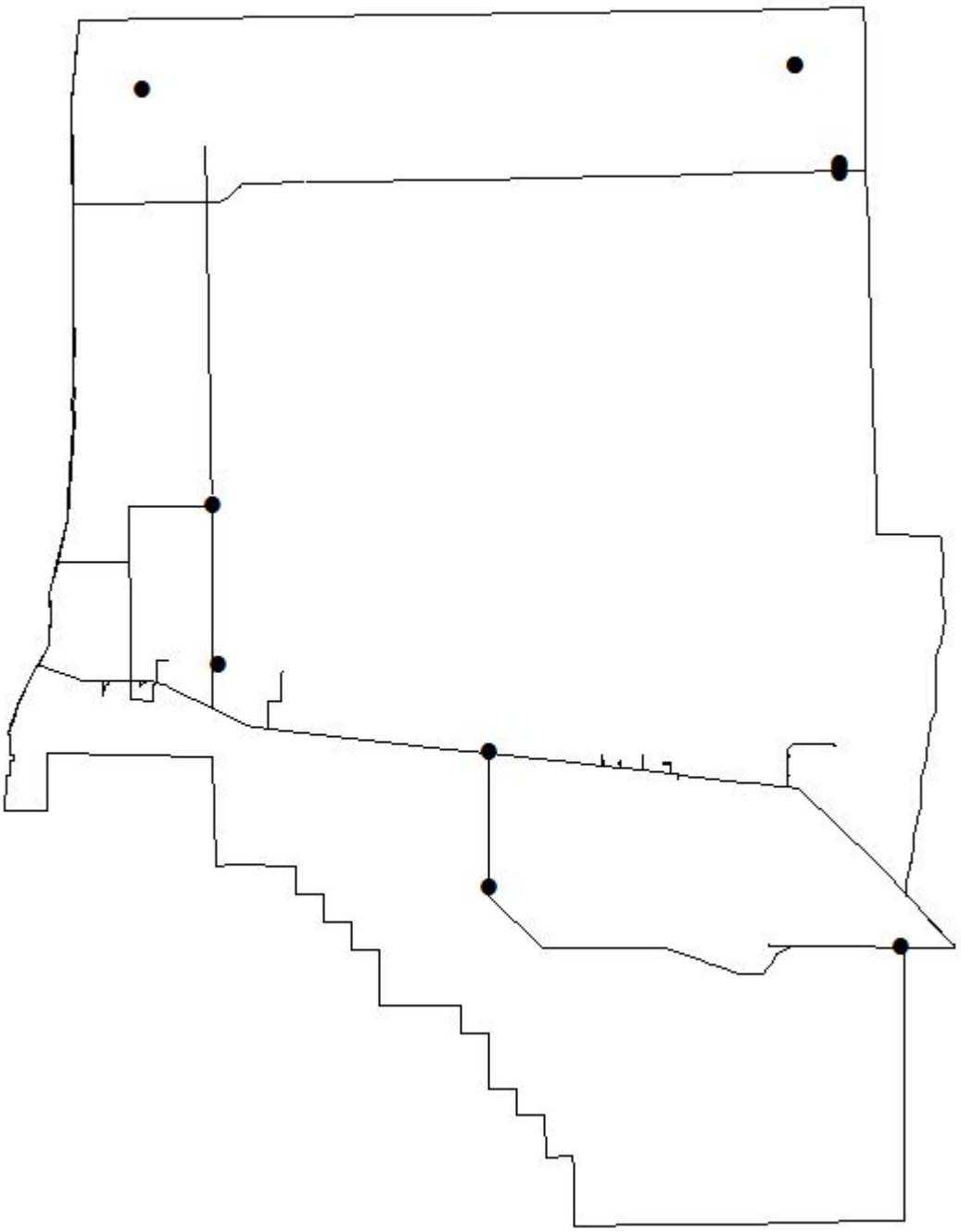
Distribution of Everglades Pigmy Sunfish, *Elassoma evergladei.*



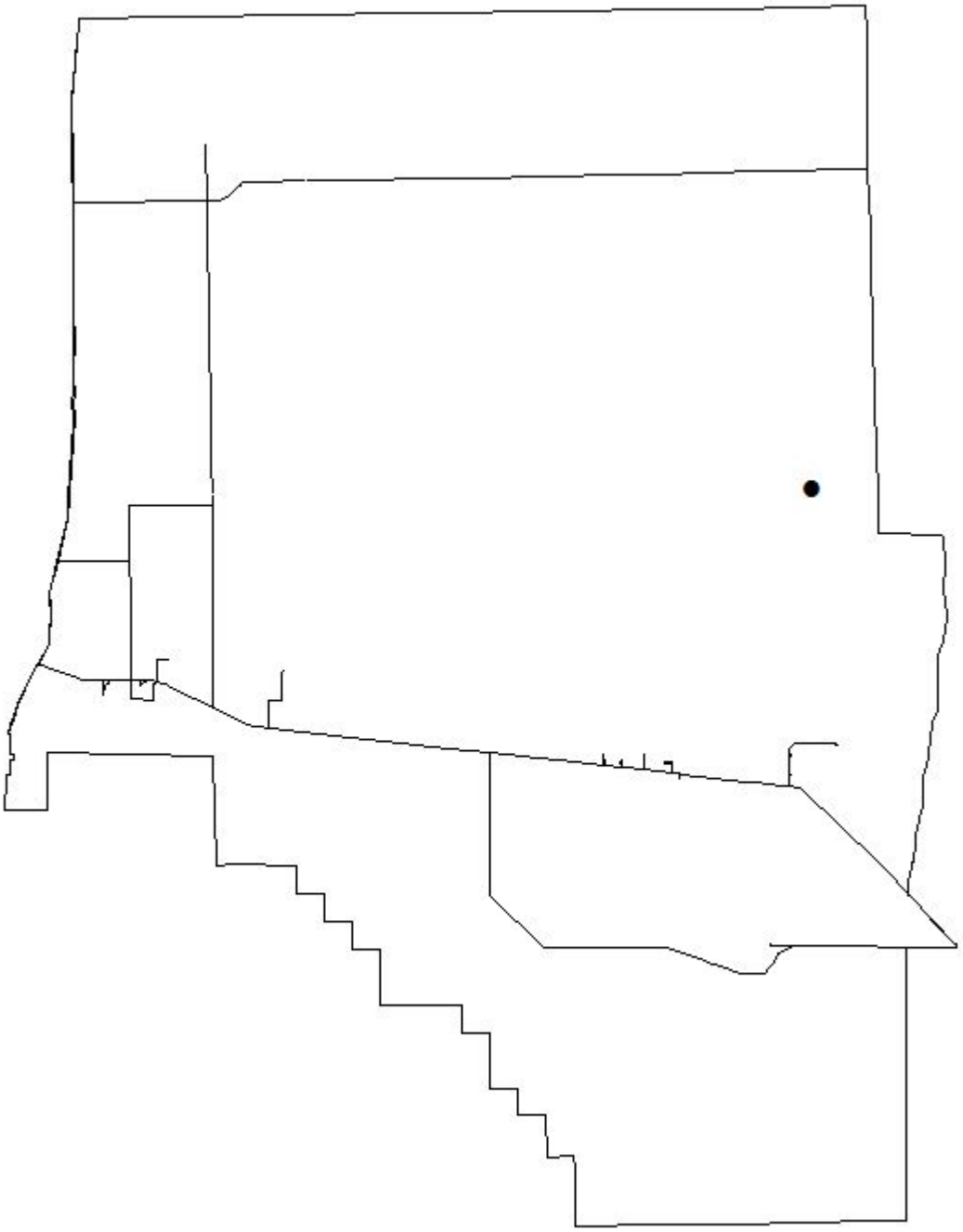
Distribution of Ladyfish, *Elops saurus.*



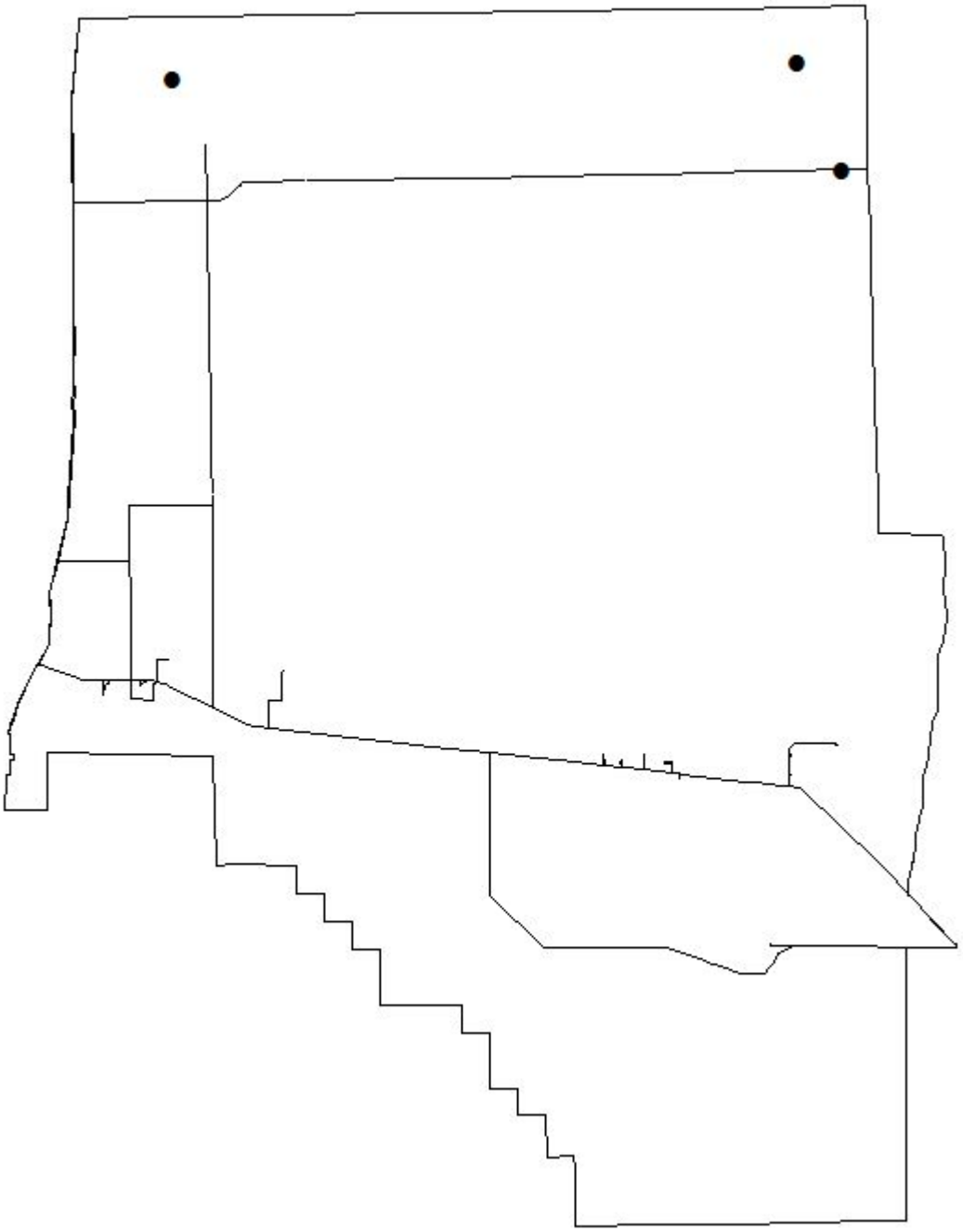
Distribution of Bluespotted Sunfish, *Enneacanthus gloriosus.*



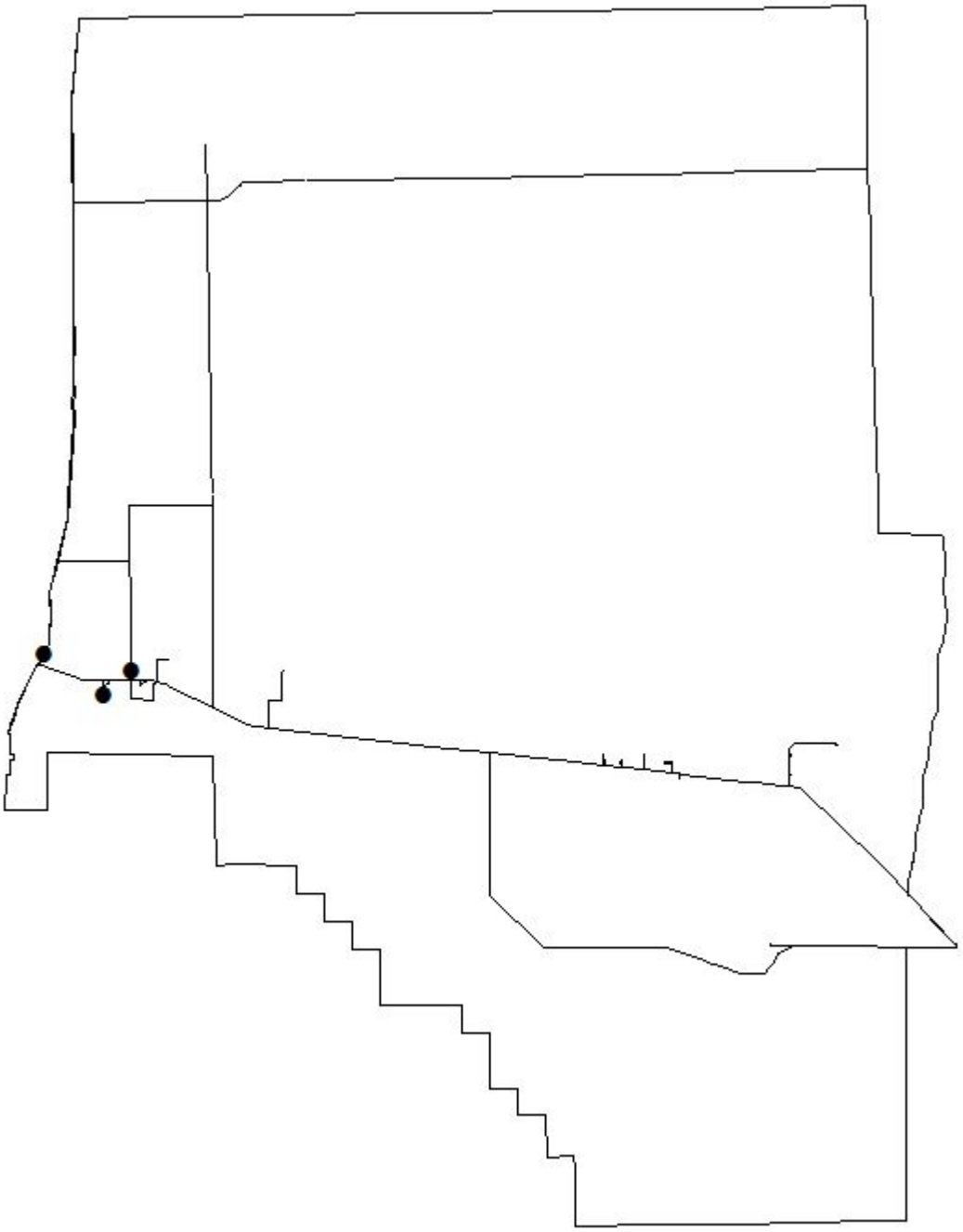
Distribution of Lake Chubsucker, *Erimyzon sucetta.*



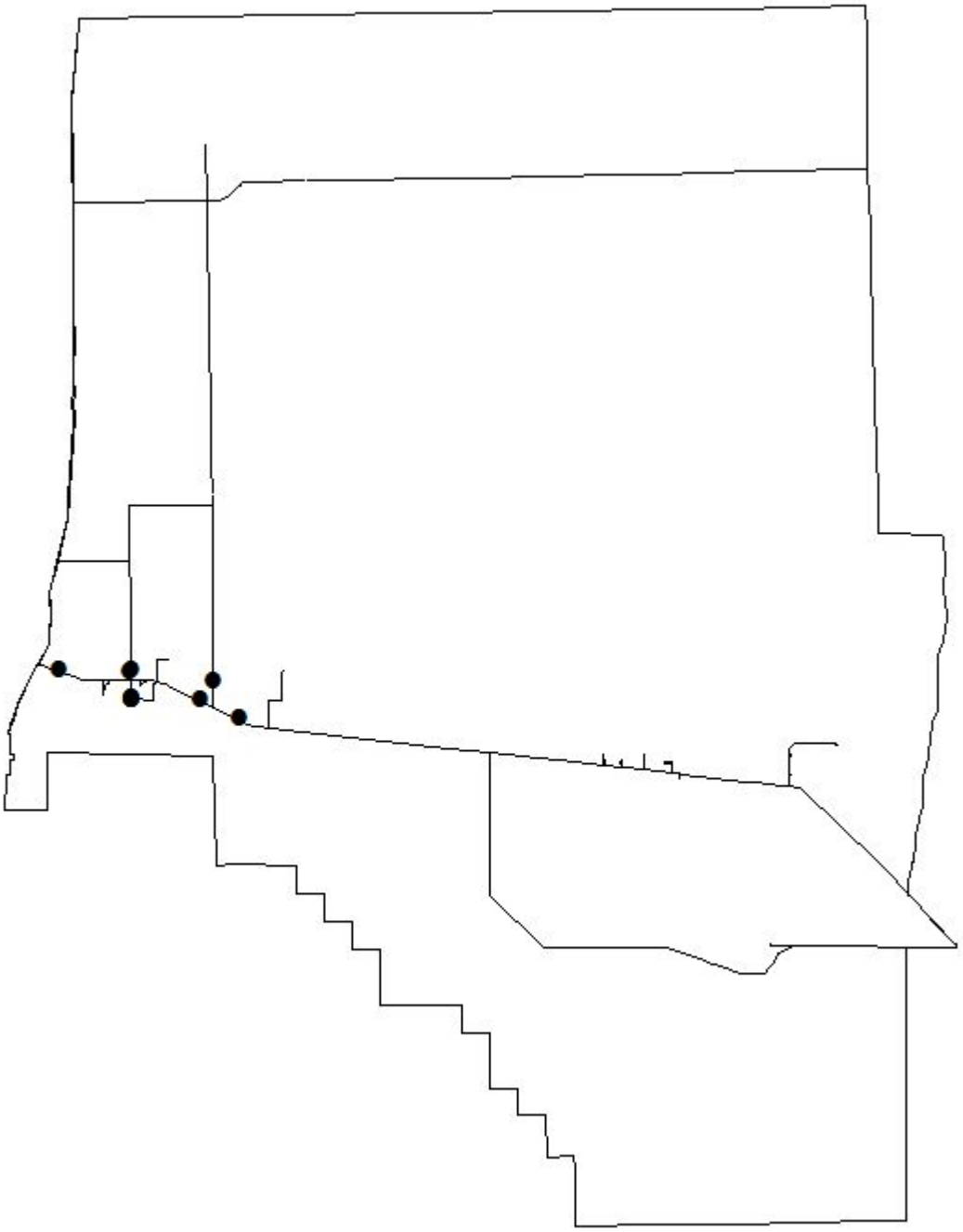
Distribution of Redfin Pickerel, *Esox americanus*.



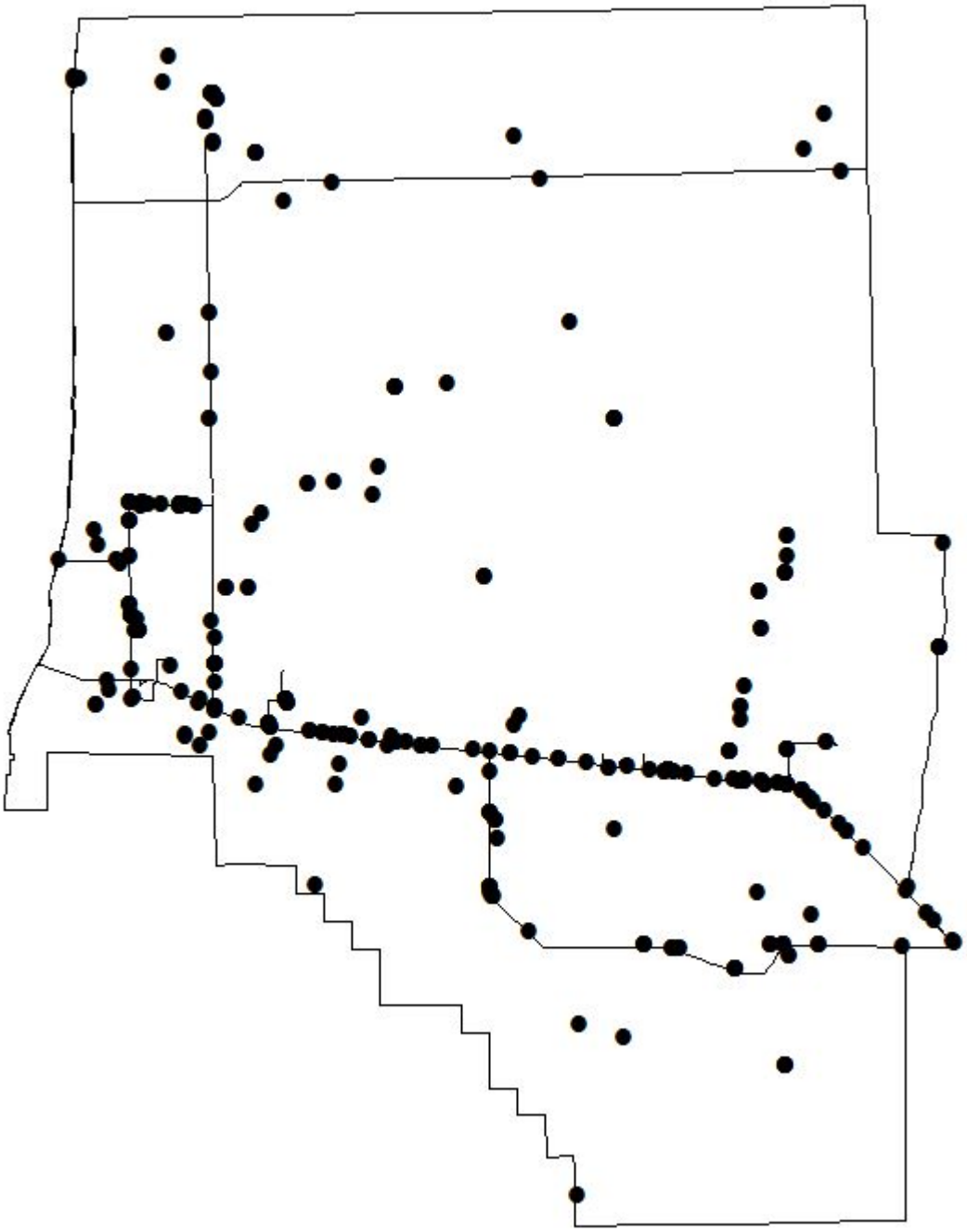
Distribution of Swamp Darter, *Etheostoma fusiforme*.



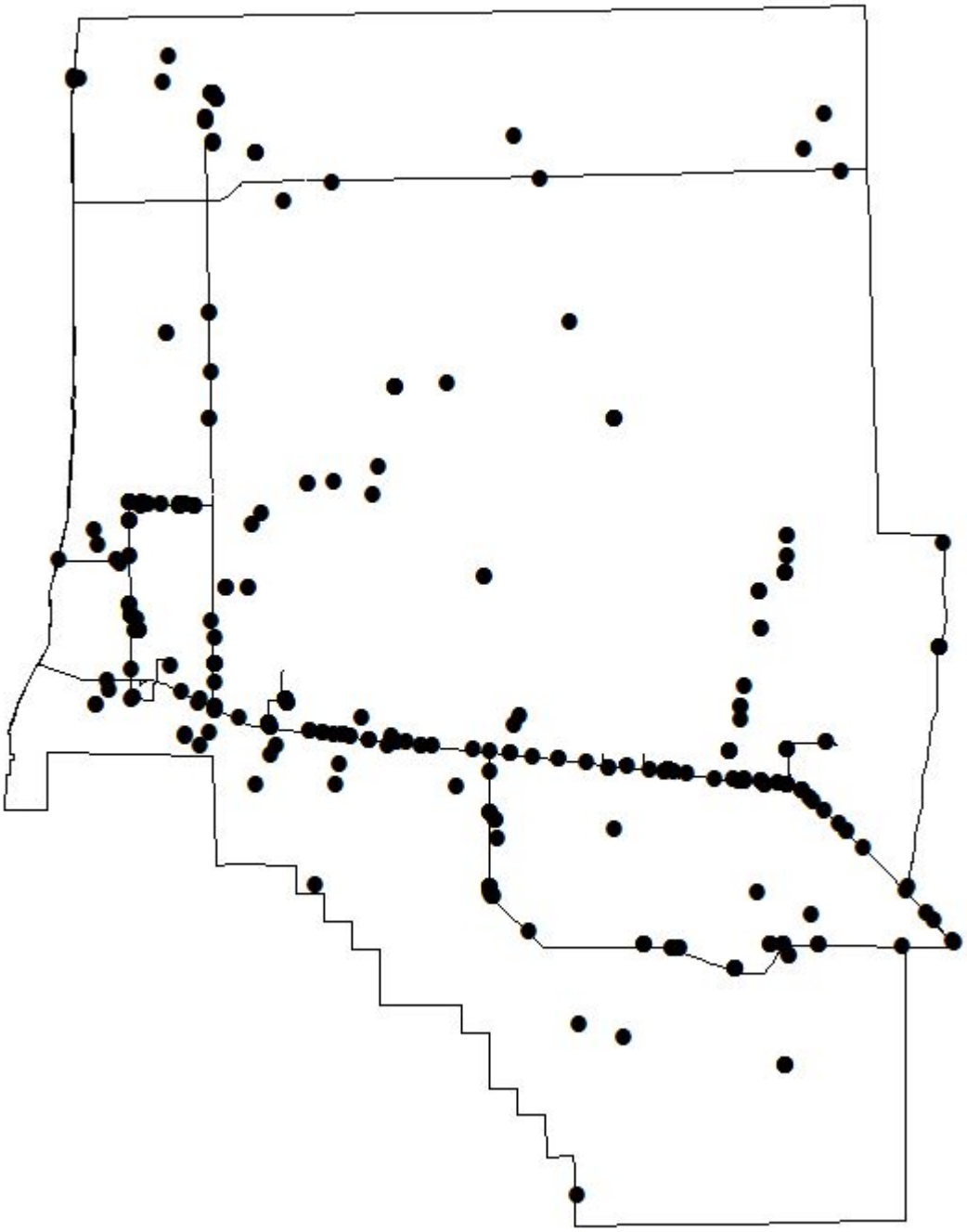
Distribution of Tidewater Mojarra, *Eucinostomus harengulus.*



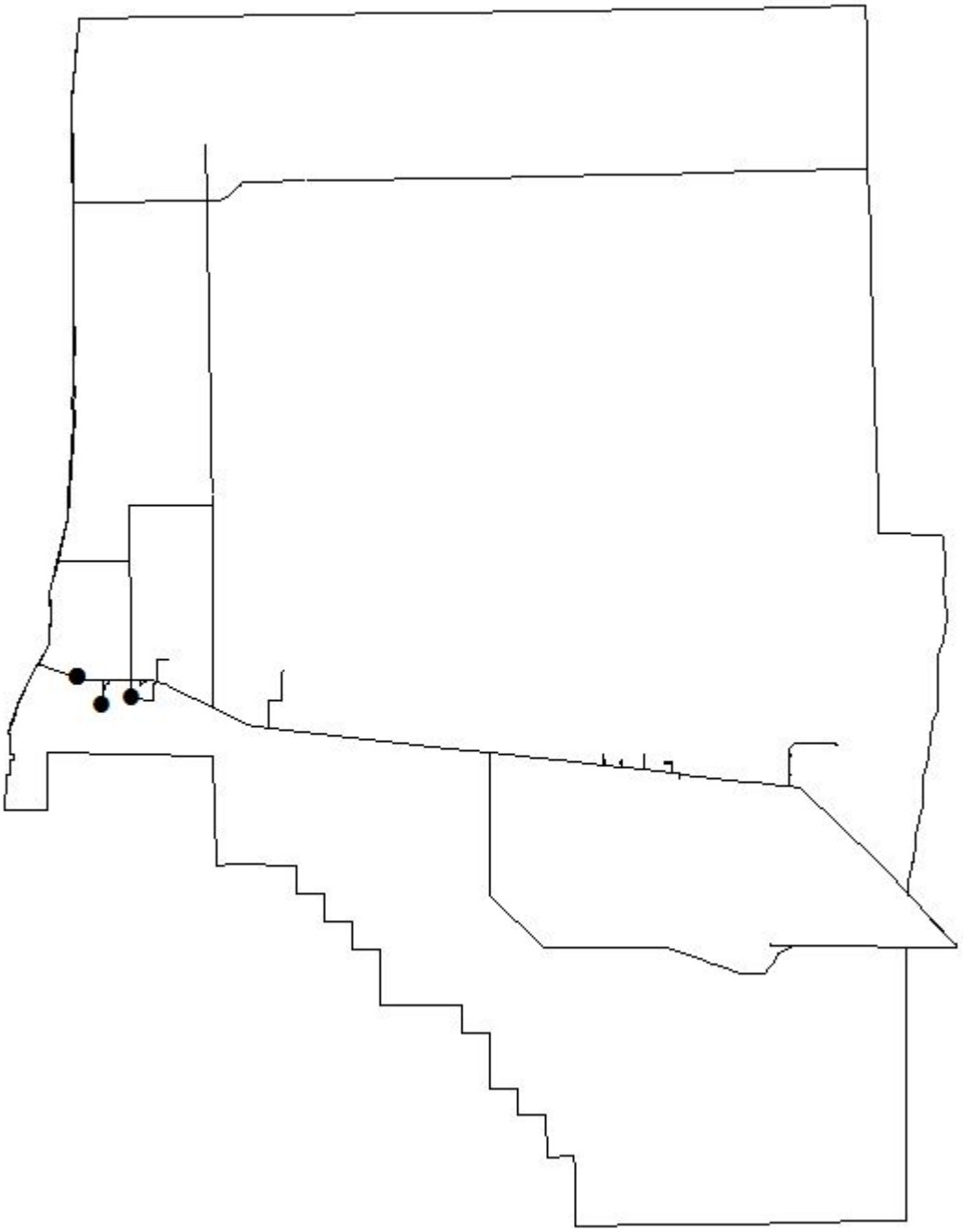
Distribution of Striped Mojarra, *Eucinostomus plumieri.*



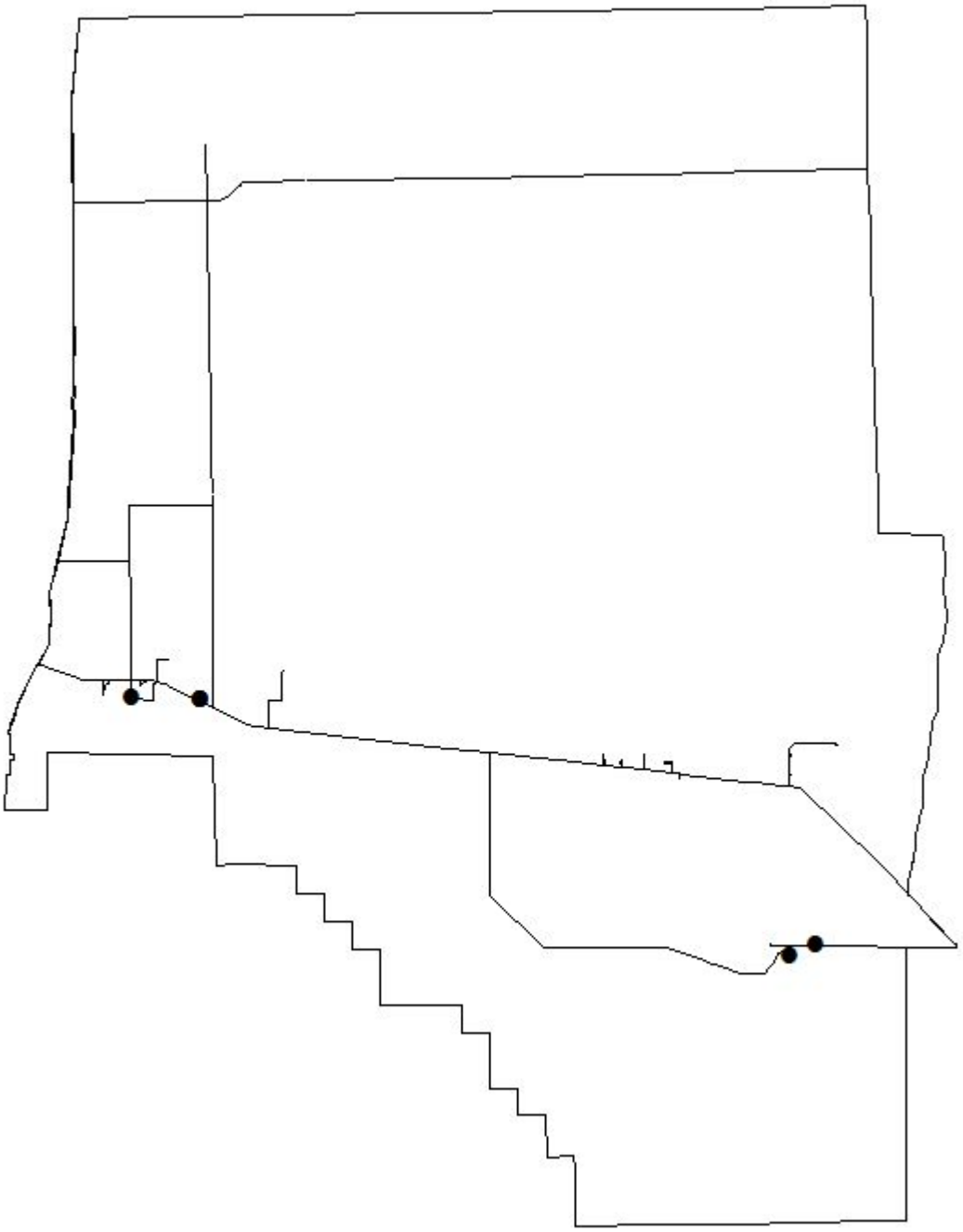
Distribution of Golden Topminnow, *Fundulus chrysotus.*



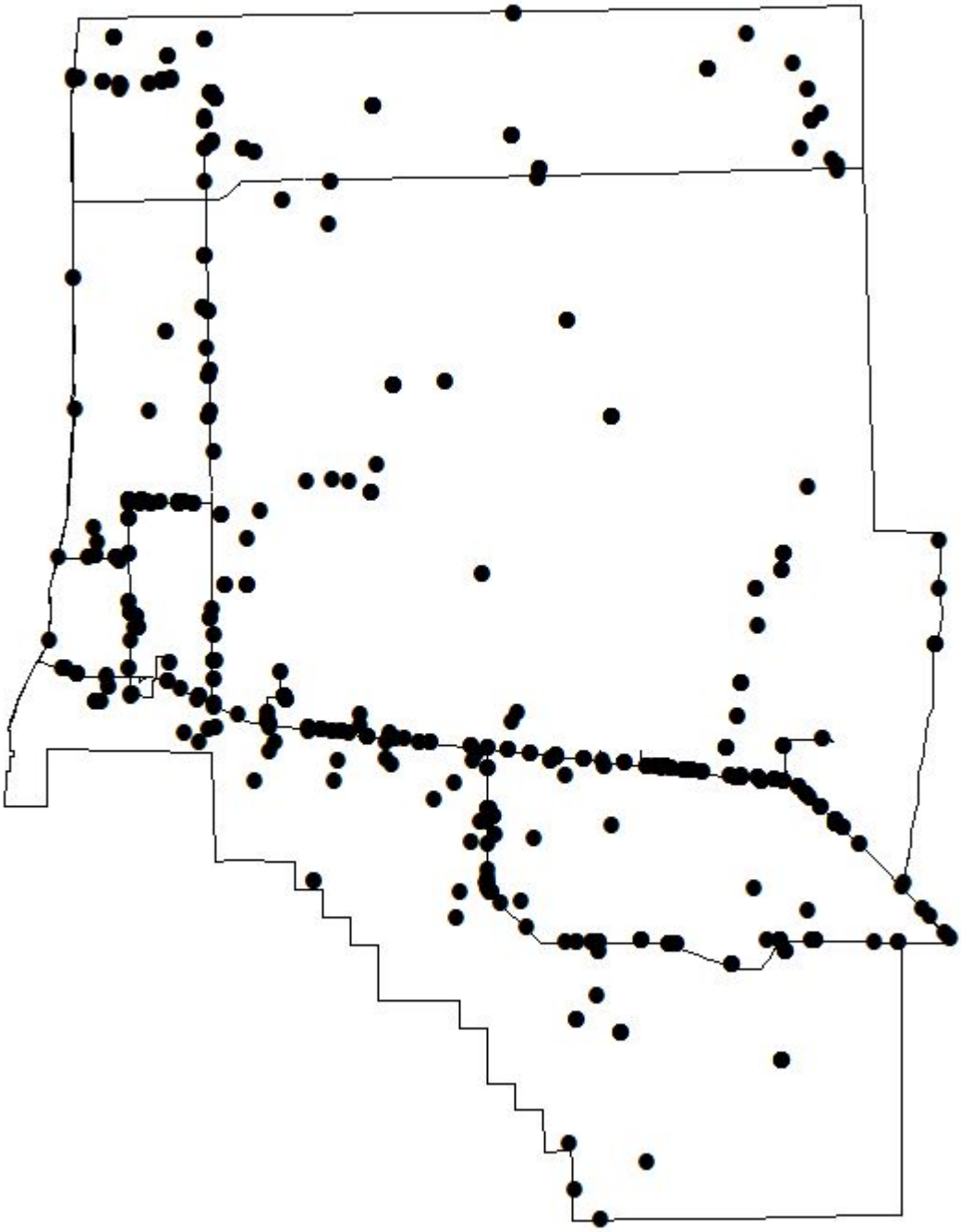
Distribution of Marsh Killifish, *Fundulus confluentus.*



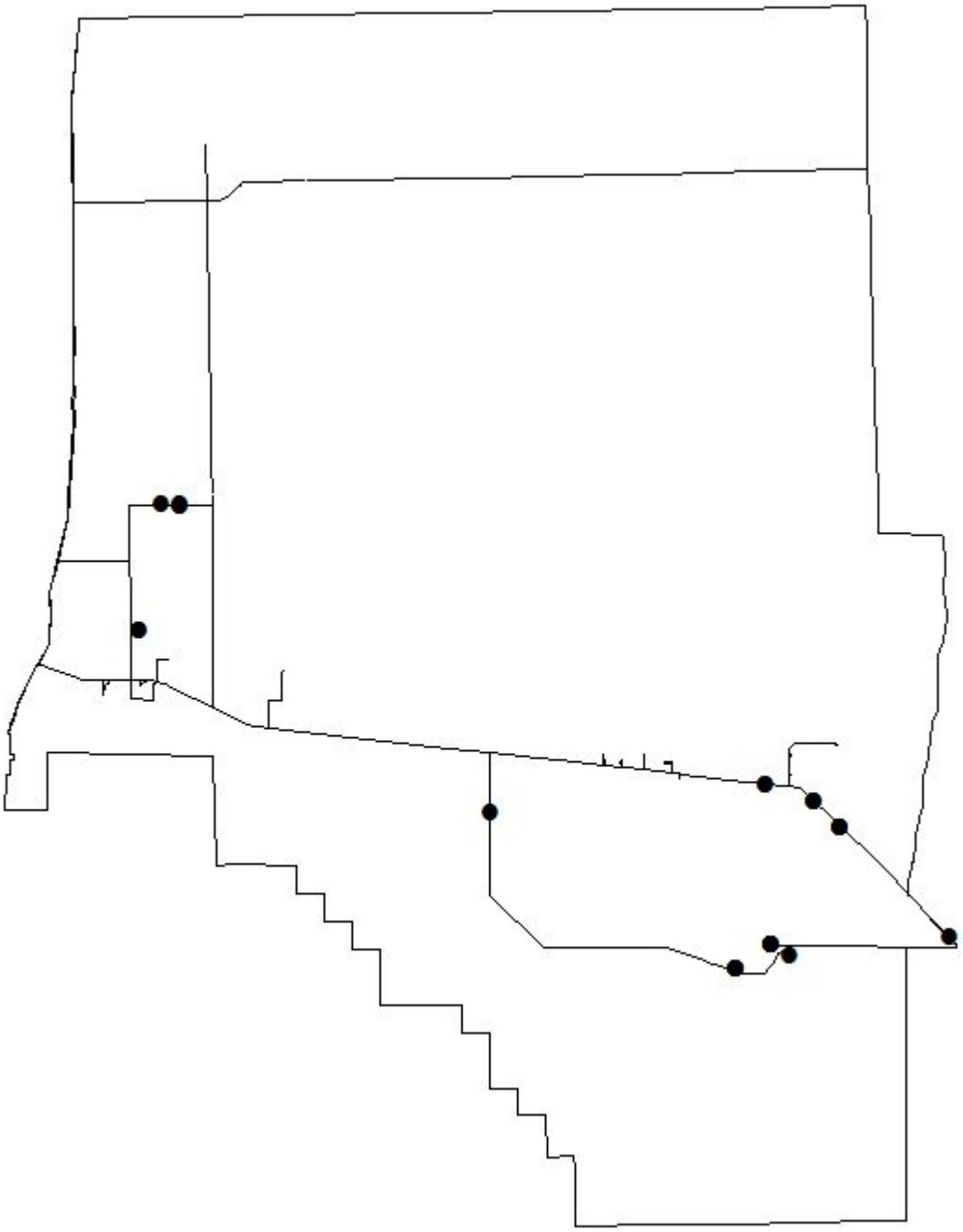
Distribution of Gulf Killifish, *Fundulus grandis.*



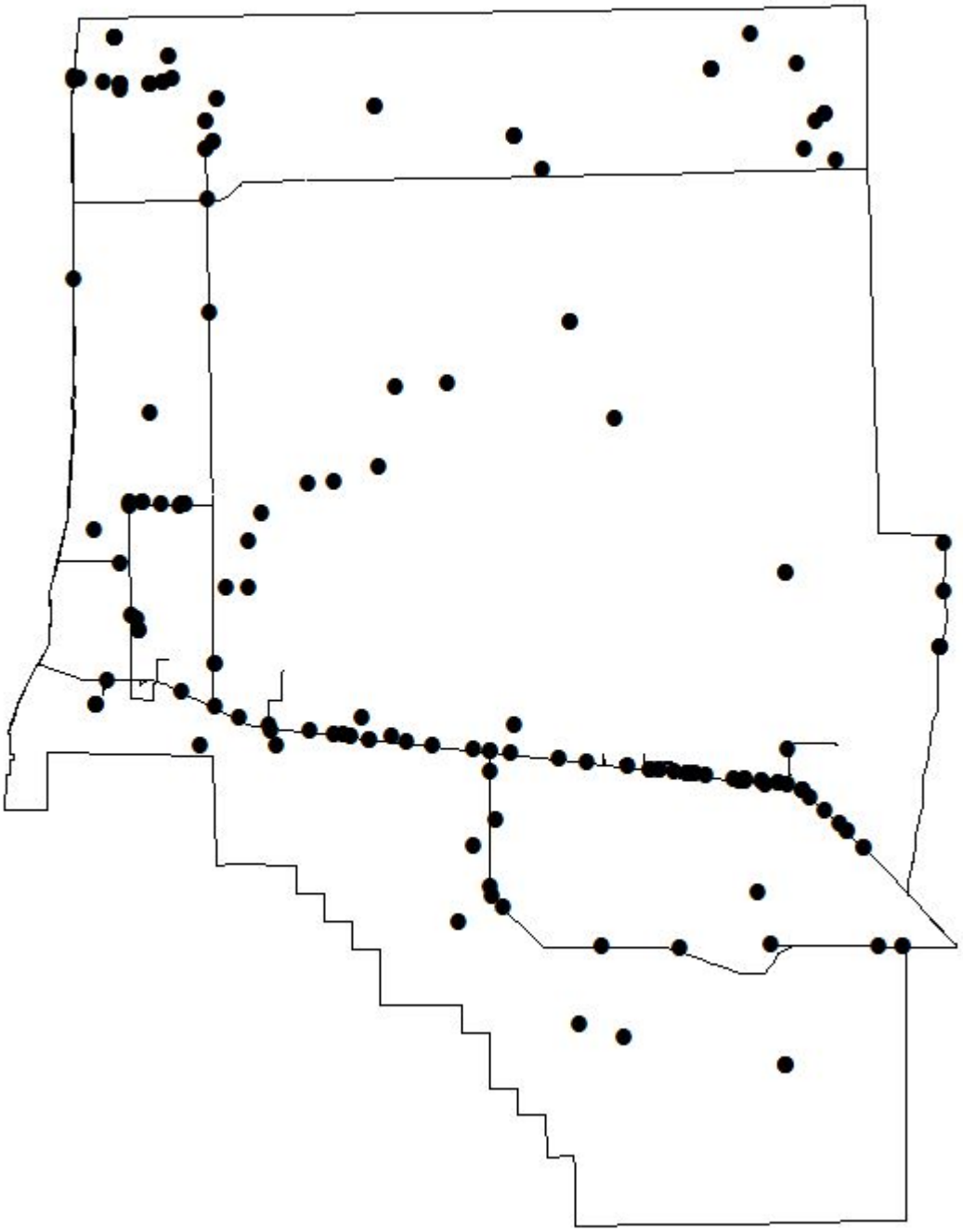
Distribution of Seminole Killifish, *Fundulus seminolis.*



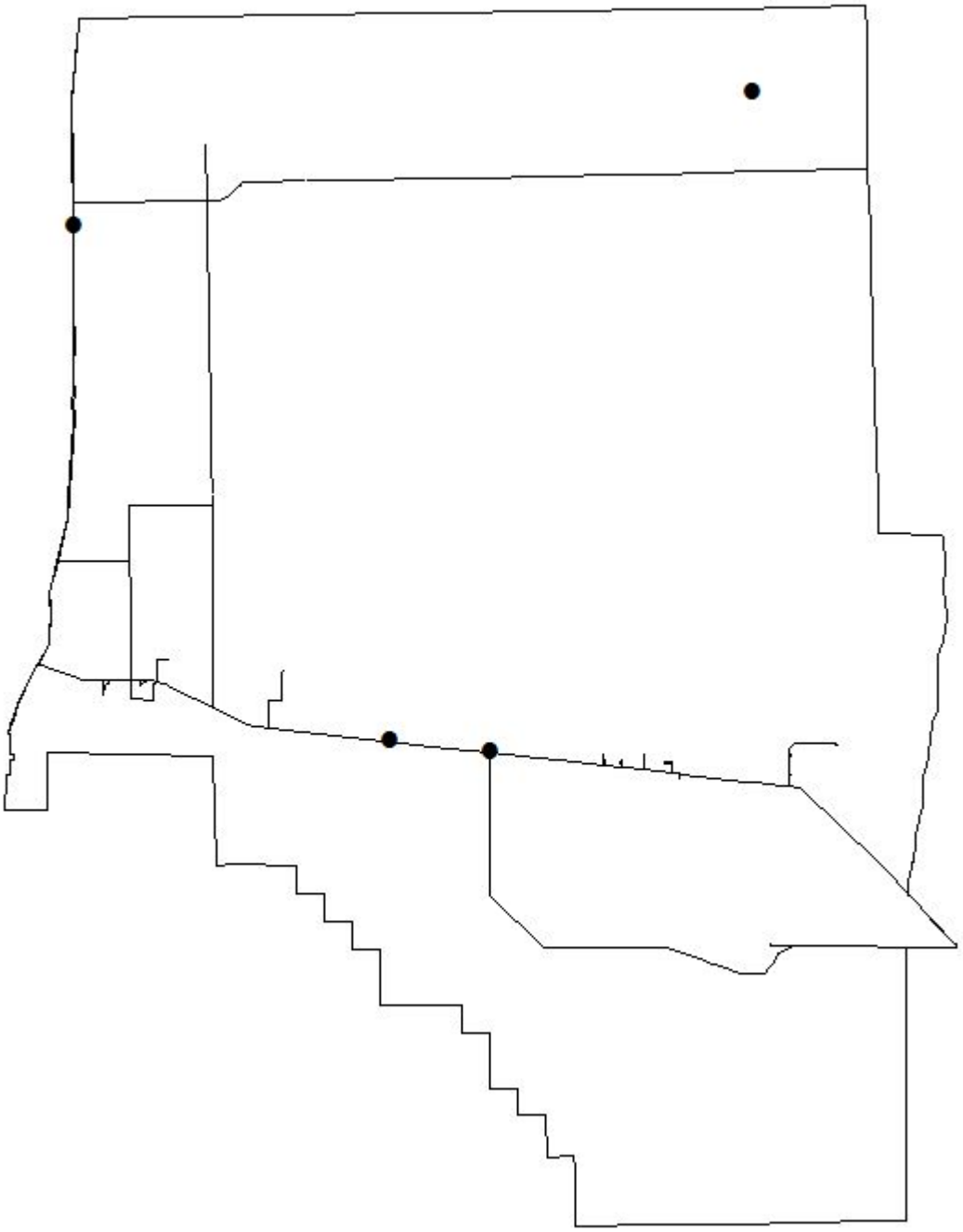
Distribution of Eastern Mosquitofish, *Gambusia holbrooki*.



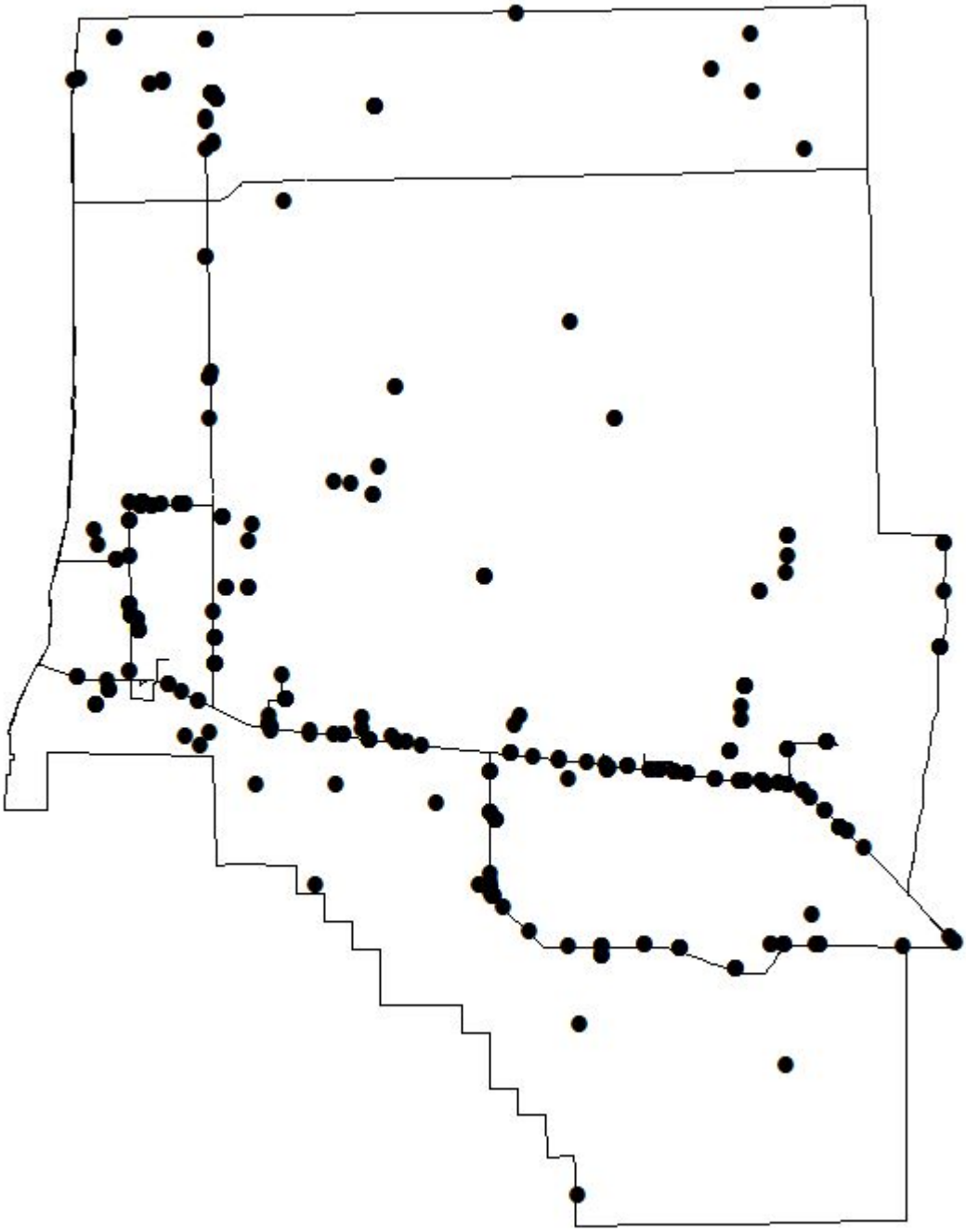
Distribution of Jewel Cichlid, *Hemichromis letourneauxi.*



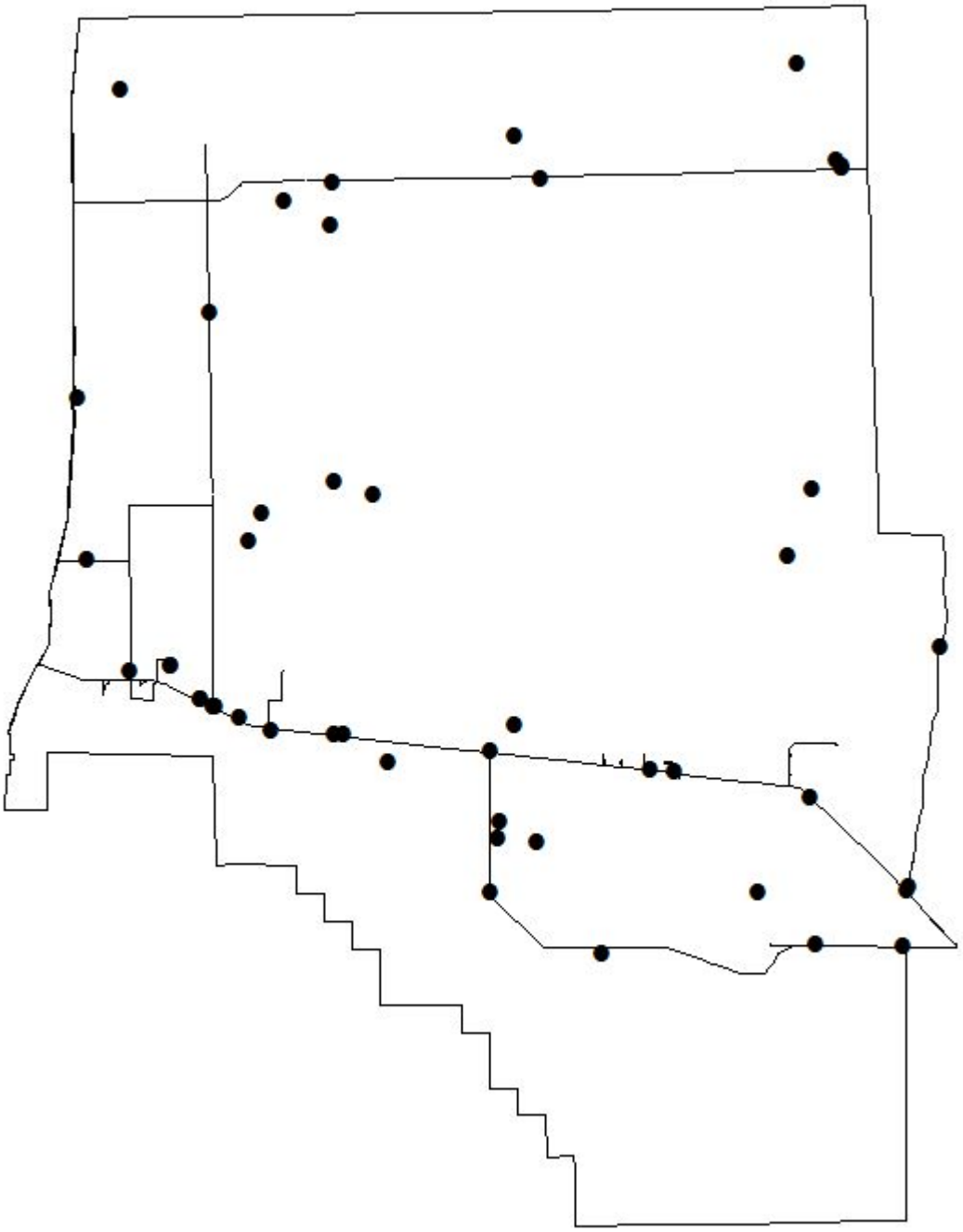
Distribution of Least Killifish, *Heterandria formosa.*



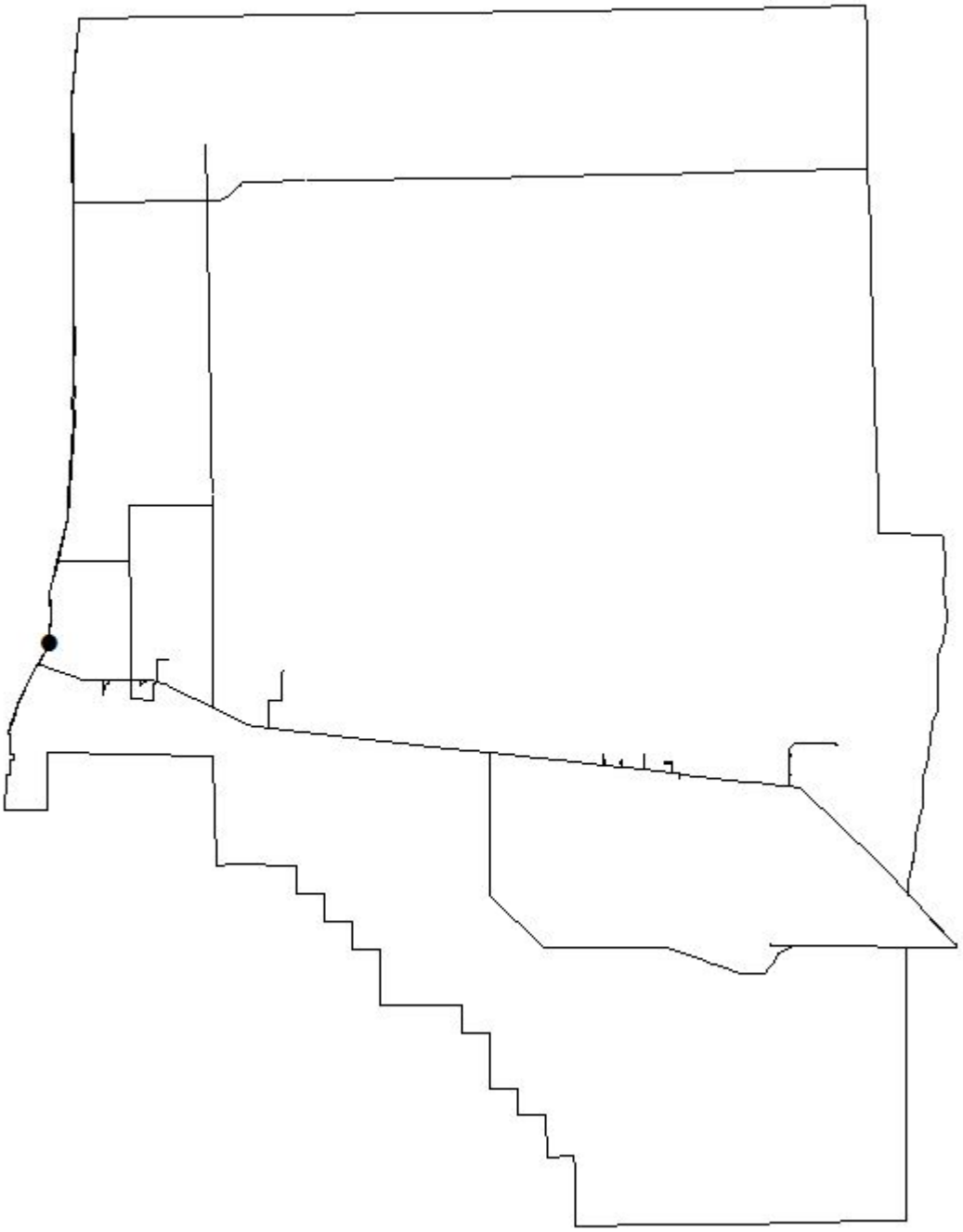
Distribution of Brown Hoplo, *Hoplosternum littorale.*



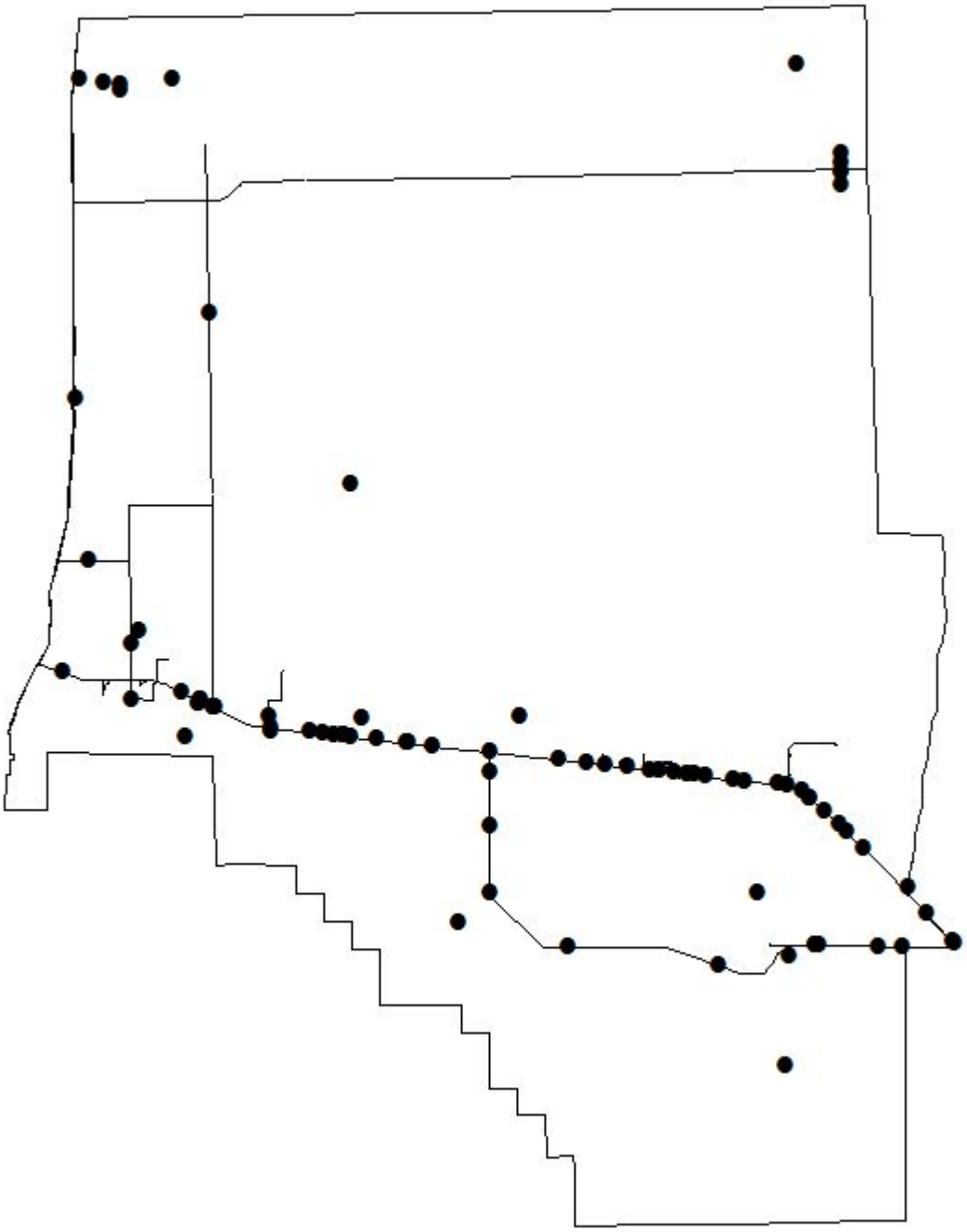
Distribution of Flagfish, *Jordanella floridae.*



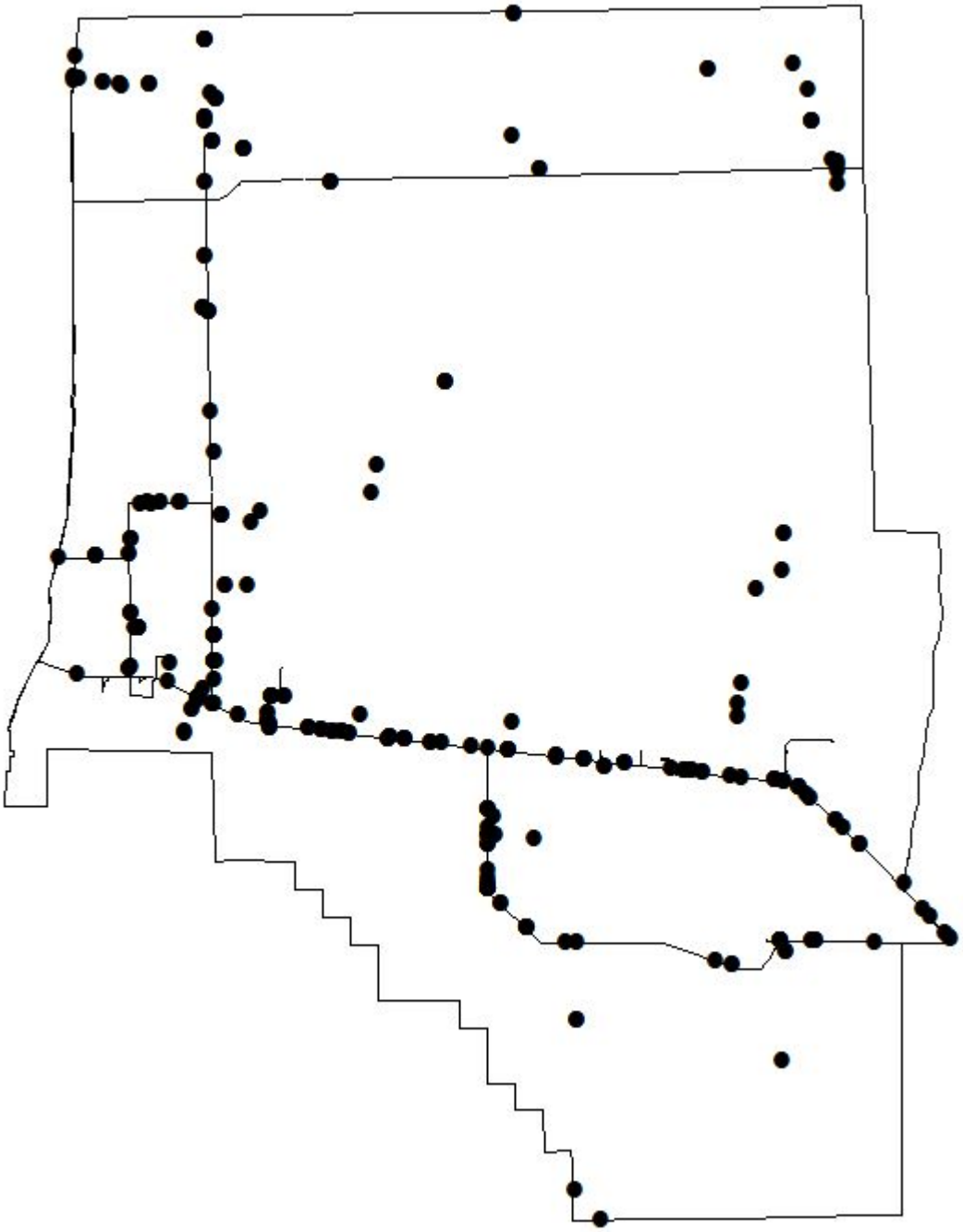
Distribution of Brook Silverside, *Labidesthes sicculus.*



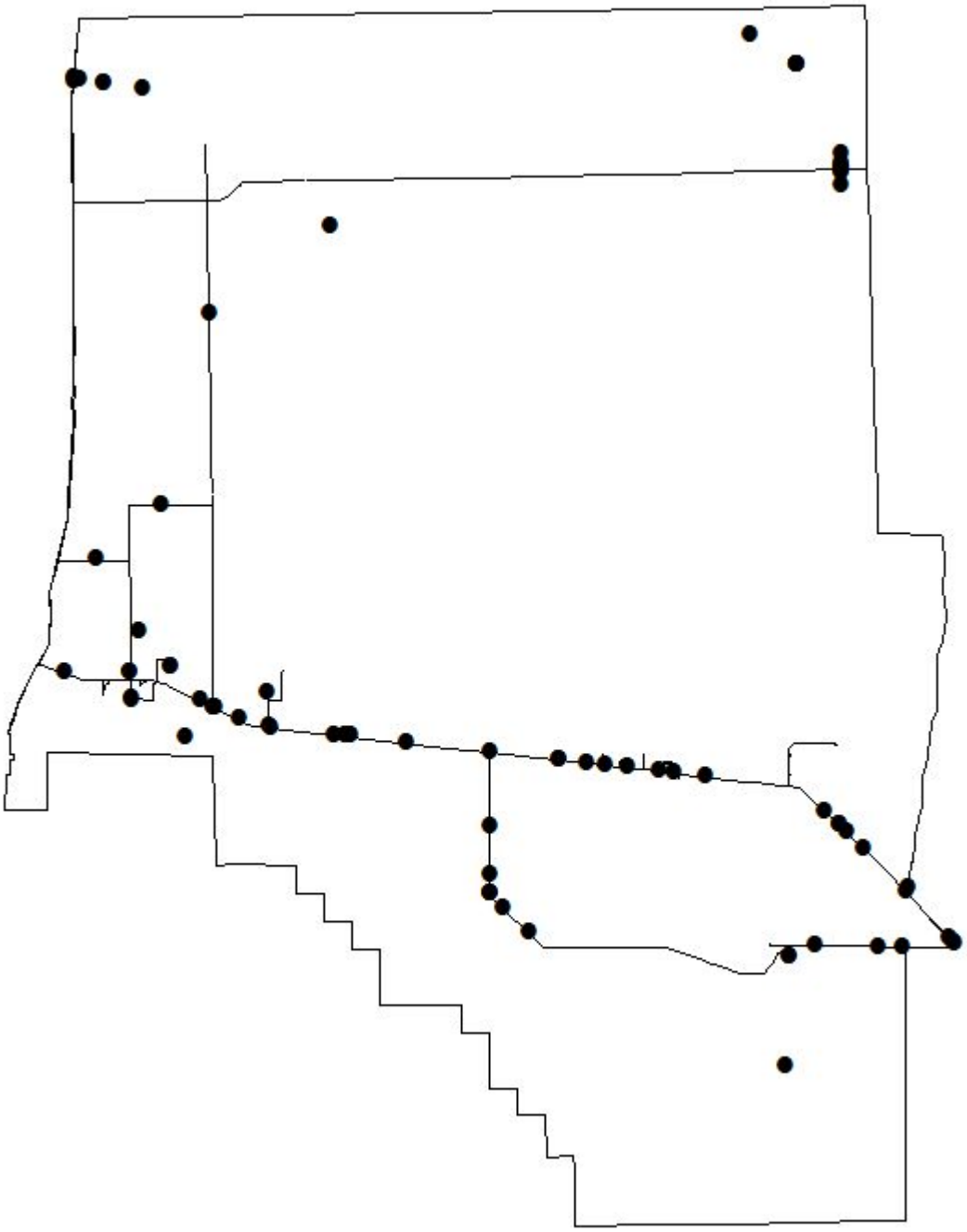
Distribution of Pinfish, *Lagodon rhomboids.*



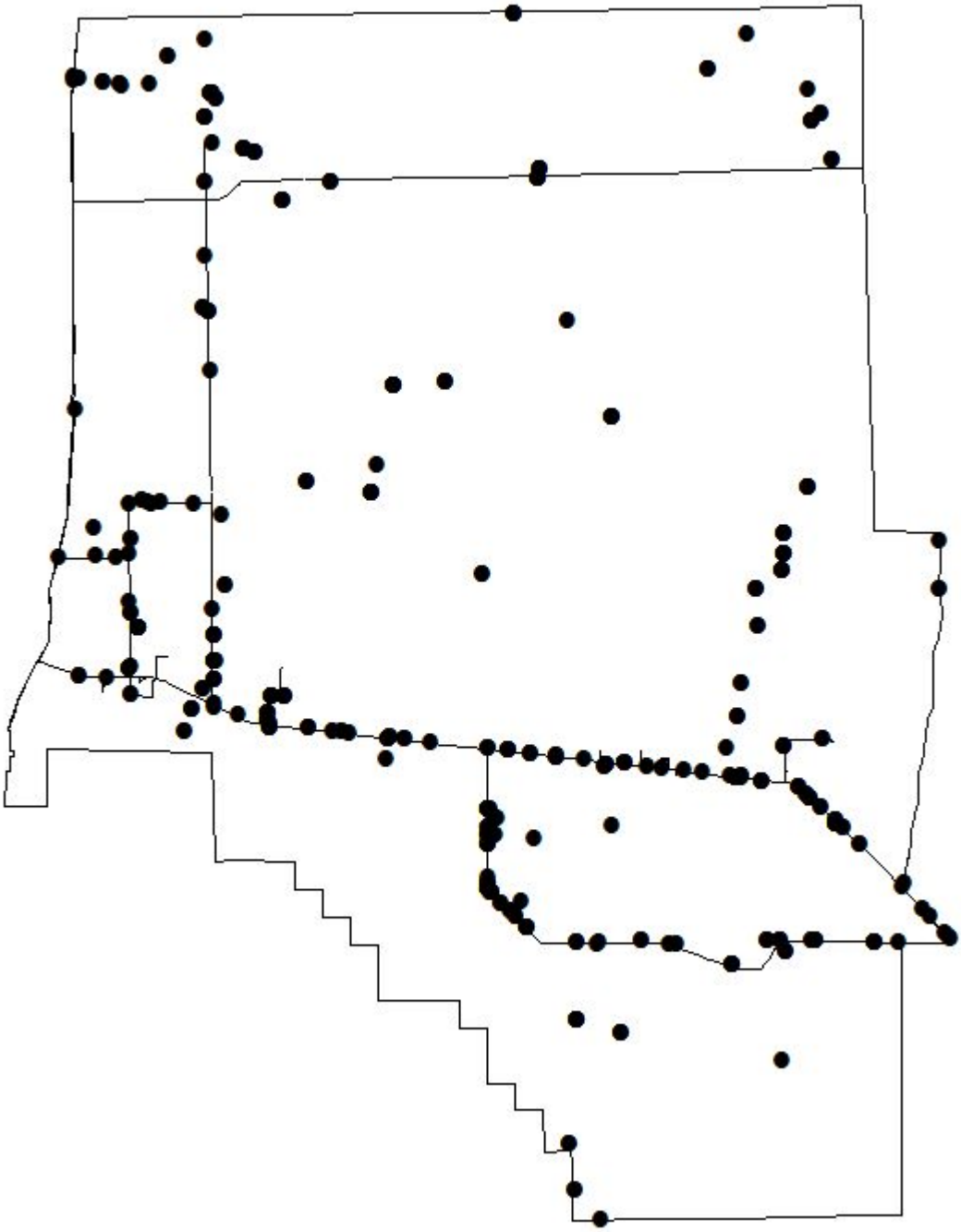
Distribution of Florida Gar, *Lepisosteus platyrhincus.*



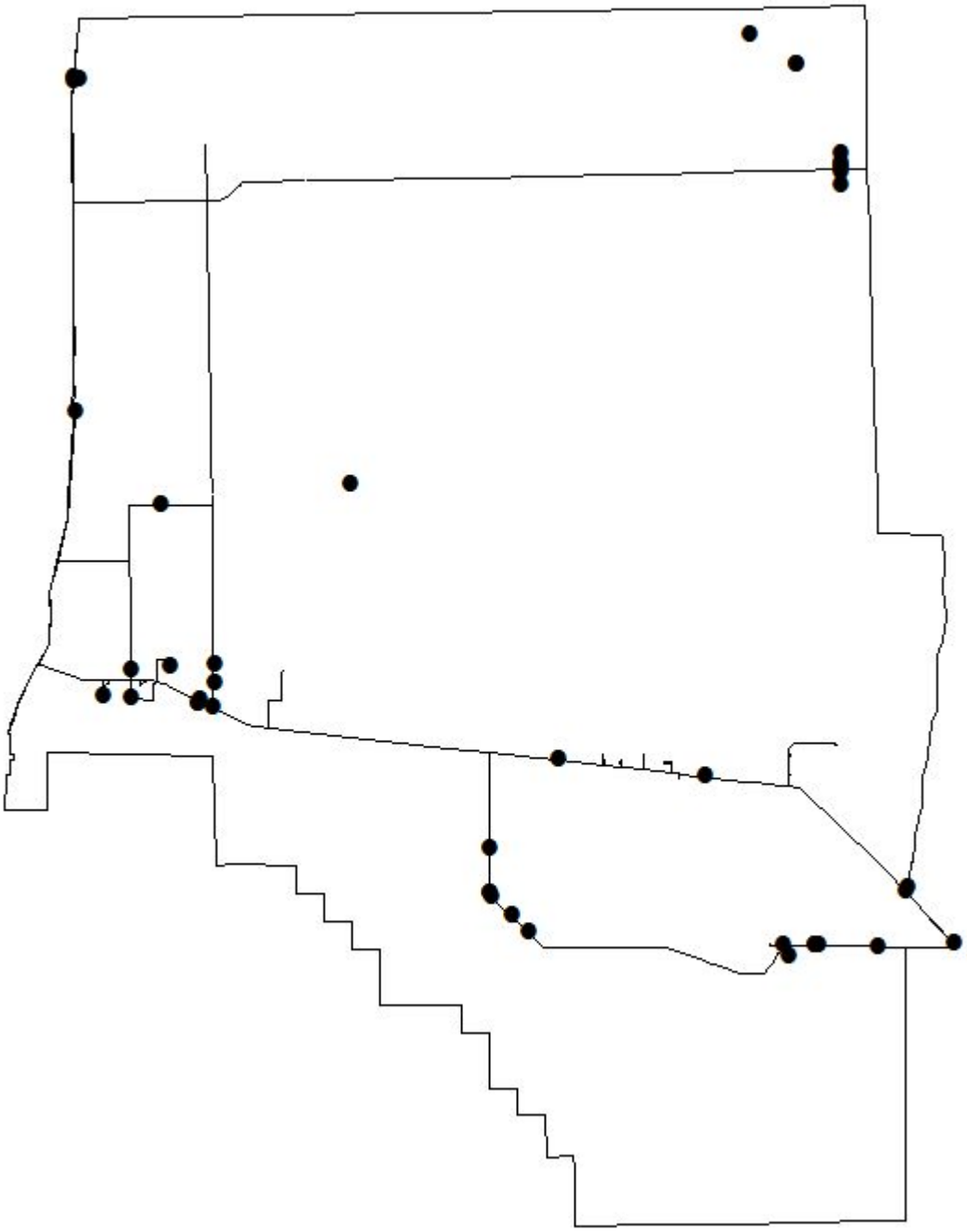
Distribution of Warmouth, *Lepomis gulosus.*



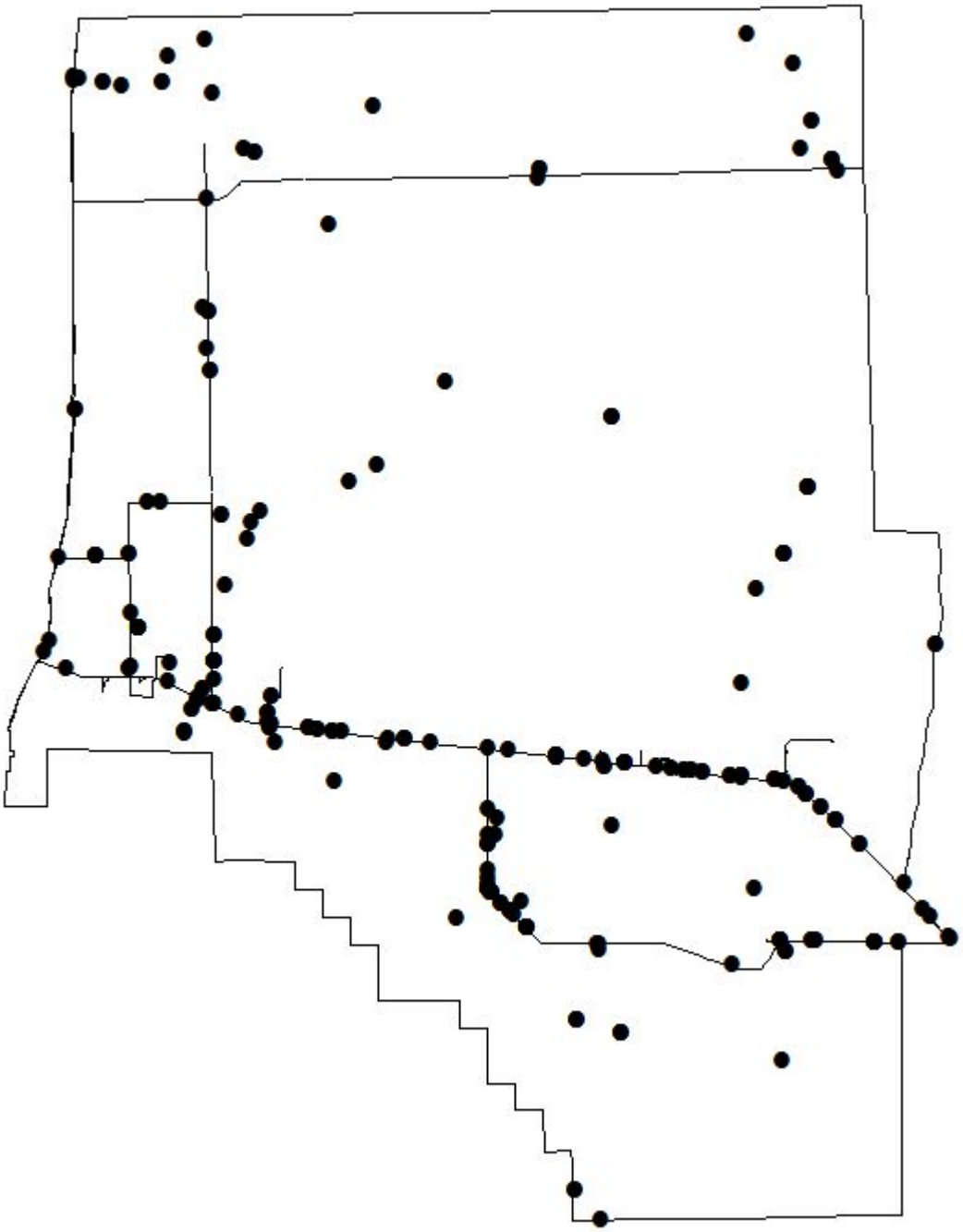
Distribution of Bluegill, *Lepomis macrochirus.*



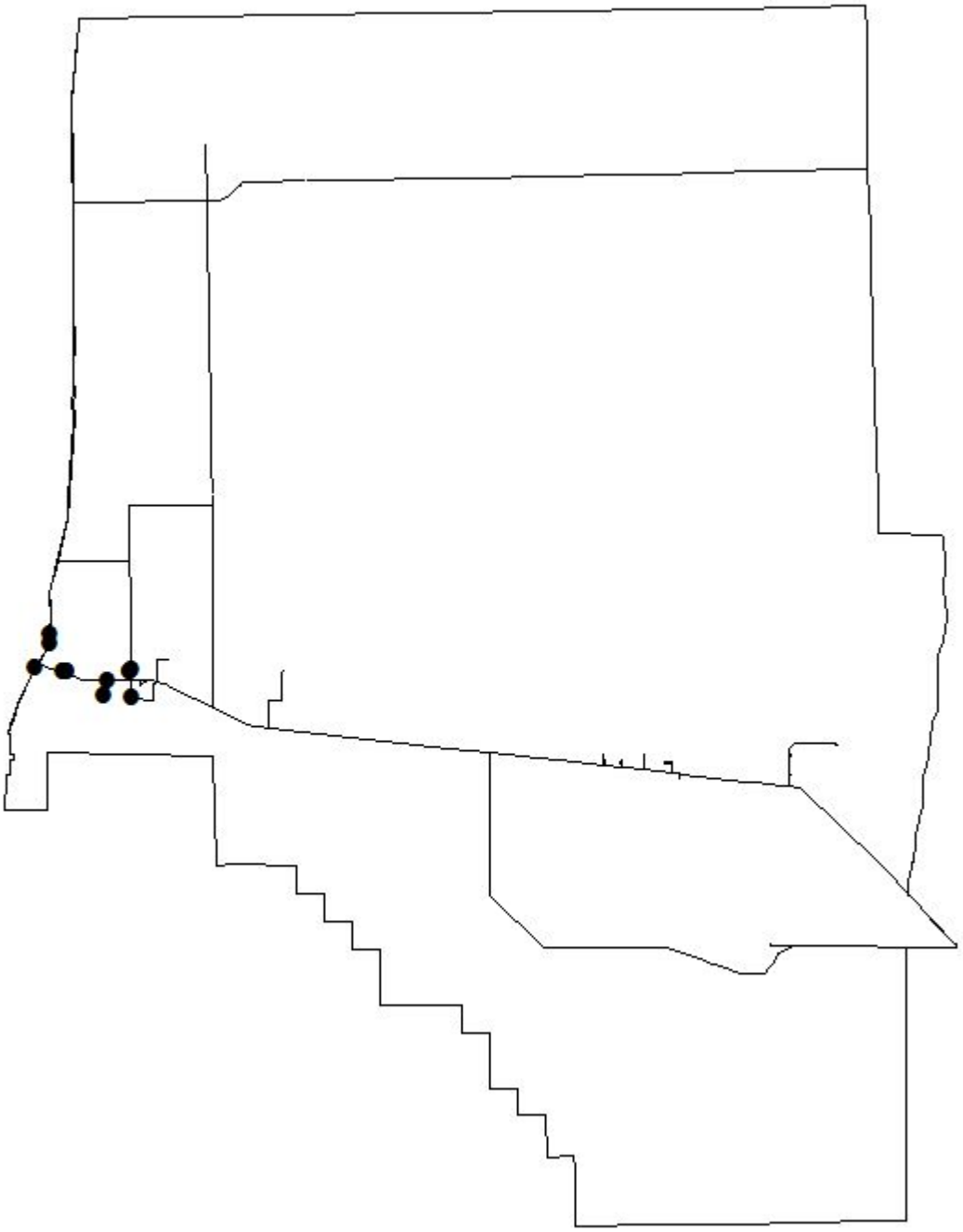
Distribution of Dollar Sunfish, *Lepomis marginatus.*



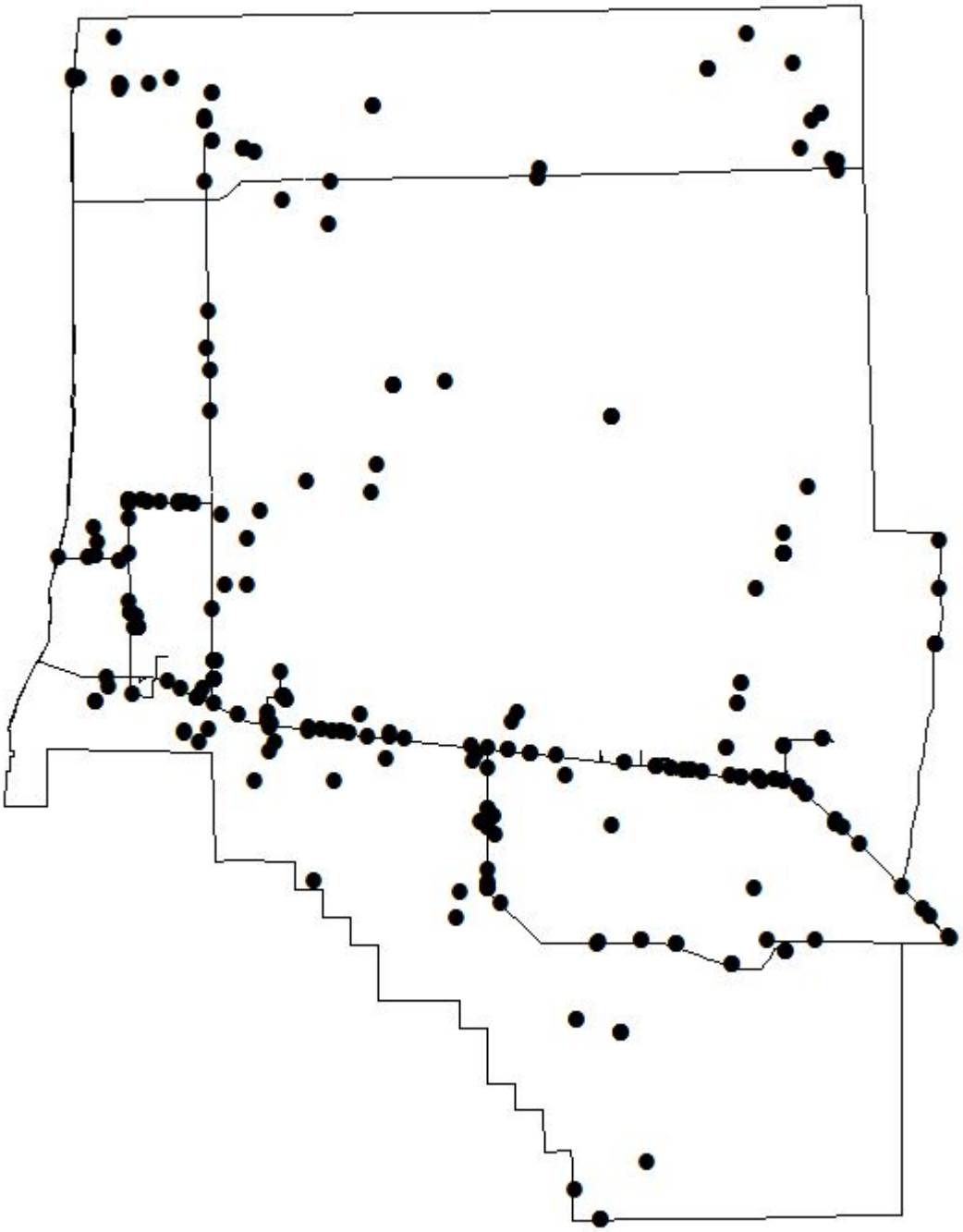
Distribution of Redear, *Lepomis microlophus.*



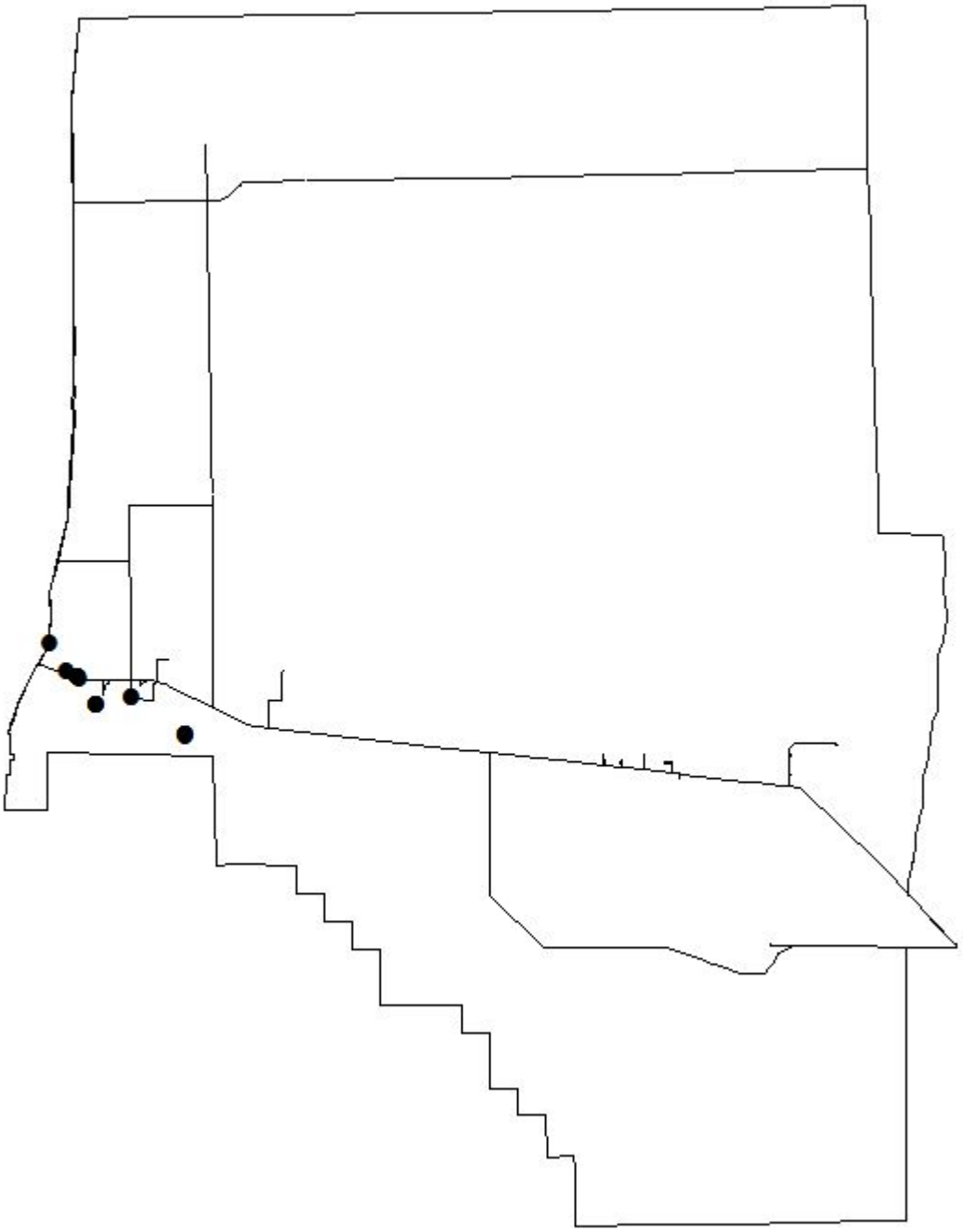
Distribution of Spotted Sunfish, *Lepomis punctatus.*



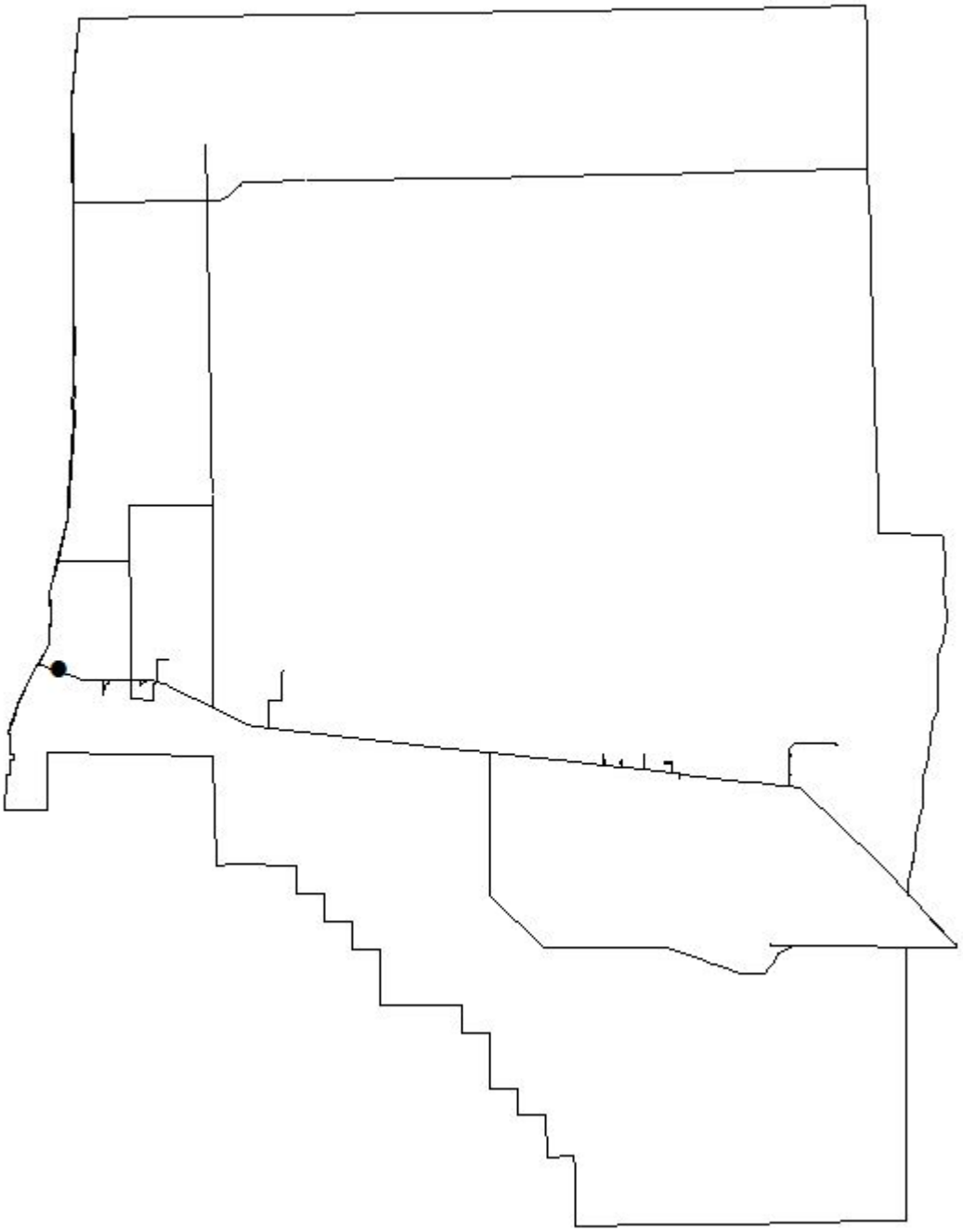
Distribution of Crested Goby, *Lophogobius cyprinoids.*



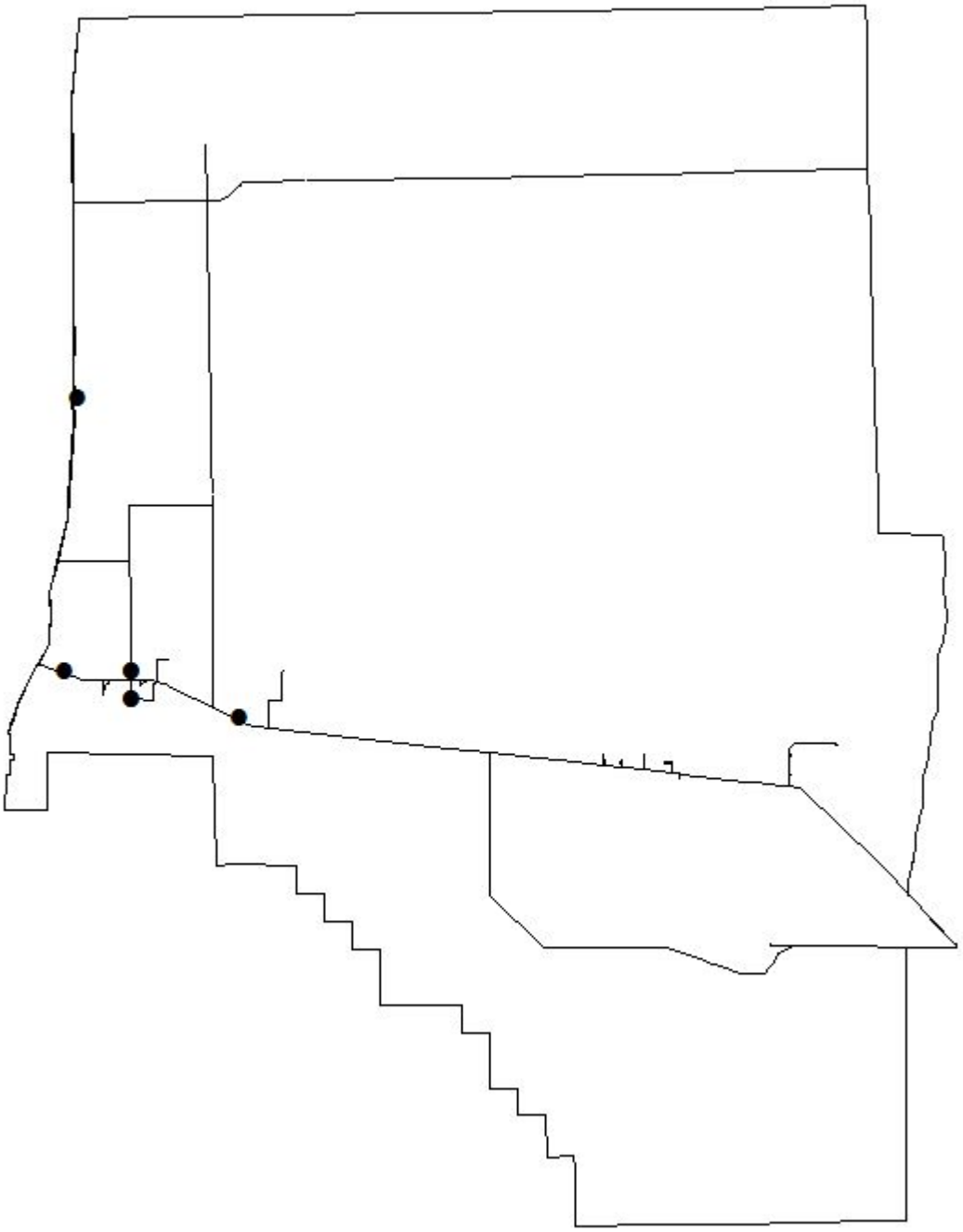
Distribution of Bluefin Killifish, *Lucania goodei.*



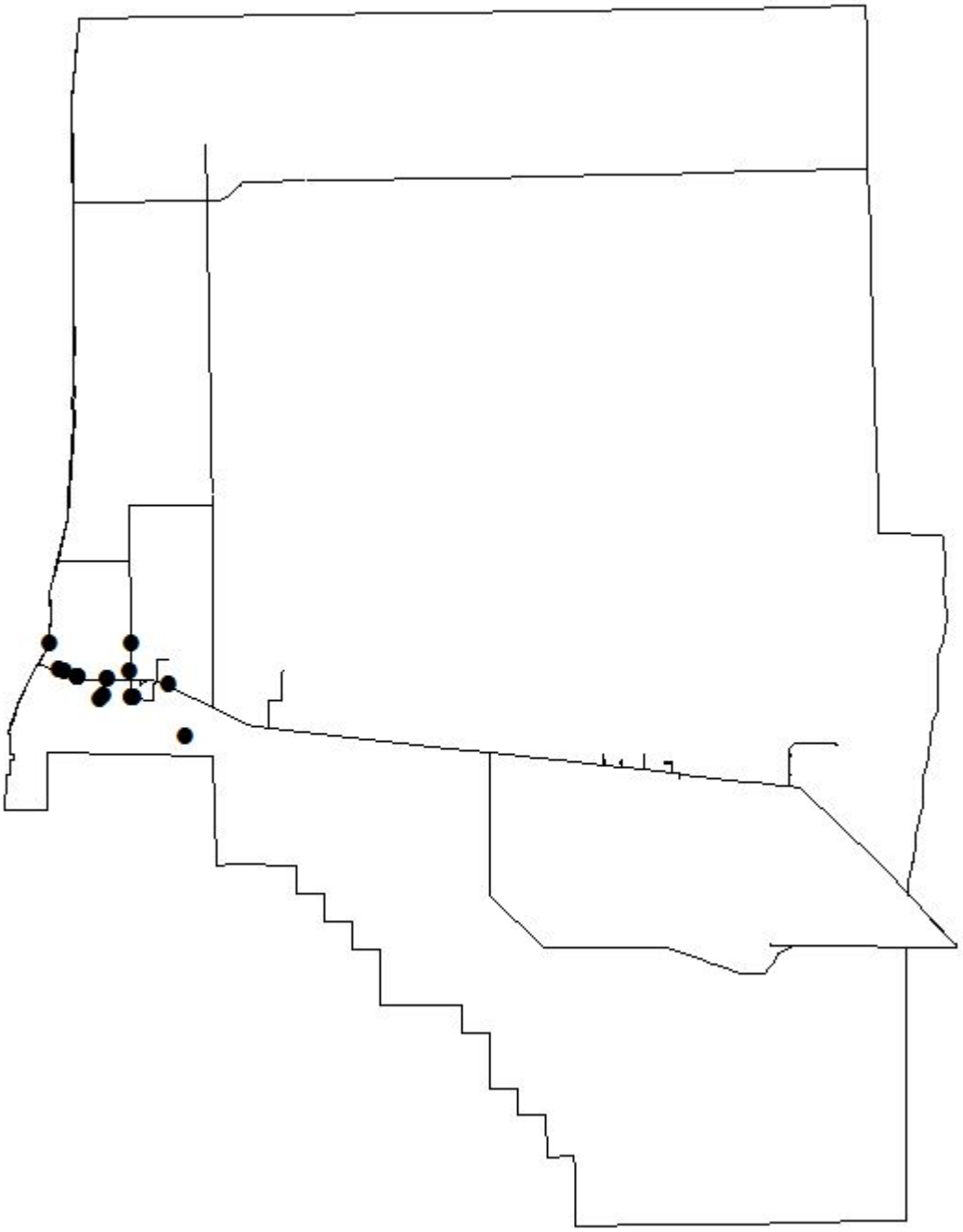
Distribution of Rainwater Killifish, *Lucania parva.*



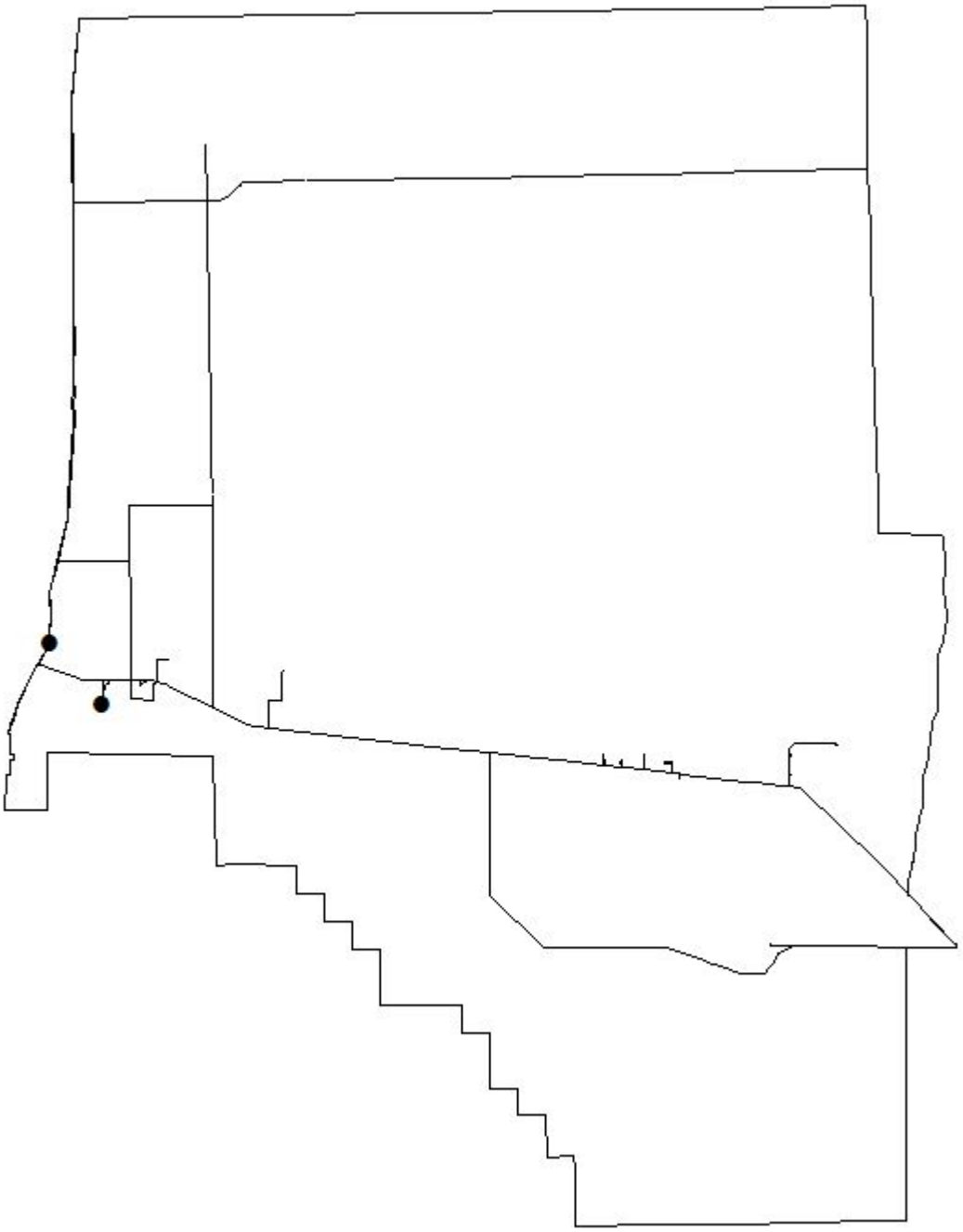
Distribution of Gray Snapper, *Lutjanus griseus.*



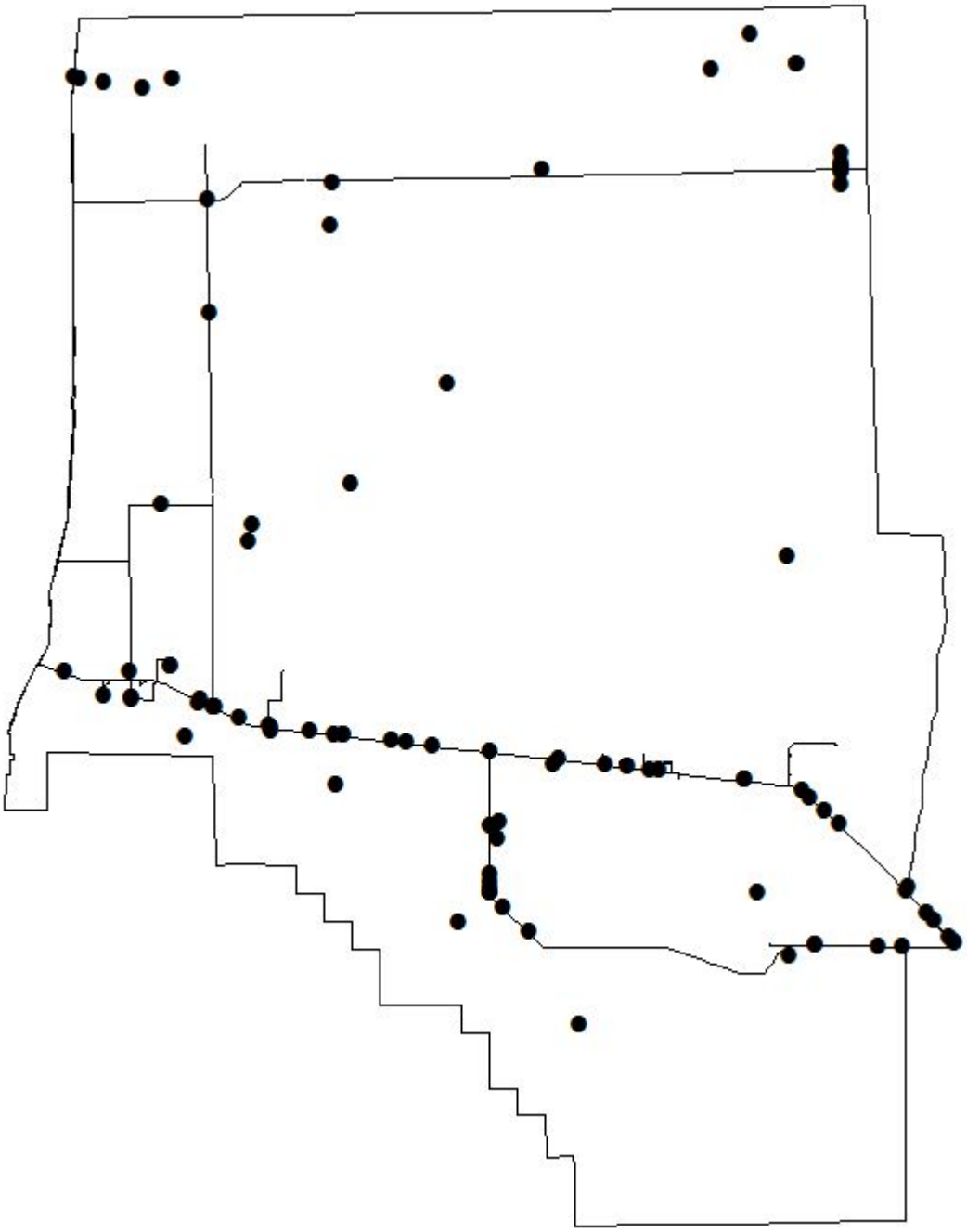
Distribution of Tarpon, *Megalops atlanticus.*



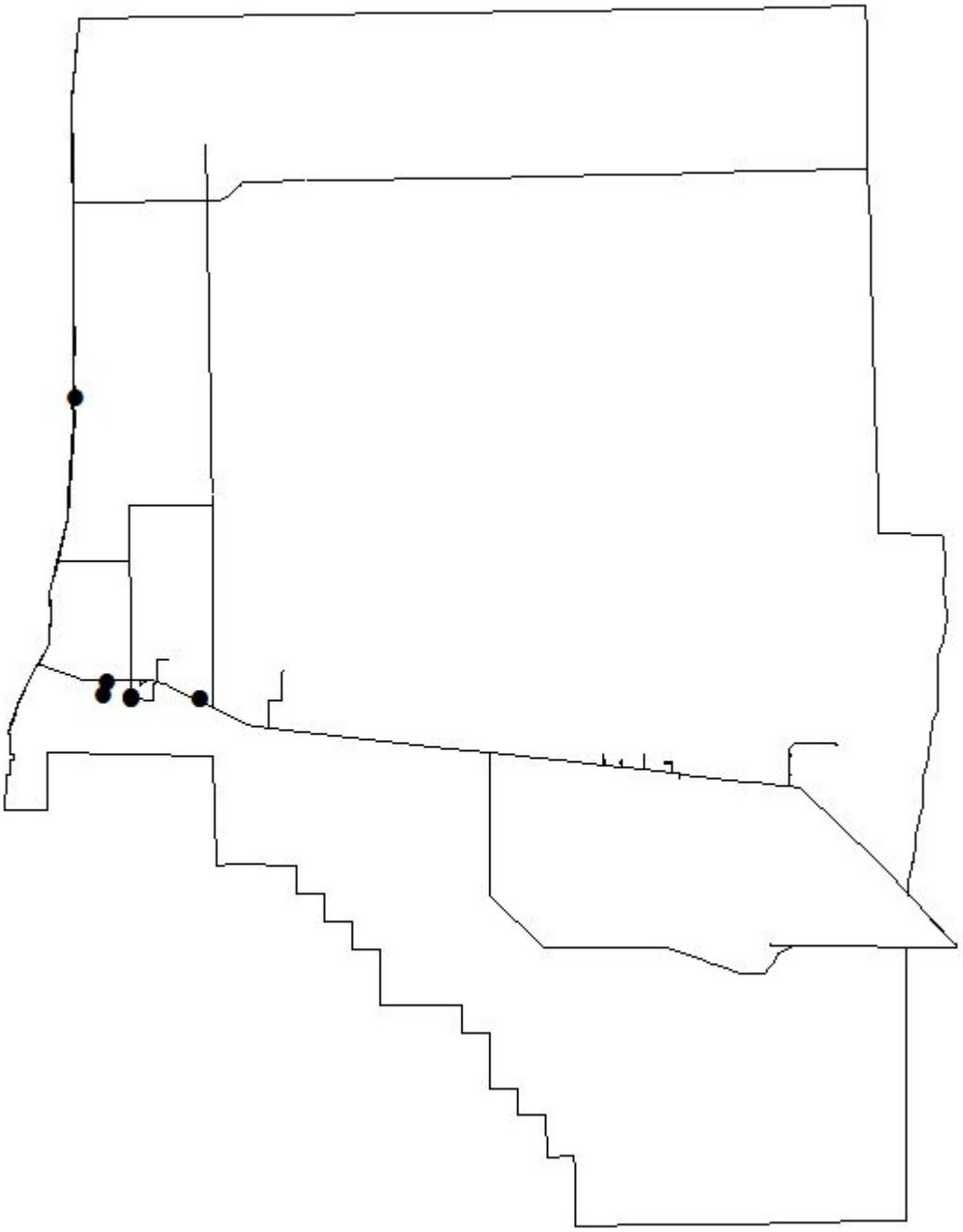
Distribution of Inland Silverside, *Menidia beryllina.*



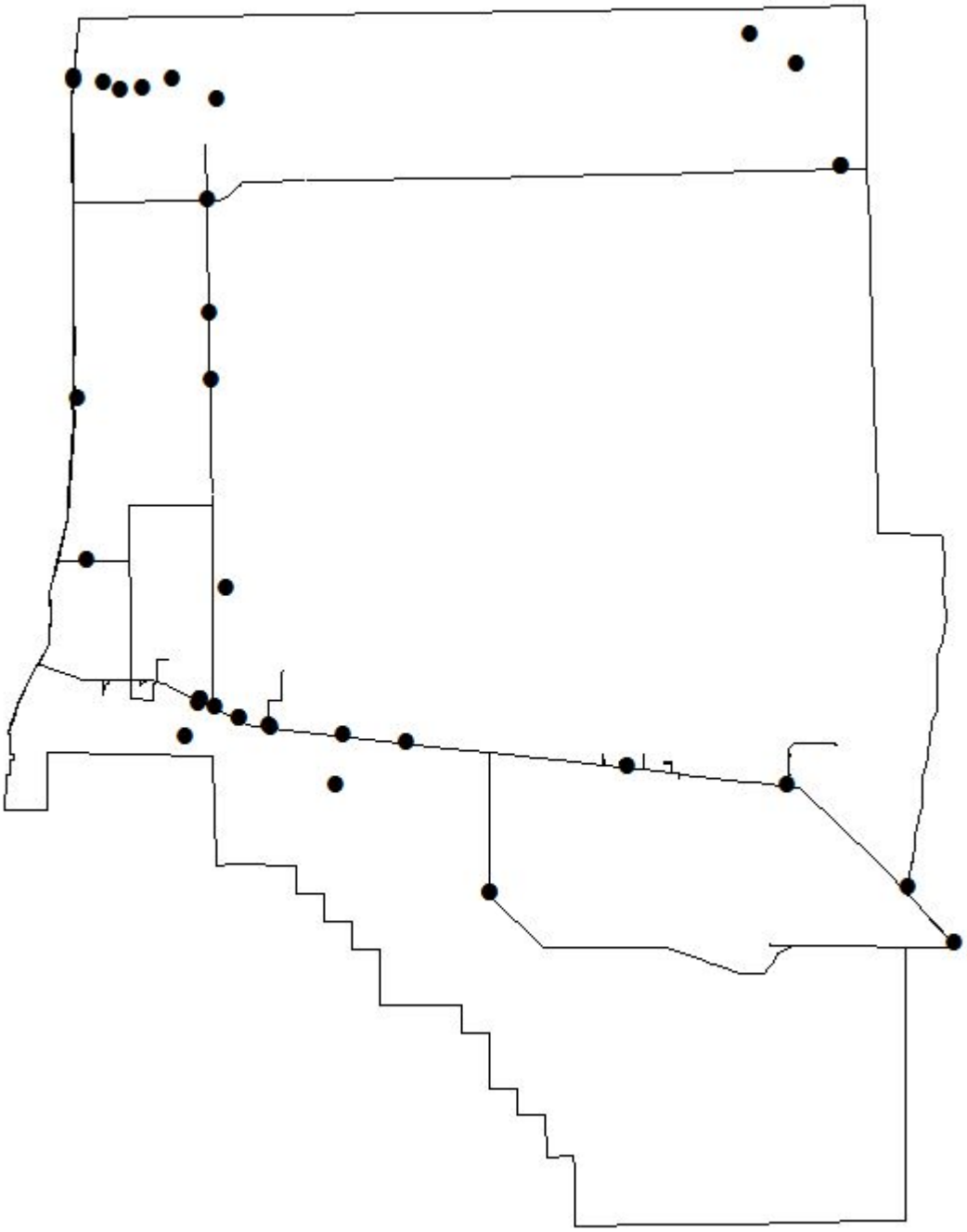
Distribution of Clown Goby, *Microgobius gulosus.*



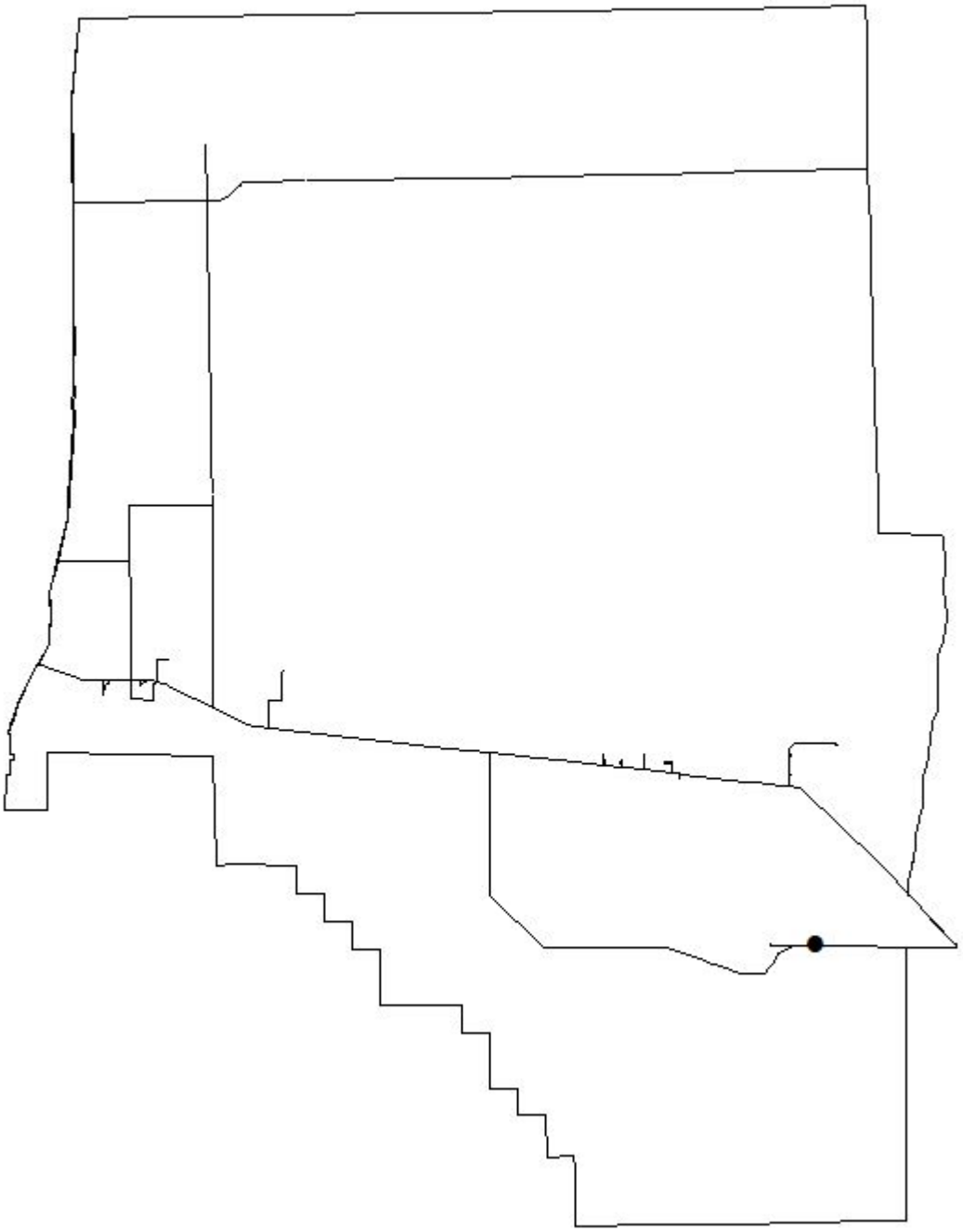
Distribution of Largemouth Bass, *Micopterus salmoides.*



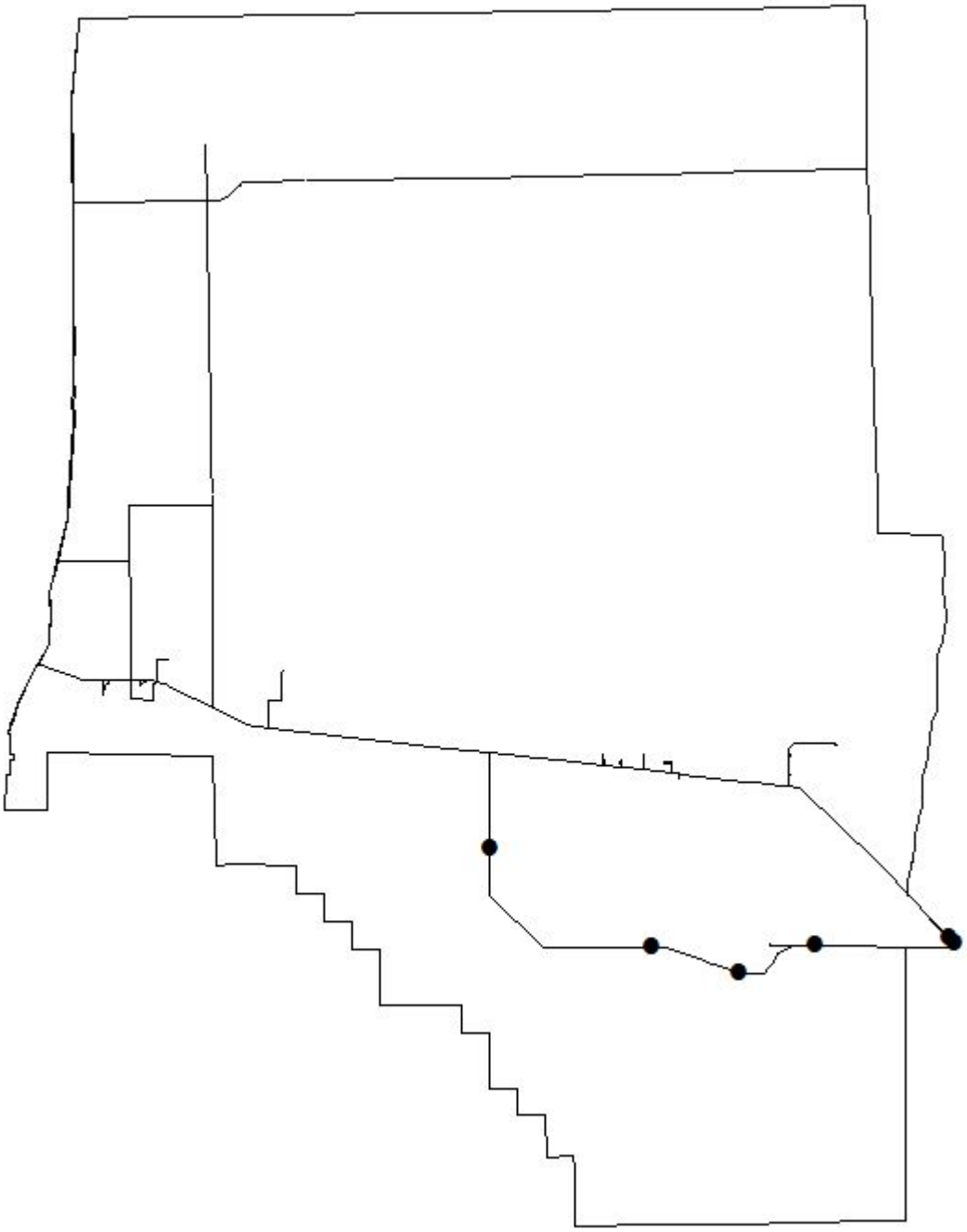
Distribution of Striped Mullet, *Mugil cephalus.*



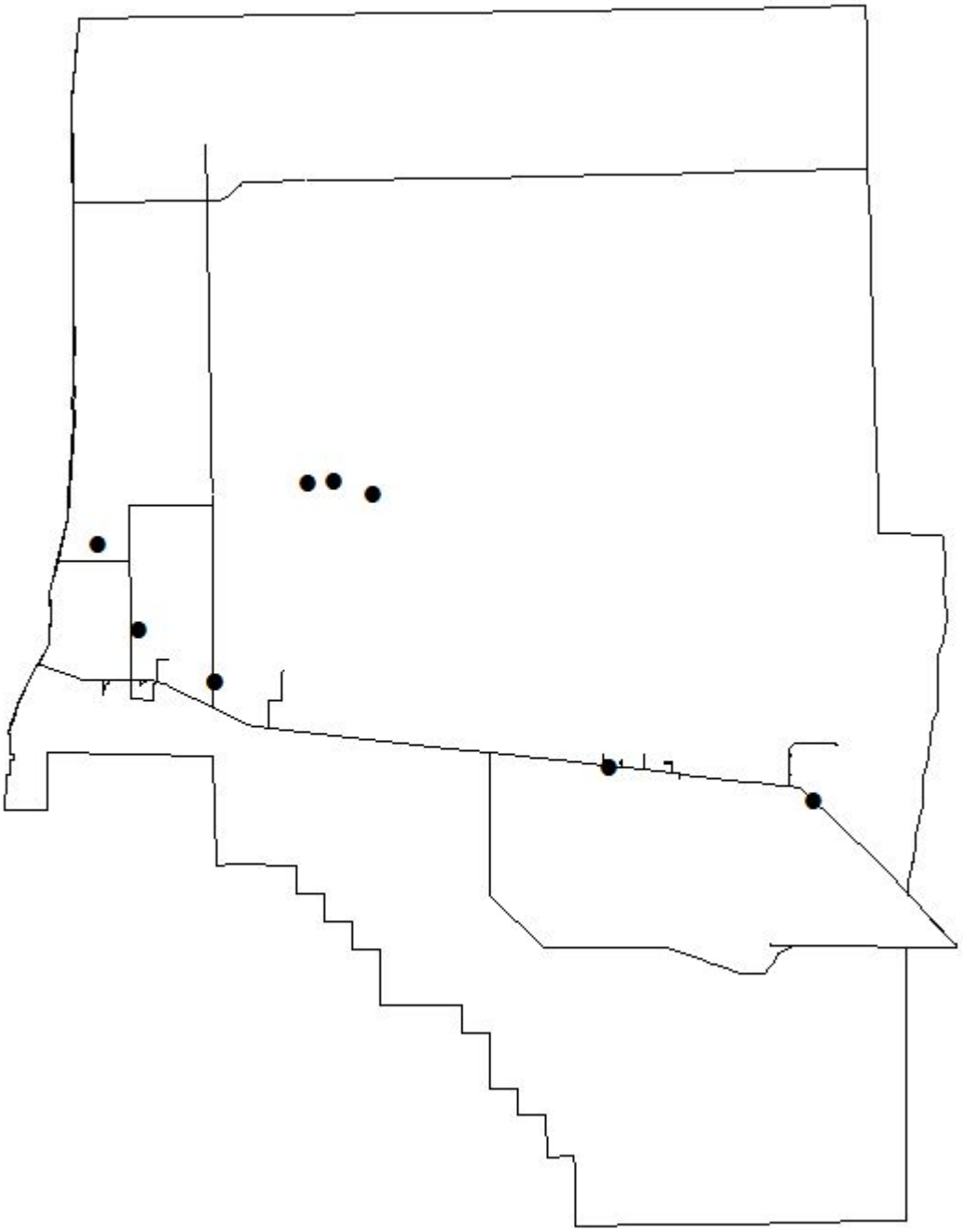
Distribution of Golden Shiner, *Notemigonus crysoleucas.*



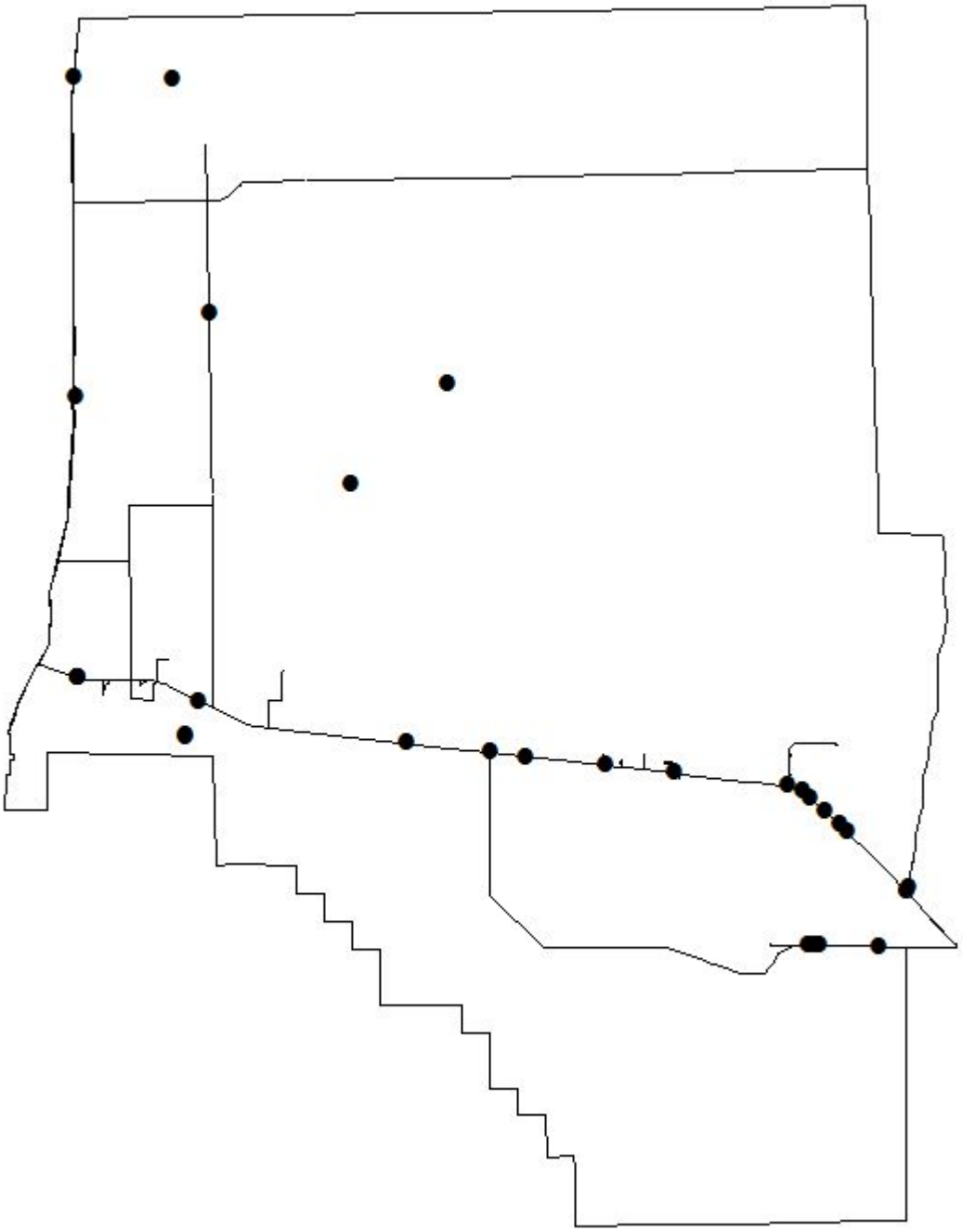
Distribution of Taillight Shiner, *Notropis maculatus.*



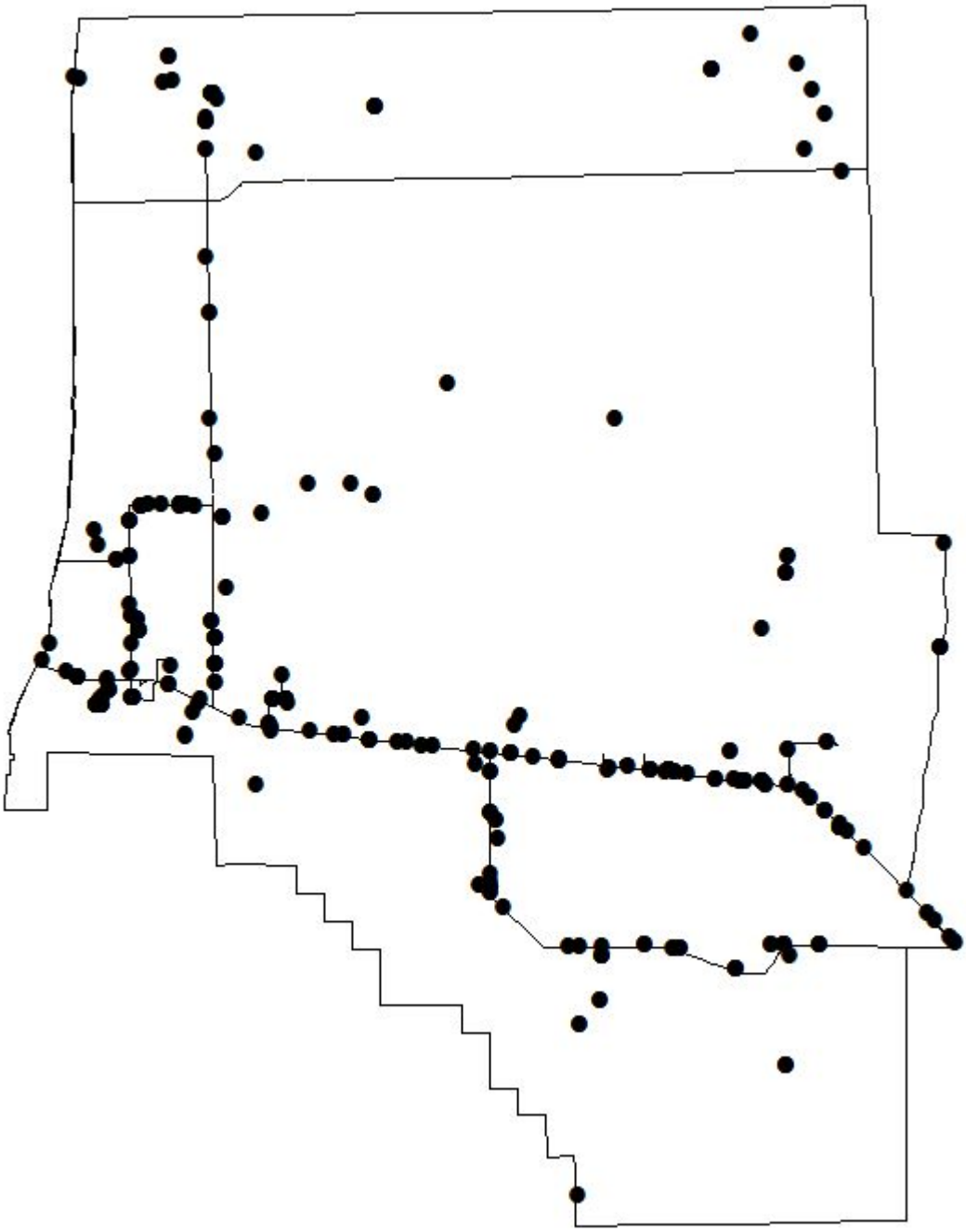
Distribution of Coastal Shiner, *Notropis petersoni*.



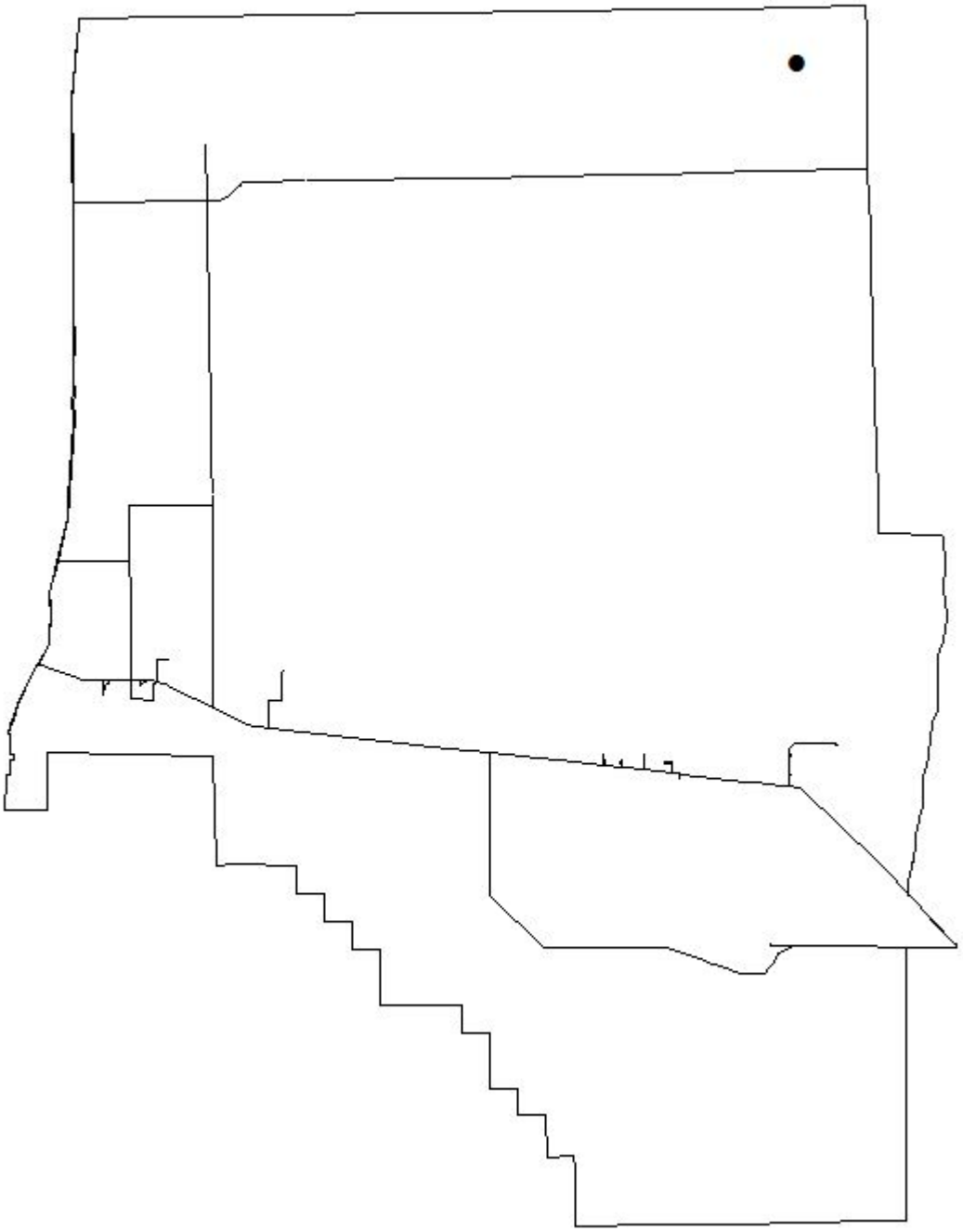
Distribution of Tadpole Madtom, *Noturus gyrinus.*



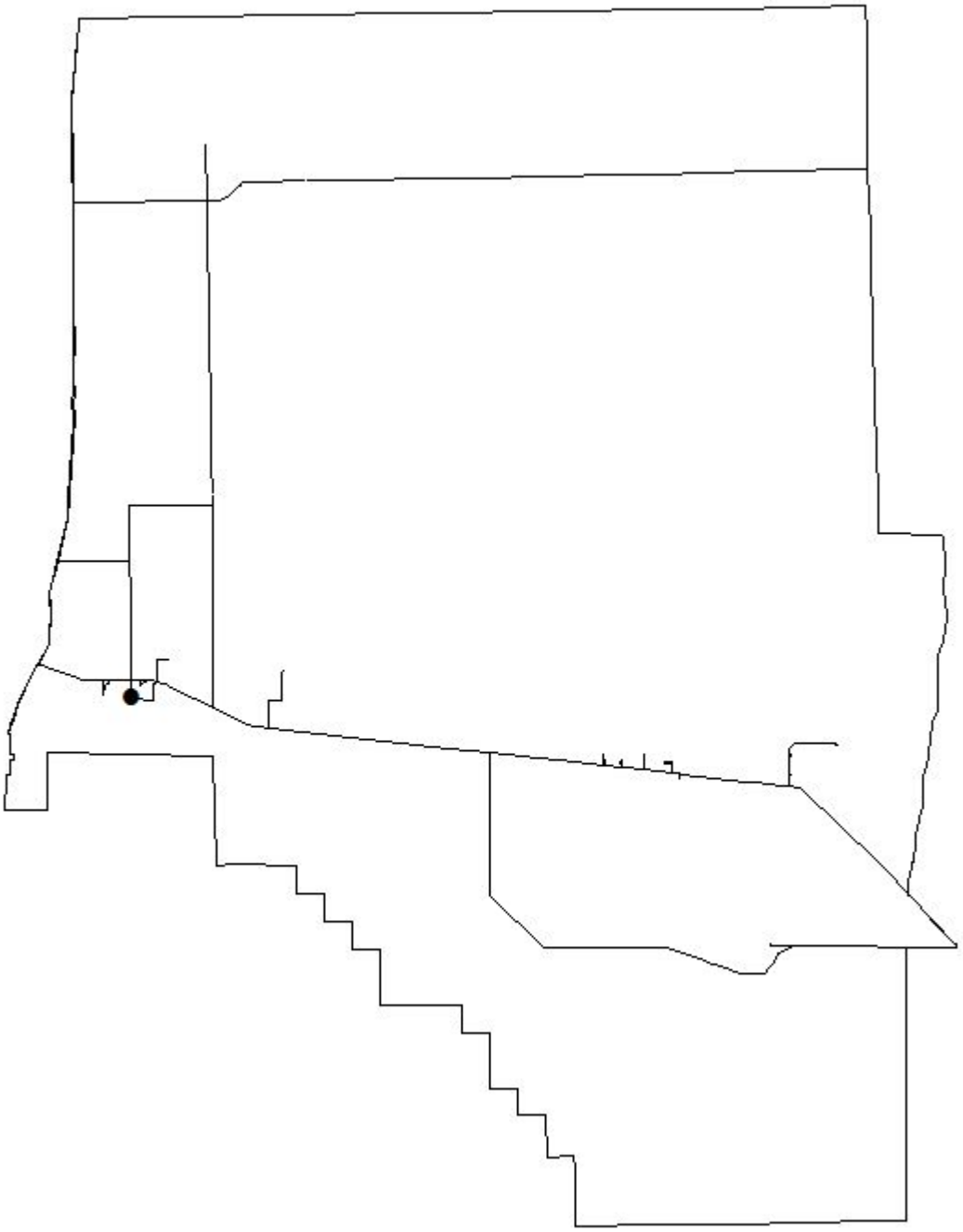
Distribution of Blue Tilapia, *Oreochromis aureus.*



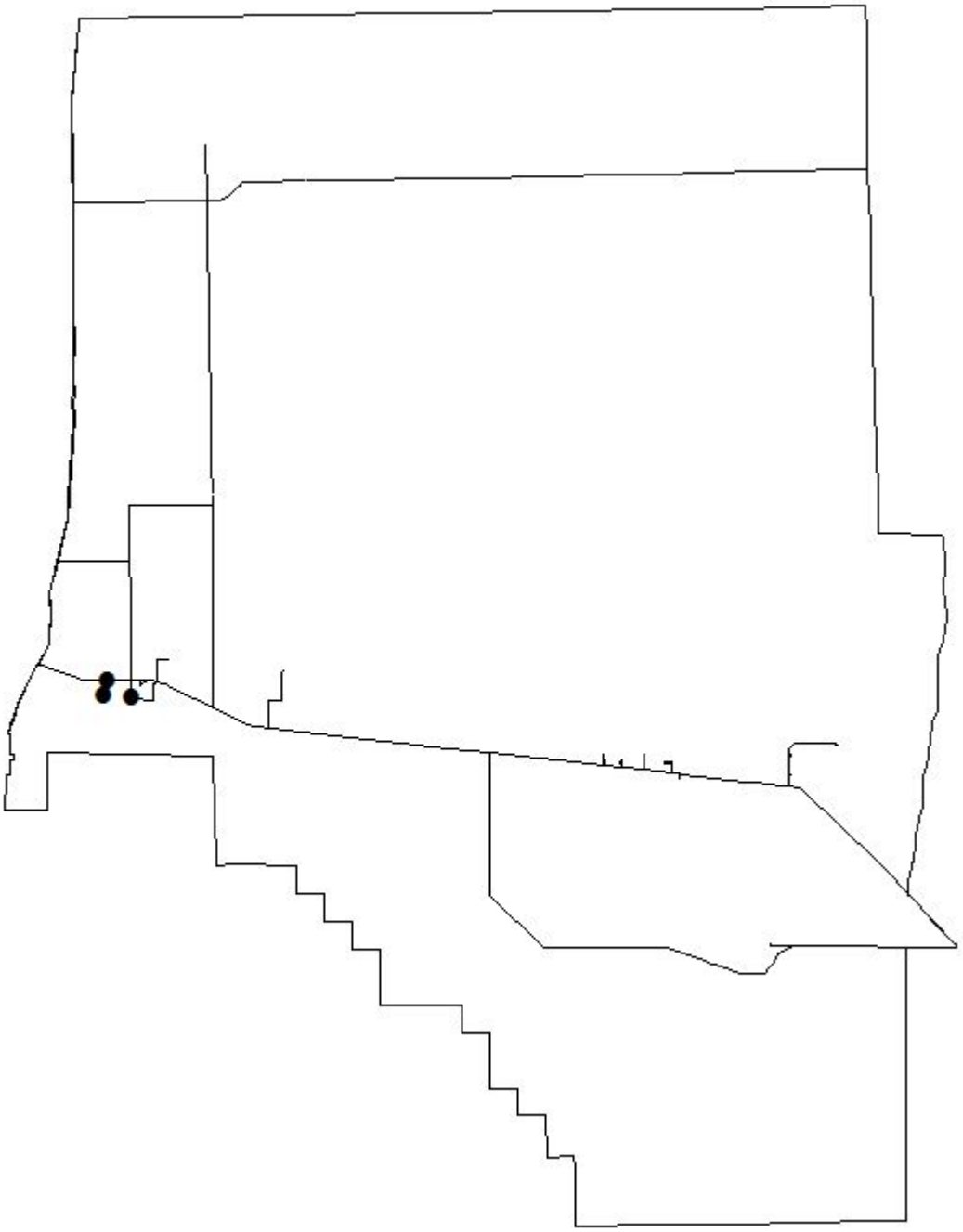
Distribution of Sailfin Molly, *Poecilia latipinna.*



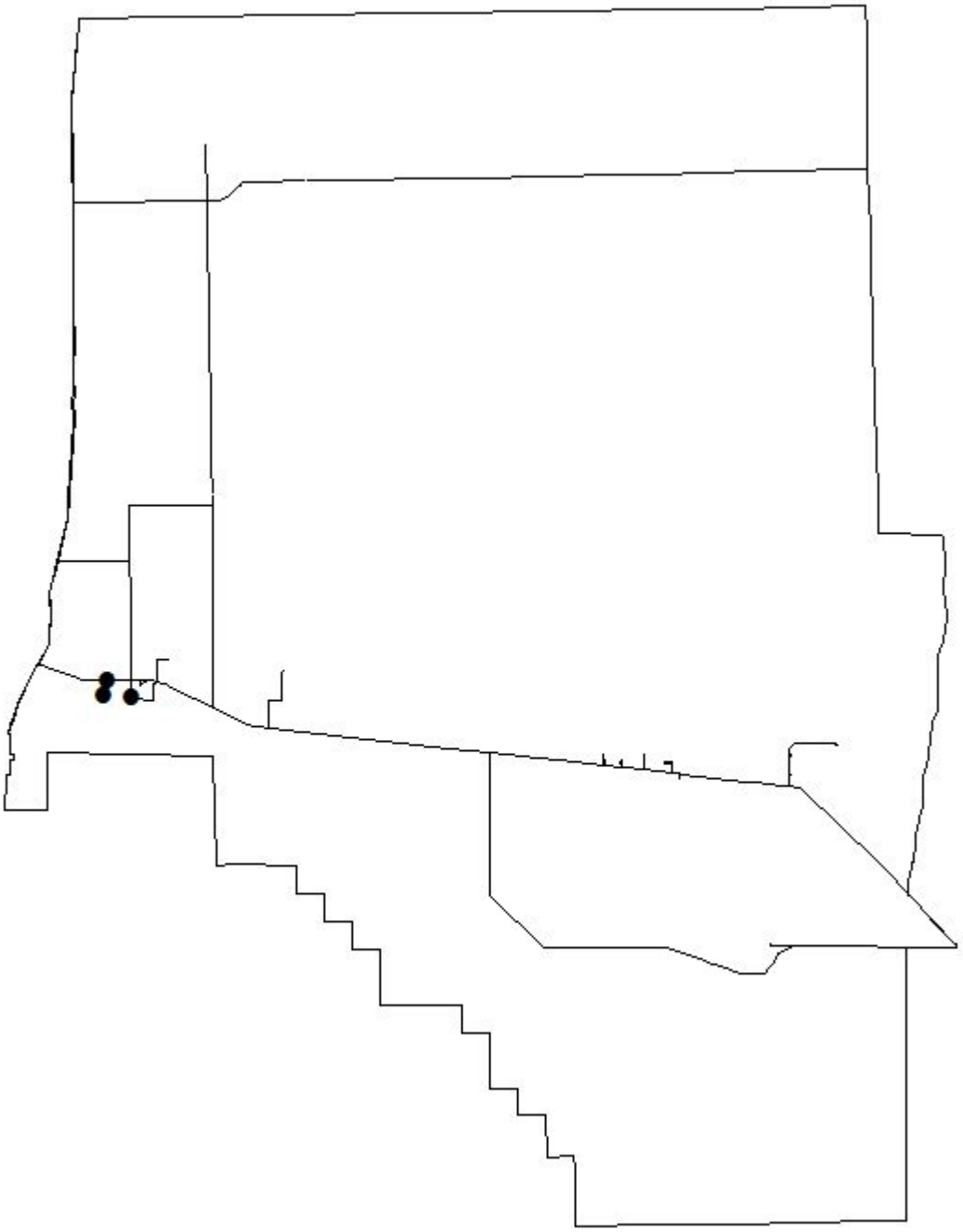
Distribution of Black Crappie, *Pomoxis nigromaculatus.*



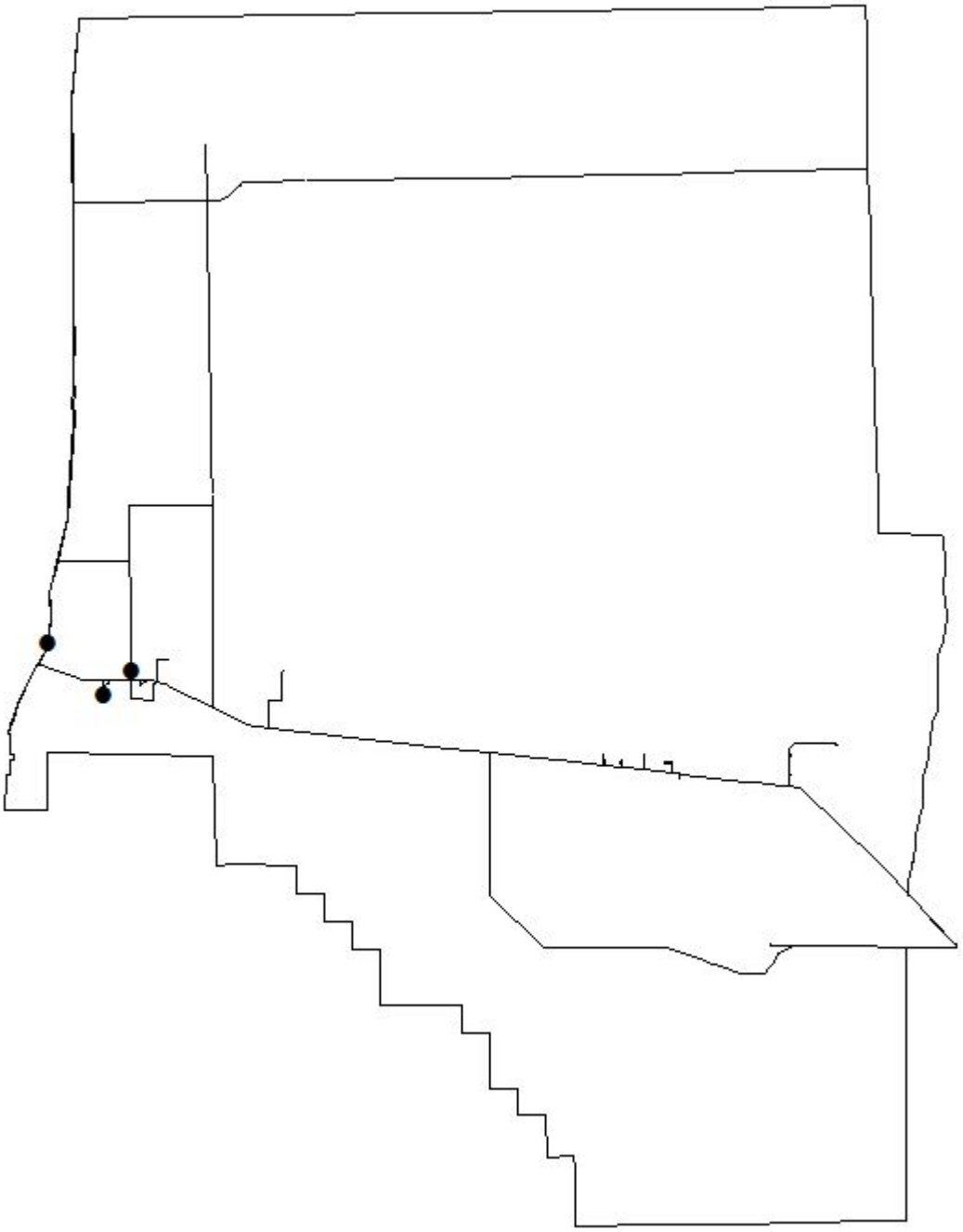
Distribution of Red Drum, *Sciaenops ocellatus.*



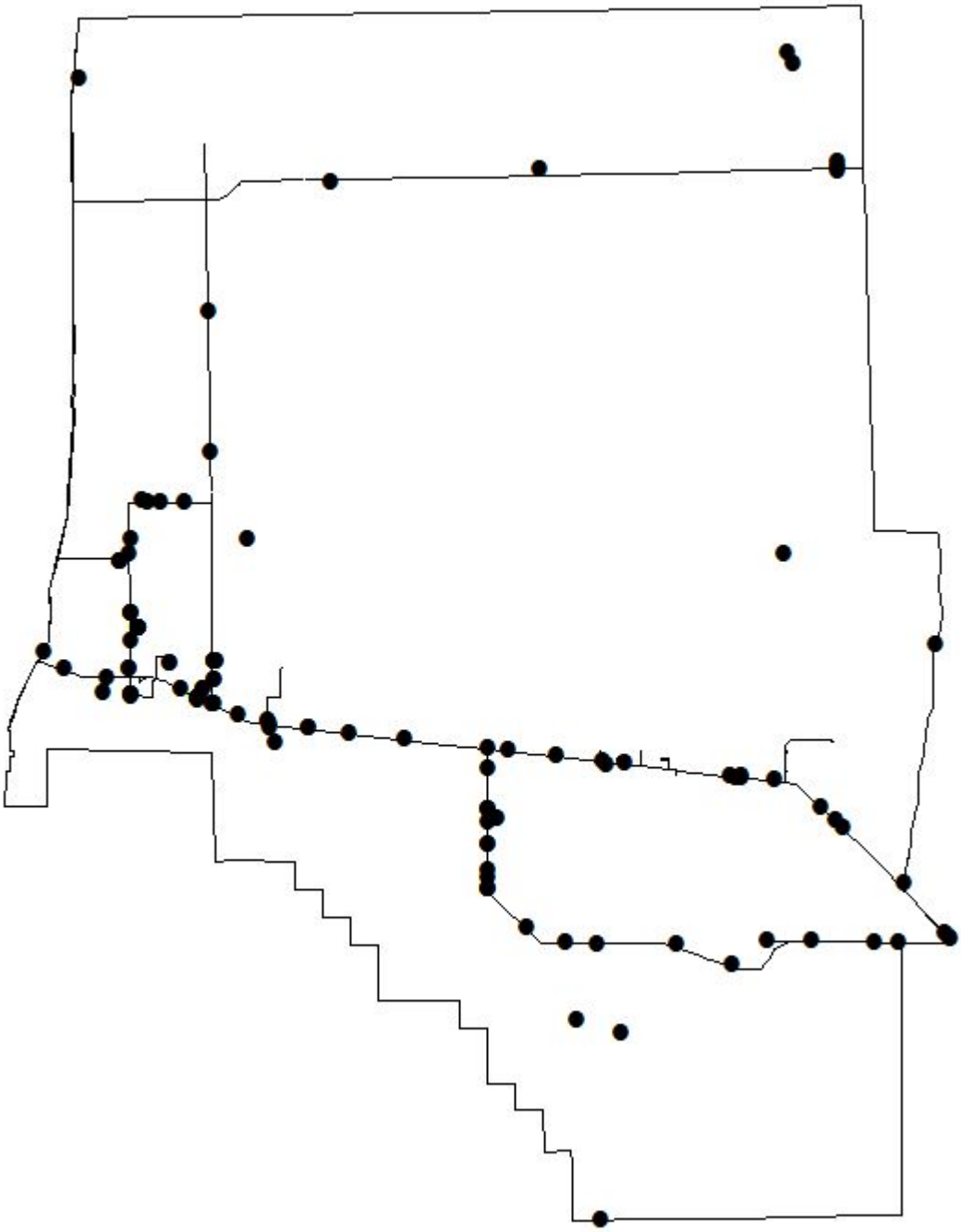
Distribution of Atlantic Needlefish, *Strongylura marina.*



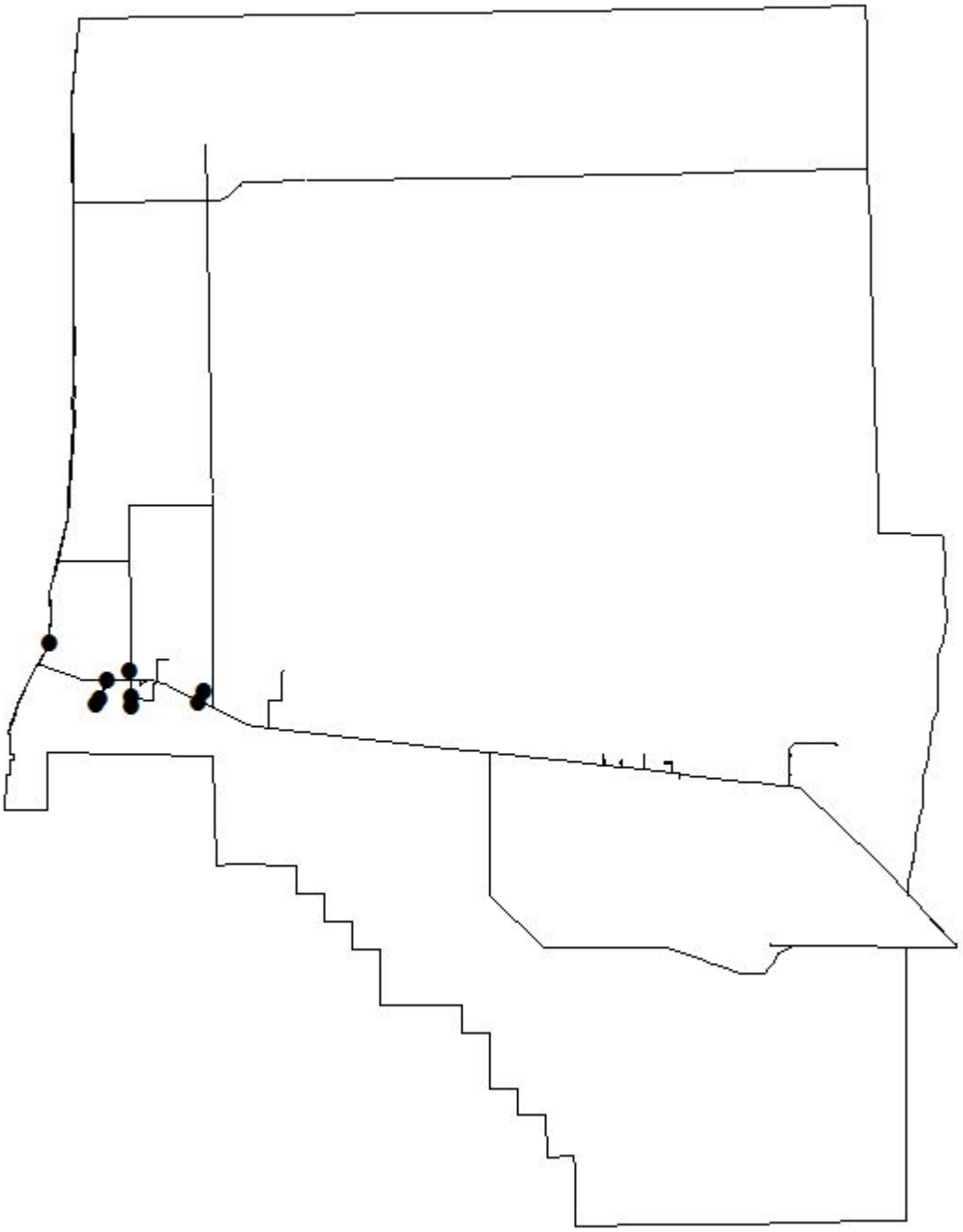
Distribution of Redfin Needlefish, *Strongylura notata.*



Distribution of Timucu, *Strongylura timucu.*



Distribution of Spotted Tilapia, *Tilapia mariae.*



Distribution of Hogchoker, *Trinectes maculatus.*

## APPENDIX 2: POTENTIAL BIG CYPRESS FISH LIST

5: Very Likely: Reported to be present in BCNP
4: Likely: Found in similar habitats in nearby regions of south Florida
3: Possible: Occurs in nearby regions of south Florida
2: Not Likely: Scarce habitat in BCNP or not present in nearby regions of south Florida
1: Very Unlikely: Habitat does not occur in BCNP or is rarely if ever present in south Florida

FLMNH = Specimen(s) in Florida Museum of Natural History

| Family | Common name | Species | Sampled in current study | 5 | 4 | 3 | 2 | 1 | notes |
|---|---|---|---|---|---|---|---|---|---|
| Lepisosteidae | Longnose Gar | *Lepisosteus osseus* | | | | | | X | 6 |
| | Florida Gar | *Lepisosteus platyrhincus* | **X** | X | | | | | 1 |
| Amiidae | Bowfin | *Amia calva* | **X** | X | | | | | 1 |
| Elopidae | Ladyfish | *Elops saurus* | **X** | | | X | | | 2 |
| Megalopidae | Tarpon | *Megalops atlanticus* | **X** | | X | | | | 2 |
| Anguillidae | American Eel | *Anguilla rostrata* | **X** | X | | | | | 1 |
| Clupeiidae | Gizzard Shad | *Dorosoma cepedianum* | **X** | | | X | | | 7 |
| | Threadfin Shad | *Dorosoma petenense* | | | X | | | | 8 |
| Engraulidae | Bay Anchovy | *Anchoa mitchilli* | | | | X | | | 9 |
| Cyprinidae | Golden Shiner | *Notemigonus crysoleucas* | **X** | X | | | | | 1 |
| | Ironcolor Shiner | *Notropis chalybaeus* | | | | | | X | 10 |
| | Taillight Shiner | *Notropis maculatus* | **X** | X | | | | | 1 |
| | Coastal Shiner | *Notropis petersoni* | **X** | X | | | | | 11 |
| | Pugnose Minnow | *Opsopoeodus emiliae* | | | | | X | | 12 |
| Catostomidae | Lake Chubsucker | *Erimyzon sucetta* | **X** | X | | | | | 1 |
| Ictaluridae | White Catfish | *Ameiurus catus* | | | | | X | | 13 |
| | Yellow Bullhead | *Ameiurus natalis* | **X** | X | | | | | 1 |
| | Brown Bullhead | *Ameiurus nebulosus* | **X** | X | | | | | 1 |
| | Channel Catfish | *Ictalurus punctatus* | | | | X | | | 3 |
| | Tadpole Madtom | *Noturus gyrinus* | **X** | | X | | | | 2 |
| Clariidae | Walking Catfish | *Clarias batrachus* | **X** | X | | | | | 1 |
| Ariidae | Hardhead Catfish | *Arius felis* | **X** | | X | | | | 14 |
| | Gafftopsail Catfish | *Bagre marinus* | | | | X | | | 15 |
| Callichthyidae | Brown Hoplo | *Hoplosternum littorale* | **X** | X | | | | | 16 |
| Loricariidae | Vermiculated Sailfin Catfish | *Pterygoplichthys disjunctivus* | | | | | | X | 17 |
| | Orinoco Sailfin Catfish | *Pterygoplichthys multiradiatus* | | | | | X | | 18 |
| Esocidae | Redfin Pickerel | *Esox americanus* | **X** | | | X | | | 19 |
| | Chain Pickerel | *Esox niger* | | | X | | | | 3 |
| Aphredoderidae | Pirate Perch | *Aphredoderus sayanus* | | | | X | | | 20 |
| Atherinidae | Brook Silverside | *Labidesthes sicculus* | **X** | X | | | | | 1 |
| | Inland Silverside | *Menidia beryllina* | **X** | | X | | | | 2 |
| Apocheilidae | Mangrove Rivulus | *Rivulus marmoratus* | | | | | X | | 21 |
| Fundulidae | Diamond Killifish | *Adinia xenica* | | X | | | | | 1 |
| | Golden Topminnow | *Fundulus chrysotus* | **X** | X | | | | | 1 |
| | Marsh Killifish | *Fundulus confluentus* | **X** | X | | | | | 1 |
| | Gulf Killifish | *Fundulus grandis* | **X** | | | X | | | 4 |
| | Lined Topminnow | *Fundulus lineolatus* | | | | | | X | 22 |
| | Redface Topminnow | *Fundulus rubrifrons* | | | | | X | | 23 |
| | Seminole Killifish | *Fundulus seminolis* | **X** | X | | | | | 1 |
| | Longnose Killifish | *Fundulus similis* | | | | | X | | 4 |

## Appendix 2. continued.

| Family | Common name | Species | Sampled in current study | 5 | 4 | 3 | 2 | 1 | notes |
|---|---|---|---|---|---|---|---|---|---|
| | Bluefin Killifish | *Lucania goodei* | **X** | X | | | | | 1 |
| | Rainwater Killifish | *Lucania parva* | **X** | | X | | | | 1 |
| Poeciliidae | Pike Killifish | *Belonesox belizanus* | **X** | X | | | | | 24 |
| | Mosquitofish | *Gambusia holbrooki* | **X** | X | | | | | 1 |
| | Least Killifish | *Heterandria formosa* | **X** | X | | | | | 1 |
| | Sailfin Molly | *Poecilia latipinna* | **X** | X | | | | | 1 |
| Cyprinodontidae | Sheepshead Minnow | *Cyprinodon variegatus* | **X** | X | | | | | 1 |
| | Goldspotted Killifish | *Floridichthys carpio* | | | | | X | | 4 |
| | Flagfish | *Jordanella floridae* | **X** | X | | | | | 1 |
| Belonidae | Atlantic Needlefish | *Strongylura marina* | **X** | | | X | | | 25 |
| | Redfin Needlefish | *Strongylura notata* | **X** | | | X | | | 26 |
| | Timucu | *Strongylura timucu* | **X** | | X | | | | 1 |
| Synbranchidae | Asian Swamp Eel | *Monopterus albus* | | | | | | X | 27 |
| Elassomatidae | Everg. Pygmy Sunfish | *Elassoma evergladei* | **X** | X | | | | | 1 |
| Centropomidae | Common Snook | *Centropomus undecimalis* | **X** | X | | | | | 1 |
| | Tarpon Snook | *Centropomus pectinatus* | | | | | X | | 28 |
| Centrarchidae | Bluespotted Sunfish | *Enneacanthus gloriosus* | **X** | X | | | | | 1 |
| | Warmouth | *Lepomis gulosus* | **X** | X | | | | | 1 |
| | Bluegill | *Lepomis macrochirus* | **X** | X | | | | | 1 |
| | Dollar Sunfish | *Lepomis marginatus* | **X** | X | | | | | 1 |
| | Redear Sunfish | *Lepomis microlophus* | **X** | X | | | | | 1 |
| | Spotted Sunfish | *Lepomis punctatus* | **X** | X | | | | | 1 |
| | Largemouth Bass | *Micropterus salmoides* | **X** | X | | | | | 1 |
| | Black Crappie | *Pomoxis nigromaculatus* | **X** | | X | | | | 3 |
| Percidae | Swamp Darter | *Etheostoma fusiforme* | **X** | X | | | | | 1 |
| Echeneidae | Sharksucker | *Echeneis naucrates* | **X*** | | | | | X | 29 |
| Carangidae | Crevelle Jack | *Caranx hippos* | **X** | | | X | | | 2 |
| Lutjanidae | Gray Snapper | *Lutjanus griseus* | **X** | | | X | | | 30 |
| | Striped Mojarra | *Eugerres plumieri* | **X** | X | | | | | 1 |
| | Spotfin Mojarra | *Eucinostomus argenteus* | | | | | X | | 31 |
| | Silver Jenny | *Eucinostomus gula* | | | | X | | | 32 |
| | Tidewater Mojarra | *Eucinostomus harengulus* | **X** | | | X | | | 33 |
| Sparidae | Sheepshead | *Archosargus probatocephalus* | **X** | | X | | | | 1 |
| | Pinfish | *Lagodon rhomboides* | **X** | | | | X | | 34 |
| Sciaenidae | Red Drum | *Sciaenops ocellatus* | **X** | | | X | | | 2 |
| Cichlidae | Peacock Cichlid | *Cichla ocellaris* | | | | | | X | 35 |
| | Oscar | *Astronotus ocellatus* | **X** | | X | | | | 2 |
| | Black Acara | *Cichlasoma bimaculatum* | **X** | X | | | | | 1 |
| | Mayan Cichlid | *Cichlasoma urophthalmus* | **X** | | X | | | | 36 |
| | Jewelfish | *Hemichromis letourneauxi* | **X** | | | | X | | 37 |
| | Banded Severum | *Heros severum* | | | | | X | | 38 |
| | Blue Tilapia | *Oreochromis aureus* | **X** | | | X | | | 2 |
| | Mozambique Tilapia | *Oreochromis mossambicus* | | | | | | X | 39 |
| | Jaguar Guapote | *Parachromis managuense* | | | | X | | | 40 |
| | Spotted Tilapia | *Tilapia mariae* | **X** | X | | | | | 1 |
| Mugiliidae | Mountain Mullet | *Agonostomus monticola* | | | | | X | | 41 |
| | Striped Mullet | *Mugil cephalus* | **X** | X | | | | | 1 |
| Eleotridae | Fat Sleeper | *Dormitator maculatus* | | | | X | | | 42 |
| | Spinycheek Sleeper | *Eleotris amblyopsis* | | | | | | X | 43 |
| | Bigmouth Sleeper | *Gobiomorus dormitor* | | | | | | X | 44 |
| Gobiidae | Frillfin Goby | *Bathygobius soporator* | **X** | | | | | X | 45 |
| | Crested Goby | *Lophogobius cyprinoides* | **X** | | | X | | | 2 |

## Appendix 2, Continued.

| Family | Common name | Species | Sampled in current study | 5 | 4 | 3 | 2 | 1 | notes |
|---|---|---|---|---|---|---|---|---|---|
| | Naked Goby | *Gobiosoma bosc* | | | X | | | | 46 |
| | Clown Goby | *Microgobius gulosus* | **X** | | | X | | | 5 |
| Achiridae | Lined Sole | *Achirus lineatus* | | | | X | | | 47 |
| | Hogchoker | *Trinectes maculatus* | **X** | | X | | | | 5 |
| | | **Current Total:** | **64** | 37 | 14 | 21 | 13 | 11 | |

| | |
|---|---|
| Species known in BCNP (Column 5) = | 37 |
| Low range | |
| Species probably in BCNP (Columns 5+4) = | 51 |
| Species possibly in BCNP (Columns 5+4+3) = | 72 |
| Max. species possible (Columns 5+4+3+2) = | 85 |
| High range | |

**Notes:**

1: Present in Big Cypress (Loftus & Kushlan 1987)
2: Present in ENP (Loftus & Kushlan 1987)
3: Present in ENP (Loftus & Kushlan 1987) and Lake Trafford (F. Morello, FL FWCC pers. comm.)
4: Present in Everglades drainage, Collier county (FLMNH) and ENP (Loftus & Kushlan 1987)-primarily marine
5: Present in Everglades drainage, Collier county (FLMNH) and ENP (Loftus & Kushlan 1987)
6: Present in Lake Okeechobee (FLMNH), And Water Conservation Area 2a (Loftus and Kushlan 1987) ** Few records in south Florida
7: Present in Lake Okeechobee (FLMNH) and Homestead canals (Loftus & Kushlan 1987) ** Few records from south Florida, but may enter L-28 canal.
8: Present in Tamiami Canal ENP (Loftus & Kuslan 1987) and Lake Trafford (F. Morello. FL FWCC pers. comm.)
9: Present in Everglades drainage Collier county (FLMNH), ENP (Loftus and Kushlan 1987) ** Primarily marine.
10: Present in Lake Okeechobee (FLMNH) ** No records south of Lake Okeechobee.
11: Present in Big Cypress (Loftus and Kushlan 1987)
12: Present in Big Marco Pass drainage??, Collier county and Lake Okeechobee (FLMNH) ** Validity of Collier county record unknown, no other records south of Lake Okeechobee.
13: Present in Lake Okeechobee (FLMNH) and Lake Trafford (F. Morello, FL FWCC pers. comm.) ** Few records in south Florida
14: Present in ENP (Loftus & Kushlan 1987)
15: Present in ENP (Loftus & Kushlan 1987)** Primarily marine.
16: Present in Lake Trafford (F. Morello, FL FWCC, pers. comm.) & collected by USGS researchers in Big Cypress
17: Present in Tampa Bay drainage (FLMNH) ** No records in south Florida.
18: Present In Dade and Broward county (FLMNH) and Lake Trafford (Shafland pers. comm.)
19: Present in ENP (Loftus pers. com.) and Lake Trafford (Morello pers. comm.) ** Few records south of Lake Okeechobee.
20: Present in ENP (Loftus pers. comm.) ** Few records south of Lake Okeechobee.
21: Present in ENP (Tabb & Manning 1961) ** Primarily marine.
22: Present in Lake Okeechobee drainage (FLMNH) ** No records south of Lake Okeechobee.
23: Present in Lake Trafford ** Lack of information on this species.
24: Present in Big Cypress (http://nas.er.usgs.gov)
25: Present in Lake Okeechobee and Collier county coastal waters (FLMNH, ENP)
26: Present in ENP (Loftus and Kushlan 1987)

## Appendix 2, Continued.

27: Present in east coast canals ** Has not been found outside of canals in Dade county
28: Present in ENP (Loftus and Kushlan 1987) ** Few records from SW gulf coast
29: ** Rare in freshwater; was not on list prior to sighting
30: Present in ENP (Loftus and Kushlan 1987)
31: Present in Everglades drainage, Collier county (FLMNH) ** Primarily marine, *E. harengulus* apparently replaces this species in low salinity waters.
32: Present in ENP Loftus and Kushlan 1987) ** Primarily marine.
33: ** No local records, but records of *E. argenteus* in south Florida freshwaters may be this species.
34: Present in Florida freshwaters (FLMNH) ** Primarily marine
35: Present in east coast canals (FLMNH) ** Has not spread from east coast canals.
36: Present in ENP (Loftus, unpublished data - 1987)
37: Present in east coast canals and ENP (Loftus & Kushlan 1987; FLMNH) and Lee County (http://www.swfwc.org/ANS) ** These populations may be spreading
38: Present in east coast canals and ENP (J. Kline, ENP, 2004) ** Has not spread far from east coast canals.
39: Present in east coast canals (Loftus & Kushlan 1987; FLMNH) ** Has not spread from east coast canals.
40: Present in east coast canals and ENP (FLMNH) ** Has begun to spread west into ENP
41: Present in south Florida freshwaters (Loftus & Kushlan 1987) ** No records from SW gulf coast
42: Present in ENP and Big Marco Pass drainage (Loftus and Kushlan 1987; FLMNH) ** Few records from SW gulf coast
43: Present in Florida freshwaters (FLMNH) ** No records from SW gulf coast
44: Present in east coast canals (Loftus & Kushlan 1987; FLMNH) ** No records from SW gulf coast
45: ** Rare in freshwater; was not on list prior to collection
46: Present in Big Cypress (Loftus & Kushlan 1987)-record is from brackish water
47: Present in Everglades drainage, Collier county (FLMNH) and ENP (Loftus and Kushlan 1987)