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Brimleyana, the Journal of the North Carolina State Museum of Natural History, will appear at irregular intervals in consecutively numbered issues. Contents will emphasize zoology of the southeastern United States, especially North Carolina and adjacent areas. Geographic coverage will be limited to Alabama, Delaware, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia.

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Fishes of the Waccamaw River Drainage

JOHN R. SHUTE[1], PEGGY W. SHUTE[1] AND DAVID G. LINDQUIST

Department of Biology,
University of North Carolina at Wilmington,
Wilmington, North Carolina 28406

ABSTRACT.— From 1976 through February 1981, we made 827 collections of fishes from 75 stations in Lake Waccamaw and the Waccamaw River and tributaries; they yielded a total of 56 species from 18 families. Additional records increased the probable total to 62 species. At least five of the Waccamaw species are endemic or exclusively shared with one other drainage. These aspects of the Waccamaw indicate that it is unique among Atlantic Coastal Plain drainage systems. Geological and zoogeographical evidence suggest that the Waccamaw River once drained a larger area extending into the inner Coastal Plain and Piedmont. Uplifting of the Cape Fear Fault resulted in piracy of the Waccamaw headwaters, creating the present Cape Fear drainage. Faunal resemblances between the drainages lend support to this theory.

INTRODUCTION

Since the description of the Waccamaw killifish, *Fundulus waccamensis,* silverside, *Menidia extensa*, and darter, *Etheostoma perlongum*, by Hubbs and Raney (1946), Lake Waccamaw, North Carolina, has been the subject of both biological and physiographical studies (Frey 1948a,b, 1949, 1951) alluding to the relatively high level of fish diversity and endemism. Louder (1962a) provided a checklist of fishes and Hueske (1948) discussed fishery resources. Four species from the lake have been subjects of biological studies: *Notropis petersoni* (Davis and Louder 1971); *F. waccamensis* (Shute et al., ms.); *M. extensa* (Davis and Louder 1969); and *E. perlongum* (Lindquist et al. 1981; Shute et al., in press).

Apart from those of the lake, the fishes of the Waccamaw drainage have received little attention. Louder (1962b) included the Waccamaw drainage in a survey of the Lumber and Shallotte River drainage in North Carolina, and the major purpose of his survey was to evaluate the recreational fishery potential. Fowler (1935) reported on several collections from the Waccamaw drainage in South Carolina.

The Waccamaw is unique among Atlantic coastal drainages. Its overall fish diversity is quite high and includes a number of endemics and forms shared with but one other drainage. Presently two undescribed species of fish are known to occur within the Waccamaw drain-

[1] Present address: Department of Zoology and Entomology, University of Tennessee, Knoxville, TN 37916.
Direct reprint requests to DGL.

age. Seventeen species of plants and animals considered of special concern by biologists were listed from in and around Lake Waccamaw by Teulings and Cooper (1977). Parts of the Waccamaw River's upper reaches have been proposed for inclusion in the National and Scenic Rivers System (Anonymous 1978) because of their relatively undisturbed nature and the river's unique assemblage of flora and fauna.

Geological evidence suggests that the Waccamaw River once drained a much larger area, extending into the inner Coastal Plain and Piedmont. As discussed later, zoogeographical evidence supports this theory, which may explain the high species diversity.

This study was intended to provide a baseline of information on the overall distribution of fishes within the drainage, with special emphasis on the endemic and undescribed forms, because habitat alteration could present a definite problem for most of the unique fishes. There is limited suitable habitat for the species with upland affinities, and impoundment or channelization projects could prove disastrous.

STUDY AREA

The Waccamaw River drainage lies entirely within the low Coastal Plain of North and South Carolina, draining an area of approximately 4000 km^2 (Fig. 1). It is a relatively young system, believed to have been formed during the Late Pleistocene, 32,000 to 75,000 years ago (Zullo and Harris 1979). Sediments consist of Pleistocene sands underlain by the fossiliferous Waccamaw Formation, a limestone formation that is exposed in some areas of the river. The Surry Scarp forms the western border of the system, and to the north the Cape Fear Fault forms a barrier separating the Cape Fear Basin from the Pee Dee Basin (Zullo and Harris 1979).

Friar Swamp

Friar Swamp is the principal feeder system to Lake Waccamaw. Originating from Council Mill Pond (approximately 15 km north-northwest of Lake Waccamaw), this small stream flows south and converges with Slap Swamp, Buckhead Branch, and Gum Swamp to form Big Creek (Fig. 1). Big Creek is a typical blackwater stream with a sandy, muck bottom and an abundance of aquatic vegetation along its shoreline.

Lake Waccamaw

Lake Waccamaw is the largest of the Carolina Bays, with a total area of 3618 ha. Most of its 22.9 km shoreline is characterized by sandy, low-gradient beaches. Vast beds of maidencane, *Panicum hemitomum*, extend offshore along the eastern, southern, and western shores of the lake. Cape Fear spatterdock, *Nuphar luteum sagitifollium*, grows in

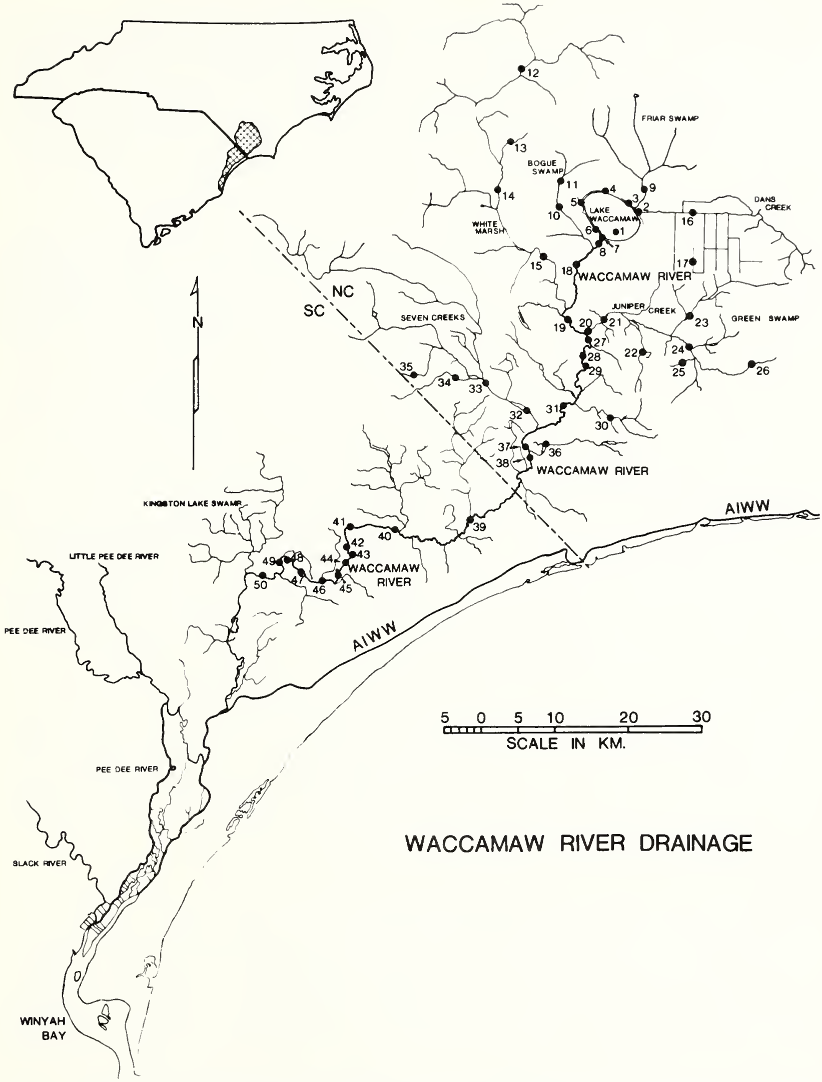

Fig. 1. Map of the Waccamaw River drainage, North and South Carolina, showing fish sampling localities.

dense beds off the northern and northeastern shores. The bottom is mainly sand and fibrous peat. Over the peat bottom, generally toward the middle of the lake, thick stands of bushy-pondweed, *Najas guadalupensis*, occur and a green alga, *Nitella* sp., is seasonally abundant. Average depth of the lake is 2.3 m, and maximum depth is 3.3 m.

In addition to Big Creek, the lake is fed by three smaller streams: Little, Second, and Third creeks. Acid water from these streams is neutralized by the calcareous Waccamaw limestone formation, which underlies the lake and is exposed along the north shore (Frey 1951).

Man-made canals surround much of Lake Waccamaw. They are characterized by dense vegetation (mainly alligator-weed, *Alternanthera philoxeroides;* duckweed, *Lemna perpusilla;* and beggar tick, *Bidens laevis*) and steep, grassy roadside banks, and are open to the lake and the Waccamaw River.

Waccamaw River

The Waccamaw River originates at the south shore of Lake Waccamaw and flows southward approximately 225 km to its confluence with the Pee Dee River at Winyah Bay, South Carolina. The river is sluggish and meandering with an average gradient of only 6.44 cm/km. Above Juniper Creek (Fig. 1), much of the river is less than 15 m wide with the exception of an area known locally as "The Fishponds," located just below Bogue Swamp. Here, for a distance of several hundred meters, the river widens to approximately 50 to 60 m. Below Juniper Creek the river widens considerably, and before crossing the North Carolina/South Carolina state line averages around 75 m wide.

Seasonally, water levels in the river fluctuate considerably. High water occurs in late winter and throughout the spring. During summer and fall the waters recede, creating shallow, sandy stretches.

Bogue Swamp

Bogue Swamp is the first tributary to the Waccamaw River, originating approximately 6.5 km northwest of Lake Waccamaw and flowing 13 km southeast before entering the river (Fig. 1). This is a small, sand-bottom stream, often intermittent during dry months.

White Marsh

Brown Marsh, Elkton Marsh, and Red Hill Swamp flow from the upper part of White Marsh, approximately 23 km northwest of Lake Waccamaw. White Marsh is a sluggish, muck-bottom stream that flows southeast for 33 km before entering the Waccamaw River. Stations sampled during our survey were in Red Hill Swamp and the main stream of White Marsh (Fig. 1). Aquatic vegetation was dense in the areas collected, and station 15 was heavily obstructed with roots, stumps and water-logged branches.

Juniper Creek

Juniper Creek is the largest tributary to the Waccamaw River in North Carolina and is the first to enter the river from the east (Fig. 1). It is formed by the confluence of Muddy Branch and Bear Pen Island, Honey Island and Alligator swamps. Juniper Creek and its tributaries form the major drainage system for Green Swamp. Many interconnecting man-made canals east of Lake Waccamaw join Honey Island Swamp with Dans Creek of the adjacent Cape Fear Drainage. These canals are normally 3 to 5 m wide and 1 to 2 m deep.

Upper Juniper Creek is generally narrow (6 to 8 m) and shallow, and flows year-round. The channel widens to approximately 25 m downstream and becomes sluggish. Before reaching the river it again narrows and flow increases. Much of this stream is characterized by sand bottom and patches of dense aquatic vegetation. The wide, sluggish areas are generally richer in organic debris, and sphagnum moss, *Sphagnum* sp., grows in dense mats along the shoreline. Juniper Creek flows west approximately 35 km to its junction with the Waccamaw River.

Seven Creeks

The headwaters of Seven Creeks are formed by Toms Fork, Mill Branch, and Juniper, Brissett, Gum, Beaver Dam, and Monie swamps. This predominantly muck-bottom stream flows approximately 16 km southeast until reaching the Waccamaw River 13 km above the North Carolina/South Carolina state line. Areas sampled were clogged with a tangle of old tree stumps, roots, and waterlogged branches. Aquatic vegetation was present but not dense.

Many smaller tributaries not discussed also flow into the Waccamaw River. During our survey, no South Carolina tributaries were sampled. Kingston Lake Swamp forms the largest of the Waccamaw River tributaries above the Atlantic Intracoastal Waterway (AIWW). Several small streams and canals connect the Waccamaw and Pee Dee rivers before their confluence at Winyah Bay.

METHODS

From January 1979 through February 1981 a total of 827 collections was made from 75 stations within the Waccamaw River drainage (Table 1). Stations la through m, 2a,b,c, 3, 4, 5, 6, and 7 were sampled monthly during this period. The remaining stations were sampled on an irregular basis, sometimes only once. Six of the mid-lake stations in Lake Waccamaw are treated as one throughout this paper (Station 1i).

Most collections were made with seines varying in size from 3 m × 1.2 m to 15.2 m × 1.8 m, typically with 3 mm mesh. Offshore stations in Lake Waccamaw (and one Waccamaw River station) were sampled with a small otter trawl measuring 2.8 m × 1.3 m at the mouth and lined with 3 mm mesh. Dip nets of various sizes were also used. A representative sample of fishes was usually field preserved in 10% formalin and later stored in 70% ethanol. Large or extremely common species were occasionally returned to the water (some were photographed before release) and records are based on field identifications. Museum specimens and literature records were verified where possible.

Nomenclature follows that used by Robins et al. (1980). Most specimens are housed in the University of North Carolina at Wilmington Fish Collection (UNCW).

Table 1. Sampling stations. US = U.S. highway, CR = county road; NC = N.C. highway.

NORTH CAROLINA

COLUMBUS COUNTY

1a. Lake Waccamaw, north shore public beach on NC 214.
1b. Lake Waccamaw, northeast shore at Hobbs Harbor on NC 214.
1c. Lake Waccamaw, northeast shore just west Big Creek.
1d. Lake Waccamaw, southeast shore at northern boundary state park.
1e. Lake Waccamaw, south shore at southern boundary state park.
1f. Lake Waccamaw, south shore just east dam.
1g. Lake Waccamaw, south shore just above dam.
1h. Lake Waccamaw, southwest shore.
1i. Lake Waccamaw, mid-lake.
1j. Lake Waccamaw, north offshore transect.
1k. Lake Waccamaw. north offshore transect.
1l. Lake Waccamaw, northeast offshore transect.
1m. Lake Waccamaw, south offshore transect.
2a. Big Creek Wildlife Access Area on SR 1947.
2b. Big Cr. trib. at second bridge going east on SR 1947.
2c. Big Cr. at first bridge going east on SR 1947.
3. Waccamaw canal, northeast shore lake on SR 1947.
4. Waccamaw canal, north shore lake on NC 214.
5. Waccamaw canal, northeast shore lake at junction NC 214 and SR 1957.
6. Waccamaw canal, southwest shore lake.
7. Waccamaw River just below dam on south shore lake.
8a. Waccamaw R. from below station 7 to approx. 1.6 river km below lake.
8b. Waccamaw R. between 1.6 and 3.2 river km below lake.
8c. Waccamaw R. between 3.2 and 4.8 river km below lake.
8d. Waccamaw R. between 4.8 and 6.4 river km below lake.
9. Big Cr. at bridge on US 74-76, 4.4 km W Lake Waccamaw.
10. Bogue Swamp, 1.6 km ESE Hallsboro on CR 1736.
11. Bogue Swamp, 1.2 km E Hallsboro on US 74-76.
12. Red Hill Swamp, 16.1 air km N Whiteville on CR 1700.
13. White Marsh trib., 6.4 air km NNE Whiteville on CR 1700.
14. White Marsh, 3.2 km E Whiteville on US 74-76.
15. White Marsh, 8 air km S Hallsboro on CR 1001.
16. drainage canal, 2.4 km S Bolton on NC 211.
17. drainage canal, 9.2 km S Bolton on NC 211.
18. Waccamaw R. at Crusoe Island, 4 air km NE Old Dock.
19. Waccamaw R., 2.4 air km SE Old Dock on CR 1928.
20. Brunswick Co. line; Juniper Cr., oxbow just above confluence Waccamaw R., 4.8 air km ESE Old Dock.

21. Juniper Cr., overflow pond on CR 1928, 5.6 air km ESE Old Dock.
31. Waccamaw R., 7.2. air km NE Pireway, "Reeve's Ferry."
32. Seven Crs., approx. 1.6 km N Pireway on NC 905.
33. Seven Crs., 8 air km NW Pireway on CR 1108.
34. Juniper Swamp, 13.7 air km NW Pireway on CR 1118.
35. Toms Fork, 12.9 air km SE Tabor City on CR 1119.
37. Brunswick Co. line; Waccamaw R., 1.6 air km SE Pireway on NC 904.
38. Brunswick Co. line; Waccamaw R., 1.6-9.7 river km S of NC 904 bridge.

BRUNSWICK COUNTY

22. Aligator Swamp, just N Exum on CR 1335.
23. Big Swamp, 17.7 km S Bolton on NC 211.
24. Juniper Cr., 1.6 air km E Makatoka on CR 1340.
25. Juniper Cr. trib., 3.5 air km SE Makatoka on Cr 1342.
26. Juniper Cr., 29.8 km S Bolton on NC 211.
27a. Columbus Co. line; Waccamaw R. just below confluence Juniper Cr., 5.2 air km SE Old Dock.
27b. Columbus Co. line; Waccamaw R., approx. 1.6 river km below confluence Juniper Cr., 6 air km SE Old Dock.
28. Columbus Co. line; Waccamaw R., 6.4. air km SE Old Dock, approx. 6.4 river km above NC 130.
29a. Columbus Co. line; Waccamaw R., 7.2 air km SE Old Dock, approx. 2.8 river km above NC 130.
29b. Columbus Co. line; Waccamaw R., 8 air km SE Old Dock, approx. 1.6 river km above NC 130.
29c. Columbus Co. line; Waccamaw R. at NC 130 bridge.
30. Wet Ash Swamp, 5.3 air km NE Longwood on NC 130.
36. Scippeo Swamp, 3.2 air km WNW Longwood on CR 1300.

SOUTH CAROLINA

HORRY COUNTY (all stations on Waccamaw River)

39. approx. 3.2 air km SE Longs. 0.8 km N to 2.4 km S of SC 9 bridges.
40. 0.8 km S Red Bluff on SC 31.
41. approx. 4.8 river km W Red Bluff.
42. 4.8 air km N Nixonville.
43. 3.2 air km NNW Nixonville.
44. 2.4 air km NW Nixonville at SC 105.
45. 2.4 air km WNW Nixonville.
46. 0.8 air km NW Grahamville.
47. 7.2 air km SE Hickory Grove.
48. 2.4 air km SE Hickory Grove.
49. 5.6 air km W Conway (Hardee's Ferry).
50. 4 air km W Conway.

ANNOTATED SPECIES LIST

Lepisosteidae — gars

Lepisosteus osseus (Linnaeus), longnose gar. The longnose gar occurs throughout the entire system. Most specimens are from Lake Waccamaw and the main channel of the Waccamaw River. Stations: 1a,c,d,e,f,g, 2b,c, 7, 8a,b,c,d.

Amiidae — bowfins

Amia calva Linnaeus, bowfin. This species appears to be uncommon in Lake Waccamaw, but specimens have been taken throughout the canal system and upper parts of the Waccamaw River. Tightly packed schools of very young bowfin were occasionally observed, and large adults were commonly seen in the river during low water. Stations: 1d, 3, 4, 5, 8a,b,c,d, 9.

Anguillidae — freshwater eels

Anguilla rostrata (Lesueur), American eel. The American eel is common throughout the entire system, in all habitat types sampled where adequate cover exists. Stations: 1a,g,h,i, 2a,c, 7, 8a,b,c,d, 14, 19, 27b, 28, 29a,b,c, 33, 37, 38, 43, 44, 49.

Clupeidae — herrings

Alosa pseudoharengus (Wilson), alewife. Nine juveniles of this anadromous species were collected from a single locality in the mainstream of the river. Station: 42.

Alosa sapidissima (Wilson), American shad. Baker (1968) indicated that the American shad ran upstream in the Waccamaw River as far north as Juniper Creek. No specimens were collected during our survey.

Dorosoma cepedianum (Lesueur), gizzard shad. All of our collections of this species are from Lake Waccamaw. Most specimens were seined from open shoreline areas at night, but small schools were occasionally encountered while trawling at mid-lake stations. R. H. Moore (pers. comm.) reported gizzard shad from lower sections of the Waccamaw River in South Carolina, Stations: 1a,c,f,i.

Dorsoma petenense (Günther), threadfin shad. Threadfin shad were introduced into Lake Waccamaw to provide forage for game species (Nichols 1975). There is no record of successful overwintering and no specimens were taken during our survey.

Umbridae — mudminnows

Umbra pygmaea (DeKay), eastern mudminnow. The mudminnow occurs throughout the system where suitable habitat exists — standing waters with dense growth of aquatic vegetation — and was common in the canals around Lake Waccamaw. Louder (1962a) reported several specimens collected during a half-acre rotenone sample along the northeast shoreline of the lake. We collected specimens from the lake on one occasion. Stations: 1d, 2b,c, 3, 5, 7, 8d, 9, 12, 21, 24, 25.

Esocidae — pikes

Esox americanus Gemlin, redfin pickerel. The redfin pickerel is common throughout most of the system, except Lake Waccamaw where it was rarely taken. Louder (1962a) reported nine specimens from near the mouth of Second Creek along the northeast shore of the lake. Our only collection from the lake was from an overflow area on the southeastern shore; most of our specimens were taken from standing (often stagnant), weed-choked waters of small streams, canals, and occasionally the main river channel. Stations: 1d, 2a,b,c, 3, 5, 6, 8c,d, 9, 10, 12, 13, 15, 24, 25, 29a,c, 49, 50.

Esox niger Lesueur, chain pickerel. This species is also common throughout much of the area surveyed. Frey (1951) and Louder (1962a) reported its presence in the lake. Our only specimen from the lake is a large adult (400-500mm TL) found in a gill net set off the southeastern shore. The main channel of the Waccamaw River and some of its larger tributaries appear to support the best populations of chain pickerel. Stations: 1e, 2a,b,c, 3, 6, 7, 8c,d, 12, 19, 29a,c, 38, 40, 42, 46, 47, 50.

Cyprinidae — minnows and carps

Cyprinus carpio Linnaeus, carp. Carp are reported by local residents to be abundant in Lake Waccamaw. Indeed, the 1979 annual bow-fishing tournament held at the lake produced 2,860 pounds of carp and longnose gar. Despite these reports, we collected only three carp during our survey and sighted several large adults at one of the canal stations. Louder (1962a) listed this species for the first time from Lake Waccamaw, and (1962b) also reported it from Bogue Swamp and White Marsh Swamp, both tributaries to the Waccamaw River. In addition, R. H. Moore (pers. comm.) reported carp from the lower sections of the river in South Carolina. Stations: 1b,i, 6, 7.

Hybognathus regius Girard, eastern silvery minnow. Although the eastern silvery minnow is common in the main channel of Waccamaw River in South Carolina, our survey produced the first specimens from the river in North Carolina. Specimens were collected in open sluggish waters devoid of aquatic vegetation. Stations: 29a, 38, 39, 40, 42, 44, 46.

Notemigonus crysoleucas (Mitchill), golden shiner. The golden shiner occurs in a wide variety of habitats throughout the system, but collections usually consist of only a few individuals. It was most often encountered in standing water, and occasionally in the mainstream of the river. Stations: 1a,b,c,e,g,h, 2a,c, 4, 6, 7, 12, 28, 38, 44.

Notropis chalybaeus (Cope), ironcolor shiner. Ironcolor shiners occur throughout most of the main channel of the Waccamaw River.

Louder (1962a) reported two specimens from the northeast shore of Lake Waccamaw, and we collected one specimen from the lake. Specimens identified by Fowler (1935) as *Erogala formosa* (Putnam) (=*N. hypselopterus*) from the Waccamaw drainage were determined to be a mixture of *N. chalybaeus* and *N. cummingsae*. *Notropis chalybaeus* was often found in association with *N. petersoni*, although it was never as numerous. Stations: 1g, 7, 19, 28, 29a,c, 39, 49.

Notropis cummingsae Myers, dusky shiner. The dusky shiner also appears to be largely confined to the main channel of the river. Small schools were often encountered in open parts of the river, generally those lacking dense vegetation. There are no reports of the species from Lake Waccamaw. Stations: 7, 8a,d, 19, 27a, 28, 29a,c, 50.

Notropis hudsonius (Clinton), spottail shiner. Louder (1962b) reported seven specimens of the spottail shiner from Big Creek, the principal feeder stream to Lake Waccamaw. Records also exist from the Waccamaw River in North Carolina (Menhinick, ms.; Gilbert and Burgess 1980). According to Gilbert and Burgess (1980), this species inhabits large, sluggish coastal rivers and brackish waters on the Atlantic slope. The Big Creek locality does not fit this habitat description. The previously mentioned records for *N. hudsonius*, especially Big Creek, may be based on misidentifications. However, museum specimens for these records in the Waccamaw drainage could not be located for examination. During our survey, no spottail shiners were collected.

Notropis maculatus (Hay), taillight shiner. This cyprinid is distributed throughout much of the Waccamaw system. Louder (1962b) found it in Bogue Swamp, but it does not appear to be present in Lake Waccamaw. However, one population was located in a canal on the southwest shore of the lake, and another in Big Creek not far from its mouth. Other populations exist in the mainstream of the Waccamaw River. Stations: 2a, 6, 29a, 37, 38.

Notropis petersoni Fowler, coastal shiner. This is perhaps the most widespread and abundant cyprinid throughout the system. The Lake Waccamaw population was originally described at *Notropis waccamanus* by Fowler (1942) and later placed in the synonymy of *N. petersoni* by Frey (1951). Davis and Louder (1971) discussed the biology of the species in North Carolina waters (including Lake Waccamaw). We encountered it in all habitat types sampled, with the notable exception of the canals around Lake Waccamaw. Stations: 1,a,b,c,d,e,f,g,h,i,l,m, 2a,c, 7, 8a,b, 19, 27b,c, 31, 37, 38, 39, 40, 42, 44, 47, 49, 50.

Catostomidae — suckers

Erimyzon oblongus (Mitchill), creek chubsucker. This species is common throughout the system in a wide variety of habitats. Frey (1951) first reported it from Lake Waccamaw, and apparently our single specimen represents the only other published record from the lake. We encountered difficulties in identifying certain individuals, especially juveniles, which often appear to be intermediate between *E. oblongus* and *E. sucetta*. Rohde et al. (1979) also experienced similar difficulties with specimens from southeastern North Carolina. Hanley (1976) concluded that hybrids between *E. oblongus* and *E. sucetta* do occur, and that these hybrids may backcross with both parental stocks. Stations: 1e, 2a,c, 6, 7, 14, 19, 21, 28, 29c.

Erimyzon sucetta (Lacépède), lake chubsucker. Very few lake chubsuckers were taken during our survey and none from Lake Waccamaw, although Louder (1962a) reported four specimens from the northeast shore of the lake. Most of our specimens were taken in heavily vegetated areas of standing or slow-moving water. Stations: 3, 7, 21, 30.

Minytrema melanops (Rafinesque), spotted sucker. Our specimens came from the main channel of the Waccamaw River and were taken from open, moving waters with little or no cover. Stations: 19, 38.

Ictaluridae — freshwater catfishes

Ictalurus catus (Linnaeus), white catfish. The white catfish is widespread throughout Lake Waccamaw and the main channel of the Waccamaw River. Several adults exceeding 400 mm TL were trawled from mid-lake stations. Stations: 1a,b,c,e,h,i, 7, 8a,b,c, 28, 29a, 38, 44, 47.

Ictalurus melas (Rafinesque), black bullhead. Louder (1962b) reported the black bullhead from Red Hill Swamp (White Marsh tributary) and Shingletree Swamp (Waccamaw River tributary). We collected no specimens and found no museum specimens, and its occurrence in the Waccamaw drainage is doubtful. Menhinick et al. (1974) suggested that Louder's records probably referred to *I. nebulosus*.

Ictalurus natalis (Lesueur), yellow bullhead. No specimens of the yellow bullhead were taken from Lake Waccamaw during our survey, but several were collected from the main channel of the Waccamaw River. Louder (1962a) reported one small specimen from the northeast shore of the lake. Stations: 8a,b,d, 19, 29a,47.

Ictalurus nebulosus (Lesueur), brown bullhead. The brown bullhead has not previously been reported from Lake Waccamaw, but we collected four specimens there during our survey. E. F. Menhinick (pers. comm.) collected two specimens from Toms Fork Creek, a tributary to Seven Creeks. Stations: 1b,h.

Ictalurus platycephalus (Girard), flat bullhead. We discovered one adult flat bullhead in a gill net set off the southeastern shore of Lake Waccamaw, which represents only the second published report of this species from the lake. Louder (1962a) reported a specimen from along the northeast shore of the lake. The species is also present in the Waccamaw River below Conway, South Carolina (R. H. Moore, pers. comm.). Station: 1e.

Ictalurus punctatus (Rafinesque), channel catfish. Although no specimens of the channel catfish were collected during our survey, R. H. Moore (pers. comm.) reported its presence in the lower reaches of the Waccamaw River.

Noturus gyrinus (Mitchill), tadpole madtom. The tadpole madtom has been taken in a variety of habitats throughout much of the system. Most of our specimens came from the lake and the main channel of the Waccamaw River. This madtom generally avoids swifter sections of the river and was usually associated with thick vegetation or debris. Frey (1951) discussed variation between populations from the North Carolina Bay Lakes (including Lake Waccamaw). Stations: 1a,c,e,f,g,h,i, 2c, 5, 7, 8a, 38, 40, 46.

Noturus insignis (Richardson), margined madtom. This species was taken exclusively from areas of flowing water and abundant cover in the main channel of the Waccamaw River. It appeared to be the dominant ictalurid species captured in the river. Stations: 7, 8a,d, 19, 28, 29a,b, 38.

Noturus species, broadtail madtom. Two distinct populations of this undescribed madtom exist in the Waccamaw drainage. The form found in the main channel of the Waccamaw River, taken by us from Station 19 and downstream sites, is also found in the adjacent Cape Fear drainage (Jenkins and Palmer 1978). It often occurred with *N. insignis*. Specimens from Lake Waccamaw clearly differ from the river specimens, but the degree of differentiation has not yet been determined (R. E. Jenkins, pers. comm.). The closest relative appears to be *N. leptacanthus* (Jenkins and Palmer 1978). The Lake Waccamaw form (found throughout the lake and directly below the dam) was often found in cans and bottles as well as under tiles placed as experimental spawning sites for the Waccamaw darter. Broadtail madtoms appear to be relatively common in the lake and may outnumber *N. gyrinus*. Stations: 1a,c,d,f,i,j,k,l,m, 7, 19, 28, 29a, 38, 50.

Amblyopsidae — cavefishes

Chologaster cornuta Agassiz, swampfish. The swampfish was never common at any locality. It was encountered in standing or sluggish waters, usually choked with aquatic vegetation or debris. No record of this species from Lake Waccamaw exists and we found none there during our survey. Stations: 2b,c, 6, 7, 8a,b,c,d, 24, 25, 26.

Aphredoderidae — pirate perches

Aphredoderus sayanus (Gilliams), pirate perch. Although Louder (1962a) reported the pirate perch from Lake Waccamaw, and E. F. Menhinick (pers. comm.) also collected one lake specimen, we collected none from the lake. Pirate perch do occur in standing or sluggish and heavily vegetated waters elsewhere throughout the system. Stations: 2a,b,c, 3, 4, 6, 7, 8a,b,c,d, 10, 12, 13, 15, 17, 19, 20, 21, 22, 24, 25, 26, 27a, 29b,c, 30, 38, 39, 43.

Cyprinodontidae — killifishes

Fundulus chrysotus (Günther), golden topminnow. The range of the golden topminnow was originally thought to extend along the Atlantic coast only as far north as the Santee drainage, South Carolina (Shute 1980). Recently, however, specimens were collected by R. H. Moore (pers. comm.) from the Waccamaw River at Bucksville, South Carolina, 12.5 air km south-southeast of Conway. We examined the specimens and concur with Moore's identification. In addition, specimens from Waverly Mills, South Carolina (Waccamaw drainage) identified as this species by Fowler (1935) have been verified.

This species prefers river backwaters, slow-moving streams, or ditches, and is usually associated with dense growths of aquatic vegetation (Shute 1980). Ample habitat certainly exists throughout most of the drainage and additional populations quite likely exist.

Fundulus diaphanus (Lesueur), banded killifish. Fowler (1935) reported the banded killifish from Waverly Mills (presumably on the Waccamaw River), South Carolina. These specimens were examined by Hubbs and Raney (1946) and re-examined by us, and are typically *F. diaphanus*. This represents the southernmost extent of the species' range (Gilbert and Shute 1980). No banded killifish were collected during our survey.

Fundulus lineolatus (Agassiz), lined topminnow. We collected this species from Lake Waccamaw for the first time. The species is rare in the lake but common throughout the swamps and canals of the system. Specimens are usually encountered in standing, heavily-vegetated, dark-stained waters. Stations: 1c,g,h, 2a,b,c, 3, 6, 7, 13, 14, 17, 20, 21, 22, 24, 27a, 28, 29c, 30, 37, 38, 40.

Fundulus waccamensis Hubbs and Raney, Waccamaw killifish. The Waccamaw killifish was originally described as a Lake Waccamaw endemic by Hubbs and Raney (1946). Recently, however, Bailey (1977) reported specimens believed to be *F. waccamensis* from Lake Phelps, most of which lies in Washington County in northeastern North Carolina. Specimens from Lake Phelps examined by us and E. F. Menhinick (pers. comm.) were found to differ slightly from *F. waccamensis* in respect to head length, interorbital width, and caudal peduncle length. This slight differentiation might tend to lessen the possibility that *F. waccamensis* was accidentally introduced into Lake Phelps.

In the Waccamaw system, this killifish occurred at nearly all lake stations sampled. In addition, it was found (especially during winter months) throughout the lower parts of Big Creek, the canals around the lake, and in the headwaters of the river just below the dam. The Waccamaw killifish typically inhabits the shallow, sandy shoreline of the lake where it is often associated with dense stands of *Panicum hemitomum*. No specimens have been taken in the river farther than 100 m below the lake. Stations: 1a,b,c,d,e,f,g,h,i,l, 2a,b,c, 3, 4, 5, 6, 7.

Poeciliidae — livebearers

Gambusia affinis (Baird and Girard), mosquitofish. The mosquitofish was collected throughout the entire system in nearly every habitat type sampled, but was never collected while trawling at mid-lake stations and was only rarely taken at other stations within the lake. Stations. 1a,b,c,d,e,f,g,h, 2a,b,c, 3, 4, 5, 6, 7, 8a,b,c,d, 9, 10, 12, 14, 19, 20, 21, 22, 27a,b, 28, 29a,b,c, 30, 31, 33, 34, 36, 37, 38, 39, 40, 42, 43, 44, 49, 50.

Heterandria formosa Agassiz, least killifish. This diminutive poeciliid was only collected from one station in the South Carolina section of the Waccamaw River, and is probably more abundant in the extreme lower reaches of the river. Fowler (1935) reported it from Waverly Mills, South Carolina (Waccamaw drainage). Station: 42.

Atherinidae — silversides

Menidia extensa Hubbs and Raney, Waccamaw silverside. The Waccamaw silverside is possibly the most abundant fish in Lake Waccamaw. It also has the most limited distribution of the described endemic species in the lake. Specimens have never been collected in Big Creek or the canals surrounding the lake. A few stragglers (washovers) are occasionally taken below the dam, but never more than 30 or 40 m downstream from the lake. This species inhabits open, non-vegetated waters along the shoreline of the lake and is occasionally taken in offshore waters. Stations: 1a,b,c,d,e,f,g,h,i, 7.

Percichthyidae — temperate basses

Morone americana (Gmelin), white perch. The white perch is common in Lake Waccamaw and is considered to be the predominant game species there. It was encountered, often in large numbers, at mid-lake trawl stations. Except for one adult from Big Creek and another from below the dam, the species was not collected outside the lake during our survey. The specimen from Big Creek was injured and may have been released by a fisherman. R. H. Moore (pers. comm.) reported white perch from the lower Waccamaw River and Winyah Bay in South Carolina. Stations: 1a,b,c,e,f,g,i, 2a, 7.

Morone saxatilis (Walbaum), striped bass. Baker (1968) indicated that this anadromous species runs up the main channel of the Waccamaw River almost as far north as Juniper Creek. No specimens were collected during our survey.

Centrarchidae — sunfishes

Acantharchus pomotis (Baird), mud sunfish. This secretive species was rarely encountered during our survey and was never collected from Lake Waccamaw. Louder (1962a) reported it from a rotenone station along the northeast shore of the lake, an area where feeder streams enter and aquatic vegetation is abundant. We usually found it in areas of standing water where submergent vegetation was extremely dense. Stations: 2b, 3, 8d, 9, 13, 15.

Centrarchus macropterus (Lacépède), flier. Louder (1962a) reported the flier from Lake Waccamaw. Bruce B. Collette (pers. comm.) also collected an adult from the north shore of Lake Waccamaw in 1958. We collected no specimens from the lake, but found the species throughout much of the rest of the drainage, where it preferred standing or sluggish water, usually with an abundance of aquatic vegetation. Stations: 2b,c, 4, 5, 6, 9, 10, 12, 28, 34, 38, 43.

Elassoma evergladei Jordan, Everglades pygmy sunfish. Three specimens of the Everglades pygmy sunfish, the first to be reported from Lake Waccamaw, were collected from a swampy area on the southeastern shore of the lake. Major populations appear to be confined mainly to Juniper Creek and tributaries where it is often associated with an undescribed pygmy sunfish. Specimens were usually collected from weedy, shallow backwaters of small streams. Stations: 1d, 17, 21, 23, 24, 25, 26, 30.

Elassoma zonatum Jordan, banded pygmy sunfish. Louder (1962a) reported this pygmy sunfish from Lake Waccamaw, where it was collected with rotenone from dense vegetation along the northeast shore. We did not find it in the lake, but specimens were commonly taken from the surrounding canals and Big Creek. The species is common throughout the system, except where replaced by *E. evergladei* and the undescribed form. The habitat is similar to that of *E. evergladei*. Stations: 2a,b, 3, 4, 5, 6, 7, 8a,b,c,d, 9, 10, 12, 13, 15, 19, 20, 22, 27b, 29c, 30, 33, 34, 38.

Elassoma species, undescribed pygmy sunfish. This species, closely related to *E. zonatum* (Böhlke and Rohde 1980), has only been collected from two streams in the Waccamaw drainage. It is relatively common throughout Juniper Creek, where its distribution and habitat closely parallel those of *E. evergladei*. It is also collected regularly from one Big Creek tributary (Station 2b), and has been taken once in the main channel of Big Creek (Station 2c) and once at Station 2a. The absence of this species from other streams within the system suggests a limited distribution. Olmsted and Cloutman (1978) reported collecting an undescribed *Elassoma* species from Black Creek (Pee Dee drainage) in the Sandhills National Wildlife Refuge, South Carolina, but this report appears to be based on misidentified *E. zonatum* (F. C. Rohde, pers. comm.). Pygmy sunfish superficially resembling this species have been collected by Rohde (pers. comm.) from Jasper County, South Carolina (Savannah drainage). In addition to stations listed below, three specimens were recently collected from a canal just east of Lake Waccamaw (not mapped). Stations: 2a,b,c, 21, 24, 25, 26.

Enneacanthus chaetodon (Baird), blackbanded sunfish. This centrarchid was collected from only six localities throughout the system, where it occurs in standing, heavily vegetated waters. Aquatic pondweed, *Potamogeton* sp., was often present where specimens were collected. Stations: 2a,b,c, 6, 8d, 21.

Enneacanthus gloriosus (Holbrook), bluespotted sunfish. The bluespotted sunfish is distributed throughout the entire system but was collected only once from Lake Waccamaw during our survey. It occurs in quiet weedy backwaters of the Waccamaw River and tributaries. Stations: 1d, 2a,b,c, 3, 4, 5, 6, 7, 10, 16, 21, 23, 24, 26, 29c, 38.

Enneacanthus obesus (Girard), banded sunfish. Louder (1962a) reported this small species from Lake Waccamaw, and we collected it there once. It was collected at scattered localities throughout the system, and many specimens came from the Juniper Creek area. Habitat preferences are similar to those of the other *Enneacanthus* species. Stations: 1d, 2a,b,c, 3, 8, 17, 21, 23, 26, 30.

Lepomis auritis (Linnaeus), redbreast sunfish. Major populations of this sunfish appear to be confined to the Waccamaw River; few specimens were collected from Lake Waccamaw, and only two individuals were taken from Big Creek. The redbreast sunfish was stocked in Lake Waccamaw by the North Carolina Wildlife Resources Commission (Nichols 1975). Stations: 1,g,j, 2a, 7, 8a, 19, 27a, 28, 29a,b, 31, 37, 38, 39, 40, 42, 44, 49, 50.

Lepomis gibbosus (Linnaeus), pumpkinseed. The pumpkinseed was commonly collected from Lake Waccamaw and the main channel of the Waccamaw River, but was clearly absent from most of the smaller tributaries. Adult specimens were often trawled from open waters of the lake. Stations: 1a,d,g,h,i, 2a,b,c, 3, 4, 7, 8a,d, 21, 29c, 37.

Lepomis gulosus (Cuvier), warmouth. Although both Louder (1962a) and Frey (1951) reported this species in Lake Waccamaw, we took none from the lake during our survey. The species was common in Big Creek, the canals around Lake Waccamaw, and many Waccamaw River tributaries, where it occurs in quiet, weedy streams and river backwaters. Stations: 2a,b,c, 4, 6, 7, 12, 14, 20, 21, 38, 40.

Lepomis macrochirus Rafinesque, bluegill. Bluegills are common throughout the entire Waccamaw system, including Lake Waccamaw. Specimens were associated with some type of cover, usually aquatic vegetation or cypress stumps. Despite its abundance, large adults were rarely taken. Stations: 1a,b,c,e,g,h,i, 2a,b,c, 3, 4, 6, 7, 8a,b,c, 12, 14, 21, 24, 29a,c, 31, 33, 34, 37, 38, 39, 40, 44, 49, 50.

Lepomis marginatus (Holbrook), dollar sunfish. Two adult specimens, taken on separate occasions, were collected from the south shore of Lake Waccamaw above the dam. This is the first report of the species from the lake. Throughout the system the dollar sunfish has been collected in shallow, weedy backwaters of the river and tributaries, as well as in borrow pits in the Green Swamp. Stations: 1g, 2a,c, 7, 8b,c, 19, 21, 27b, 29a, c, 37, 38, 39, 40.

Lepomis microlophus (Günther), redear sunfish. The redear sunfish was introduced into the Waccamaw drainage to establish another suitable game species (Louder 1962b; Nichols 1975, and pers. comm.). During our survey no specimens were collected from Lake Waccamaw and only one was collected from the Waccamaw River in south Carolina. Louder (1962b) reported specimens from Big Creek, Gum and Grey swamps (White Marsh tributaries), Tabor City Run (Seven Creeks tributary), and South Ash Swamp (direct tributary to Waccamaw River). Station: 42.

Lepomis punctatus (Valenciennes), spotted sunfish. Frey (1951) first reported the spotted sunfish in Lake Waccamaw. We failed to collect any from the lake during our survey and took specimens only from two localities on the Waccamaw River. Louder (1962b) reported the species present throughout much of the system, and included several specimens from Big Creek. Preferred habitat appears to be quiet, vegetated backwaters. Stations: 38, 40.

Micropterus salmoides (Lacépède), largemouth bass. Largemouth bass are common throughout Lake Waccamaw and much of the Waccamaw River. Outside the lake the species appeared to be most common in the main channel of the river and its larger tributaries. Stations: 1a,c,d,e,g,h,l,k, 2a,c, 6, 7, 8a,b, 14, 29a, 37, 38, 39, 49, 42.

Pomoxis nigromaculatus (Lesueur), black crappie. Although Louder (1962a) reported this species to be one of the most important game fishes in Lake Waccamaw, it was not often collected during our survey. The species has been found in habitats ranging from open lake waters to flood ponds of small swamps. Stations: 1a,e,i, 7, 12, 44.

Percidae — perches

Etheostoma fusiforme (Girard), swamp darter. The swamp darter is the most widespread percid in the Waccamaw system, occurring in nearly every habitat type sampled. It is particularly abundant in the offshore waters of Lake Waccamaw. The northern subspecies, *Etheostoma fusiforme fusiforme* (Girard) reaches it southernmost limit in the Waccamaw River (Collette 1962), but is replaced by the southern species, *E. f. barratti* (Holbrook), in the Pee Dee River (of which the Waccamaw is a tributary). All of our specimens were the nominate subspecies, but extensive studies have not been conducted. Bailey and Frey

(1951) studied variation in darters of the subgenus *Hololepis* from some natural lakes of North Carolina (including Lake Waccamaw). Stations: 1a,b,c,d,e,f,g,h,i,m, 2a,c, 3, 4, 6, 7, 14, 21, 22, 27b, 28, 29c, 33, 37, 39, 44, 49.

Etheostoma olmstedi Storer, tessellated darter. With very few exceptions, this darter is confined to the main channel of the Waccamaw River. Few other streams in the system offer suitable habitat, which most often was shallow, moving water over sand or fine gravel substrate. Stations: 7, 8a,b,c,d, 19, 27a,b, 28, 29a,b,c, 31, 33, 38, 39, 40, 41, 42, 43, 44, 47, 49.

Etheostoma perlongum (Hubbs and Raney), Waccamaw darter. We collected the Waccamaw darter from all localities sampled within Lake Waccamaw. In spring and summer months it is common along the shallow shoreline of the lake, sometimes in association with emergent vegetation, but during colder months specimens are more often collected in offshore waters. *Etheostoma perlongum* is sometimes taken below the dam and in the upper headwaters of the Waccamaw River, where it is found in association with *E. olmstedi* and where specimens exhibiting characters intermediate between the specie are often collected. Stations: 1a,b,c,d,e,f,g,h,i,j,k,l,m, 7,8a.

Etheostoma serriferum (Hubbs and Cannon), sawcheek darter. The sawcheek darter is widely distributed throughout the system, but no specimens were collected from Lake Waccamaw. The species prefers standing or sluggish and heavily vegetated water, often rich in organic debris, and often occurs in the same habitat as pygmy sunfishes. Stations: 2b, 4, 6, 7, 8d, 13, 19, 21, 22, 24, 26, 27a, 28, 29a,c, 30, 33, 37, 38, 40, 42, 43, 44.

Perca flavescens (Mitchill), yellow perch. The yellow perch is common in Lake Waccamaw and occasionally was collected in the Waccamaw River. It occurs in open waters with little cover, and is taken by anglers, especially from areas around the dam. Stations: 1a,b,e,f,g,i,k,l,m, 2a, 7, 8d, 38, 42.

Soleidae — soles

Trinectes maculatus (Bloch and Schneider), hogchoker. We collected the hogchoker only from the lower reaches of the Waccamaw River, where specimens were taken in quiet, sluggish open waters over mud bottoms. Stations: 40, 44, 48, 49, 50.

DISCUSSION

A drainage is defined by Jenkins et al. (1972) as "an interconnected major group of streams, or systems entering the marine habitat. . . ." Geographically, the Waccamaw River is a tributary in the Pee Dee drainage, and the Waccamaw and Pee Dee rivers converge to form the upper part of Winyah Bay, an estuarine habitat. We propose that

Winyah Bay forms an effective barrier limiting faunal exchange between the two rivers, at least for most of the freshwater forms. Therefore, we argue that the Waccamaw should be viewed as a separate drainage that limits dispersal of most primary freshwater fishes. A similar situation exists between the Chowan and Roanoke Rivers, where the Chowan enters the Roanoke drainage in the estuarine habitat of Albemarle Sound. According to Jenkins et al. (1972) there is "some merit in considering it (the Chowan) a separate drainage."

Fifty-six species of freshwater and diadromous fishes were collected from the Waccamaw drainage during our survey. These include four families of secondary freshwater fishes (Lepisosteidae, Cyprinodontidae, Poeciliidae and Atherinidae), and four families of diadromous fishes (Anguillidae, Clupeidae, Percichthyidae, and Soleidae), with the remaining ten families representing primary freshwater forms (mostly after Myers 1938). Most of the secondary freshwater and diadromous species behave as primary forms, and two — *Fundulus waccamensis* and *Menidia extensa* — are known only from fresh water. Nine additional species—*Alosa sapidissima*, *Dorosoma petenense*, *Notropis hudsonius*, *N. hypselopterus*, *Ictalurus melas*, *I. punctatus*, *Fundulus chrysotus*, *F. diaphanus* and *Morone saxatilis* — have been reported (various sources listed in text) from the Waccamaw River and tributaries. Of these, *Fundulus chrysotus* and *F. diaphanus* have been examined and verified by us. *Alosa sapidissima*, *Notropis hudsonius*, *Ictalurus punctatus* and *Morone saxatilis* were not verified, but probably do occur. It is doubtful that the remaining three species — *Dorosoma petenense*, *Notropis hypselopterus*, and *Ictalurus melas* — are found in this drainage. Compared to other small Atlantic Coastal Plain drainages, the Waccamaw drainage has an unusually high species diversity (Table 2). This can be partly attributed to the lentic habitats of Lake Waccamaw, from which 44 species have been collected by us or otherwise reported.

The Waccamaw and Little Pee Dee (Big Swamp and Lumber systems) once occupied a much larger basin draining areas of the inner Coastal Plain and Piedmont. Approximately 75,000 years ago the uplift of the Cape Fear Fault (roughly paralleling the Cape Fear River) resulted in elevation of land southwest of the Cape Fear River and subsequent pirating of the upper parts of the Waccamaw and Little Pee Dee systems by the Cape Fear (Zullo and Harris 1979). Stream flow was diverted along this fault to form the Cape Fear River, leaving the Waccamaw and Little Pee Dee systems with greatly reduced drainage basins confined largely to the Coastal Plain. Zoogeographic evidence also suggests a close relationship between these drainages. Three species of fish are shared exclusively by the Cape Fear and Pee Dee drainages: *Semotilus lumbee*, Sandhills chub (Snelson 1980); *Hybopsis* species, thinlip chub (Jenkins and Lachner 1980); and *Noturus* species, broadtail madtom (Jenkins and Palmer 1978). However, only one of these, the broad-

Table 2. Number of species (genera) found in fresh waters of selected Atlantic coastal drainages.

Family	Waccamaw [1]	Shallotte [2]	White Oak [3]	Newport [3]	South Carolina [4]
Lepisosteidae	1(1)	1(1)	1(1)	1(1)	-
Amiidae	1(1)	-	-	-	1(1)
Anguillidae	1(1)	1(1)	1(1)	1(1)	1(1)
Clupeidae	2(2)	-	1(1)	1(1)	-
Umbridae	1(1)	1(1)	1(1)	1(1)	1(1)
Esocidae	2(1)	2(1)	2(1)	2(1)	2(1)
Cyprinidae	7(4)	5(3)	3(2)	3(3)	7(2)
Catostomidae	3(2)	1(1)	3(2)	2(1)	3(2)
Ictaluridae	7(2)	3(2)	5(2)	5(2)	6(2)
Amblyopsidae	1(1)	-	1(1)	1(1)	1(1)
Aphredoderidae	1(1)	1(1)	1(1)	1(1)	1(1)
Cyprinodontidae	4(1)	1(1)	-	-	2(1)
Poeciliidae	2(2)	1(1)	1(1)	1(1)	3(3)
Atherinidae	1(1)	-	-	-	1(1)
Percichthyidae	1(1)	-	-	-	-
Centrarchidae	17(7)	12(7)	10(5)	10(6)	16(7)
Percidae	5(2)	3(1)	4(2)	4(2)	5(2)
Soleidae	1(1)	-	1(1)	1(1)	1(1)
TOTALS	58(32)	32(21)	35(22)	34(23)	51(27)

1. Only species collected or verified by us during present survey.
2. Data from Louder (1962b). Only specimens listed from fresh water.
3. Data from Rohde et al. (1979). *Eucinostomus argenteus*, *Lagodon rhomboides*, and *Dormitator maculatus* not included.
4. Combined Ashepoo, Combahee, Broad, and New rivers. Data modified from Swift et al. (1977) with additional species from Anderson (1964); record of *Chaetodipterus faber* not included.

tail madtom, is known from the Waccamaw. The remaining two species are known from the Lumber and Lynches rivers of the Pee Dee drainage. Therefore, it is not surprising that much of the ichthyofauna of the lower Pee Dee (Waccamaw, Lumber and Big Swamp systems) is shared with the Cape Fear drainage (Average Faunal Resemblance Index = 84; Jenkins et al. 1972). Indeed, only two other rivers of the Central Atlantic Slope (Neuse and Tar) show a greater degree of faunal resemblance (Average Faunal Resemblance Index = *94;* Jenkins et al. 1972).

Additionally, *Etheostoma fusiforme fusiforme* reaches the southern terminus of its range in the Waccamaw River (Collette 1962). *Etheostoma f. barratti* is found from the Pee Dee drainage (to which the Waccamaw is an eastern tributary) southward. The presence of *E. f. fusiforme* in both the Waccamaw and Cape Fear rivers and its absence from the Pee Dee provides further evidence of past connections between the two drainages and suggests a faunal separation of the Waccamaw from the Pee Dee. We suggest that populations of *E. f. fusiforme* were probably present in the Little Pee Dee system (as in the Cape Fear and Waccamaw) before the uplift of the Cape Fear Fault. *Etheostoma f. barratti* from the Pee Dee then invaded the Lumber via the Little Pee Dee, replacing the nominate subspecies. There was possibly little or no opportunity for such upstream dispersal of *E. f. barratti* into the Waccamaw because of salinity barriers, and therefore the populations of *E. f. fusiforme* persisted.

Only one known connection between the Waccamaw and Cape Fear rivers presently exists. A series of man-made canals, dug to improve tree farm drainage, connects Honey Island Swamp (Juniper Creek tributary) with Dans Creek of the Cape Fear drainage and Big absence Creek which drains into Lake Waccamaw (Fig. 1). Only a limited number of species should be able to negotiate the small, shallow and often stagnant canals, thus limiting substantial faunal exchange. The undescribed *Elassoma* was recently collected in one of these canals just east of Lake Waccamaw, which suggests the possibility that it may have gained access to the Big Creek system via the canals from Juniper Creek. This may explain of the species from areas west of the Waccamaw River and other tributaries of the river (apart from Juniper Creek and Big Creek) even where habitat appears suitable. Northward expansion of its range would be possible through the canal system into the Cape Fear drainage. Collecting in adjacent Cape Fear drainages has, however, provided no specimens.

According to Jenkins et al. (1972), lowland endemics or exclusively shared forms are not common on the Central Atlantic Slope. The Waccamaw has at least five of these. *Etheostoma perlongum* and *Menidia extensa* are Waccamaw endemics. *Fundulus waccamensis* is either endemic to the Waccamaw or shared with Lake Phelps (coastal Albemarle drainage), pending taxonomic decisions. The undescribed *Elassoma* is probably shared between the Waccamaw and Savannah drainages (F. C. Rohde, pers. comm.). The undescribed *Noturus* is represented by two forms within the Waccamaw drainage; specimens from Lake Waccamaw represent a population superficially distinct from the Waccamaw River population and may represent another Waccamaw endemic. The form present in the Waccamaw River is also found in rivers of the lower Pee Dee and Cape Fear drainage (Jenkins and Palmer 1978; Jenkins, pers. comm.).

In summary, the Waccamaw drainage is unique among small central Atlantic coastal drainages in having a highly diversified fish fauna including endemic and exclusively shared forms. The Waccamaw and Little Pee Dee systems once extended farther north into the inner Coastal Plain and Piedmont. These streams were beheaded by the uplifting of the Cape Fear Fault and subsequent formation of the Cape Fear River, resulting in faunal similarities between the drainages.

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A Taxonomic Analysis of Pseudemyd Turtles (Testudines: Emydidae) from the New River, and Phenetic Relationships in the Subgenus *Pseudemys*

Michael E. Seidel

Biological Sciences and N. Bayard Green Museum, Marshall University, Huntington, West Virginia 25701

ABSTRACT.— The morphology and geographical origin of a disjunct population of aquatic turtles, genus *Pseudemys (= Chrysemys* auct.) in the New River of Virginia and West Virginia are analyzed. Previous identification of these turtles as *"Chrysemys" floridana* is reappraised by comparison of shell proportions, color patterns, and cranial morphology to those of other species and subspecies of *Pseudemys (sensu stricto).* Discriminant analysis of 28 cranial characters broadly separates redbelly turtles *(P. rubriventris, P. nelsoni, P. alabamensis)* from New River *Pseudemys* and most populations of *P. concinna* and *P. floridana.* Based on morphological similarities, New River *Pseudemys* are identified as eastern river cooters, *P. c. concinna.* Natural history information and recent extensions of the known range suggest that *Pseudemys* in the New River represents a natural, established population. A late Pleistocene dispersal of cooters from the Virginia-North Carolina Piedmont Plateau into the New River is proposed.

INTRODUCTION

Bayless (1972) reported a population of cooter turtles in the New River at Bluestone Reservoir, Summers County, West Virginia. This locality is in the southern part of the state where the New River, a Kanawha-Ohio River tributary, enters from Virginia (Fig. 1). He tentatively identified the turtles in Bluestone Reservoir as *"Chrysemys" floridana,* without assigning them to subspecies. This population is broadly disjunct from the range of cooters in the Mississippi and lower Ohio River valleys and is isolated by the Atlantic-Ohio divide from the nearest populations in the Virginia and North Carolina Piedmont Plateau (Fig. 1).

Despite a thorough analysis of key morphological characters, Bayless (1972) failed to clearly establish the taxonomic status and probable geographical origin of the New River *Pseudemys.* This was unavoidable due to the poorly understood systematic and distributional relationships between *Pseudemys floridana* (LeConte) and *Pseudemys concinna* (LeConte) in northern parts of their ranges (Crenshaw 1955; Minton 1972; Pritchard 1979; Martof et al. 1980). Further uncertainty developed when Bayless' voucher specimens at the National Museum of Natural History (USNM 192635-7) were reidentified in 1973 as redbelly turtles, *Pseudemys rubriventris* (LeConte) (Fran I. McCullough, pers.

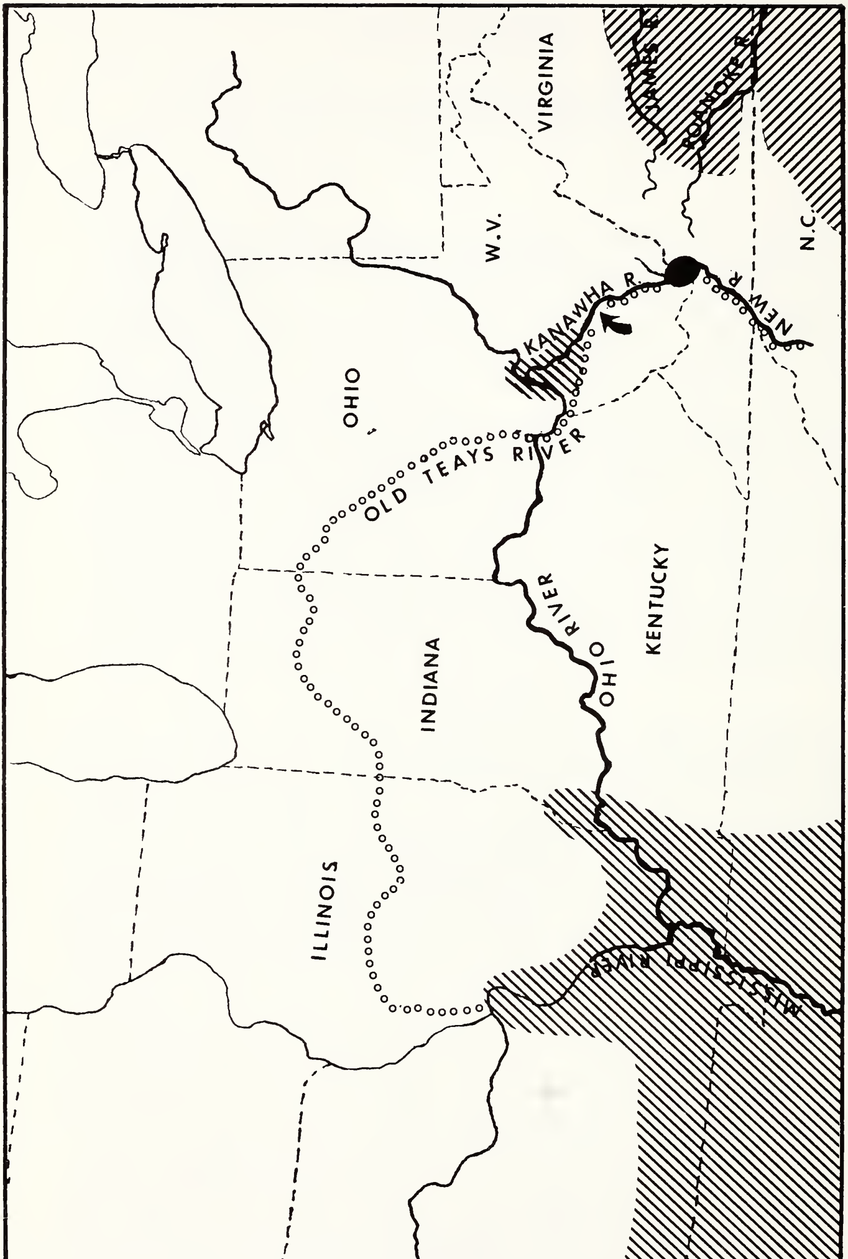

Fig. 1. Distribution of cooters in the upper Mississippi River Valley, Kanawha-Ohio River Valley, and Virginia and Carolina Piedmont. Dark oval indicates known range of *Pseudemys* in New River of Virginia and West Virginia. Location of Kanawha Falls indicated by arrow.

comm.). This species is known to occur only in drainage basins of the Atlantic slope (Conant 1975). Based on external morphology of the New River specimens, Carl H. Ernst (pers. comm.) suggested possible *P. rubriventris* influence in the population and the possibility of a *P. floridana* x *rubriventris* hybrid swarm similar to that reported in North Carolina by Crenshaw (1965). All that remained evident was that the turtles collected from the New River at Bluestone Reservoir belong to the subgenus *Pseudemys (sensu* McDowell 1964; Vogt and McCoy 1980). This subgenus includes *P. floridana, P. concinna* and a *P. rubriventris* series of *P. nelsoni* Carr, *P. alabamensis* Baur and *P. rubriventris.*

The present study, which analyzes cranial structure, shell morphology, color patterns and incidental natural history data, was designed to evaluate the taxonomic position and probable origin of *Pseudemys* in the New River. Although a systematic analysis of the subgenus *Pseudemys* was not the original or primary objective of the study, problematic levels of speciation and questionable validity of traditional key characters necessitated comparisons with all taxa in the subgenus, especially those with more northerly distributions.

MATERIALS AND METHODS

Twelve adult *Pseudemys* from the New River were examined and morphologically compared to other forms of the subgenus *Pseudemys.* The New River sample includes a specimen collected in Giles County, Virginia, in 1975; seven individuals collected in Bluestone Reservoir in May 1980; and the four specimens from Bluestone Reservoir described by Bayless (1972). Weaver and Rose (1967) found shell depth, nuchal (= cervical) scute underlap, and gular scute overlap especially useful in separating *P. floridana, P. concinna,* and *P. nelsoni.* These measurements were taken on New River *Pseudemys* and initially calculated as ratios following the methods of Weaver and Rose (1967) to allow direct comparison to their data. For subsequent shell comparisons among adult (153-300 mm carapace length) New River *Pseudemys, P. rubriventris,* and northern subspecies of *P. concinna* and *P. floridana* (Fig. 3): shell depth was calculated as a ratio of height to carapace length; gular scute overlap was calculated as 10X the ratio of gular scute length (dorsal surface) to plastron length; and nuchal scute underlap was calculated 10X the ratio of cervical scute length (ventral surface) to carapace length. Measurements were made with Helios or bow outside calipers. Characters traditionally used by Carr (1952) and Crenshaw (1955), such as patterns and coloration of head, neck, plastron and carapace, were also analyzed.

For phenetic analysis of adult cranial morphology, skulls from 4 Bluestone specimens were compared to skulls of 8 *P. rubriventris,* 4 *P. nelsoni,* 3 *P. alabamensis,* 5 *P. f. floridana,* 6 *P. f. peninsularis,* 13 *P. f. hoyi,* 5 *P. c. concinna,* 5 *P. c. suwanniensis,* 8 *P. c. hieroglyphica,* 9 *P. c.*

mobilensis and 6 *P. c. texana.* All specimens were adults and ranged from 27 to 57 mm skull length. Although the sex of some of the skulls examined was not identified, it was evident that none of the samples was skewed heavily toward males or females. Twenty-nine measurements were made on each cranium and mandible (± 0.1mm): condylobasal length (midline length of skull, from posterior aspect of occipital condyle to anteriormost point of premaxillae); interquadratal width; supraoccipital length; pterygoid width (least); interpterygoid process width (greatest); orbital height and orbital width; narial height and width; prefrontal length (midline); interorbital width (least); postorbital length (width of postorbital arch, least distance from orbit to superior temporal fossa); postorbital-quadratojugal breadth (least distance between superior temporal fossa and ventral ridge of quadratojugal); jugal-quadratojugal length (least distance between orbit and tympanic cavity); maxillary alveolar width (least); foramen magnum width and height; basisphenoid-basioccipital length; interforamina stapediotemporale width (distance between the temporal-stapedial foramina); anterior skull width (at anterior rim of tympanic cavity); posterior skull width (at posterior rim of tympanic cavity); intersquamosal breadth (distance between posterior aspects of squamosals); premaxillary height (midline); temporal arch width (least distance between rim of tympanic cavity and superior temporal fossa); otic capsule length (from posterior rim of tympanic cavity); dentary-coronoid height; dentary breadth (midline); dentary alveolar width (lateral); and lingual alveolar width (proximal to median ridge of dentary).

Due to intra- and interspecific size variation, regression analysis was applied to all skull measurements to remove linearly-related effects of size. Condylobasal length was used as the independent variable for regression analysis of the other variables. The SAS General Linear Models procedure produced residual values for each character; these values were used as "size-free" variables. Using these 28 variables, the SAS discriminant analysis procedure tested for homogeneity of within-group covariance matrices. As the 28 characters measured showed no evidence of heterogeneity of the within-group covariance matrices, groups (taxa) were compared by step-wise discriminant analysis using the computer program, BMD07M (Dixon 1974), which generates canonical variates with maximum between-group variance relative to within-group variance. The canonical variate means are plotted on the first two axes, and analysis of variance describes significant differences between groups ($P < 0.05$). Using canonical functions, the posterior probability of each turtle belonging to its respective group is computed and classified accordingly.

ABBREVIATIONS

ACE, United States Army Corps of Engineers, Huntington District.
AMNH, American Museum of Natural History.
CM, Carnegie Museum of Natural History.
FMNH, Field Museum of Natural History.
KU, University of Kansas Museum of Natural History.
MCZ, Museum of Comparative Zoology, Harvard University.
MES, Collection of Michael E. Seidel.
NCSM, North Carolina State Museum of Natural History.
UMMZ, University of Michigan Museum of Zoology.
USNM, National Museum of Natural History.
WVBS, West Virginia Biological Survey, Marshall University.

SPECIMENS EXAMINED

P. alabamensis: MCZ 1659-61, 1663, 1898; AMNH 107676. *P. nelsoni:* UMMZ 127059-60; AMNH 75640; MCZ 54131, 54684. *P. rubriventris:* AMNH 71276, 71280, 71282, 71293, 76175, 79132, 79134, 80218, 81869, 90641-42, 90644; CM 34409, 37272, 39672, 45188; FMNH 22137; MCZ 1666, 1671, 1674, 1677, 12877, 76679, 157828; MES 132. *P. f. floridana:* FMNH 8222; MCZ 1635, 1651, 46221-22; USNM 25260; AMNH 50985, 75641; NCSM 5884-85, 5927-28, 5930, 8518. *P. f. peninsularis:* FMNH 22074; UMMZ 12937, 130081, 44976; AMNH 64156, 69899, 110189; MCZ 19179. *P. f. hoyi:* KU 1176-79, 1185, 2221, 2800, 2830-31, 40166; MCZ 29080-81. *P. c. concinna:* USNM 8920, 15990, 60895, 92529-31; FMNH 22138; MCZ 1642, 1664, 12764, 54680; AMNH 75649; NCSM 10328, 17339, 20128, 20240, 20253. *P. c. suwanniensis:* UMMZ 127058, 129385; AMNH 80233; FMNH 22473; MCZ 43030, 54675, 54679. *P. c. mobilensis:* AMNH 69908; MCZ 1636-39, 1648-50, 1652, 42327. *P. c. hieroglyphica:* USNM 9659, 79449, 86728, 102679, 104397; CM 60560; CM (field series) 38068-69, 38071-72, 38077, 38107, 38132, 38134, 38155; UMMZ 101754, 128176, 133845; AMNH 69901-02, 69905-06; WVBS 3155, 3965. *P. c. texana:* USNM 26424, 26438, 78518; UMMZ 133836, 154982; MCZ 46483; KU 39986, 49630; AMNH 111960; MES 75. New River *Pseudemys:* USNM 192635-37; WVBS 4093; MES 489, 526, 528-29, 863, 865; UMMZ 88488; two adults released; two hatchlings MES uncataloged; shell bones ACE FS1-68, FS2-81, FS2-183.

RESULTS

Analysis of patterns and color in adult specimens from Bluestone Reservoir (Fig. 2) showed strong similarities to *P. concinna.* In all 12 specimens the submarginals contain dark markings that are usually open circles rather than the smudgelike or solid circles common in *P. rubriventris* and *P. floridana* (Carr 1952; Mount 1975). In most individuals the bridge has an extensive dark pattern that contacts the submarginal markings. The pleurals have relatively thin yellow-tan lines and some individuals show the clearly defined "C" figure on pleural II typical of *P. concinna.* Ventral and supratemporal stripes on the head and

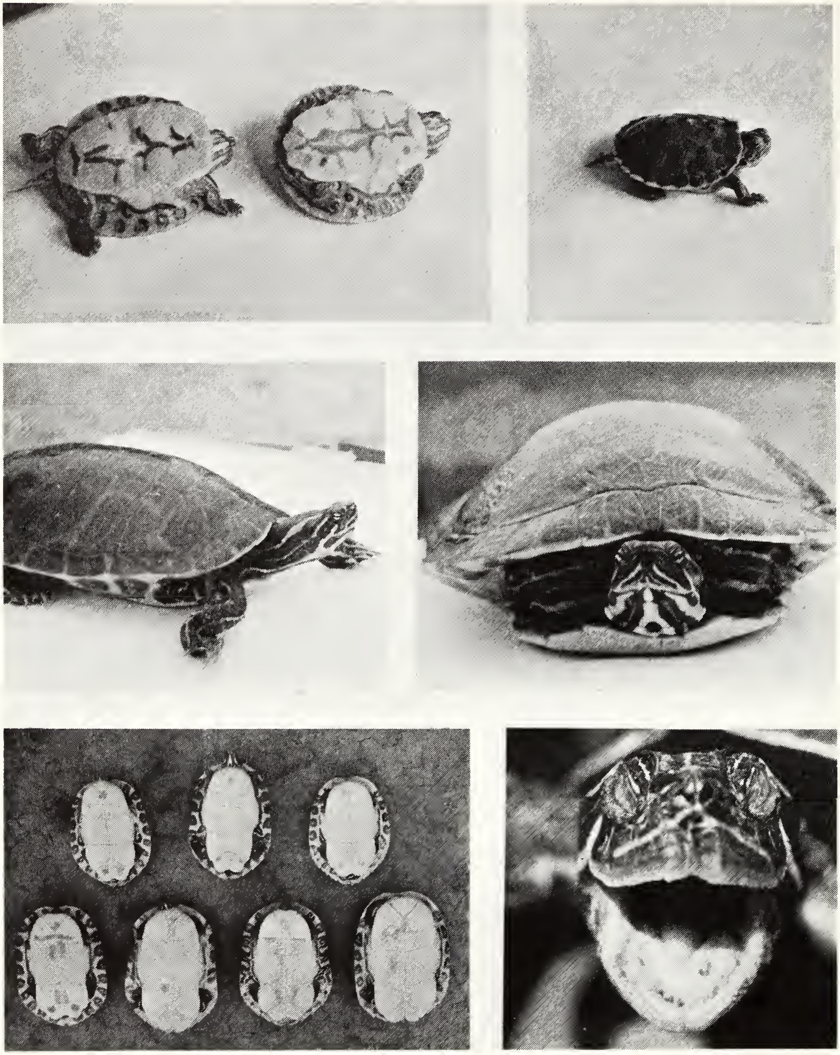

Fig. 2. Ventral and dorsal views of hatchling (above) and adult (middle and below) *Pseudemys* from Bluestone Reservoir, Summers County, West Virginia.

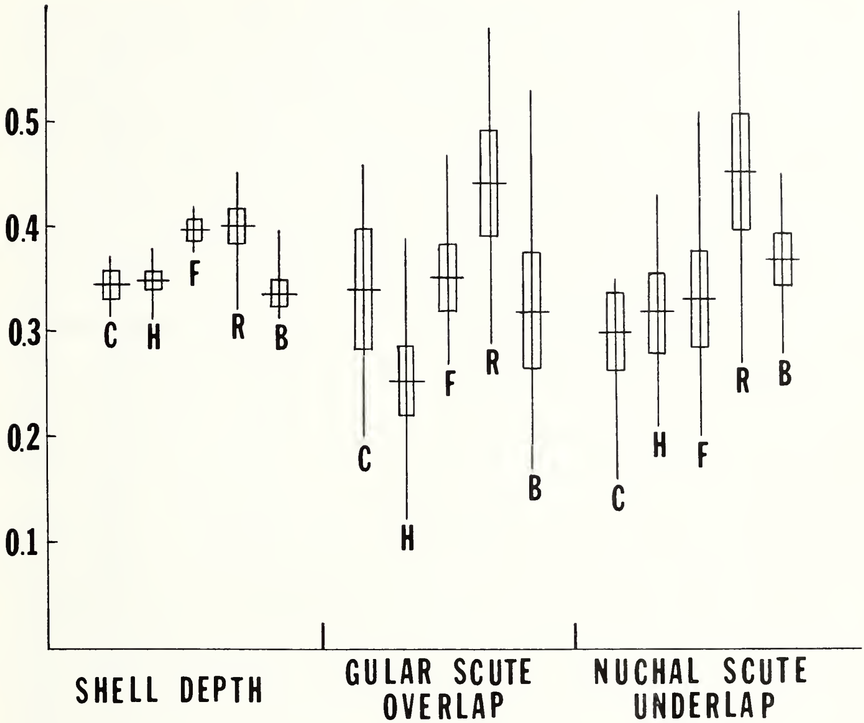

Fig. 3. Measurements of 7 *P. c. concinna* (C) from Virginia and North Carolina; 11 *P. c. hieroglyphica* (H) from Indiana and Tennessee; 8 *P. f. floridana* (F) from North Carolina, South Carolina and Georgia; 14 *P. rubriventris* (R) from Massachusetts, New Jersey, Pennsylvania, Delaware, Virginia and North Carolina; 12 *Pseudemys* (B) from New River, Virginia and West Virginia. Horizontal lines are means, vertical lines are ranges, rectangles are one standard deviation. Values are ratio calculations described in MATERIALS AND METHODS.

neck are broad whereas paramedian dorsal stripes are very narrow, sometimes convergent or obscure. All seven New River specimens that I collected have a yellow plastron that was lightly tinged with orange in two individuals. Plastral markings typical of *P. concinna* are present on each turtle, but less prominent in older specimens (Fig. 2). Slight fading of markings and coloration was evident after 2 to 3 months in captivity. The cutting edge (tomium) of the upper jaw in most individuals is weakly emarginate and the lower jaw is moderately serrate (Fig. 2). Four skulls which were analyzed show no evidence of a vomerine shelf contributing to the crushing (alveolar) surface of the upper jaw, a unique characteristic of species in the *rubriventris* series (McDowell 1964).

Twelve adult New River turtles examined have a shell depth range of 31.1 to 39.4 (ratio calculations following Weaver and Rose 1967), which broadly overlaps the range reported for *P. concinna* but falls below the ranges of *P. floridana* and *P. nelsoni.* Nuchal scute underlap ratios in New River *Pseudemys,* 16.0 to 23.4, are greater than in *P. concinna* but are within the combined range of ratios for *P. floridana* and *P. nelsoni.* The gular scute overlap ratio was highly variable (7.9-18.8), falling within the combined ratio range reported for all three species (Weaver and Rose 1967). Because most of the specimens examined by Weaver and Rose were from Florida, shells of adult *Pseudemys* from northern localities were measured and compared to New River specimens. These ratios (Fig. 3) again indicate a shallow shell depth in New River turtles (B) and *P. concinna* (C,H). Gular scute overlap and nuchal scute underlap are greater in *P. rubriventris* (R), than in New River specimens (B) and northern subspecies of *P. floridana* (F) and *P. concinna* (C,H). However, these two characters are highly variable and apparently not effective in separating *P. concinna* and *P. floridana* outside of Florida.

Results from the discriminant analysis of all *Pseudemys* skulls are presented in Figure 4. On the first canonical axis (K_1) plots of skulls in the *rubriventris* series (A,N,R) are clearly disjunct from all forms except *P. c. texana* (T). Broad separation is seen between *P. rubriventris* (R) and New River *Pseudemys* (B). Also noteworthy is the separation, on the second canonical axis (K_2) of *P. alabamensis* (A) from *P. rubriventris* (R) and *P. nelsoni* (N). The first two axes account for 51% and 12% of the total dispersion, respectively. In order of increasing importance, temporal arch width, jugal-quadratojugal length, interorbital width and dentary alveolar width were the most influential characters providing separation on the first axis (Table 1a). Anterior skull width, dentary alveolar width, and lingual alveolar width contributed most to separation on the second axis (Table 1a). All individuals were classified into their appropriate taxa, except one *P. c. mobilensis* that was placed in *P. f. floridana* and one *P. f. hoyi* that was placed in *P. c. hieroglyphica.* The *P. c. mobilensis* specimen (MCZ 1651) was collected within the

Table 1. Coefficients for the most influential morphological variables (measurements of cranium and mandible) in three discriminant analyses (a,b,c) of *Pseudemys*.

	a		*b*		*c*	
Variable	axis 1	axis 2	axis 1	axis 2	axis 1	axis 2
Narial height	--	--	--	--	-1.24	0.97
Interorbital width	-1.43	--	2.14	--	--	--
Jugal-quadratojugal length	-1.04	--	--	-2.11	--	--
Maxillary alveolar width	--	--	1.42	--	--	--
Foramen magnum width	--	--	--	--	1.19	--
Basisphenoid-basioccipital length	--	--	--	--	-0.97	--
Anterior skull width	--	0.98	1.64	--	--	--
Temporal arch width	0.99	--	--	1.67	--	--
Dentary alveolar width	1.59	-1.20	-2.76	--	--	0.61
Lingual alveolar width	--	1.51	--	2.55	-0.75	--
Prefrontal length	--	--	--	--	--	0.89

range of *P. f. floridana* (Mobile, Alabama) and a resemblance to *P. floridana* was noted prior to discriminant analysis. This skull was re-identified as *P. f. floridana* for subsequent comparison. The misclassification of a *P. f. hoyi* skull as *P. c. hieroglyphica* is not surprising considering the proximity of means (H,Y) for these forms (Fig. 4). This skull was reassigned to *P. c. hieroglyphica* in further analyses. Based on the 28 cranial characters measured, analysis of variance indicated significant differences comparing New River *Pseudemys* to all taxa ($P < 0.01$) except *P. c. concinna* ($P > 0.05$), *P. c. suwanniensis* (> 0.01), and *P. c. mobilensis* ($P > 0.01$).

To further analyze the relationships of New River *Pseudemys* to *P. floridana* and *P. concinna*, discriminant analysis of skulls was applied again, with the *rubriventris* series omitted. Results of this analysis are similar to the first, but three clusters now become apparent (Fig. 5): a western and Mississippi Valley group (*P. c. texana, P. f. hoyi, P. c. hieroglyphica;* TYH), an eastern *P. concinna* group (*P. c. suwanniensis, P. c. mobilensis, P. c. concinna,* and New River *Pseudemys;* SMCB), and an eastern *P. floridana* group (*P. f. floridana, P. f. peninsularis;* FP). Noteworthy is the broad separation (on the first axis, K_1) of *P. f. hoyi* from other *P. floridana* skulls and its extensive overlap with *P. concinna* (Fig. 5). The first two canonical axes account for 49% and 20% of the total dispersion, respectively. In order of increasing importance, maxillary alveolar width, anterior skull width, interorbital width and dentary alveolar width are the most influential characters providing separation on the first axis (Table 1b). Temporal arch width, jugal-quadratojugal length and lingual alveolar width contributed most to separation on the second axis (Table 1b). All individuals were classified into their assigned groups. Results from analysis of variance show New River skulls significantly different from all taxa ($P < 0.05$) except *P. c. concinna* and *P. c. suwanniensis* (canonical means enclosed by broken lines in Fig. 5).

A third discriminant analysis of skulls, with *P. f. floridana* and *P. f. peninsularis* removed, was applied to further clarify relationships with the races of *P. concinna* (Fig. 6). The first two canonical axes collectively account for 77% of the total dispersion. Characters most responsible for separation on the first two axes are presented in Table 1c. Results from this comparison indicate a very close phenetic relationship between the eastern river cooter, *P. c. concinna* (C) and New River *Pseudemys* (B) (Fig. 6).

Observations on reproduction of cooters recently collected from Bluestone Reservoir, discovery of a previously overlooked museum record, and examination of archeological material have also contributed to a better understanding of *Pseudemys* in the New River. Three adult females from Bluestone Reservoir, collected 15 May 1980 and X-rayed 7 June (following the method of Gibbons and Greene 1979) showed no

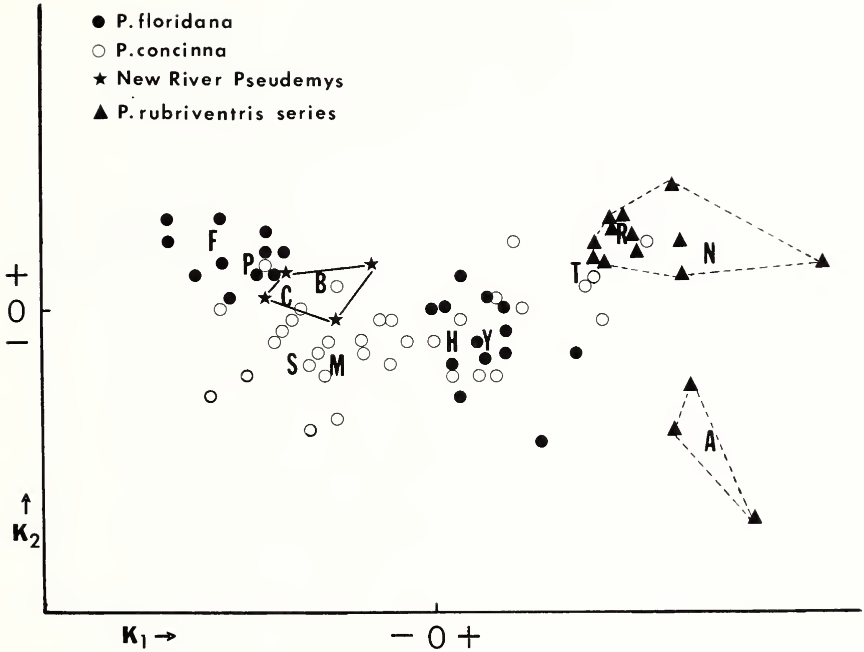

Fig. 4. Variates for skulls of the subgenus *Pseudemys* plotted on the first (K_1) and second (K_2) canonical axes. Individual skulls represented by symbols, and letters represent canonical variate means for *P. alabamensis* (A), New River *Pseudemys* (B), *P. c. concinna* (C), *P. f. floridana* (F), *P. c. hieroglyphica* (H), *P. c. mobilensis* (M), *P. nelsoni* (N), *P. f. peninsularis* (P), *P. rubriventris* (R), *P. c. suwanniensis* (S), *P. c. texana* (T), *P. f. hoyi* (Y). Values for New River *Pseudemys* connected by solid lines. Broken lines connect the most dispersed values for *P. rubriventris* and *P. nelsoni* collectively, and values for *P. alabamensis*.

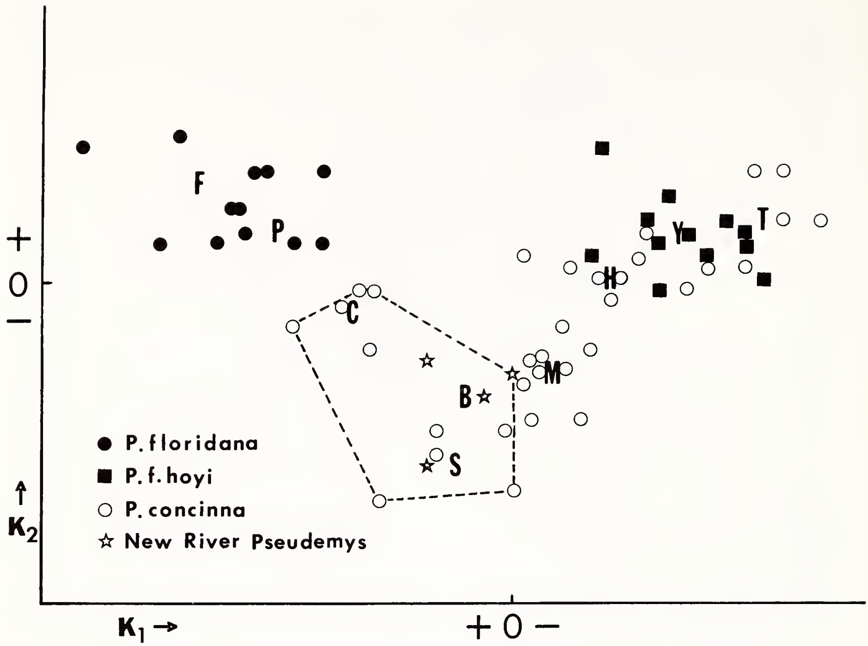

Fig. 5. Variates for skulls of *P. floridana* and *P. concinna* plotted on the first (K_1) and second (K_2) canonical axes. Individual skulls represented by symbols, and letters represent canonical variate means for New River *Pseudemys* (B), *P. c. concinna* (C), *P. f. floridana* (F), *P. c. hieroglyphica* (H), *P. c. mobilensis* (M), *P. f. peninsularis* (P), *P. c. suwanniensis* (S), *P. c. texana* (T), *P. f. hoyi* (Y). Broken lines connect and enclose New River skulls and plots for the subspecies *P. c. concinna* and *P. c. suwanniensis*, which show no significant difference ($P > 0.05$) from New River *Pseudemys*.

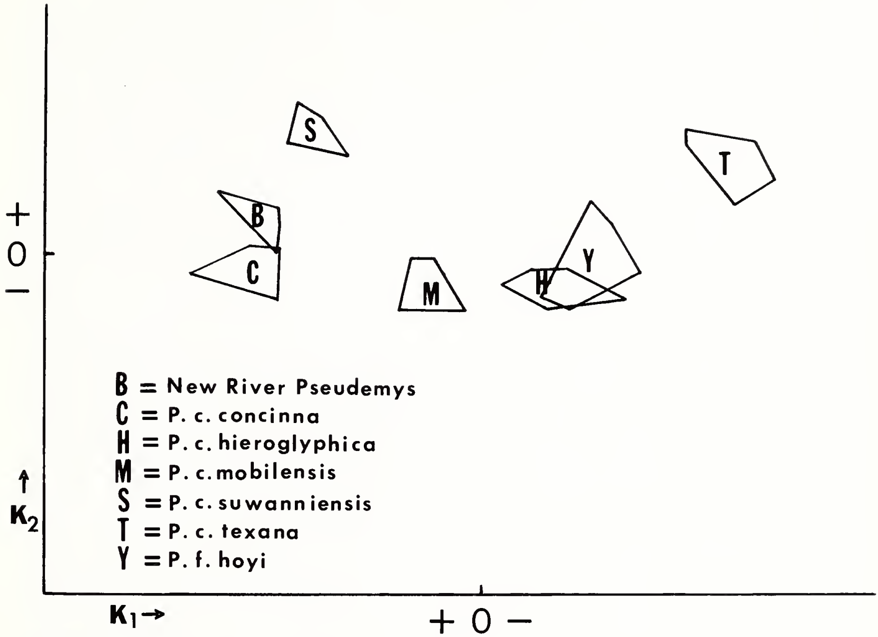

Fig. 6. Variates for skulls of *P. concinna* plotted on the first (K_1) and second (K_2) canonical axes. Lines connect the most dispersed values about canonical means, which are represented by letters.

evidence of ripe (shelled) eggs. One of these females, dissected on 9 July, contained no oviducal eggs. A second female held in laboratory deposited eight eggs 10-21 July, three of which were incubated at 30-35° C in moist vermiculite. Two hatched on 4 September and the third was apparently infertile. Unlike *P. rubriventris* the two hatchlings have yellow plastrons, and unlike *P. floridana* the plastrons are extensively patterned (Fig. 2). Dark markings also appear on the ventral surface of each marginal (submarginal) and throughout the bridge. These hatchlings and adults, maintained in laboratory and offered a wide variety of food for three months, were entirely herbivorous. A juvenile *P. concinna* (UMMZ 88488, fluid preserved), collected 3.2 km east of Hinton in the Greenbrier River (near its junction with the New River below Bluestone Reservoir), Summers County, West Virginia, has markings nearly identical to the Bluestone hatchlings. This fluid preserved specimen, presumably overlooked by other investigators, was taken in 1934 (collector unknown) and confirms the presence of cooters in the New River system prior to the construction of Bluestone Dam, 1942-1949. Thus, the hypothesis presented by Bayless (1972) that the impoundment created new habitat necessary for establishment of an introduced population can be dismissed. Further evidence for a relatively long natural history of *Pseudemys* in the New River comes from examination of turtle bones recovered from an archeological site (46SU3, Fort Ancient Village 1100-1300 AD) at Bluestone Reservoir (Applegarth et al. 1978). A peripheral ACE FS2-81, pleural ACE FS2-183, and hypoplastron FS1-68 were identified as *Pseudemys* cf. *P. concinna* by Dale R. Jackson (pers. comm.).

DISCUSSION

The cooter species *P. concinna* and *P. floridana* have had a long, confused taxonomic history. Following LeConte's (1830) original descriptions, Carr (1935, 1952) considered *P. concinna* and *P. floridana* a conspecific assemblage of eight subspecies under *P. floridana.* However, Carr (1952) commented that at least the Florida races, *P. f. peninsularis* and *P. f. suwanniensis,* were broadly sympatric and behaved as separate biological species. Crenshaw (1955) partitioned the cooters, recognizing both *P. concinna* and *P. floridana.* A major weakness of Crenshaw's conclusion is that it was based primarily on relationships between Florida forms, without a thorough understanding of ecological and morphological relationships of populations elsewhere. Another criticism of Crenshaw's work is that it relied heavily on highly variable characters such as markings and pigmentation, which may show greater variation within a population than between species. These phenotypic characters may also be subject to strong environmental influence. Mount (1975) reported that the color of markings fades rapidly in captive *P. concinna* and concluded that pigmentation in cooters has little systematic value.

Moreover, Ewert (1979) demonstrated that, at least in map turtles of the genus *Graptemys,* diagnostic head markings may be altered by varying incubation temperatures and therefore are not entirely under genetic control. Nevertheless, the taxonomic arrangement of Crenshaw (1955), although never published with full supporting documentation, has generally been followed (Conant 1961, 1975; Ernst and Barbour 1972; Wermuth and Mertens 1961, 1977).

Fahey (1980) proposed that *P. concinna* once again be placed in the synonymy of *P. floridana*, a conclusion based exclusively on examination of turtles from Louisiana. Although Fahey's results suggest the presence of a single species in the restricted region of his study, they certainly do not substantiate relationships throughout the ranges of *P. floridana* and *P. concinna.* In addition to Fahey's report, there are numerous published references to either weak morphological separation or putative hybridization between *P. floridana* and *P. concinna* in the Mississippi Valley and areas to the west (Brown 1950; Smith 1961; Anderson 1965; Webb 1970; Barbour 1971; Minton 1972; Mount 1975). Traditional key characters, such as plastral markings and a "C" figure on the second pair of pleurals, which are used to distinguish *P. concinna* from *P. floridana*, are not consistent for central and western populations that are seemingly convergent in some characters. Ward (1980) found no cranial characters with which he could separate the midwestern subspecies *P. f. hoyi* and *P. c. hieroglyphica* and placed them in synonymy. My results from discriminant analysis of cranial morphology (Figs. 4, 5, and 6) support that decision. However, conclusions regarding conspecific status for all turtles assigned to *P. concinna* and *P. floridana,* especially eastern forms, must await a comprehensive and geographically broad analysis.

Based on shell markings and proportions, overall pigmentation, and cranial morphology, New River *Pseudemys* are clearly distinct from *P. rubriventris.* The emarginate tomial surface of New River specimens (Fig. 2) might be interpreted as a weakly developed notch bordered by cusps, characteristic of species in the *rubriventris* series (Carr 1952; Ernst and Barbour 1972). Weak cusps, however, have been reported in several populations of cooters allopatric and sympatric with redbelly turtles (Carr 1952; Crenshaw 1955; and personal examination of skulls: CM 60560, UMMZ 127058, MCZ 54680). Furthermore, prominent cusps are typical in *P. c. texana* (Ernst and Barbour 1972). Jackson (1978) cautioned that little taxonomic weight should be given to trophic structures in *Pseudemys.* The overall similarity in cranial morphology of *P. c. texana, P. nelsoni,* and *P. rubriventris* (Fig. 4) may represent convergence of character states resulting from similar feeding habits.

A shallow carapace with evidence in some individuals of a "C" on pleural II, and extensive dark markings on plastral, axillary and inguinal scutes, are characteristics of New River cooters that justify their assignment to *P. concinna*. Further indication that these turtles are referrable to *P. concinna* comes from discriminant analysis of cranial morphology. Skulls of New River turtles are phenetically close to *P. c. concinna* and *P. c. suwanniensis,* and broadly separated from all forms of *P. floridana* (Fig. 5).

Recent evidence of fertile eggs, numerous sight records of basking adults, discovery of bones 700 to 800 years old, rediscovery of a museum specimen collected in 1934, and extensions of the known range 22 km south of Bluestone Reservoir to Giles County, Virginia and 2 km northeast of Bluestone Reservoir in the Greenbrier River, West Virginia, support the hypothesis that cooters in the New River represent a natural, established population. Assuming an origin not involving human interference, there are two possible avenues for dispersal that could have allowed *P. concinna* to enter the New River. The first is an early Pleistocene invasion from the Mississippi Valley (embayment region) through the old Teays River, which followed the course of the present Kanawha and New Rivers (Fig. 1). An argument for this route is supported by the occurrence of cooters referrable to the Mississippi Valley subspecies *P. c. hieroglyphica* in the lower Kanawha River, Mason County, and Mud River, Cabell County, West Virginia (Seidel and Green, in press). To examine this relationship, twelve New River specimens were compared to seven adult and two subadult *P. c. hieroglyphica* from Reelfoot Lake, Tennessee. New River *P. concinna* differ from these turtles in having: a lower carapace with the highest point at the middle; shell not usually constricted at the region of the sixth marginal; fewer concentric light lines on the carapace; dark markings on the bridge that frequently contact submarginal blotches; alveolar surface of lower jaw relatively narrow; and fewer and broader stripes on the head and neck, especially ventrally. These characteristics are more typical of the Piedmont subspecies, *P. c. concinna* (Carr 1952; Mount 1975). Although the New River is a Kanawha River tributary, it is separated from the Ohio and Mississippi River valleys (inhabited by *P. c. hieroglyphica*) by Kanawha Falls (Fig. 1). This falls is believed to be one of the largest natural river barriers east of the Rocky Mountains (Jenkins et al. 1971). Furthermore, rapids and cataracts in New River Gorge just above Kanawha Falls provide an effective barrier to fish distribution between the Kanawha and New Rivers (Hocutt et al. 1979). Therefore, preglacial dispersal of cooters from the Mississippi Valley into the upper Teays (New) River may not have been possible.

A second potential avenue for dispersal of *P. concinna* is over the Atlantic-Ohio divide of Virginia and North Carolina. Wright (1934), Thompson (1939), Dietrich (1959), and Ross (1969), reported late Pleistocene stream captures of the New River by the James and Roanoke, two rivers inhabited by *P. c. concinna* in the Piedmont (Martof et al. 1980; and Fig. 1). Comparisons of New River *P. concinna* to five adult, fluid preserved *P. c. concinna* from the Piedmont of North Carolina indicate an overall greater similarity in markings and shell shape than seen comparing New River cooters to *P. c. hieroglyphica.* This relationship is also supported by cranial morphology. In Figures 4-6, New River specimens clearly plot closer to *P. c. concinna* than to *P. c. hieroglyphica.* Although the subspecies of river cooters are not well defined and their distinguishing characteristics are inconsistent within and between populations (Mount 1975; and pers. observ.), *Pseudemys* in the New River of Virginia and West Virginia are most similar morphologically to the eastern river cooter and are here assigned to *P. c. concinna*. Therefore, I suggest that during the Pleistocene, *P. c. concinna* ranged farther up Piedmont streams in Virginia and North Carolina and gained access to the New River through stream capture. The presence of the eastern painted turtle, *Chrysemys picta picta*, in the upper Tennessee (Ernst 1970) and New River systems offers additional evidence that this corridor has been used in the dispersal of aquatic turtles. *Chrysemys p. picta* is typically an Atlantic Slope subspecies that is replaced by the midland painted turtle, *C. p. marginata,* in the Ohio River system. Two specimens from Mercer County, West Virginia (WVBS 4238, 4415) and two specimens from Summers County, Bluestone Reservoir (MES 866, 868) are referrable to the eastern subspecies. Two additional specimens from Bluestone Reservoir (MES 867, 869) have characteristics typical of *C. p. picta* x *p. marginata* intergrades. River cooters are highly aquatic turtles and less likely than painted turtles to enter a new drainage by terrestrial migration (Ernst and Barbour 1972). However, the preference of *P. c. concinna* for rocky, fast-running stream habitats (LeConte 1836; Carr 1952; Pritchard 1979) might have facilitated its dispersal through small-stream captures.

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Small Mammals in Openings in Virginia's Dismal Swamp

ROBERT K. ROSE

Department of Biological Sciences, Old Dominion University, Norfolk, Virginia 23508

ABSTRACT.— In a study of small mammals of openings in the Dismal Swamp of Virginia, seven species were obtained using pitfall traps. Samples included several species rarely caught in the Swamp —seven specimens of the Dismal Swamp subspecies of the southern bog lemming, *Synaptomys cooperi helaletes*, the first collected in this century; two least shrews, *Cryptotis parva*; and 15 southeastern shrews, *Sorex longirostris fisheri*. Results are compared to previous studies, conducted primarily in forested habitats, in which the white-footed mouse, *Peromyscus leucopus*, and the golden mouse, *Ochrotomys nuttalli*, were numerically dominant.

INTRODUCTION

The Great Dismal Swamp, originally occupying much of the area between Virginia's James River drainage system and North Carolina's Albemarle Sound, has long been recognized as a vegetationally distinctive region with many unusual features. It has been subjected to clearing, burning, ditching, farming, and other land-use practices during the past 250 years, has long experienced a dropping water table, and is now approximately 850 km^2 (85,000 ha) in extent (Carter 1979). In 1974 the Great Dismal Swamp National Wildlife Refuge (GDSNWR) was established. At the end of 1980 it was 41,026 ha in extent, 24 percent (9,866 ha) of it in North Carolina. Kirk (1979) provided an excellent summary of the history and lore of the Swamp.

Although there are conflicting historical reports about the abundance of wildlife in the Swamp (see Handley 1979), it is clear that the survival of some species there has been aided by remoteness and limited access to the public, as well as by the existence of large tracts of suitable habitat. For example, the only population of the black bear, *Ursus americanus americanus* Pallas, on the Virginia Coastal Plain, and perhaps the largest populations of the bobcat, *Lynx rufus floridanus* Rafinesque, are found in the Refuge and environs. However, its remoteness and relative inaccessibility have also apparently contributed to the dearth of studies of birds and mammals in the Swamp; apart from species lists, comparatively little is known about the wildlife.

The first systematic studies of mammals in the Swamp were conducted by the Bureau of Biological Surveys, U. S. Department of Agriculture, during the period 1895-1898. Handley (1979), in an exhaustive review that included an examination of field notebooks and unpublished manuscripts, reported that collections of Dismal Swamp mammals were made during a total of 23 weeks in that period. A number of new species (now recognized as subspecies) were collected then, mostly near Lake Drummond. The greater short-tailed shrew, *Blarina brevicauda telmalestes* Merriam; southeastern shrew, *Sorex longirostris fisheri* Merriam; southern bog lemming, *Synaptomys cooperi helaletes* Merriam; and muskrat, *Ondatra zibethicus macrodon* (Merriam), were collected and named then. During the same period Rhoads and Young (1897) described the dark-colored meadow vole, *Microtus pennsylvanicus nigrans* Rhoads, from nearby northeastern North Carolina. In sum, the Dismal Swamp and nearby coastal marshes have several mammals that are morphologically distinguishable from other populations of these species, strongly suggesting genetic and perhaps geographic isolation of their populations in the past. One of Handley's (1980) concerns was that man-induced changes in the Swamp may have removed the ecological barriers between Swamp and upland subspecies. The likely result of such an event would be loss of the Dismal Swamp subspecies through genetic "swamping out" of the smaller gene pool. Of course, this is the equivalent of ecological extinction of the taxon.

C. S. Brimley (1897) was among the investigators who wrote about Dismal Swamp mammals, for he included the results of small mammal collections made between 1891-1894 by the Smithwick brothers near the head of Albemarle Sound in his history of the mammals of Bertie County, North Carolina. Brimley later (1905) summarized the findings of several investigators, including collections from the northeastern corner of North Carolina close to the Swamp. Both papers, while including some Dismal Swamp information, were based mostly on small mammals that Brimley and his brother collected near Raleigh, Wake County, from 1888 to 1900.

After a hiatus of about 25 years, sporadic collecting in the Swamp resumed in the 1930s. Handley's 1953 visits for a week each in February and June seem to have been typical of the trapping efforts made there. One of the longer mammal studies conducted in the Swamp was that of F. E. Breidling, Old Dominion University (ODU), who in 1979-1980 trapped four study areas for one week during each of three seasons.

Handley (1979) reported that the entire known Dismal Swamp fauna of mice and shrews consists of 12 species. Most investigators have found the white-footed mouse, *Peromyscus leucopus easti* Paradiso, to be the most common small mammal, and about half of them have also caught numerous golden mice, *Ochrotomys n. nuttalli* (Harlan), and short-tailed shrews, *Blarina brevicauda*. Five other species—the cotton mouse, *Peromyscus g. gossypinus* (Harlan); eastern harvest mouse, *Reithrodontomys h. humulis* (Audubon and Bachman); southern bog lemming; and southeastern shrew—were found to be numerous by only one or two collectors. Handley (1979) attributed this to spotty distributions and local abundances. Finally, four species—the woodland vole, *Microtus pinetorum scalopsoides* (Audubon and Bachman); the house mouse, *Mus musculus domesticus* Rutty; the least shrew, *Cryptotis p. parva* (Say); and the meadow vole—were seldom caught by any collector, which may mean that the habitats required by these species are rarely found in the Swamp (Handley 1979).

On 23 February 1980, David Harrelson, a senior biology student at ODU, and I began a study of the small mammals of openings in the GDSNWR. The term "openings" refers to any area in which a significant level of shading provided by tree canopy is absent. These habitats are vegetated predominantly by cane, *Arundinaria gigantea*; softstem rush, *Juncus effusus*; sedges; grasses; and herbaceous forbs. Many openings also have small trees and shrubs, plus a number of woody vines; the most common of these are red maple, *Acer rubrum*; blackberry, *Rubus allegheniensis*; grape, *Vitis* spp.; and greenbriers, *Smilax* spp.

MATERIALS AND METHODS

Pitfall traps, made of No. 10 tin cans sunk into the ground flush with the soil surface and half-filled with water, were used to collect small mammals. Seven pitfall traps were dug and placed on 23 February, but adverse weather, including a record snowfall that covered the area for the first two weeks in March, delayed until 20 March the setting of twenty-eight additional traps. All 35 traps were set within 150 m of Jericho Ditch, north of Williamson Ditch, under the 110 kv electrical powerline in the northwestern corner of the GDSNWR.

On 10 April, 10 pitfall traps were placed 9 km away, under the same powerline near East Ditch, also in an area dominated by cane, grasses, and rushes. This area had a higher proportion of standing water than did the Jericho Ditch site. All traps were removed from the ground on 2 May 1980.

RESULTS

Only one small mammal, a *Microtus pennsylvanicus*, was captured in the seven traps from 23 February to 20 March. However, a total of 43 small mammals of seven species was trapped during the study period at the Jericho Ditch site (Table 1). At the East Ditch site, three small mammals of three species were caught (Table 1).

Based on the number of small mammals captured in 100 trap-nights, the relative density of small mammals appeared to be greater in the Jericho Ditch area (2.43) than in the East Ditch area (1.36). (One trap in place for one night equals one trap-night; relative density = N/trap nights X 100.) This difference in density may be due in part to the greater vegetational diversity of the Jericho Ditch site, and to the greater proportion of standing water on the East Ditch site.

Table 1. Number and species of small mammals trapped in the Dismal Swamp between 23 February and 2 May (Jericho Ditch area) and 10 April and 2 May (East Ditch area) 1980. "Others" refers to the results of previous investigations in the Dismal Swamp, mostly in the 1895-1906 period, but including Handley in 1953 (from Handley 1979, Table 1).

Species	Jericho Ditch	East Ditch	Others
	2/23 to 5/2	4/10 to 5/2	
Sorex longirostris	14	1	15
Blarina sp.	15		39
Cryptotis parva	2		1
Peromyscus leucopus	1		112
Ochrotomys nuttalli	1		50
Microtus pennsylvanicus	4	1	8
Synaptomys cooperi	6	1	21
	43	3	
Number mammals/100 trapnights	2.43	1.36	

DISCUSSION

Compared to previous investigators, we caught few individuals of the two most common species, *Peromyscus leucopus* and *Ochrotomys nuttalli*. This is not unexpected, because they are predominantly forest-dwellers and we restricted our trapping to openings dominated by herbaceous vegetation. However, the 40 m wide powerline right-of-way was bordered on both sides by maple-gum forest. Consequently, the proximity to nearby suitable habitat for these climbing species may explain their presence in the openings. Handley's 1953 study, which produced 34 *P. leucopus* and 14 *O. nuttalli* out of a total of 56 specimens, showed the typical numerical dominance of these two species. Breidling (1980) caught 15 *P. leucopus* and 4 *Ochrotomys* using live traps on four forested study plots.

We caught a relatively large number of meadow voles and southern bog lemmings (Table 1). Only 29 individuals of these two microtine species had previously been collected in the Swamp. Although he took one meadow vole in 1953, Handley (1979) contended that *Synaptomys* had not been collected there since November 1898. According to Handley (1979, 1980) several investigators, including himself, have speculated on the likely extinction of the Dismal Swamp subspecies of the southern bog lemming, *Synaptomys cooperi helaletes*. We took specimens from both sides of Jericho Ditch, and one specimen near East Ditch. The cane-grass-sedge vegetation type is dominant under the powerline, and it is possible that *S. c. helaletes* occurs throughout this habitat. Starting in 1895, Fisher caught 21 specimens of southern bog lemming in the Swamp, mostly in cane patches near Lake Drummond. We took one *Synaptomys* in cane, but the remainder were captured in mixed grassland in which softstem rush was abundant. Meadow voles were present in the mixed grass habitat, but not in the cane.

By far our greatest success was in trapping shrews (Table 1). We captured 15 *Sorex longirostris fisheri*, which is as many as had been obtained by all previous investigators (Handley 1979). We caught 2 specimens of the least shrew, *Cryptotis parva*, compared to 1 taken by previous investigators, and 15 *Blarina*, compared to 39 collected in earlier studies. Our comparatively high success in capturing shrews is probably related to use of pitfall traps. An advantage of pitfall traps is that they more readily capture certain species of small mammals than do snap (or break-back) traps (Rose and McKean 1980). Rose (1980) reported the capture of 18 southeastern shrews in pitfall traps and none in snap traps. The conclusion that southeastern shrews are not effectively taken by snap (or live) traps is borne out by published records (reviewed by Rose 1980; French 1980).

Handley's (1979) fears that *S. longirostris fisheri* has been genetically "swamped out" through introgression with the smaller upland *S. l. longirostris* Bachman may be unfounded, at least for populations in the northwestern corner of the Swamp in 1980. With a mean total length of 95.8±2.3 mm, the 1980 Dismal Swamp southeastern shrews are much longer than any of the upland subspecies (French, pers. comm.). Whether these values are larger than the 1890s *S. l. fisheri* is uncertain, for Handley (1979:310, Table 1) did not give standard measurements for the 15 *S.l. fisheri* collected by Fisher and housed in the National Museum, nor have I examined the specimens. Nevertheless, the large size of the 1980 specimens suggests that *S. l. fisheri* has maintained genetic isolation from *S. l. longirostris.*

Similarly, the *Blarina* were large and undoubtedly referrable to *B. brevicauda telmalestes*, which Handley (1979) called the greater short-tailed shrew. Jones et al. (1979) referred to the taxon as *Blarina telmalestes*, the Dismal Swamp short-tailed shrew. This disparity of usage correctly indicates that the taxonomy of the genus *Blarina* is in flux. According to Tate et al. (1980) the Dismal Swamp is one region in which two distinctive sizes of *Blarina* occur, perhaps sympatrically; the larger is *B. brevicauda* and the smaller *B. carolinensis.*

The total number of species trapped in our study—seven—compares well with previous studies. Handley obtained the same number in 1953, and of the four other studies he summarized (1979, Table 1), two obtained more species (8 and 9) and two obtained fewer species (4 and 6). Considering that this study was conducted at the end of winter, when mammal densities are usually at their lowest levels, it seems likely that other seasonal studies of the openings in the Dismal Swamp will provide additional useful information.

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A New Milliped of the Genus *Brevigonus* from South Carolina, with Comments on the Genus and *B. shelfordi* (Loomis) (Polydesmida: Xystodesmidae)

Rowland M. Shelley
North Carolina State Museum of Natural History,
P.O. Box 27647, Raleigh, North Carolina 27611

ABSTRACT.— Brevigonus arcuatus, new species, is characterized by a broadly curved acropodite in which the distal zone is moderately long and possesses either simple or reflexed tips. Its congener, B. shelfordi (Loomis), is distinguished by absence of a distal zone and apical curve, and its abbreviated acropodite terminates at the distal extremity of the peak. An improved generic diagnosis is possible. *Brevigonus* is characterized by the spine at the base of the acropodite, and by the proximal location of the medial flange, which arises on the basal zone and ends on the peak and separates *Brevigonus* from the related genus *Sigmoria*.

In 1980 I attempted to dispose of a long standing taxonomic problem in the Xystodesmidae by erecting the new genus *Brevigonus* for *Cleptoria shelfordi* Loomis. Hoffman (1967) removed this species from *Cleptoria* but did not assign it to another genus. Before publication I collected extensively in and near the range of *shelfordi*, the north side of the Savannah River in the Piedmont Plateau of South Carolina, to try to discover other species for this genus. Finding none, however, I reluctantly concluded that there was no alternative to a monotypic taxon. Two basic gonopodal variants of *shelfordi* were at hand, but they clearly were not reproductively isolated. Consequently, I proposed the genus *Brevigonus* to emphasize what I considered the most distinctive feature of *shelfordi*, its shortened gonopodal acropodities.

I did not know in 1980, however, that a form I was referring to *Sigmoria* was actually closely related to *shelfordi*. I had collected this species several times in piedmont South Carolina but had assigned it to *Sigmoria* because of the overall curvature of the acropodite. Not until I was well into revising *Sigmoria* did I realize that this species was congeneric with *shelfordi*, and by that time the *Brevigonus* paper had been published. The new species shares several features with *shelfordi* that make for a sound generic diagnosis, but shortness of the gonopodal acropodites is unfortunately not one of them. This trait is a specific characteristic of *shelfordi*; the acropodites of the new species are long and form a broadly curved arch, which is the basis for its specific name, *arcuatus*. *Brevigonus* was thus a regrettable choice for a generic name, since it is based on a derived character of only one species and not on a trait shared by all components of the genus. A better name would have emphasized the spines on the basal zones (see terminology of the acropodite section in Shelley 1981a) or the proximal locations of the medial flanges, which originate on the basal zones in *shelfordi* and *arcuatus*. Although an inappropriate name, however, *Brevigonus* was validly proposed and must be retained for the taxon encompassing these two species.

There are positive aspects to the belated inclusion of *arcuatus* in *Brevigonus*. Improved diagnoses of the genus and of *shelfordi* are now possible, and certain anatomical features of *shelfordi* can now be more accurately interpreted. Moreover, *arcuatus* evinces a close relationship between *Brevigonus* and *Sigmoria* as opposed to one between *Brevigonus* and *Cleptoria* as previously stated (Shelley 1980). The significance of the flange on the medial surface of the acropodite, for example, was not evident when *shelfordi* was studied alone, because the shortened acropodite of this species terminates at the peak and lacks the distal zones and apical curves present in *arcuatus* and species of *Sigmoria*. *Brevigonus shelfordi* is thus a modified species that lacks the distal 1/3 to 1/2 of the normal apheloriine acropodite. Consequently, the medial flange of *shelfordi* did not previously show any resemblance to the flanges of certain species of *Sigmoria*, but the similarity is obvious in *arcuatus*, since it possesses the distal sections of the acropodite. *Brevigonus* can now be partly defined as an apheloriine genus with a flange on the medial face of the acropodite, arising on the proximal portion of the basal zone and terminating on the proximal portion of the peak. It differs from *Sigmoria* in the more proximal location of the flange, which is located on the peak (arising at the anterior bend) or the distal zone in this genus. The flange is variable in *Brevigonus* and is reduced or vestigial in individuals of both species. The margin is also irregular, and the flange may extend straight across the anterior bend as shown in Figure 3, or curve parallel to the acropodite stem as shown in Figures 8-9 of *shelfordi* in my 1980 paper. The apparent distal lobes on the acropodites of the latter individuals can now be recognized as the termination points of the medial flanges, which end on the distal portions of the acropodites in *shelfordi* only because this structure is shortened. Thus by clarifying the significance of the medial flange, *arcuatus* reveals a close phylogenetic affinity between *Brevigonus* and *Sigmoria*, which is confirmed by one other character—the reflexed tips on males in the southern part of the range of *arcuatus*. These individuals, from Abbeville County, South Carolina, have reflexed tips identical to those of certain species of *Sigmoria*, for instance *S. latior* (Brolemann). No other apheloriine taxa in the southeastern Atlantic lowlands display this termination of the acropodite, and its presence in species of *Sigmoria* and *Brevigonus* is strong evidence of a close relationship between the two genera. No such evidence exists of a relationship between *Brevigonus* and *Cleptoria*. My comments to this effect in 1980 were based on what I

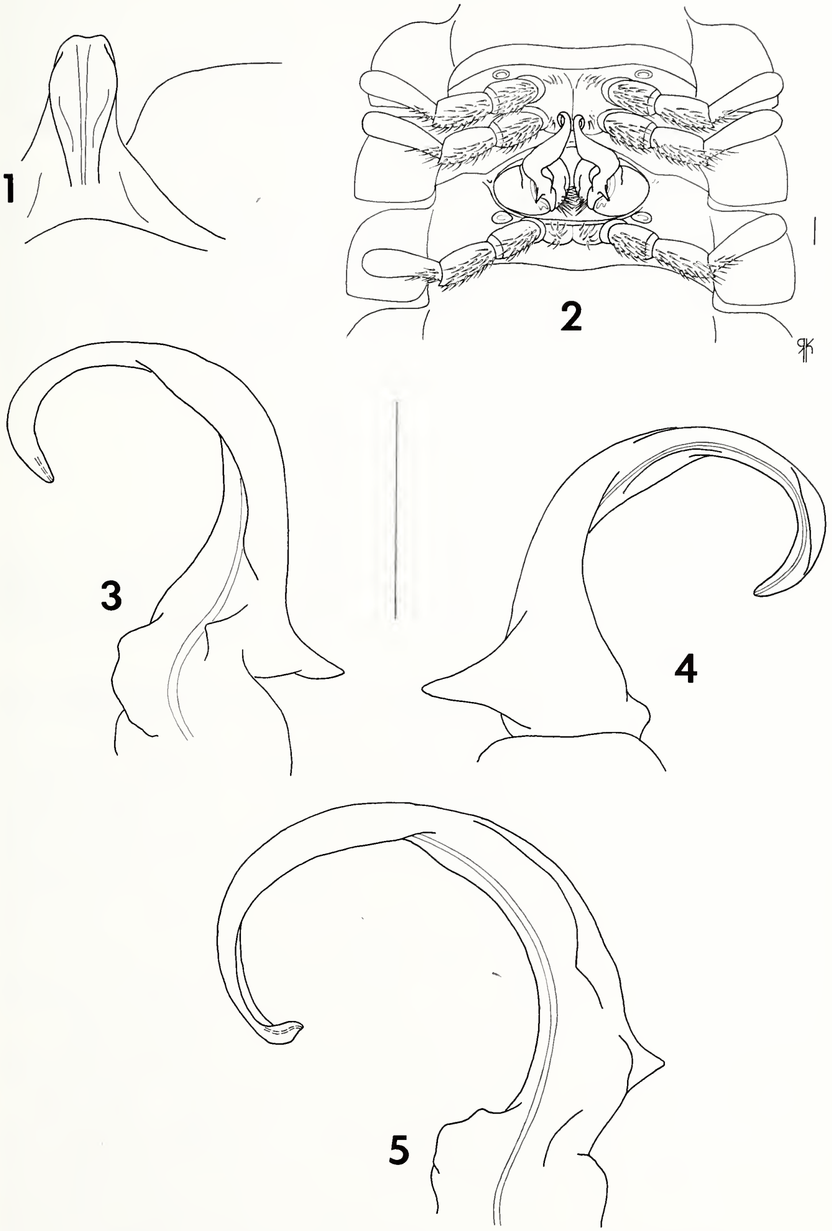

Fig. 1-5. *Brevigonus arcuatus*, new species. 1, process of 4th sternum of holotype, caudal view. 2, gonopods *in situ*, ventral view of paratype. 3, telopodite of left gonopod of holotype, medial view. 4, the same, lateral view. 5, telopodite of left gonopod of male from 5.8 km. SE Lowndesville, Abbeville Co., medial view. Scale line for Fig. 2 = 1.00 mm; line for other Figures = 1.16 mm for 1, 1.40 mm for 3-4, and 1.00 mm for 5.

now realize are only coincidental similarities between the gonopods of *shelfordi* and those of certain forms of *Cleptoria*, based on the shortened acropodites and other derived features of *shelfordi*, which just happen to resemble aspects of *Cleptoria* gonopods. Consequently, these statements about a relationship between *Brevigonus* and *Cleptoria* must now be discounted.

This paper presents amended diagnosis of both *Brevigonus* and *shelfordi*, a description of *arcuatus*, and new information on generic and specific ranges. All specimens of *arcuatus* included in this study are deposited in the North Carolina State Museum (NCSM) collection, the invertebrate catalog numbers of which are shown in parentheses. Other materials are in the collection of Richard L. Hoffman (RLH), Radford University, Radford, Virginia.

Brevigonus Shelley

Brevigonus Shelley 1980:32-34.

Type species.— *Cleptoria shelfordi* Loomis 1944.

Description.— The following comments on gonopods are supplemental to the somatic description in my 1980 account, and present a parallel treatment to the description of *Sigmoria* (Shelley 1981a), thus facilitating comparisons.

Gonopods *in situ* either crossing in midline or extending forward in subparallel arrangement over anterior edge of aperture and between 7th legs. Coxae large, without apophysis, connected by membrane only, no sternal remnant. Prefemur generally large, with or without large, cuneate process arising on dorsal side. Acropodite thick and heavy, either curving broadly through flattened peak into moderate distal zone and forming arc with variable diameter, or terminating abruptly at distal extremity of peak, with distal zone and apical curve absent; basal zone relatively long; anterior bend broad, moderate to poorly defined; peak flattened to gently curved; apical curve broad, smoothly continuous with peak; distal zone moderately long, curving broadly into arch of acropodite and directed toward basal zone, tapering smoothly apically. Termination variable; in forms with distal zone, either narrowly rounded, simple tip, or reflexed tip; in forms without distal zone, broad, blunt, occasionally notched tip. Basal sone usually with prominent basal spine on ventral surface and flange of variable width and configuration on medial face, arising proximally and continuing to termination on peak; latter with or without small acute spur at termination point of flange. Distal zone with remnant of lateral flange extending from proximal portion to about 2/3 length, usually represented by thickened rim near outer margin. Prostatic groove arising in pit on prefemur, crossing to lateral side of acropodite at anterior bend and continuing to terminal opening on simple or reflexed tips, or on distal extremity of peak.

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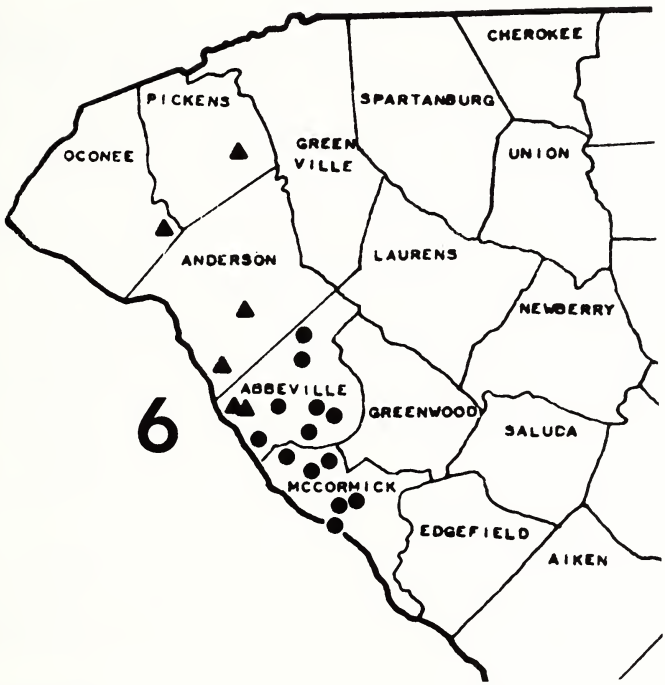

Fig. 6. Distribution of *Brevigonus:* triangles, *arcuatus*; dots, *shelfordi*.

Range.— Western Piedmont Plateau of South Carolina, from eastern Pickens and Oconee counties to central McCormick County. The genus is best represented in the Savannah River Valley of McCormick, Abbeville, and Anderson counties.

Species.— Two.

Brevigonus shelfordi (Loomis)

Cleptoria shelfordi Loomis 1944:172-173, Fig. 4. Chamberlin and Hoffman 1958:28.

Brevigonus shelfordi Shelley 1980:35-41, Figs. 1-13.

Diagnosis.—Distinguished by following features of male gonopods: acropodites crossing *in situ;* prefemoral process present, cuneate; acropodite short, terminating abruptly at distal extremity of peak, distal zone and apical curve absent; with or without sharply acute spur on medial face of acropodite distal to flange.

Description.— As with the generic description, the following comments on gonopods supplement my 1980 description and present an account parallel to those of species of *Sigmoria*.

Gonopods *in situ* with acropodites crossing at midline of aperture, extending over opposite sides of aperture and projecting slightly across anterior margin. Prefemoral process short and subtriangular, cuneate. Acropodite thick and heavy, curving into peak and terminating abruptly at distal extremity of peak; distal zone and apical curve absent; peak overhanging and extending usually beyond level of prefemoral process, directed subperpendicularly to basal zone; basal zone long, usually about 2/3 of acropodite length, with or without broad, caudally directed spine basally on ventral margin; anterior bend variable, broad and poorly defined to sharp and well defined; peak flattened to slightly curved, relatively short, no more than 1/3 of acropodite length; distal extremity of peak (termination of acropodite) variable—blunt, slightly rounded, or indented with hood-like lobe overhanging basal projection. Medial flange usually present, occasionally reduced and vestigial, arising on basal zone distal to spine, extending beyond anterior bend and terminating on peak, margin irregular. Peak with or without sharply acute spur on medial face distal to flange. Prostatic groove running along medial face of basal zone, crossing to lateral side at anterior bend, terminating on inner corner of basal projection of peak.

Remarks.— The specimens from Oconee County are now referred to *arcuatus*, as mentioned in the ensuing account. Otherwise, the range of *shelfordi*, as represented by the available material, remains unchanged from 1980.

Since it is now apparent that the medial flange is homologous to that of *Sigmoria*, the question arises as to whether the spur might be homologous to the tooth of *latior* and other species of *Sigmoria*. This seems plausible, but the material at hand provides no clues to resolve the issue.

As mentioned, the acropodite of *shelfordi* is merely an extremely shortened one in which the distal zone and apical curve are absent. Given the preponderance of long, curved acropodites in the tribe Apheloriini, such an abbreviated structure can only be interpreted as a derived character.

Brevigonus arcuatus, new species
Figs. 1-5

Type specimens.— Male holotype (NCSM A2075) and 4 M and 2 F paratypes collected by R. M. Shelley and W. B. Jones, 12 June 1978, from Pickens Co., SC, 13.6 km (8.5 mi.) E Pickens, along SC highway 192 at George's Creek. Three M and 2 F, and 7 M and 1 F, paratypes collected at same locality by R. M. Shelley on 8 May 1977 and 2 August 1977, respectively. Male and female paratypes deposited in Florida State Collection of Arthropods and private collection of R. L. Hoffman.

Diagnosis.— Characterized by following features of male gonopods: *in situ* arrangement parallel; prefemoral process absent; acropodite long, curving distally into broad arch, apical curve and distal zone present, without spur on peak; tip of distal zone variable, simple or reflexed.

Holotype.— Length 49.6 mm, maximum width 11.5 mm, W/L ratio 23.2%, depth/width ratio 62.2%. Segmental widths (in mm) as follows:

collum	7.8	10th-13th	11.5
2nd	8.9	14th	11.3
3rd	10.1	15th	11.0
4th	10.4	16th	10.6
5th	11.0	17th	9.4
6th-9th	11.4	18th	6.9

Color in life: paranota bright red, color indented slightly mediad along caudal edges; metaterga and collum glossy black, without stripes.

Somatic features similar to *shelfordi* (see Shelley 1980), with following exceptions: Width across genal apices 5.2 mm, interantennal isthmus broad, 1.8 mm. Antennae moderately long and slender, reaching back to caudal edge of 3rd paranota, relative lengths of antennomeres 2>3>4 = 5>6>1>7. Facial setae as follows: epicranial, interantennal, frontal, and genal absent, clypeal about 10-10, labral about 14-14.

Dorsum very glossy, slightly coriaceous on anterior portions of paranota. Latter moderately depressed, subcontinuous with slope of dorsum. Collum very broad, extending well beyond ends of following tergite. Caudolateral corners of paranota rounded through segment 7, becoming blunt and progressively more acute thereafter.

Process of 4th sternum (Fig. 1) enormous, much longer than widths of adjacent coxae; processes of 5th sternum large, knobs between 4th legs subequal to widths of adjacent coxae, flattened areas between 5th legs produced into knobs, shorter than widths of adjacent coxae; sternum of segment 6 slightly elevated into two small lobes between 6th legs, convexly recessed between 7th legs to accommodate curvatures of acropodites, 7th legs set slightly farther apart than 6th. Postgonopodal sterna bilobed on segments 8-10, with thick patches of stiff setae on lobes, becoming flattened with varying shallow grooves and impressions and fewer setae posteriorly. Coxae with low tubercles beginning on segment 10, becoming spine-like on 14 and continuing posteriorly.

Gonopodal aperture elliptical, 4.1 mm wide and 2.2 mm long at midpoint, strongly indented on anteriolateral edges, sides thickened and elevated above metazonal surface. Gonopods *in situ* (Fig. 2, of paratype) with acropodites in subparallel arrangement, extending forward over anterior edge of aperture between 7th legs, not overlapping or touching. Gonopod structure as follows (Fig. 3-4): prefemoral process absent, with elevated setose ridge at location of process but without sclerotized projection. Acropodite moderately thick and heavy, curving distally into broad arch, flattened at peak, overhanging and extending well beyond level of prefemur; basal zone with large, caudally directed spine basally on ventral surface and small basal lobe on inner surface above prefemur; anterior bend moderately sharp, located at nearly 1/3 length; peak relatively flat, about 1/4 of acropodite length; apical curve present, broad, located at about 3/4 length; distal zone present, long, curving broadly into arch; tip narrowly rounded, not reflexed, directed toward basal zone. Medial flange arising on basal zone just distal to spine, extending across anterior bend and terminating at midlength of peak, edge curved inward proximally and outward distally, obscurring short section of acropodite stem at anterior bend. Spur absent. Lateral flange present but greatly reduced, forming short rim on distal zone. Prostatic groove running along inner surface of acropodite basally, crossing to lateral side at anterior bend and continuing to tip.

Male paratypes.— The male paratypes agree essentially with the holotype in all particulars.

Female paratype.— Length 48.0 mm, maximum width 11.4mm, W/L ratio 23.8%, depth/width ratio 67.5%. Agreeing closely with holotype in somatic details except paranota more strongly depressed, creating appearance of more highly arched body.

Cyphopods *in situ* with valves visible in aperture, receptacle situated internally against coxae. Receptacle relatively small, located anteriad to and not overlapping valves, surface finely granulate. Valves moderate, inner one slightly larger, surface finely granulate.

Variation.— Several aspects of the gonopods vary. The size of the spine changes, being generally smaller in material from Abbeville County and greatly reduced in one male from Anderson County. The acropodite tends to be thinner and the apical curve broader in the southern specimens, and all males from Abbeville County posses a reflexed tip (Fig. 5). The tip is simple on all other specimens. Specimens from Anderson County have a sharp spine projecting mediad at the base of the medial flange in addition to that at the base of the acropodite, but this structure is absent from the Abbeville County males. All males have an elevated ridge on the prefemur but lack a prefemoral process.

Ecology.— *Brevigonus arcuatus* occurs under thin leaf layers on relatively hard substrates near rivers or creeks. It is sometimes found on the vertical bank of streams and has rarely been taken more than 6 to 9 m from a water source.

Distribution.— Piedmont Plateau physiographic province of central-western South Carolina, from southeastern Pickens to southwestern Abbeville counties. Specimens examined as follows (all collected by the author unless otherwise stated):

SOUTH CAROLINA: *Oconee Co.*— Clemson vic., under dead pig, 2M, F, 18 July 1962, J. A. Payne (RLH). *Pickens Co.*— 13.6 km. (8.5 mi.) E Pickens, along SC hwy. 192 at George's Cr., 3M, 2F, 8 May 1977 (NCSM A 1559); 7M, F, 2 August 1977 (NCSM A1617); and 5M, 2F, 12 June 1978, R. M. Shelley and W. B. Jones (NCSM A2075)

TYPE LOCALITY. *Anderson Co.*— 12.6 km. (7.9 mi.) SE Anderson, along SC hwy. 459 at Rocky R., M, F, 7 May 1977 (NCSM A1550); 10.1 km. (6.3 mi.) NE Iva, along SC hwy. 413 at Rocky R., 2M, 2F, 11 June 1978, R. M. Shelley and W. B. Jones (NCSM A2066); and 6.4 km. (4 mi.) SW Iva, along unnumbered rd. off SC hwy. 187 at Generostee Cr., M, 7 May 1977 (NCSM A1549). *Abbeville Co.*— 5.8 km. (3.6. mi.) SE Lowndesville, along SC hwy. 232 at Deal Cr., M, F, 6 May 1977 (NCSM A1544); and 4.2 km. (2.6 mi.) SW Lowndesville, along SC hwy. 70. 0.5 km. (0.3 mi.) SW jct. SC hwy. 64, M, 6 May 1977 (NCSM A1545).

Remarks.— The unusually large process of the 4th sternum, the longest of any apheloriine milliped known to me, is one of the key features of *arcuatus*. The structure is also longer than the widths of the adjacent coxae in two species of *Croatania* (Shelley 1977), but in these forms it is apically divided and bent anteriad. In *arcuatus*, the process projects directly ventrad and is not divided, although there is a very slight apical indentation. The process is shaped similarly in *shelfordi* but is shorter, being subequal in length to the coxal widths. A long 4th sternal process is thus characteristic of the genus.

Of interest is the fact that, except for *Sigmoria tuberosa* Shelley in the mountains of Swain County, North Carolina, the longest 4th sternal processes in the tribe Apheloriini are found in species in the Piedmont Plateau, and mostly in South Carolina. Hoffman (1967, Fig. 4) showed that the structure is longer than the adjacent coxal widths in *Cleptoria abbotti* Hoffman, which occurs along the southern side of the Savannah River in piedmont Georgia, but otherwise all species demonstrating this condition occur north of the river. However, not all the apheloriine millipeds in South Carolina are so well endowed. The process is shorter than the widths of the adjacent coxae in *Sigmoria latior* (Brolemann), *Cleptoria macra* Chamberlin, and all three species of *Furcillaria*; and is subequal in length in *Sigmoria quadrata* Shelley and *S. laticurvosa* Shelley (Shelley 1981a, 1981b; Hoffman 1967). Consequently, enlargement of this process seems to have evolved independently in four distantly related genera (*Cleptoria, Croatania, Sigmoria,* and *Brevigonus*). Or could this be an ancestral trait that has been retained by certain species in these genera? At present we have insufficient information on other apheloriine taxa to answer this question, since past authors have largely ignored the configuration of the 4th sterna. Having observed sternal variation in many species, however, I incline toward the latter interpretation and suggest that the length, and possibly also the shape, of the 4th sternal process might be indicators of distant phylogenetic relationships. The 4th sternum certainly warrants more attention than it has received, and other authors are encouraged to examine and illustrate it in their species so we will be better able to interpret its significance through a more complete knowledge of variation.

Another unusual feature of *arcuatus* is the presence of both simple and reflexed tips. I know of no other apheloriine species possessing such broad variation, and I consider the forms in Figures 3 and 5 to be conspecific because material from intervening areas in Anderson County displays intermediate conditions. The reflexed tips in Abbeville specimens of *arcuatus*, coupled with the medial flanges in *arcuatus* and some forms of *shelfordi*, are evidence of affinity with *Sigmoria*. However, the more proximal location of the flange on the basal zone in *arcuatus* and *shelfordi*, plus the spine at the base of the acropodite in these two species, justify generic separation from *Sigmoria*.

I include with *arcuatus* the geographically and anatomically disjunct males from Oconee County listed with *shelfordi* in my 1980 paper. Lacking a prefemoral process, and possessing a stronger basal spine and more broadly curved acropodite than other males of *shelfordi*, these males conform more to the description of *arcuatus*. However, they also differ from other specimens of *arcuatus* in having more massive gonopods, broader medial flanges, reduced acropodal curvatures, and broader tips. Perhaps there is a third species of *Brevigonus* in Oconee County, which is unknown except for these specimens. Several trips to Clemson and areas in Oconee County, however, have failed to produce more individuals, and I therefore include this sample under *arcuatus* pending discovery of additional material.

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New Records of Marine Fishes from the Carolinas, With Notes on Additional Species

Steve W. Ross

North Carolina Division of Marine Fisheries, P.O. Box 769, Morehead City, North Carolina 28557

Garnett W. Link, Jr.

University of North Carolina Institute of Marine Sciences, Morehead City, North Carolina 28557

and

Kerry A. MacPherson

Brunswick Biological Laboratory, Carolina Power & Light Company, Southport, North Carolina 28461

ABSTRACT.— The distributional status of fifteen marine fishes from Carolina waters is discussed. Eleven are new records to the area, the remainder being species previously or presently considered rare. The second collected specimen of *Daramattus americanus* and the first from the Carolinas is reported and illustrated. New maximum size records are established for *Paraconger caudilimbatus, Lepophidium jeannae,* and *Hemanthias leptus.* Some reproductive data are included for *Prionotus stearnsi.*

Biological sampling in North and South Carolina marine waters continues to yield fishes new to or once considered rare in the area (e.g., Graffe 1972; Ross and Fast 1977; Anderson et al. 1979; Burgess et al. 1979; Böhlke and Ross 1981). Most of the species recently reported from the Carolinas occurred in reef areas and had tropical affinities (Anderson and Gutherz 1964; Ross and Fast 1977; Anderson et al. 1979). The fishes in this report represent a mixture of zoogeographic affinities and habitat associations. Eleven of the fifteen species reported are new records to this area and the remainder are species presently or previously considered rare.

Specimens were collected by trawl, hook and line, gill net, seine, and by sampling the traveling screens of Carolina Power & Light Company's Brunswick Steam Electric Plant (BSEP) on the lower Cape Fear River at Southport, North Carolina. Standard lengths are given unless otherwise noted. Nomenclature follows Robins et al. (1980). Specimens are deposited at the Florida State Museum, University of Florida (UF) and the University of North Carolina Institute of Marine Sciences (UNC).

Congridae

Paraconger caudilimbatus (Poey). The margintail conger is a rarely collected species previously reported from the Bahamas, southeastern coast of Florida near St. Lucie Inlet, Cuba, the Gulf of Mexico, and Guiana (Kanazawa 1961; Böhlke and Chaplin 1968; Randall et al. 1977). Manooch (1975) reported specimens tentatively identified as *P. caudilimbatus* from Carolina waters. We add the following records off of North Carolina: 33° 07'N, 77° 49'W, 58 m, 11 November 1978, night trawl over live bottom (404 mm TL; UF 30590); 33° 57'N, 76° 28'W, 61 m, 8 December 1978, night hook and line over live bottom (542 mm TL; UF 30591); and ≃ 34° 30'N, 75° 50'W, ≃ 61 m, February 1979, night hook and line over live bottom (455 mm TL; UF 30592). The above collections were during darkness and near live bottom, suggesting that this species, like other congrids, is nocturnal and may seek shelter in reefs during the day. All of the above specimens exceed the maximum size (356 mm TL) recorded by Böhlke and Chaplin (1968).

Gadidae

Melanogrammus aeglefinus (Linnaeus). The haddock normally occurs in northern waters on both sides of the Atlantic, ranging along North America from Newfoundland to deep waters off Cape Hatteras (Leim and Scott 1966). Bigelow and Schroeder (1953) mentioned that haddock are seldom caught near shore and perhaps never in the littoral zone or brackish waters. On 10 March 1979, two specimens were captured by gill net in the Neuse River, North Carolina, between Adams Creek and South River (≃ 35° 00'N, 76° 38'W, ≃ 3 m). Both were about the same size, but only one was retained (417 mm; UF 27969). Water temperature and salinity recorded in the caputre vicinity on 9 March 1979 were 16° C and 4 0/00, respectively. This collection represents the southernmost and one of the most inshore records for haddock.

Ophididae

Brotula barbata (Schneider). One bearded brotula was collected from the BSEP traveling screens, Southport, North Carolina (Cape Fear River) on 18 July 1975 (192 mm; UF 30595). The previously recorded range of *B. barbata* included one record from Bermuda (Beebe and Tee-Van 1933) and other records from the Caribbean (Jamaica and Cuba), Florida, and northern Gulf of Mexico (Hubbs 1944). Our record represents the northernmost extent of this species, which appears to be rare north of the Gulf of Mexico.

Lepophidium jeannae Fowler. Although *L. jeannae* was recorded from Raleigh Bay, North Carolina (*Silver Bay* Station 1268, Bullis and Thompson 1965), Hoese and Moore (1977) reported its northernmost occurrence as Georgia. This species was also listed from the Cape Fear area by Wenner et al. (1979b, 1980). Four mottled cusk eels were collected off Cape Fear, North Carolina (33° 06'N, 77° 51'W, 67.7 m) by trawl in an area of sand and live bottom on 11 November 1978 (230 mm, 249 mm, 258 mm, 270 mm; UF 30599). Our specimens were much larger than the size (200 mm) given by Hoese and Moore (1977) and generally larger than those (238 mm max.) examined by Robins (1960).

Holocentridae

Myripristis jacobus Cuvier. The blackbar soldierfish was reported from tropical Atlantic waters of Florida, the Bahamas, the northern Gulf of Mexico and through the Caribbean to Brazil (Hoese and Moore 1977). Dahlberg (1975) mentioned that this species occurs in deeper waters off the Georgia coast and Powles and Barans (1980) reported one specimen off Charleston, South Carolina. Two specimens, both gravid females (91 and 99mm; UF 30598), were trawled off Cape Fear, North Carolina (33° 03'N, 78° 02'W, 42 m) during the early morning hours of 27 June 1978. Their occurrence during darkness is not surprising, considering that holocentrids are nocturnal feeders, typically hiding under ledges or in caves during the day (Randall 1968; Greenfield 1974). This behavior would make them practically inaccessible to trawl capture during daylight and may result in underestimations of their occurrence.

Grammicolepidae

Daramattus americanus (Nichols and Firth). The grammicolepid fishes are generally deep sea, widely scattered, and rarely collected. Worldwide there are five recognized species, but there is considerable confusion concerning validity and relationships, particularly in the genus *Daramattus*. Lack of specimens for study and lack of understanding of the effects of allometric growth contribute to this confusion. Smith (1960) described *Daramattus*, including two species: one new, *D. armatus*, and one originally described as *Xenolepidichthys americanus* by Nichols and Firth (1939). Only four specimens were known to Smith, three of which seemed to be *D. armatus* from Japan (1) and South Africa (2) and the fourth (*D. americanus*) from Georges Bank in the Western Atlantic. One of the two South African specimens of *D. armatus* was later redescribed as *D. barnardi* (Smith 1968).

According to Hugh H. Dewitt (pers. comm.) the type of *D. americanus* has 13 gill rakers and 39 total dorsal elements, not 20 and 38, respectively, as given by Nichols and Firth (1939). Considering this change, our single specimen collected off North Carolina by trawl on 29 September 1979 at 33° 32'N, 76° 39'W, 232 m (56 mm; UF 30669) seems referable to *D. americanus*. Meristic and morphometric data are presented in Table 1. Fresh coloration was as follows: body generally silvery, shading dorsally to a darker blue-gray; dark, spiny projections

Table 1. Meristic and morphometric data for *Daramattus americanus* (UF 30669). All measurements made to the nearest 0.1 mm with dial calipers.

Counts	
Dorsal	VI,32
Anal	II,34
Pectoral	15,15
Gill rakers (total)	14,15
Spiny body scutes (excluding postorbital spine)	11,11
Spines along anal base (left)	34
Spines along dorsal base (left)	33
Measurements	
SL	56.3
TL	94.4
Depth	46.5
Horizontal eye diameter	7.9
Head length	16.9
First dorsal spine	28.3
Second dorsal spine	28.3
First anal spine	63.4
Pectoral length	7.0
Pelvic length	14.7
Pelvic origin to first anal spine	10.7
Pectoral base to pelvic origin	16.7

on body are included in the 14-15 dark, vertical stripes that vary in length; dorsal and pectoral fins clear; pelvic and anal fins with some black bands; caudal with 2-3 black bands (Fig. 1).

This is only the second specimen yet collected of this species; however, further study, especially on allometric growth effects, may reveal that *D. armatus* and *D. americanus* are conspecific.

Gasterosteidae

Gasterosteus aculeatus Linnaeus. A threespine stickleback was collected from the BSEP traveling screens on 21 February 1979 (52 mm; UF 30594). It was previously known only as far south as Chesapeake Bay (Burgess and Lee 1980).

Apeltes quadracus (Mitchill). The fourspine stickleback has previously been reported in North Carolina from a single specimen collected in the Trent River, Craven County (Rhode et al. 1979). We report two additional specimens from North Carolina: Stumpy Point Bay, Pamlico Sound, 18 February 1975 (40 mm; UF 30593), and a gravid

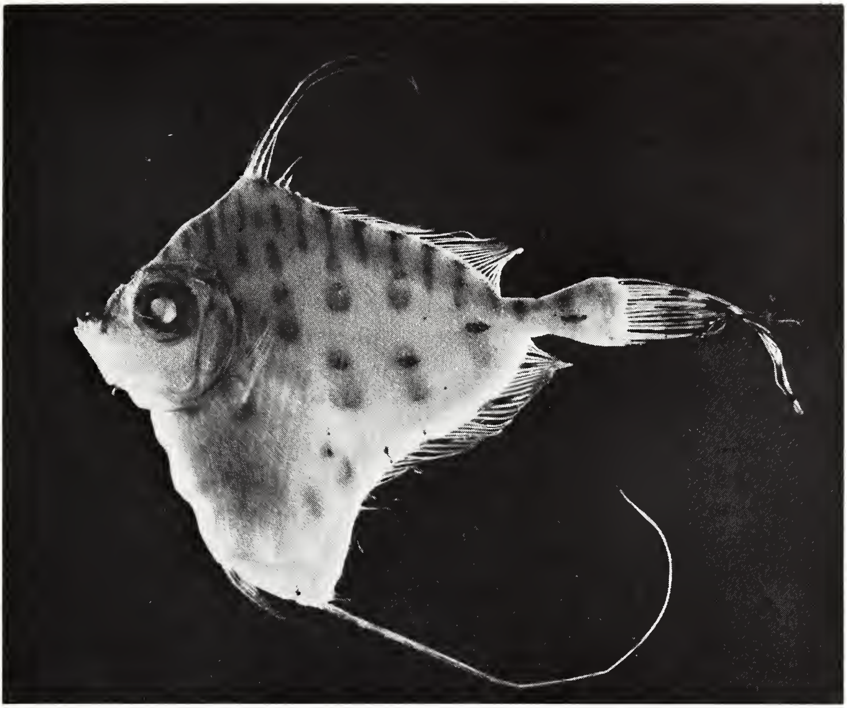

Fig. 1. *Daramattus americanus*, UF 30669, 56.3 mm SL specimen collected off North Carolina.

female from Shallowbag Bay, Roanoke Island, Dare County, 17 March 1978 (40 mm; UF 30670).

SYNGNATHIDAE

Oostethus brachyurus (Bleeker). The opossum pipefish, *O. b. lineatus,* is a relatively small tropical species commonly found in fresh and brackish waters of Central America, but only rarely reported from North America (see review in Gilmore 1977; Dawson 1979). Although Dawson (1979) reported its occurrence as far north as New Jersey, this species has not previously been recorded from North Carolina waters.

Six specimens were collected on five separate occasions from the BSEP traveling screens: 14 September 1976 (151 mm; UF 30605); 3 October 1976 (164 mm; UF 30673); 23 October 1976 (153 mm; UF 30674); 20 November 1978 (62 mm, 85 mm; UF 30607); and 5 December 1978 (89 mm; UF 30606). Collection salinities and temperatures ranged from 23.5 to 29.0 0/00 and 17.0 to 24.2° C, respectively. The three largest specimens were adult males with developed but empty brood pouches. Gilmore (1977) indicated that this species spawns from July through November in fresh water of the Indian River, Florida area. Dawson

(1970) also suggested that spawning in Mississippi waters occurred during the same period. Although adults seem to prefer fresh or estuarine environments, juveniles and larvae apparently spend some time in marine waters (Böhlke and Chaplin 1968; Gilbert and Kelso 1971; Hastings and Bortone 1976). Further sampling may reveal that *O. b. lineatus* is more common in North Carolina and that a breeding population exists.

Syngnathus elucens Poey. One shortfin pipefish was collected on 1 October 1968 at 34° 53'N, 75° 29'W (115 mm; UNC 9926). This represents a considerable range extension from the previously recorded distribution of Bermuda, the Bahamas, southern Florida, the northeastern Gulf of Mexico, and the Greater and Lesser Antilles to Surinam (Herald 1942; Böhlke and Chaplin 1968; Dawson 1972).

Serranidae

Hemanthias leptus (Ginsburg). One specimen of the longtail bass was collected by hook and line in 168 m off Murrells Inlet, South Carolina, on 20 August 1979 (456 mm; UF 27790). This species was previously known only from the northwestern Gulf of Mexico (Hoese and Moore 1977), hence our record represents a significant range extension. This specimen also greatly exceeds the previously reported maximum size of 310 mm (Briggs et al. 1964). Although the specimen was poorly preserved, it did retain a yellowish lateral bar from the eye to the posterior margin of the opercle. The caudal fin was bright yellow, the soft anal and dorsal pale yellow, and the other fins nearly clear. The body was generally silver with a pale golden color dorsally. These colors, especially the yellow bar across the opercle, are similar to those of *H. vivanus* (Walls 1975; Hoese and Moore 1977). Meristics agreed well with those of Ginsburg (1952, 1954), except that lateral line scales were 73 (left) and 59 (right), and Ginsburg gave a range of 78 to 86. Discrepancies may be due to the poor condition of our specimen.

Haemulidae

Anisotremus surinamensis (Bloch). The black margate is known from the Bahamas, southern Florida, throughout the Caribbean and Gulf of Mexico to Brazil (Hoese and Moore 1977). Collections from the Wrightsville Beach, North Carolina area were noted by Anderson et al. (1979). A single specimen of this reef species was collected on the BSEP traveling screens on 27 December 1979 (86 mm; UF 30597).

Microdesmidae

Microdesmus longipinnis (Weymouth). Pink wormfish reportedly occur in shallow water from Charleston, South Carolina (Hammond

1973) through the northern Gulf of Mexico, Cayman Islands, and Bermuda (Dawson 1969). Two specimens were collected in the lower Cape Fear River, North Carolina: one from the BSEP traveling screens (237 mm; UF 30596) on 23 March 1977, and the other from an unknown locality in the lower Cape Fear River (67 mm; UF 30671). A third specimen from the lower Cape Fear, unavailable for study, is deposited in the UNC collections. Our collections represent the first records of microdesmids in North Carolina.

Triglidae

Prionotus ophryas Jordan and Swain. The bandtail searobin was first reported from North Carolina waters by Bullis and Thompson (1965): 34° 00.5'N, 76° 21'W, 54-60 m, 5 September 1979, and subsequently by Wilk and Silverman (1976): 34° 20'N, 76° 52'W, 25 m, 17 November 1971 (200 mm TL); 34° 11.5'N, 76° 47'W, 31 m, 16 November 1971 (140 mm TL); 33° 27.5'N, 77° 24'W, 32 m, 24 May 1972 (190 mm TL). We have compiled a number of additional records from R/V *Dan Moore* surveys and other collections (Table 2), which include the northernmost record (DM 3754) of this species. Most *P. ophryas* were collected over sand bottoms; however, they are known to occur near live bottoms (S. W. Ross, pers. obs.) and calico scallop beds (Schwartz and Porter 1977; pers. obs.). Although not one of the most common of the offshore searobins, this species is regularly encountered in a depth range of 24 to 60 m (Table 2).

Prionotus stearnsi Jordan and Swain. Fourteen shortwing searobins were collected by trawl on three occasions: 33° 41'N, 76° 42'W, 152 m, 19 May 1978 (63 mm; UF 30601); 33° 02'N, 77° 53'W, 113 m, 27 June 1978 (76-105 mm; UF 30602); and 34° 29'N, 75° 58'W, 57 m, 13 December 1978 (92 mm; UF 30600). The June collection contained six females with ripe gonads, data for which are included in Table 3. Very ripe females (125 and 130 mm) were reported in August near the Tortugas by Longley and Hildebrand (1941). Lewis and Yerger (1976) suggested that both sexes reach maturity by 60 mm and found well developed ova (0.6 mm diameter) in October and December. The large gonads and eggs from the June specimens (Table 3) indicated that these fish were probably near spawning. Shortwing searobins had previously been reported from off Cape Fear, North Carolina (Bullis and Thompson 1965; Wenner et al. 1979a, 1979b), although Roberts-Goodwin (1981) had listed them as far north as South Carolina and Hoese and Moore (1977) only north to Georgia.

Table 2. Collection data for *Prionotus ophryas* off the Carolinas. DM = R / V *Dan Moore* station number; GWL = G. W. Link collection number.

No.	Data	Remarks
DM 3267	33°58'N, 77°12'W, 31.1 m, 4 Oct. 1977	1-Gravid ♀, 172 mm, UNC 13843
DM 3327	33°09'N, 78°05'W, 33.0 m, 7 Nov. 1977	1-Gravid ♀, 147 mm, UF 24583
DM 3352	34°07'N, 77°13'W, 29.3 m, 16 Nov. 1977	
DM 3385	31°56'N, 79°43'W, 40.2 m, 18 Jan. 1978	1- ♀, 104 mm, UNC 14708
DM 3386	31°56'N, 79°42'W, 45.7 m, 18 Jan. 1978	
DM 3652	34°16'N, 77°08'W, 25.6 m, 21 Sep. 1978	
DM 3727	33°20'N, 78°07'W, 29.3 m, 10 Nov. 1978	4 Specimens
DM 3728	33°19'N, 78°12'W, 29.3 m, 10 Nov. 1978	1 Specimen
DM 3736	33°04'N, 77°57'W, 47.5 m, 11 Nov. 1978	1 Specimen
DM 3744	34°07'N, 76°38'W, 36.6 m, 15 Nov. 1978	1 Specimen
DM 3751	34°27'N, 76°17'W, 32.9 m, 6 Dec. 1978	1 Specimen
DM 3754	34°33'N, 76°03'W, 40.2 m, 6 Dec. 1978	1- ♂, 98 mm, UNC 15242
DM 3850	34°28'N, 76°14'W, 36.6 m, 8 Mar. 1979	
DM 3911	33°27'N, 78°07'W, 23.8 m, 15 Oct. 1979	
DM 3915	33°09'N, 78°04'W, 34.7 m, 17 Oct. 1979	
DM 3922	33°04'N, 77°58'W, 42.1 m, 21 Oct. 1979	1, 106 mm, UF 30672
DM 3923	34°00'N, 76°24'W, 47.5 m, 21 Oct. 1979	1, 118 mm, UF 30603
DM 4280	34°27'N, 76°16'W, 32.9 m, 20 Jan. 1980	1, 93 mm, UF 30604
GWL-73-5	East of Cape Lookout on Scallop Grounds, 30.5 m, 30 Apr. 73	1- ♂, 114 mm, UNC 7852
GWL-73-10	34°28.8'N, 76°16'W, 32.3 m, 23 May. 1973	1- ♂, 142 mm, UNC 7921 1-Gravid ♀, 119 mm, UNC 7921
GWL-81-1	East of Cape Lookout on Scallop Grounds, 30.5 m, 27 Mar. 1981	1, 103 mm

Table 3. Length, weight, and sex data of *Prionotus stearnsi* collected on 27 June 1978 (UF 30602).

SL (mm)	Wt. (g)	Sex	Ovary wt. (g)+	Gonad index*	Egg diameter size range (mm)
76	8.7	♀	0.3	3.45	0.4-0.7
83	13.1	♂			
88	12.4	♂			
88	11.7	♀	1.5	12.82	0.3-0.8
89	12.8	♀	0.8	6.25	0.3-0.6
90	15.6	♂			
90	15.2	♂			
91	14.3	♂			
95	17.3	♂			
96	16.0	♀	0.7	4.38	0.4-0.7
97	15.7	♀	0.5	3.18	0.3-0.6
105	20.4	♀	0.6	2.94	0.5-0.8

+ Both gonads combined.

* Gonad index = gonad weight ÷ (body weight - gonad weight) × 100.

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Nesting and Management of the Atlantic Loggerhead, *Caretta caretta caretta* (Linnaeus) (Testudines: Cheloniidae) on Cape Island, South Carolina, in 1979.

John B. Andre[1] and Larry West
Cape Romain National Wildlife Refuge, Route 1, Box 191, Awendaw, South Carolina 29429

ABSTRACT.—Nesting activity of the Atlantic loggerhead turtle, *Caretta caretta caretta,* was monitored on Cape Island, Cape Romain National Wildlife Refuge, South Carolina, in 1979. The nesting season encompassed 106 days, beginning in mid-May and continuing through August. An estimated total of 1,093 clutches was laid on the island with an average of 136.6 nests/km. Seventy-one percent of all turtle emergences on the beach were false crawls (non-nesting emergences). Three-hundred seventy-nine nests were removed to an on-site, predator-proof hatchery, which produced 10,185 hatchlings from 117 nests. Mean clutch size was 117.0 (SD = ± 4.31)and hatching success was 74.4%. Raccoons and erosion destroyed most of the natural nests, but 714 of them produced 3.605 hatchlings. On 4 September, 17.8 cm of rainfall associated with Hurricane David drowned or washed away all unhatched eggs in the nesting areas and hatchery. To reduce predator-induced mortality, 82 raccoons were removed from Cape Island prior to and during the turtle nesting season. This resulted in a 25% reduction in first night predation from 1978 levels. An average of 2.2 (SD = ± 1.84) nests were destroyed per night in 1979 compared to 7.5 nests per night in 1978.

INTRODUCTION

The major worldwide nesting areas of loggerhead turtles, *Caretta caretta* (Linnaeus), are in the southeastern United States, southeastern Africa, and eastern Australia. In the United States, *C. c. caretta* nests primarily on the beaches of North and South Carolina, Georgia, and the Atlantic and Gulf coasts of Florida (U.S. Fish and Wildlife Service 1979). Cape Island, in Cape Romain National Wildlife Refuge (CRNWR), probably has more nesting activity than any other South Carolina loggerhead rookery.

In light of the classification of loggerheads as Threatened (Federal Register, 28 July 1978), it is imperative that rookeries be protected and managed to maximize loggerhead productivity. Little is known of the fates of hatchling loggerheads in the ocean, but probably very few reach sexual maturity. This unknown also necessitates that management activities be directed at increasing the number of loggerhead hatchlings reaching the ocean.

Factors adversely affecting loggerhead productivity on or near Cape Island are predators, poachers, erosion and inundation, and

[1]Present address: U.S. Fish and Wildlife Service, P. O. Box 87, Kilauea, Kauai, Hawaii 96754

commercial fishing. Raccoons, *Procyon lotor,* are major egg predators (Stancyk et al. 1980; Hopkins et al. 1979; Davis and Whiting 1977; and Gallagher et al. 1972) and, if not controlled, can reduce loggerhead productivity to zero. Erosion and inundation are responsible for the loss of many egg clutches on Cape Island. Shrimp trawling also reduces loggerhead productivity by drowning turtles caught in trawls (Ulrich 1978).

This paper documents and describes loggerhead nesting activity at Cape Island in 1979 and management practices initiated at CRNWR to increase loggerhead productivity, i.e. the number of hatchlings entering the ocean. Management practices include the operation of a hatchery and a predator control program.

The Study Area

Cape Island is approximately 8 km long and 2.4 to 0.1 km wide. The barrier island is a part of the Santee River Delta complex (Price 1955). Cape Island owes some of its origin to sediments supplied by the Santee River (Brown 1977), and diversion of a large part of the Santee's flow into the Cooper River in 1941 decreased its sediment load. This factor was responsible for the shift from a stable or depositional phase to a destructive, erosional phase at Cape Island (Aburawi 1972). Since 1941 the island has eroded over 215 m at several points (Stephen et al. 1975), and erosion continues to move the steep, narrow front beach landward at a rate of about 10 m/yr (Christopher H. Ruby, pers. comm.). This erosion, combined with the wind and high tides that accompanied Hurricane David on 4 September 1979, breached the island at two locations. The hurricane also removed some of the remaining dune system, thus reducing loggerhead nesting habitat.

The front beach and primary dune system are used by nesting loggerheads. Landward of the steep, narrow beach are dunes and tidal wash-over areas (see Caldwell 1959 for a complete description of Cape Island beach types). Large elongate dunes lie parallel to the beach and grade (abruptly to gradually) into small, isolated clumps of dunes.

MATERIALS AND METHODS

Surveys of the Cape Island beach were conducted from 18 May to 28 August to document loggerhead nesting activity. Each survey began about one hour after dark and ended at dawn. Data recorded during each survey included the numbers of freshly laid nests, false crawls, and nests destroyed by predators. An average of 4.2 (range 1-7) surveys was conducted each week during the 15 week nesting season. Estimates of total weekly nesting activity (Table 1) were obtained by summing the numbers of nests and false crawls observed on surveys during that week, dividing the sums by the number of surveys conducted, and multiplying these means by seven. Data reported from 1978 were extracted from

Table 1. Estimated total numbers and mean (± one standard deviation) numbers of nests and false crawls per week, and the number of surveys conducted each week, on Cape Island in 1979.

Sample period	Number of nests		Number of false crawls		Number of surveys
	Estimated	$\bar{x}\pm SD$	Estimated	$\bar{x}\pm SD$	
18-24 May	23	3.3±2.31	40	5.7±6.43	3
25-31 May	52	7.5±6.36	115	16.5±2.12	2
1-7 June	133	19.0	161	23.0	1
8-14 June	107	15.3±4.04	264	37.7±7.51	3
15-21 June	101	14.4±5.13	332	47.4±21.48	5
22-28 June	104	14.8±4.12	278	39.7±9.27	6
29 June - 5 July	113	16.2±5.04	290	41.5±10.42	6
6-12 July	79	11.3±8.34	291	41.5±18.79	4
13-19 July	97	13.8±4.55	407	58.2±22.33	5
20-26 July	110	15.8±1.50	294	42.0±17.63	4
27 July - 2 August	77	11.0±2.19	174	24.8±9.79	6
3-9 August	49	7.0	28	4.0	1
10-16 August	36	5.2±3.19	48	6.8±3.31	6
17-23 August	9	1.3±1.38	15	2.1±2.41	7
24-28 August	3	0.5±0.58	1	0.3±0.50	4
Totals	1093		2738		63

CRNWR report files and measurements of variation were not available.

To increase loggerhead productivity, nests were moved to a predator-proof exclosure (hatchery) located behind a 2 m high primary dune that protected the eggs from erosion and saltwater inundation. Nests were found by following crawl tracks. The site was then carefully probed with a metal pole to locate the eggs, which were excavated by hand, removed from the nest, and placed in a plastic bucket containing about 5 cm of moist sand. The eggs were then covered with moist sand from the nest cavity to reduce evaporation and temperature fluctuation. In probing for nests, 1-3 eggs at the top of the egg mass were broken in approximately 10 clutches during the nesting season. The in-nest orientation of eggs was not maintained when transferred to the hatchery. Clutches that were partly destroyed by raccoons received the same treatment, except that eggs from different clutches were combined so that each transplanted group contained at least 60 eggs. Exhumed eggs were usually less than four, never more than twelve, hours old, and were placed in the hatchery within two hours of collection.

Hatchery clutches, spaced 0.6 m apart, were reburied in holes approximating the dimensions of natural nest cavities. Eggs were placed in the holes until they held a complete clutch or at least 60 eggs. A shallow layer of moist sand was placed over the egg mass and lightly packed by hand, then additional sand layers were placed and packed until the cavity was filled. Each nest in the hatchery was marked with a flag indicating the nest number, number of eggs and date laid. Hatchling turtles were removed from the hatchery before daylight, released on the beach berm, and allowed to crawl down the beach and enter the ocean unaided.

The hatchery consisted of two pens (6.1 X 12.2 m and 6.1 X 18.3 m) placed together. Both enclosures were 1.8 m tall and the sides and tops were enclosed with 5.1 X 10.2 cm welded wire. A 91 cm width of chicken wire was buried around the perimeter of the pens to prevent predators from digging under the sides. Fiberglass panels, 76 cm tall, were placed around the pens to prevent wind-blown sand from covering nests and to keep ghost crabs, *Ocypode quadrata*, and rats, *Rattus rattus* and *R. norvegicus*, from entering the hatchery. The sparse vegetation within the hatchery was removed by hand to protect the eggs from penetration and entanglement by plant roots.

An egg and hatchling predator control program was conducted from April 1979 through the loggerhead nesting season. Raccoons were captured with live and leg-hold traps. Methods of raccoon population management were outlined by Ehrhart (1979).

RESULTS AND DISCUSSION

Nesting Activity

The 1979 loggerhead nesting season at Cape Island encompassed 10 days, from the first clutch on 15 May to the last clutch on 28 August. Results of 63 surveys of the Cape Island beach are depicted in Figures 1 and 2. Table 1 shows the estimated total numbers and the mean (± standard deviation) numbers of nests and false crawls per week. Since the surveys included almost 60% of the nesting season, we believe our estimates reflect actual total nesting activity.

Loggerheads on Cape Island laid 1,093 clutches in 1979 compared to 1,451 clutches in 1978. This apparent 25% decline may have been caused by rapid erosion of the beach and dune system, but past records at CRNWR indicate considerable fluctuation in annual nesting activity at Cape Island. Another possible explanation for variation in number of nests per season is the two to three year breeding cycle of female loggerheads. Kaufman (1975) and Davis and Whiting (1977) reported that female loggerheads demonstrated a two year breeding cycle in Columbia, South America, and Everglades National Park, Florida, respectively. Davis and Whiting (1977) also found that the even-year breeding population was about twice the size of the odd-year breeding population, resulting in different levels of nesting activity each year.

The frequency of false crawls or non-nesting emergences may be related to quality of nesting habitat, since Davis and Whiting (1977) observed more false crawls on poor quality beaches. Comparison of our data with other studies supports this suggestion. In 1979, 71% of all loggerhead emergences on the Cape Island beach were false crawls. The mean number per night was 25.8 (SD = ± 22.21), compared to 5.3 per night at Cape Island in 1939 (Caldwell 1959), a five-fold increase. Different data collecting methods between our study and Caldwell's probably account for part of the increase. Also, Talbert et al. (1980) found that the frequency of false crawls at Kiawah Island, South Carolina, ranged from 28.7% to 47.7%, with a mean of 40.5%, from 1972 to 1976. Kiawah Island, approximately 83 km southwest of Cape Island, has experienced much less erosion (Hayes et al. 1977).

Even though the frequency of false crawls is high, Cape Island is heavily used as a loggerhead nesting area. We found a mean of 136.6 nests/km of beach in 1979 based on the total estimated number of nests. Ehrhart (1979) reported 44.2 to 79.2 nests/km of beach at the Kennedy Space Center on the east coast of Florida, while Talbert et al. (1980) found an average of 9.5 nests/km for five nesting seasons at Kiawah Island. The nesting concentration at Cape Island indicates the importance of this island as a loggerhead rookery.

Figure 1 depicts the seasonal nesting activity of female loggerheads at Cape Island in 1979. Numbers of nests per night increased rapidly

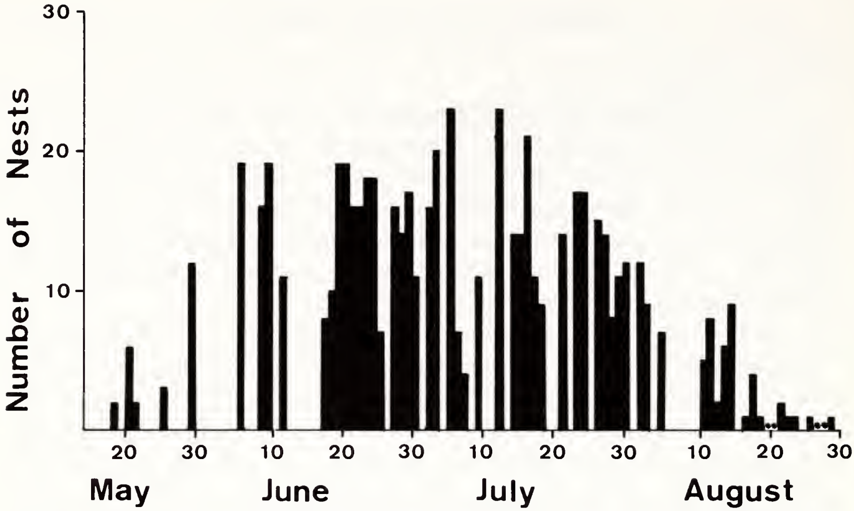

Fig. 1. Actual number of nests laid on each survey night on Cape Island in 1979. Asterisks indicate completed surveys with no nests laid; surveys were not made on other nights represented by zero nests.

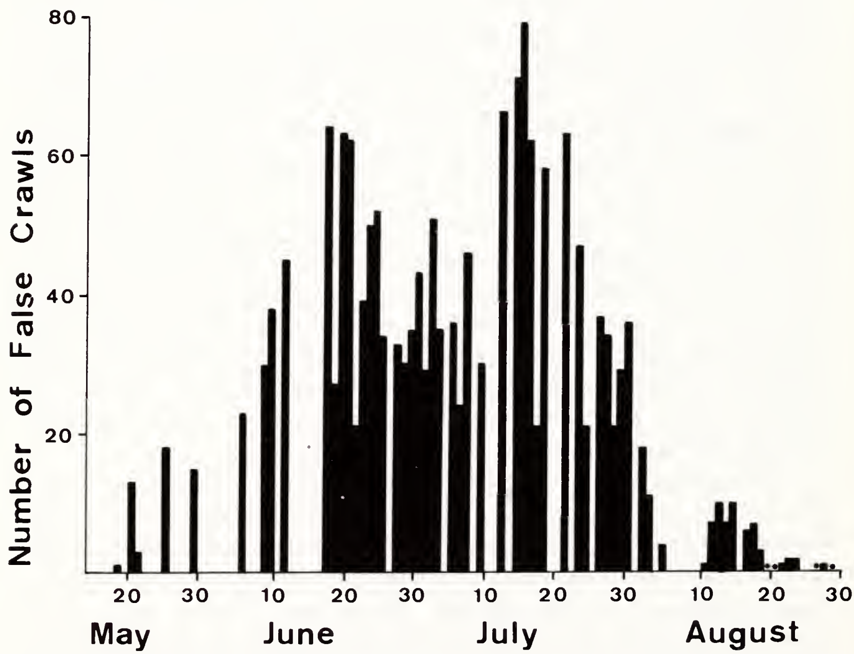

Fig. 2. Actual number of false crawls observed on each survey night on Cape Island in 1979. Asterisks indicate completed surveys with no false crawls observed; surveys were not made on other nights represented by zero false crawls.

from 18 May to the first week of June. From June through most of July nesting activity was roughly at the same level, but the numbers of nests laid per night varied considerably. In the last week of July nesting activity started to decrease until the end of the season in late August.

S. R. Hopkins of the South Carolina Wildlife and Marine Resources Department, in cooperation with the U.S. Fish and Wildlife Service, conducted a loggerhead study from 1977 (Hopkins et al. 1979) to 1979 on a 3 km section of the Cape Island beach. She found that 5.8% of 209 natural nests (nests not placed in the hatchery) hatched successfully in 1979 (Hopkins, pers.comm.). With this percentage of natural nests hatching, we can calculate natural loggerhead productivity for 1979 at Cape Island. We determined that the mean clutch size was 117, (SD = ± 4.31, N = 393), and that an average of 74.4% (N=10) of the eggs in each clutch hatched. With 5.8% of 714 nests (379 of the total 1,093 nests were transplanted) hatching successfully, the number of hatchlings produced from natural nests was estimated to be 3,605.

Hatchery Program

Loggerhead turtle hatcheries have been used since at least 1965. The early hatcheries were designed to protect eggs and hatchlings from raccoons and crabs (Richardson 1978). In addition to this function, though, the Cape Island hatchery included eggs from nests that would have been destroyed by beach erosion or saltwater inundation produced by winds and tides.

At the end of the 1979 nesting season the hatchery contained 379 nests, the first six placed there on 29 May and the last three on 16 August. The first hatchlings were released from the enclosure on 28 July and the last of the season on 3 September. The incubation period in the hatchery was about 65 days, but could not be precisely determined since tracks of the hatchlings made it difficult to determine from which nest they emerged. Hopkins (unpublished data) observed that the incubation period for natural nests on Cape Island averaged 65.3 days in 1979.

The hatchery and dune system of Cape Island were severely damaged on 4 September by 50 to 60 mph winds produced by Hurricane David and the occurrence of a 2.1 m spring tide. Prior to the hurricane, 117 nests hatched successfully in the enclosure. An average of 87.0 hatchlings emerged from each nest, resulting in the production and release of 10,185 hatchlings. From 1965 to 1976, the hatchery at Little Cumberland Island, Georgia, produced an average of 65 hatchlings/nest (Richardson 1978). We hand-released about 8,000 turtles from the hatchery, and about 2,200 hatchlings were self-released at night through a tunnel constructed from hatchery to beach.

Morning releases of hatchlings near the hatchery site were quickly discovered by Laughing Gulls, *Larus atricilla,* and Herring Gulls, *L.*

argentatus, and approximately 200 turtles were taken by these birds during the season. Losses were minimized by releasing the turtles each day at a point on the beach where gulls were not present.

We checked the condition of the hatchery on 6 September, after the hurricane had passed, and found that the unhatched eggs had drowned, regardless of the degree of embryo development. Loggerhead egg mortality from excessive rainfall and the condition of drowned eggs has been reported by Ragotzkie (1959), and our observations concur. A series of exhumed nests showed that the last that hatched had been placed in the hatchery on 28 June. Groundwater level was at or near the tops of all exhumed nests.

Most of the natural nests on Cape Island were also destroyed by the hurricane (Hopkins, pers. comm.). Of 51 unhatched nests remaining in her 3 km study area, all were destroyed by erosion or inundation produced by the hurricane. Our inspection of nesting habitat on the island after the hurricane revealed that no natural nesting sites had been effectively protected.

Predation

The major problem for management of the Atlantic population loggerhead rookeries is the raccoon (Ehrhart 1979). Destruction of nests by raccoons is the most important factor limiting turtle productivity on Cape Island. First night predation (nests destroyed on the same night laid) is almost 100% in some rookeries (Ehrhart 1979). In 1972 and 1973, raccoons took 85% and 75%, respectively, of the loggerhead nests at Cape Sable, Florida, and first night predation accounted for 87% of the destroyed nests (Davis and Whiting 1977). To reduce egg and hatchling losses, 82 raccoons were removed from the island during April through August 1979. The effect of the trapping effort is clear. In 1978, first night predation by raccoons destroyed 47% of the nests compared to 22% in 1979. The greatest number of nests destroyed on the night laid was 18 in 1978 and 7 in 1979, and the mean number of nests destroyed per night was 7.5 in 1978 and 2.2 (SD = ± 1.84) in 1979. On a 3 km section of Cape Island beach, Hopkins (unpublished data and pers. comm.) found that raccoons destroyed 95.8% of the marked nests in 1978 and 59.3% in 1979. The 1979 predation percentage would have been somewhat higher, but nests were not available to predators after Hurricane David (Hopkins, pers. comm.). Klukas (1967) and Davis and Whiting (1977) reported similar findings after initiating a raccoon control program at Cape Sable, Florida. However, trapping programs are labor intensive and must be conducted yearly to maintain effectiveness. Reproduction by raccoons, and immigration from nearby areas, quickly replace those removed by trapping.

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Distribution, Morphology and Life History of the Least Brook Lamprey, *Lampetra aepyptera* (Pisces: Petromyzontidae), in Kentucky

STEPHEN J. WALSH AND BROOKS M. BURR

Department of Zoology,
Southern Illinois University at Carbondale,
Carbondale, Illinois 62901

ABSTRACT.— Kentucky distribution records for the least brook lamprey, *Lampetra aepyptera* (Abbott), show that it is the most abundant and widespread lamprey in the state, inhabiting most major drainages where suitable habitat is available. Morphological and dentition data from over 220 specimens reveal that the recently described *Lethenteron meridionale,* from Tennessee, Alabama and Georgia, is a synonym of *L. aepyptera.* Interdrainage variation in meristic and morphometric characters of *L. aepyptera* falls within the normal range of variability for the species in the Ohio Valley.

INTRODUCTION

Although a considerable distributional and ecological literature exists for the least brook lamprey, *Lampetra aepyptera* (Abbott), little information has been published on its occurrence and life history in Kentucky. A few distributional records for the species in Kentucky were reported by Branson (1970), Burr and Mayden (1979), Burr (1980), and Clay (1975). The only information on its natural history in the state was summarized by Clay (1975), who included original observations on the demise of a population in Knob Creek, southwest of Louisville. The most complete studies on the life history of *L. aepyptera* were done in Maryland (Seversmith 1953) and Delaware (Rohde et al. 1976). Branson (1970), Clay (1975), and Clay and Carter (1957) briefly described its morphological characteristics in Kentucky. In their description of *Lethenteron meridionale,* Vladykov et al. (1975) gave the most complete morphological description of *L. aepyptera* to date. Rohde et al. (1976) summarized meristic and morphometric characteristics of the species in Delaware and the literature prior to their study.

The purposes of this paper are to (1) map and describe the Kentucky distribution of *L. aepyptera,* (2) analyze its morphological characteristics in the state, and (3) supplement published ecological information with our observations of what appears to be a neotenic population in western Kentucky, a heretofore unreported phenomenon in this species. The discovery of posterior circumoral teeth in a number of Kentucky *L. aepyptera,* and the variability of their presence, leaves little doubt that *Lethenteron meridionale* is a synonym of *Lampetra aepyptera.*

METHODS AND MATERIALS

Over 220 adults, from the institutions listed in Acknowledgments, were used for morphological comparisons between major drainages or ichthyofaunal blocks as designated by Burr (1980). All measurements were made to the nearest 0.01 mm with dial calipers. Terminology of dentition follows Hubbs and Potter (1971) and Potter (1980). The oral discs of some specimens were lightly stained with alizarin red S to facilitate tooth counts. Methods of counting and measuring were those of Vladykov and Follett (1958, 1965).

The life history of *L. aepyptera* was studied at Terrapin Creek, Graves County, Kentucky, near the Tennessee border. Collections were made from the state line north to 0.8 km south of Bell City, Kentucky. Intermittent sampling from 23 March 1978 to 4 June 1980 resulted in 138 specimens, which were fixed in 10% formalin and later transferred to 70% ethanol. Frequency of occurrence versus lengths of ammocoetes taken at Terrapin Creek on 4 June 1980 were plotted and the curve smoothed using 7 mm sliding averages (Hardisty 1961; Hardisty and Potter 1971; Rohde et al. 1976; Taylor 1965). Lampreys were blotted dry and weighed to the nearest 0.1 mg on a Sartorius analytical balance. Egg diameters were measured with an ocular micrometer at a magnification of 25-50X; no correction was made for shrinkage.

Collections of *L. aepyptera* examined, all from Kentucky, are listed below by major drainage, county, catalog number, locality, and date. The number of specimens is shown in parentheses.

Big Sandy River Drainage.— *Martin Co.*: UL 7945 (1) Rockhouse Fork of Rockcastle Cr. at Stidham, 27 March 1956. *Floyd Co.*: UL 5946 (3) John's Cr. below Dewey Dam, 27 March 1956. *Morgan Co.*: SIUC uncat. (4) Open Fork of Paint Cr. at ford, 24 March 1973.

Licking River Drainage.— *Montgomery Co.*: INHS 78829 (2) creek, 1.6 km W Means, 12 April 1968. *Rowan Co.*: UL 5228 (16) Licking R. at Cranston, 12 April 1941. *Menifee Co.*: UL 4983 (1) Beaver Cr., 8 April 1954.

Kentucky River Drainage.— *Wolfe Co.*: KNPC uncat. (2) Swift Camp Cr. just upstream from confluence Red R., 3 May 1980; UL 1014 (1) Red R. near Hazel Green, 24 November 1960.

Upper Cumberland River Drainage.— *McCreary Co.*: WCS 720-01 (9) Taylor Branch, 8.8 km E Whitley City, 16 April 1977. *Whitley Co.*: INHS 79259 (1) Youngs Cr., 1.6 km W Clio, 19 March 1978. *Rockcastle Co.*: UL 2015 (1) Clear Cr., 3.2 km S Disputanta, 3 April 1980; EKU 168 (1) Clear Cr., 3.2 km SE Disputanta, 20 March 1966.

Salt River Drainage.— *Hardin Co.*: KNPC uncat. (3) Clear Cr. downstream from overpass E Colesburg, 24 March 1978. *Bullitt Co.*: USNM 164102 (15) Knob Cr., 28 March 1950; UL 4791 (20) Knob Cr. near Mitchell Hill Road, 25 March 1950; UL 4794 (73) Knob Cr. 9.6 km NW Shepherdsville, 25 March 1950; INHS 78228 (1) creek, 9.6 km S Fairdale, 7 April 1968.

Ohio River Drainage.— *Hardin Co.*: UL 5949 (1) trib. Otter Cr. near Vine Grove, 11 March 1956; UL 4810 (6) Otter Cr., 3.2 km W Vine Grove, 13 March 1954; UL 11886 (3) Otter Cr., S Vine Grove, 6 May 1959.

Green-Barren River Drainage.— *Allen Co.*: SIUC uncat. (4) Long Hungry Cr., 1.6 km SE Mt. Zion, 18 March 1980. *Barren Co.*: SIUC uncat. (4) Peter Cr., 1.6 km SE Dry Fork, 18 March 1980. *Edmonson Co.*: UL 5229 (5) trib. Beaverdam Cr. near Brownsville, 31 March 1955. *Green Co.*: UL 11001 (1) Caney Fork at Hwy. 61, 8 April 1978. *Larue Co.*: INHS 78477 (1) Walters Cr., 6.4 km N Magnolia, 28 March 1964. *Russell Co.*: INHS 79126 (1) trib. Goose Cr., 6.4 km NE Russell Spring, 18 March 1978. *Simpson Co.*: UL 12835 (1) West Fork Drakes Cr., 1.6 km above confluence Lick Fork, 8 November 1964. *Taylor Co.*: KU 11612 (6) Big Pitman Cr., 11.8 km NW Campbellsville, 2 April 1966.

Rough River Drainage.— *Hardin Co.*: UL 11893 (19) Rough R., 25 April 1959; UL 12905 (1) trib. Rough Cr., 0.8 km S Four Corners, 22 March 1959. *Grayson Co.*: SIUC uncat. (1) Spring Fork, 1.6 km NW Tousey, 12 March 1979. *Ohio Co.*: SIUC uncat. (2) West Fork, 0.8 km N Fordsville, 11 March 1979; SIUC uncat. (2) Rocky Fork, 2.4 km SW Shreve, 12 March 1979; SIUC uncat. (1) Halls Cr., 13.3 km NE Hartford, 11 March 1979; SIUC uncat. (1) Sixes Cr., 3.2 km S Renfrow, 12 March 1979.

Lower Cumberland River Drainage.— *Trigg Co.*: SIUC uncat. (1) Donaldson Cr., 9.6 km SE Canton, 10 March 1979.

Tennessee River Drainage.— *Calloway Co.*: SIUC uncat. (1) West Fork Clarks R. at Backusburg, 27 April 1969; SIUC uncat. (4) Beechy Cr., 1.6 km SE New Concord, 23 March 1978.

Obion River Drainage.— *Graves Co.*: SIUC uncat. (138) Terrapin Cr., from Tennessee state line to 0.8 km S Bell City, 23 March 1978 - 4 June 1980.

RESULTS AND DISCUSSION

Distribution and Habitat

Lampetra aepyptera is the most common lamprey in Kentucky, occurring in all major drainages of the state except the Tradewater River and lower Ohio and Mississippi River tributaries in the extreme west (Burr 1980). The species is collected less frequently in the Kentucky River system than in other major eastern Kentucky drainages (Fig. 1). Its occurrence in direct, sandy tributaries of the Mississippi River (e.g., Obion River) in western Kentucky and Tennessee is somewhat unusual, because this area is generally inhabited by fishes characteristic of the Coastal Plain and lowlands.

Collections made in riffles and raceways of small to medium-size, sand-gravel bottom creeks during March and April often yielded adults of *L. aepyptera*. The lack of more records of this species for Kentucky is almost surely the result of few collections being made in small streams during early spring.

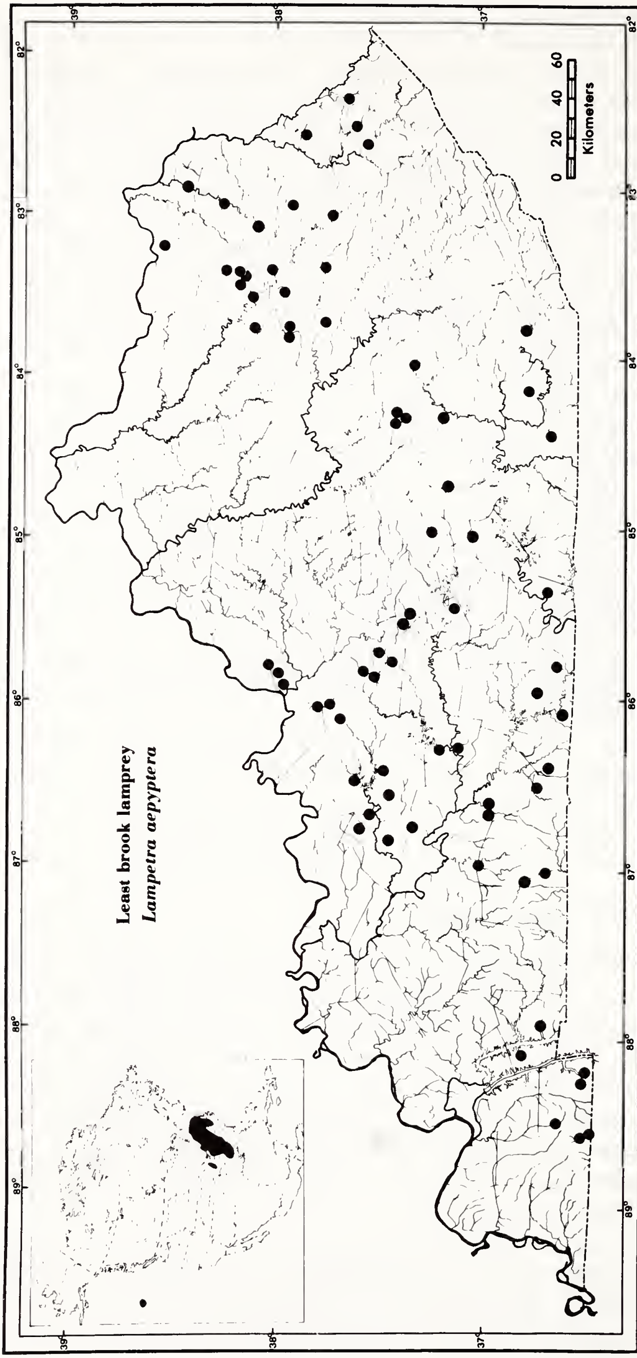

Fig. 1. Distribution of *Lampetra aepyptera* in Kentucky. Inset map represents total range of species.

TAXONOMIC STATUS OF *LETHENTERON MERIDIONALE*

Vladykov et al. (1975) described Lethenteron meridionale as a new nonparasitic lamprey from Tennessee, Alabama and Georgia. In all characters except dentition it is inseparable from *L. aepyptera,* despite the fact that the authors concluded that it was a close relative of *Lethenteron lamottenii* (now *Lampetra appendix; fide* Bailey and Rohde *in* Robins et al. 1980). As defined by Valdykov and his associates, members of the genus *Lethenteron* always possess posterior circumoral teeth and, partly because *L. meridionale* has posterior circumoral teeth, it was accordingly assigned to the genus. However, *Lampetra zanandreai,* which has been variously assigned to *Lethenteron* or *Lampetra,* occasionally lacks posterior circumorals (Zanandrea 1957; Hubbs and Potter 1971).

We found small, unicuspid posterior circumoral disc teeth in specimens of *L. aepyptera* from several drainages throughout Kentucky. The mean number of posterior circumorals in specimens having them was 7.6 (R = 1 - 22, N = 15). In most, these teeth formed an incomplete row (Fig. 2), but in two individuals there was a complete infraoral row extending between the two posterior inner laterals. In another specimen there were several small, degenerate teeth scattered throughout the posterior field of the disc. Several collections have specimens with and without posterior circumorals.

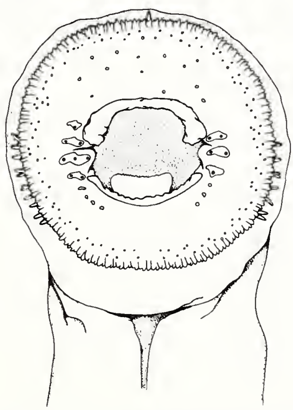

Fig. 2. Diagrammatic illustration of the oral disc of *Lampetra aepyptera*, showing incomplete row of posterior circumoral teeth. Drawn from a composite of several specimens.

We noted variation in several other disc characters used in the diagnosis of *L. meridionale.* The following counts are means based on 17 specimens of *L. aepyptera:* oral papillae 16.3 (R = 12 - 20); infraoral cusps 9.8 (R = 5 - 13); intermediate teeth in anterior field 14.3 (R = 0 - 32); inner lateral teeth 6.2 (R = 4 - 9). The counts for each of these characters as reported by Vladykov et al. overlap between *L. aepyptera* and *L.*

meridionale. Moreover, the means for number of infraoral cusps, intermediate teeth in the anterior field, and inner lateral teeth in Kentucky specimens of *L. aepyptera,* are closest to the means for these same characters in *L. meridionale* (Vladykov et al. 1975, Table 11). Further, the mean number of oral papillae and number of cusps (1 - 4) on the median inner lateral teeth of Kentucky *L. aepyptera* are similar to the means for *L. aepyptera* given by Vladykov et al. Thus, there is much variation in the dentition of *L. aepyptera.* Individual variation, populational differences, and possibly ontogenetic changes in dentition, occur. We therefore regard *Lethenteron meridionale* a synonym of *Lampetra aepyptera,* a conclusion anticipated by Rohde (1980) and formally stated by Bailey (1980). *Okkelbergia* (a monotypic genus including *aepyptera* as its only species) and *Lethenteron* were recently downgraded to subgenera of *Lampetra* (Bailey 1980), an action with which we concur.

Morphology of *Lampetra aepyptera*

The number of myomeres in *L. aepyptera* ranges from 50 to 62 (e.g., Branson 1970; Cook 1952; Raney 1941; Rohde 1976; Rohde et al. 1975, 1976; Seversmith 1953; Vladykov et al. 1975). Rohde et al. (1976) found no significant difference in the number of myomeres between ammocoetes and adults in Delaware. The number of myomeres of adults in Kentucky ranged from 52 to 62 (Fig. 3), with means between 55 and 59 in all drainages except the lower Cumberland and Tennessee rivers. The number of myomeres in 105 ammocoetes from Terrapin Creek, Graves County, ranged from 51 to 59 ($\bar{x}$ = 55.0), slightly fewer than for adults. However, the means of myomere counts are not significantly different between ammocoetes and adults. Although visually there appears to be an east to west decrease in the mean number of myomeres (Fig. 3), one way analysis of variance indicates no significant differences between the means of any of the drainages (α = 0.05). A thorough study of specimens from throughout the entire range of *L. aepyptera* is needed to determine possible significant variation in this or any other morphological character.

The most significant differences in body proportions of *L. aepyptera* involved the partially transformed (neotenic) individuals from Terrapin Creek (Obion River drainage). The secondary sexual characteristics of nuptial adults (e.g., disc length, eye diameter, second dorsal fin height, and prebranchial length; Table 1) were poorly developed in the neotenes. Because individuals in Terrapin Creek fail to fully transform, the discordant body proportion values exhibited by the population were expected. The Cumberland River population from above Cumberland Falls exhibited a relatively low proportional value for second dorsal fin height. This population is geographically isolated and the low fin value

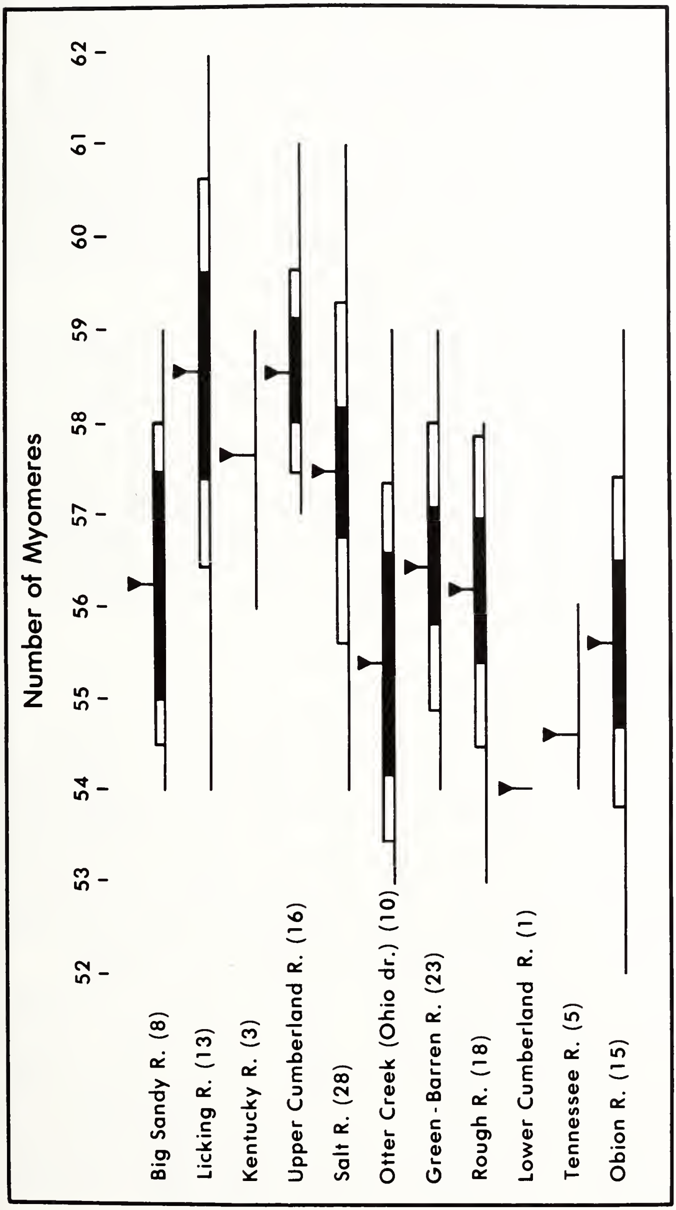

Fig. 3. Geographic variation in number of trunk myomeres in Kentucky populations of *Lampetra aepyptera*. Shown are means (vertical line with triangle), 95 percent confidence limits (black rectangle), one standard deviation on either side (outer limits of open rectangle), and ranges (basal line). Where possible the sequence of populations reflects geographic propinquity. Counts of five specimens from the upper Cumberland River were taken from Branson (1970). The number of specimens is shown in parentheses.

may result from reproductive isolation from more typical *L. aepyptera.*

Sexual differences in body proportions (Table 2) coincide reasonably well with those reported by other workers. Males have a greater disc length and second dorsal fin height than females, as noted by Rohde et al. (1976) and Vladykov et al. (1975). We confirm the observations of Vladykov et al. that males have a relatively longer tail and shorter trunk than females. Rohde et al. found that tail length increased with age in males and decreased in females. Males also have a greater prebranchial length. Kentucky specimens are substantially longer (mean TL, both sexes) than those reported by most other authors, especially in Atlantic Coast populations where a much shorter maximum and mean TL was found (Rohde et al. 1976). The mean length of the male genital papilla was 4.4 mm (R = 2.4 - 7.5, N = 57). Rohde et al. found a mean papilla length of 4.8 mm for 10 males from Delaware.

Breeding coloration in *L. aepyptera* has not been adequately described. Nest-building individuals from Peter Creek, Barren County, Kentucky, were in full nuptial color on 18 March 1980. Both sexes were mottled gray-brown on the dorsum and had light silvery-yellow venters. Black horizontal bands were present on the sides, through the eye and at the base of the first dorsal fin. Each dorsal fin had a black, speckled marginal band that was widest around the longest fin rays. A gold band extended through the base of the caudal fin and the center of each dorsal fin. The posterior margin of the caudal fin was darkly pigmented.

Aspects of Life History

Terrapin Creek is a clear, low-to-moderate-gradient tributary of Obion River. The stream consists of alternating shallow riffles and deeper pools, with a substratum of sand and gravel. In most areas the stream is 2 to 5 m wide and 0.2 to 1.0 m deep during normal water levels, and is bordered by deciduous forest throughout most of its course. Ammocoetes were generally found in mud banks along raceways and in pools with a moderate current. Transformers and neotenic individuals were generally found in debris-ridden riffles and raceways.

Between 22 February and 4 June 1980 we sampled a backwater slough of Terrapin Creek, 0.8 km south of Bell City along Hwy. 94. The slough is in a wooded area, has been inundated through beaver activity, and is fed by runoff and seepage. Thick mats of watercress and other aquatic macrophytes were abundant in the channels and pools. A pool 2.5 m wide and 1.5 m deep, with considerable mud and silt deposits, yielded large numbers of ammocoetes. Species taken with *L. aepyptera* in this beaver slough are indicated by asterisks in Table 3.

Because of the paucity of specimens for most months, only ammocoetes from the 4 June 1980 collection were used for the length-frequency analysis (Fig. 4). At least five, and possibly six, age clases are

Table 1. Mean body proportions (as percentages of TL) of *Lampetra aepyptera* from major drainages in Kentucky. Where possible the sequence of populations reflects geographic propinquity. Ranges are in parentheses.

Major drainage	TL	Disc length	Eye diameter	Second dorsal fin height	Prebranchial length	Branchial length	Trunk length	Tail length
Big Sandy R.	133.2	5.0	1.5	5.8	10.3	10.2	48.4	29.9
(N = 8)	(117-146)	(4.6-5.3)	(1.4-1.7)	(5.3-6.6)	(9.4-11.2)	(9.6-11.1)	(46.0-52.1)	(26.6-32.0)
Licking R.	130.1	5.2	1.6	5.7	10.8	11.2	49.7	27.9
(N = 13)	(110-147)	(4.7-6.2)	(1.3-1.8)	(4.9-7.0)	(8.7-12.0)	(9.9-12.3)	(43.2-55.6)	(23.4-34.5)
Upper Cumberland R.	135.2	4.7	1.5	4.4	10.2	10.5	49.9	27.3
(N = 11)	(114-152)	(4.0-5.3)	(1.4-1.9)	(3.8-6.0)	(9.7-11.3)	(9.8-11.6)	(47.5-52.3)	(25.5-29.1)
Salt R.	148.6	4.9	1.4	6.0	10.2	10.8	49.1	28.5
(N = 19)	(125-165)	(4.0-5.6)	(1.2-1.7)	(4.4-7.3)	(8.1-12.4)	(9.9-12.2)	(44.7-55.0)	(25.3-30.7)
Otter Creek (Ohio dr.)	127.4	5.3	1.6	5.9	11.5	10.4	48.5	29.3
(N = 10)	(113-156)	(4.6-6.7)	(1.4-1.9)	(5.0-7.5)	(10.3-13.0)	(8.4-12.3)	(45.3-50.7)	(27.2-32.6)
Green-Barren R.	134.6	5.4	1.6	6.1	11.4	10.6	47.6	29.2
(N = 22)	(110-163)	(4.3-6.3)	(1.3-2.0)	(5.1-7.1)	(9.7-12.5)	(9.6-11.9)	(42.9-52.7)	(26.0-35.0)
Rough R.	127.3	5.1	1.6	5.3	11.0	10.6	47.8	29.9
(N = 18)	(117-143)	(4.5-5.9)	(1.4-1.7)	(4.0-6.3)	(9.6-11.9)	(9.6-11.5)	(42.8-50.8)	(26.5-34.1)
Lower Cumberland R.	147.0	5.6	1.5	6.0	11.3	10.1	46.9	29.9
(N = 1)	---	---	---	---	---	---	---	---
Tennessee R.	122.5	5.0	1.6	5.4	11.2	10.7	48.3	28.5
(N = 5)	(115-136)	(4.1-5.8)	(1.5-1.7)	(3.8-6.2)	(10.5-12.6)	(10.1-12.2)	(46.8-50.8)	(26.4-30.9)
Obion R.	102.8	3.1	1.2	2.6	7.9	10.5	53.8	27.9
(N = 15)	(75-129)	(2.8-3.6)	(0.9-1.6)	(2.1-3.3)	(6.9-9.4)	(9.4-12.8)	(49.4-57.3)	(26.0-31.9)

Table 2. Mean body proportions (as percentages of TL) by sex of *Lampetra aepyptera* from Kentucky. Major drainages are combined. Ranges are in parentheses.

Sex	TL	Disc length	Eye diameter	Second dorsal fin height	Prebranchial length	Branchial length	Trunk length	Tail length
Males (N = 67)	134.6 (80-165)	5.4 (3.8-6.7)	1.6 (1.2-2.0)	6.0 (3.6-7.5)	11.2 (8.1-13.0)	10.7 (9.6-12.3)	47.3 (47.8-55.0)	29.7 (26.1-35.0)
Females (N = 44)	132.0 (115-158)	4.7 (4.0-5.3)	1.5 (1.3-1.9)	5.3 (3.8-6.4)	10.3 (8.7-11.9)	10.6 (8.4-12.3)	49.7 (46.0-55.6)	27.8 (23.4-31.7)

Table 3. Fishes collected with *Lampetra aepyptera* in Terrapin Creek, Kentucky, arranged in approximate descending order of relative abundance. Percentages are of total number of fishes collected between 23 March 1978 and 4 June 1980. Asterisks indicate species taken only from (*), or primarily from (**), beaver slough area.

Species	Percentage
Lampetra aepyptera	16.6
Etheostoma zonale	15.4
Etheostoma nigrum	13.6
Phenacobius mirabilis	6.7
Umbra limi **	6.3
Semotilus atromaculatus	5.0
Etheostoma (Ulocentra) sp.	3.8
Notropis camurus	3.7
Etheostoma swaini	3.3
Noturus phaeus	3.1
Etheostoma gracile **	2.9
Lepomis marginatus *	2.8
Erimyzon oblongus	2.6
Notropis umbratilis	2.5
Esox americanus **	2.0
Etheostoma parvipinne **	1.8
Lepomis cyanellus	1.2
Fundulus olivaceus	1.1
Noturus hildebrandi	1.1
Notemigonus crysoleucas	0.9
Lepomis macrochirus	0.6
Aphredoderus sayanus **	0.6
Elassoma zonatum **	0.5
Percina sciera	0.5
Gambusia affinis **	0.5
Lepomis gulosus *	0.4
Notropis fumeus	0.1
Lepomis megalotis	0.1
Ictalurus natalis	0.1
Ictalurus melas **	0.1

represented. Young-of-the-year (age class 0) individuals had a mean TL of 16 mm. Mean lengths for age classes I, II, and III were 38.6 mm, 65.0 mm, and 88.8 mm, respectively. The last curve on the frequency polygon (Fig. 4) may include two additional age classes (IV, V). As noted by other authors (Leach 1940; Hardisty 1961; Hardisty and Potter

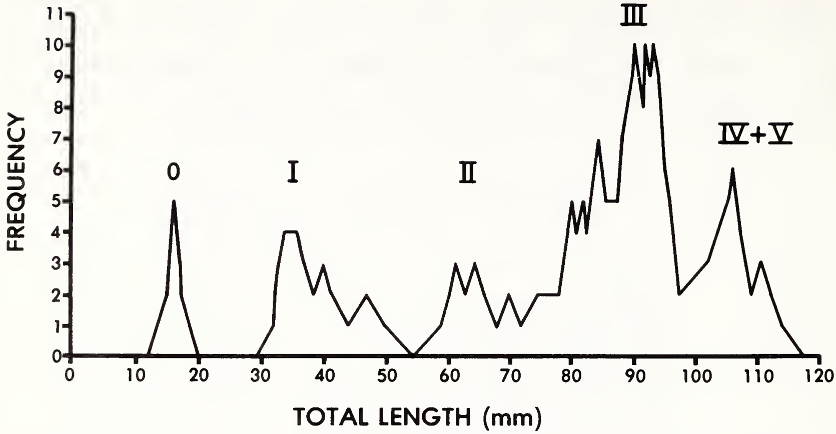

Fig. 4. Length-frequency distribution of 45 ammocoetes of *Lampetra aepyptera* from Terrapin Creek, Graves County, Kentucky, 4 June 1980. Curves were smoothed using sliding averages of 7 mm. Age classes are represented by Roman numerals.

1971; Potter and Bailey 1972; Rohde et al. 1976), difficulty arises in discerning older age classes because there may be arrested growth of larger ammocoetes, i.e., simultaneous occurrence of ammocoetes as large or larger than transforming individuals in autumn collections. Inadequate numbers of specimens from fall months prevented our testing for a period of arrested growth for the Terrapin Creek population. Transformers taken throughout the study period averaged 112 mm TL (R = 95 - 125, N = 14); neotenic individuals averaged 103 mm TL (R = 75 - 129, N = 15). The largest ammocoetes from all collections averaged 111 mm TL (R = 102 - 135, N = 22). Assuming a March spawning period, we estimate the duration of the larval stage in the Terrapin Creek population to be 4.5 years. If a period of arrested growth occurs in this population the length of the larval stage could be 5.5 years. A larval life of 3 to 5.4 years for *L. aepyptera* has been suggested by others (Hubbs 1971; Rohde et al. 1976; Seversmith 1953). Rohde et al. (1976) and Rohde and Jenkins (1980) speculated that some individuals may remain as larvae for over 6 years.

When lengths (L) and weights (W) of ammocoetes were transformed to log values and the line of best fit determined by least squares, the regression equation was Log W = 1.95 + 0.352 Log L, r = 0.99). Rohde et al. (1976) found that the weights of ammocoetes from Delaware increased as the 2.73 power of length. When we compared the linear regression for transformers and neotenic individuals combined, we found a slightly higher slope than that for ammocoetes (Log W = 1.96 + 0.248 Log L, r = 0.92).

Coefficient of condition values (K) were calculated for the Terrapin

Creek specimens from the formula $K = W X 10^5 / L^3$ (Carlander 1977). Mean K values were as follows: ammocoetes, 0.15 (R = 0.10 - 0.23, N = 107); transformers, 0.17 (R = 0.15 - 0.19, N = 14); neotenes, 0.13 (R = 0.10 - 0.17, N = 15). Rohde et al. (1976) reported substantially higher K values for *L. aepyptera* from Delaware, and found that the smallest ammocoetes had the highest K values.

Nest building and spawning behavior of *L. aepyptera* have been well documented by earlier workers (Brigham 1973; Rohde et al. 1976; Pflieger 1975; Seversmith 1953). Nesting areas typically contain large aggregations of lampreys and spawning usually involves pairs, or one female accompanied by two males. Reported water temperatures at which spawning occurs have ranged from 10 to 16^{O} C (Brigham 1973; Rohde et al. 1976; Seversmith 1953). Although spawning was not observed in Terrapin Creek, we observed nest construction by three individuals in the Barren River drainage (Peter Creek, 1.6 km SE Dry Fork, Barren Co., 18 March 1980). Our observations are similar to those of Rohde et al. (1976) and Seversmith (1953). Nest building occurred at the crest of a shallow riffle (water 15 cm deep) approximately 1.8 m from shore, over sand and loose gravel; water temperature was 12^{O} C. Of the three individuals on the nest, one left when we approached. We observed stone movement and lateral body undulations by both sexes, as described by Rohde et al. and Seversmith. The male appeared to be more active in attempting to excavate a depression. *Lampetra aepyptera* in the upper Cumberland drainage (Taylor Branch, 8.8 km E Whitley City, McCreary Co.) were found spawning with no apparent nest construction over a bedrock substratum on 16 April 1977 (W. C. Starnes, pers. comm.). As determined from preserved specimens, individuals of *L. aepyptera* in spawning condition in Kentucky have been taken as early as 22 February and as late as 1 June, with a peak of spawning activity from mid-March to early April.

Reported male to female sex ratios of adults have ranged from 1:3 (Seversmith 1953) to 2.7:1 (Rohde et al. 1976). In the largest series of adults from the Salt River drainage, Kentucky, this ratio was 2.3:1 (Knob Creek, Bullitt Co., 25-28 March 1950, N = 108).

Fecundity estimates for *L. aepyptera* have ranged from 610 to 2154 eggs produced per adult female (Rohde et al. 1976; Seversmith 1953; Valdykov et al. 1975). Rohde et al. found a positive correlation between TL of female and number of eggs produced. The number of mature ova in three Kentucky specimens (115, 142, 142 mm TL) was 1802, 2596, and 3816, respectively, and egg diameters ranged from 0.70 to 1.00 mm ($\bar{x}$ = 0.86 mm, N = 43). The number of mature ova from five neotenic females (105-119 mm TL, $\bar{x}$ = 112.4 mm) from Terrapin Creek was 572, 753, 1036, 1443, and 1541, and egg diameters ranged from 0.66 to 1.36 mm ($\bar{x}$ = 0.99 mm, N = 100). Our data for the neotenes show the trend reported by Rohde et al. (1976), that a decrease in the number of eggs produced is correlated with an increase in egg size. Increased egg size may result in a greater survival rate of fry, thereby countering the effects of reduced fecundity. Adults maturing at smaller sizes apparently divert a higher percentage of metabolic energy from growth to greater reproductive efficiency.

Only two species of lamprey, both nonparasitic, have been documented to have characteristics of neoteny — the European *Lampetra zanandreai* (Zanandrea 1957, 1961), and *Lampetra lethophaga* (Hubbs 1971) of northern California. During the spawning season, Zanandrea (1961) found 12 female ammocoetes of *L. zanandreai* that were in an advanced ("third") stage of ovarian development. The type of neoteny described by Hubbs (1971) for *L. lethophaga* involved "the maturing of apparently all individuals of both sexes in the prenuptial condition."

In Terrapin Creek, from late February through early June (the spawning season has varied greatly in the last three years, because winters have varied in severity), 7 neotenic males and 6 females were collected. They had passed through partial transformation but, although some were in full maturity (Fig. 5D shows a females turgid with ripe ova) none had developed the ordinary nuptial attributes (e.g., eye diameter, melanistic pigmentation, englargement of the two dorsal fins, development of the anal pseudo-fin, and enlargement of the disc). Three neotenic females from late February have large, ripe ova visible through the transparent body wall, a distinctive characteristic of mature females. Thus, a situation very similar to that reported by Hubbs (1971) for *L. lethophaga* seems to also have developed in the Terrapin Creek population of *L. aepyptera*. This is apparently the normal condition for the Terrapin Creek population, inasmuch as numerous collections contain no nuptial adults, which are the kind of adults normally collected during the spring throughout the remainder of Kentucky (Fig. 5A, C). Since temperatures in Terrapin Creek are similar to those of other streams that contain normal adults of *L. aepyptera*, unusual temperatures are ruled out as a factor suppressing nuptial development.

The low K values of *L. aepyptera* in Terrapin Creek, and overall low numbers of fishes in a stream that otherwise maintains a diversity of at least 30 species (Table 3), indicate that food may be scarce. The failure of this population to exhibit normal secondary sexual characters is tentatively attributed to limited food during the ammocoete stage, with a resultant lack of sufficient lipid accumulation to bring about the completion of transformation to fully nuptial adults.

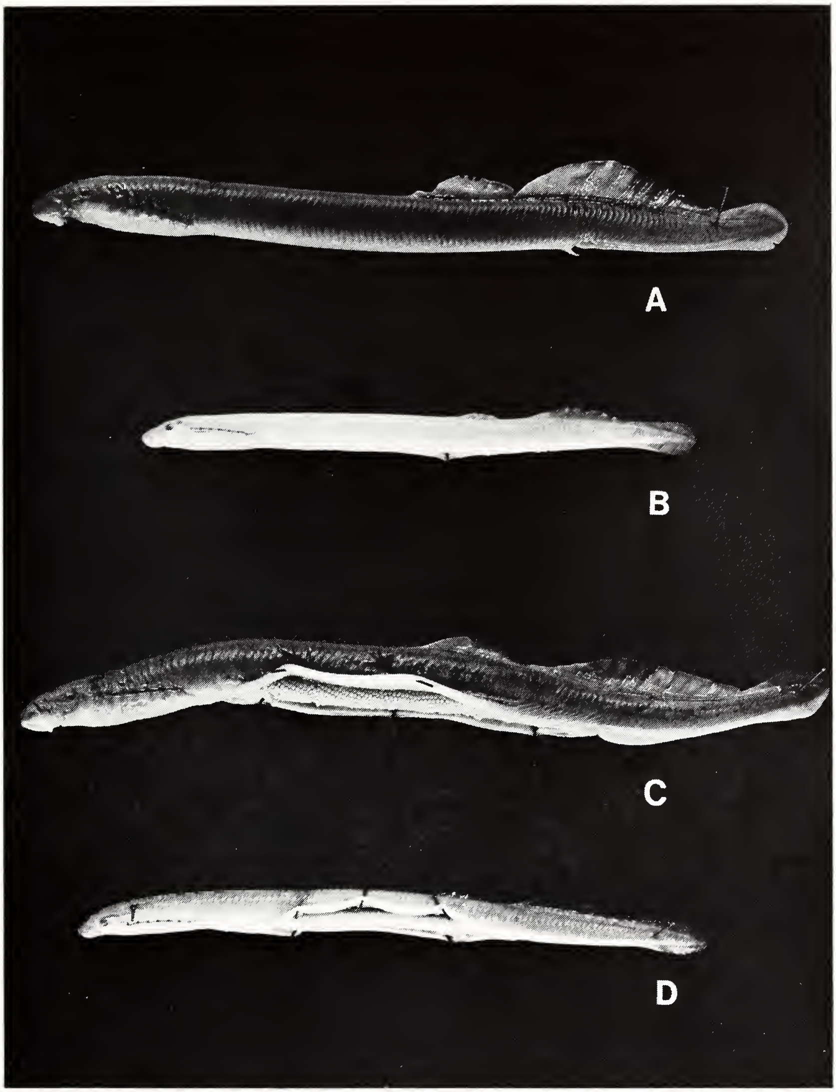

Fig. 5. Specimens of *Lampetra aepyptera* from Kentucky. A, Fully nuptial male (WCS 720-01, 136.6 mm TL) from Taylor Branch, McCreary County, 16 April 1977. B, Partially neotenic male (SIUC uncat., 101.6 mm TL) from Terrapin Creek, Graves County, 4 April 1980. C, Fully nuptial female, same data as A (147.2 mm TL), with abdominal wall pinned aside to show coelom packed with mature ova. D, Partially neotenic female, same data as B (114.8 mm TL), with abdominal wall pinned aside to show coelom packed with mature ova.

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Notes on the Distribution and Taxonomy of Short-tailed Shrews (Genus *Blarina*) in the Southeast

THOMAS W. FRENCH [1]

Department of Life Sciences,

Indiana State University, Terre Haute, Indiana 47809

ABSTRACT. — Seven hundred twenty-nine skulls of short-tailed shrews (genus *Blarina*) were examined from 152 counties in Alabama, Florida, Mississippi, North Carolina, South Carolina and Tennessee. One hundred ninety-three *B. brevicauda* and 265 *B. carolinensis* were compared by a stepwise discriminant analysis. Twenty-one central Tennessee specimens were compared to these two identified target samples. Although specimens from central Tennessee are scarce, the cranial measurements of some appear intermediate in size. Plots of the first two canonical variables show specimens from Hickman, Putnam and Warren counties, Tennessee as distinct from either *B. brevicauda* or *B. carolinensis* target clusters. A partial distribution map defining the ranges of *B. brevicauda* and *B. carolinensis* in the Southeast is presented. A possible disjunct population of *B. brevicauda* is reported from both sides of the Chattahoochee River in Alabama and Georgia.

INTRODUCTION

Short-tailed shrews of the genus *Blarina* are the most abundant and ubiquitous soricids in the Southeast. The taxonomy of this genus is currently undergoing revision, but recent publications (Genoways and Choate 1972; Ellis et al. 1978; Schmidley and Brown 1979; Tate et al. 1980) recognize a large northern form, *Blarina brevicauda*, and a small southern form, *Blarina carolinensis*, as distinct species. Another large phena, *B. telmalestes*, restricted to the vicinity of the Great Dismal Swamp of Virginia and North Carolina, is also currently recognized as distinct (Jones et al. 1979). Handley (1971) considered *B. brevicauda* and *B. carolinensis* to be entirely allopatric but contiguous, and Graham and Semken (1976) considered them to represent the parapatric coexistence of sibling species. Some early workers reported a zone of intergradation between the two phena which were then recognized as well differentiated subspecies (Merriam 1895; Cockrum 1952; Jones and Findley 1954), while others were unable to recognize intergrades (Rippy 1967; Schlitter and Bowles 1967). More recent workers have found individual areas of sympatry between *B. brevicauda* and *B. carolinensis*, both in Recent (Genoways and Choate 1972; Ellis et al. 1978; Tate et al. 1980) and Pleistocene material (Graham and Semken 1976), with only isolated cases of possible hybrids (Genoways and Choate 1972; Tate et al. 1980).

[1]Current address: Cooperative Wildlife Research Unit, Department of Natural Resources, Cornell University, Ithaca, New York 14853

Although these shrews are quite common, their exact ranges and thus the location of possible zones of sympatry are still not well known. The purpose of this paper is to more accurately define their ranges in the Southeast, to point out the intermediate nature of some Tennessee specimens, and to report a possible disjunct population of *B. brevicauda* in the upper Coastal Plain of Alabama and Georgia.

MATERIALS AND METHODS

Seven hundred twenty-nine *Blarina* skulls from 152 counties in Alabama, Florida, Mississippi, North Carolina, South Carolina, and Tennessee were examined. Five cranial measurements (condylobasal length, cranial breadth, interorbital breadth, maxillary breadth and maxillary toothrow length) were made to the neareest 0.1 mm with a vernier caliper following Jackson (1928). Specimens were measured regardless of sex or age, but included no nestlings.

Although age dimorphism has been documented by some (Guilday 1957; Choate 1972) and not by others (Ellis et al. 1978) *Blarina* is considered to be essentially adult size by the time it enters the trappable population (Guilday 1957; Dapson 1968; Ellis et al. 1978). The most noticeable differences between juvenile and adult *Blarina* are an increase in weight, total body length, and tooth wear, and a decrease in cranial height, with age. None of these characters was used to differentiate *B. brevicauda* and *B. carolinensis* in this study. Sexual dimorphism in *Blarina* has been recognized as slight by most workers, with males averaging slightly larger than females in some characters (Guilday 1957; Dapson 1968; Choate 1972; Ellis et al. 1978; Kirkland 1978). Others have reported no detectable sexual dimorphism (Graham and Semken 1976; Schmidley and Brown 1979). Neither age nor secondary sexual dimorphism of cranial characters appear to be significant when differentiating specimens of *B. brevicauda* and *B. carolinensis* in the trappable population. This presumption is supported by the near lack of overlap in cranial measurements between these two taxa reported by recent authors.

Body measurements were not used because standard body measurements were found to be variable, even within local populations, and especially because of obvious discrepancies in measuring techniques between various collectors. Guilday (1957) and Jones and Glass (1960) stressed that external measurements of *Blarina* (unless made by the same worker) should be used with caution in geographic studies. They also stressed that cranial measurements are much more constant and can be more accurately measured than body measurements. Sample body measurements of 50 *B. brevicauda* from Alabama and South Carolina are: total length 114.6 (101-125), tail length 25.2 (21.0-29.5), and hindfoot length 14.1 (12.5-15.5). Sample body measurements of 50 *B. carolinensis* from these same two states are: total length 92.2 (85-

104), tail length 19.7 (14-27), and hind foot length 11.2 (10.0-12.5).

Although specimens from central Tennessee are scarce, preliminary analysis of cranial measurements indicated that specimens from this area might be intermediate in size. A stepwise discriminant analysis was conducted on 265 *B. carolinensis* and 193 *B. brevicauda* with complete measurement data. The five previously described cranial measurements were used in this analysis and the specimens represent localities throughout the Southeast. Twenty-one central Tennessee specimens were then compared to these target samples. Seven of the central Tennessee specimens lacked condylobasal length and maxillary breadth measurements and two others lacked only maxillary breadth measurements due to breakage. Missing data were estimated for the nine specimens using the REGR option in the PAM subroutine of the Biomedical Computer Programs (Brown and Dixon 1979). In order to obtain a visual representation, the first two canonical variables were computed and plotted as described by Rao (1952) and used by Lawrence and Bossert (1967, 1969), Gipson et al. (1974), Kirkland and Van Deusen (1979), Parkinson (1979), Diersing (1980), and others. The Biomedical program PAM was used for these calculations.

RESULTS

The number of specimens examined from any one county varied from one to seventy-five. Small ranges in cranial measurements from large series suggest that small samples, other than from near the zone of contact, can usually be considered representative of the local population. Only slight overlap was found between the cranial measurements of all *B. brevicauda* and *B. carolinensis* (Table 1). Cranial measurements (mm) of two very recently weaned *B. brevicauda* from Alabama were condylobasal length 21.0 (broken); cranial breadth 11.2, 11.9; interorbital breadth 5.5, 5.8; and maxillary toothrow length 8.6, 8.9, maxillary breadth 7.6, 7.9.The lower range of each of these measurements is as great as or greater than the upper range of the same measurements from a mixed age sample of *B. carolinensis* from the Southeast (Table 1).

Perimeters of the extreme ranges of canonical variables for *B. brevicauda* and *B. carolinensis* are shown in Figure 1 to be nonoverlapping. Individual specimens from central Tennessee are identified in this figure by the first letter or letters of the county in which they were collected (Anderson, Davidson, Franklin, Hickman, Marion, Putnam, Warren and Wayne).

The most striking pattern is the clustering of the Hickman, Putnam and Warren county specimens well outside the range of both *B. brevicauda* and *B. carolinensis* canonical clusters. The Marion County specimen appears properly identified as a *B. carolinensis*, although it is located on the edge of this distribution. Seven Anderson and one Frank-

Table 1. Cranial measurements of *Blarina* from the southeastern United States. The first line for each measurement includes the mean and the number of specimens examined (in parentheses). The second line is the range and the third line is the standard deviation.

	Condylobasal length	Cranial breadth	Maxillary toothrow length	Interorbital breadth	Maxillary breadth
Blarina carolinensis	18.72 (273)	10.25 (251)	7.15 (375)	5.08 (360)	6.61 (371)
	17.4-20.1	9.4-10.9	6.6-7.7	4.6-5.5	6.0-7.1
	0.43	0.28	0.21	0.16	0.20
Blarina sp.	20.17 (3)	11.60 (3)	7.43 (6)	5.27 (6)	8.07 (6)
(Hickman, Putnam & Warren	20.0-20.3	11.4-11.9	7.2-7.7	5.1-5.5	7.8-8.4
cos., TN)	0.15	0.27	0.20	0.16	0.22
Blarina sp.	20.88 (11)	11.69 (9)	8.03 (14)	5.42 (14)	7.34 (14)
(Anderson, Davidson, Frank-	20.0-21.7	11.2-12.3	7.7-8.3	5.1-5.9	6.8-7.9
lin, Lincoln & Wayne cos.,	0.57	0.39	0.21	0.23	0.33
TN)					
Blarina brevicauda	21.88 (229)	12.03 (201)	8.55 (283)	5.61 (288)	7.67 (290)
	20.2-23.1	11.1-13.0	7.8-9.4	4.9-6.3	6.8-8.7
	0.57	0.35	0.28	0.25	0.26

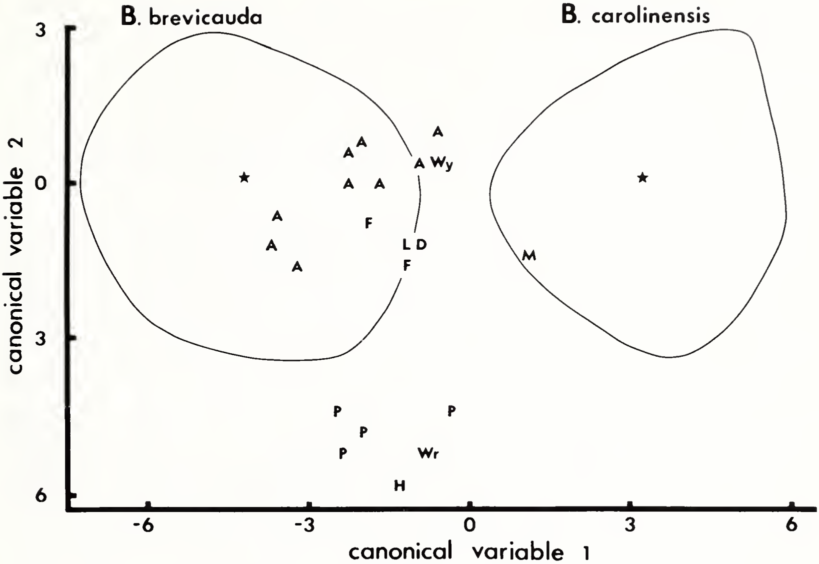

Fig. 1. Relationships of 479 *Blarina* from the Southeast as plotted by discriminant analysis (BMD P7M). Stars represent group means for *B. brevicauda* and *B. carolinensis*. Letters represent individual specimens from central Tennessee and are the first letter or letters of the counties in which the shrews were collected (Anderson, Davidson, Franklin, Hickman, Marion, Putnam, Warren and Wayne).

lin County specimens fall within the *B. brevicauda* cluster, but the remaining specimens are located outside the limits of this cluster and intermediate to the two *Blarina* species.

Blarina from Anderson, Davidson, Franklin, Lincoln and Wayne counties are probably best referred to as *B. brevicauda* and the Marion County specimen as *B. carolinensis*. The possibility of hybridization or intergradation between the two forms of *Blarina*, however, should not be ruled out.

Most Tennessee *B. brevicauda* are found in the mountainous parts of the state on the eastern and northern borders. Wayne County is located on the Highland Rim and is not particularly high in elevation, but the shrews from Franklin and Lincoln counties were collected on the Cumberland Plateau at about 2000 feet (610 m) elevation. These large shrews might represent a relict population of *B. brevicauda*, but it seems more likely that they are joined to other *B. brevicauda* populations along the length of the Cumberland Plateau. If this is true, large specimens of *Blarina* should be looked for at higher elevations in counties such as Bledsoe, Cumberland, Grundy and Sequatchie.

Many authors (Lawrence and Bossert 1967, 1969; Gipson et al. 1974; Kirkland and Van Deusen 1979; Parkinson 1979; and others) have attributed the magnitude of difference between the Hickman, Putnam, and Warren counties canonical cluster and either *B. brevicauda* or *B. carolinensis* target clusters as representative of distinct species or species hybrids. Although these results suggest that *Blarina* in central Tennessee might be distinct from both *B. brevicauda* and *B. carolinensis*, their correct identity will remain uncertain until more comparative material is available.

I produced (Fig. 2) a partial distribution map of *Blarina* using the five cranial characters as species criteria. The most notable difference between this and other distribution maps (Hall and Kelson 1959; Handley 1971; Graham and Semken 1976; Tate et al. 1980; and others) is the south and westward extension of *B. brevicauda* (synonym = *B. brevicauda churchi*) approximately 195 miles (314 km) from the mountains of Georgia into the Piedmont of Alabama. Also indicated is a possible disjunct population of *B. brevicauda* on both sides of the Chattahoochee River, Barbour County, Alabama, and in Quitman and Stewart counties, Georgia. In Alabama the largest form was overlooked by Howell (1921) because none of his specimens of *Blarina* came from the Piedmont.

Much of the southeastern distribution of these shrews approximates well established physiographic boundaries (see Fenneman 1938 and Hunt 1964 for descriptions of physiographic provinces). In North Carolina the boundary between the two species roughly follows the eastern edge of the mountains, but in South Carolina it extends southward through the Piedmont and meets the Savannah River near the center of this physiographic province. In Georgia and Alabama the boundary closely follows the Fall Line, and in Alabama it swings northeastward along the south edge of the Great Valley (between the Piedmont and Ridge and Valley physiographic provinces). In Tennessee it follows the western edge of the Smoky Mountains and appears to swing around the southern edge of the Cumberland Mountains and south of the Cumberland River. Although habitat features are often considerably different in adjacent physiographic provinces, I know of no reason why these features should limit the distribution of either form of *Blarina*.

Blarina brevicauda was discovered at three localities south of the Fall Line in Georgia and Alabama. There are few specimens (10), but the three localities appear to represent a disjunct population separated from the Piedmont populations by only about 25 air miles (40 km). The only other known disjunct populations of large Coastal Plain *Blarina* are *B. brevicauda shermani* on the Gulf coast of Florida and *B. telmalestes* in the Great Dismal Swamp of Virginia and adjacent North Carolina. Two large specimens (U.S. National Museum #268977 and North Carolina State Museum #2575) were also examined from the Coastal Plain of North Carolina (Sampson and Columbus counties). These are the only individuals examined from each of these two counties. The

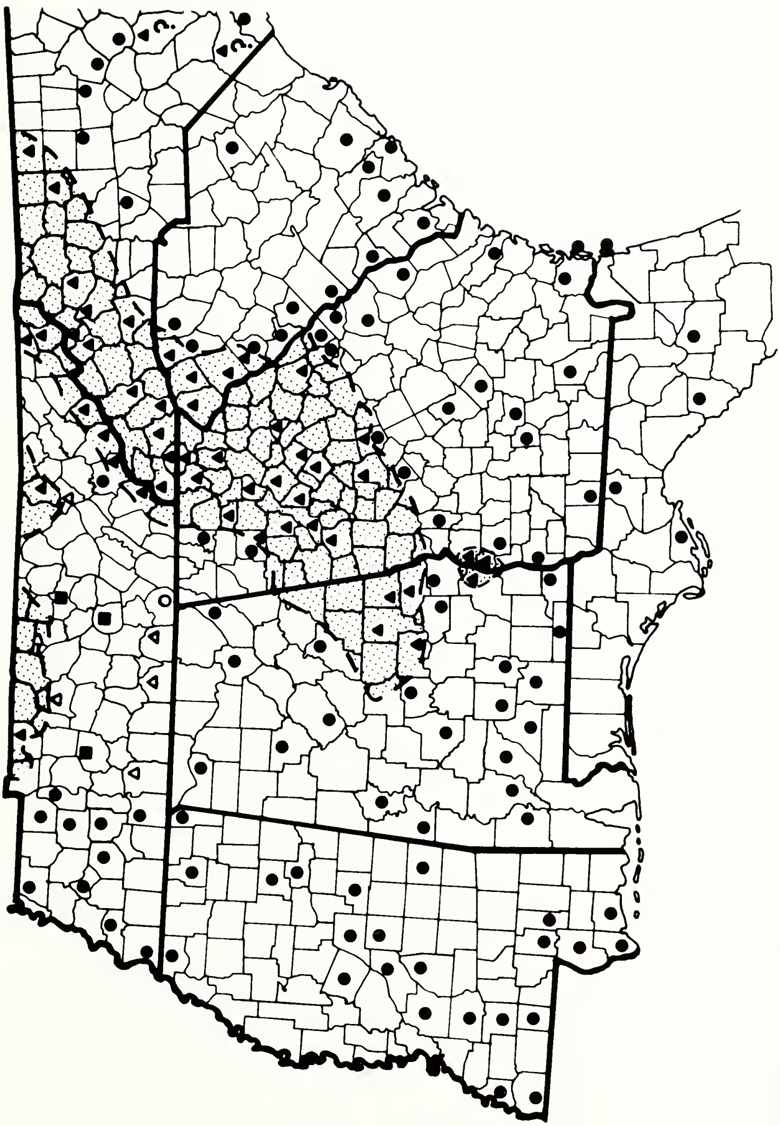

Fig. 2. Partial distribution of *Blarina* in the Southeast. Triangles represent *B. brevicauda*, circles *B. carolinensis*, and squares intermediate *Blarina* in central Tennessee. Open triangles represent central Tennessee *Blarina* that appear referable to *B. brevicauda* used in the multivariate analysis. The open circle represents the Marion County, TN specimen referable to *B. carolinensis* used in the analysis.

specimens were collected at least 110 miles (177 km) east of *B. brevicauda* populations of the North Carolina Piedmont and 125 miles (201 km) southwest of the nearest known *B. telmalestes* populations. Additional work is needed in the North Carolina Coastal Plain.

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Observations of a Small Population of Estuarine-Inhabiting Alligators Near Southport, North Carolina

WILLIAM S. BIRKHEAD

Division of Science and Mathematics, Columbus College, Columbus, Georgia 31993

AND

CHARLES R. BENNETT

National Marine Fisheries Service, Environmental Assessment Branch, Portland, Oregon 97208

ABSTRACT.— Field observations of the American Alligator, *Alligator mississippiensis,* were made incidental to a five-year study of the nursery use of Dutchman Creek estuary near Southport, North Carolina, by estuarine dependent fishes and shell fishes. Alligators were most frequently seen between April and July and occurred over a wide range of salinities. Some individuals that inhabited the lower reaches of the estuary appeared to have shifted their distribution in response to a major alteration of this habitat. After the headwaters and principal tributaries of Dutchman Creek were bisected by the discharge canal of a nuclear power plant, alligators appeared to move out of the creek and into the lower reaches of its severed tributaries adjacent to a drainage canal that received their diverted flow.

INTRODUCTION

Numerous sightings of alligators were made incidental to a five-year study of Dutchman Creek estuary, a tidal creek and salt marsh habitat located approximately 2 km west of Southport, Brunswick County, North Carolina (Birkhead et al. 1977). Since the alligator is an endangered species, and so little is known about the biology of northern populations, we felt that these observations were of interest. The fact that the habitat involved underwent a pronounced change after our study began made the situation even more interesting.

In its unaltered state, most of the freshwater flow into Dutchman Creek came from its headwaters and from three principal tributaries to the north and west. Tidal water flushed in and out twice a day by entering the creek from the Intracoastal Waterway, which bisected its lower reaches. Thus, a typical estuarine condition was established, with a salinity gradient ranging from an average of approximately 2 ppt in the upper reaches to an average of 20 ppt near its mouth (Birkhead et al. 1977). Marshes adjacent to the lower reaches of the creek and tributaries are flooded regularly with the tides. *Spartina alterniflora* is the dominant vegetation in these areas. As ground elevation increases slightly in the upper reaches of the estuary, the regularly flooded marsh grades into irregularly flooded marsh dominated by *Juncus roemerianus* (Seneca et al. 1976).

Carolina Power and Light Company began constructing a nuclear-fueled, steam electric generating plant just north of Southport approximately two years before our study began. This facility was designed to employ a once-through cooling system. The discharge canal for the cooling system was constructed during the summer and fall of 1972, along the northwestern and western edge of the salt marsh bordering Dutchman Creek. This was between 9 and 16 months after our study began. Freshwater runoff from the upper reaches of the bisected tributaries and headwaters of Dutchman Creek was diverted into a drainage canal dredged adjacent to the discharge canal (Fig. 1). The drainage canal emptied into the Intracoastal Waterway approximately 1.5 km west of the mouth of Dutchman Creek. Although the hydrographic regime of the lower reaches of the Dutchman Creek estuary was not appreciably affected by the diversion of the freshwater input, salinity increases of between 13 and 15 ppt were recorded in the upper reaches of the estuary below the canal right-of-way and at the mouths of the severed headwaters and tributaries above these canals (Birkhead et al. 1977).

The primary purpose of this paper is to denote the distribution of alligators within the Dutchman Creek estuary before, during, and after its alteration.

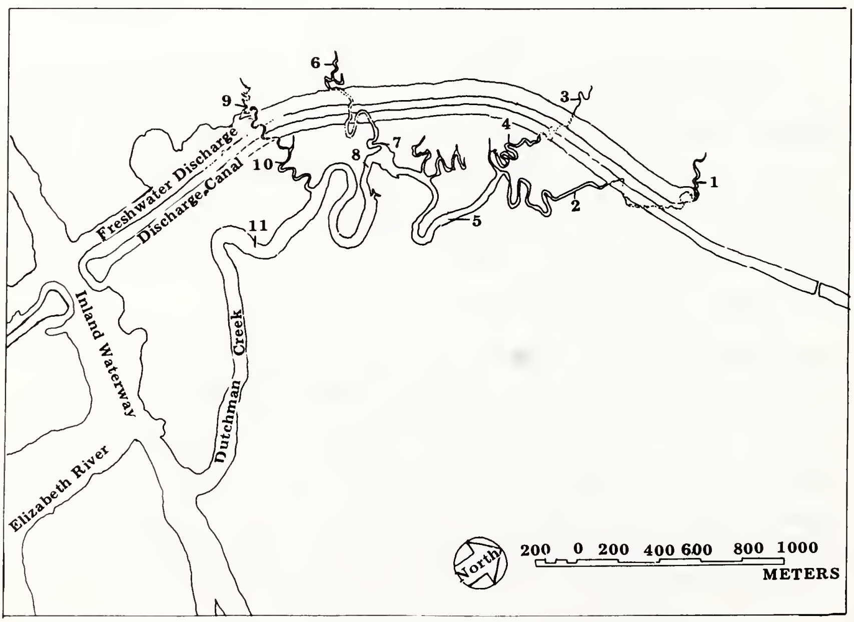

Fig. 1. Map of Dutchman Creek estuary with sampling stations.

RESULTS AND DISCUSSION

Although alligators were observed during every month of the year, the majority of sightings (76%) occurred between April and July (Table 1). The few fall and winter sightings were probably of a single alligator that inhabited the upper reaches of Dutchman Creek below the canal rights-of-way in the vicinity of station 2.

Prior to the diversion of the headwaters and principal tributaries of Dutchman Creek (sampling year 1971-72), all alligators sighted were downstream from what were then the proposed canal rights-of-way (Table 2). After the freshwater input was diverted (sampling years 1972-76), alligators virtually disappeared from the lower reaches of Dutchman Creek itself, and the majority of sightings were made in or along the northwestern and western side of the freshwater drainage canal, particularly in the vicinity of the severed headwaters and tributaries. Despite these spatial shifts, alligators appeared to be randomly distributed within the salinity regimes that were present in the estuary before and after alterations were made (Table 3).

Alligator sightings were bimodal with respect to water temperature (Table 3). Although most alligators (67%) were sighted when water temperatures were between 22°C and 30°C, several (26%) were seen when water temperatures were in the teens. The latter observations frequently involved animals that were basking during the spring, a season when air temperatures were undoubtedly higher than water temperatures.

Most of the alligators whose size could be estimated (Table 4) appeared to be between 1 and 2 m total length. The smallest individual seen was about 0.6 m long, while the largest appeared to be in excess of 2.4 m.

Since alligators observed during the course of this study were not marked, long term movements of individual animals could not be ascertained. Nevertheless, our sightings provide evidence for spatial shifts in the population inhabiting the Dutchman Creek estuary following blockage and diversion of its headwaters and principal tributaries. We suggest these reptiles may have moved because they required access to fresh water.

It is well known that tidal creeks and their associated salt marshes are highly productive habitats that serve as nursery areas for large numbers of fishes and shellfishes (Weinstein 1979). However, Chabreck (1971) and Joanen et al. (1971) noted that immature and hatchling alligators that remained under saline conditions for extended periods of time experienced significant weight losses despite the fact that food was, or appeared to be, readily available. Both authors attributed weight loss to reduced food intake. It is entirely possible that estuarine-inhabiting alligators can only make use of this productivity by either allocating their feeding activities to periods of low tide or by hunting in the brackish parts of the estuary where salinities are low and concentrations of

Table 1. Number of monthly alligator sightings made in the Dutchman Creek estuary from September 1971 through August 1976.

Year	S	O	N	D	J	F	M	A	M	Ju	Jy	A	Totals
1971-72							3	3	2	2	5		15
1972-73							1	7	1	4	2		15
1973-74	1	1		2	2			4	3	3	2	2	20
1974-75	1		1					10	1	3	3	2	21
1975-76	1		1			1	2	2	2	4	3		16
Totals	3	1	2	2	2	1	6	26	9	16	15	4	87

Table 2. Number of alligators sighted per trip in the Dutchman Creek estuary from September 1971 through August 1976. S = number of sightings, T = number of trips, S/T = sightings per trip.

	Tributaries above canal rights-of-way, or freshwater drainage canal (Stations 1,3,6,9)			Tributaries below canal rights-of-way (Stations 2,4,7,10)			Dutchman Creek (Stations 5,8,11)		
	S	T	S/T	S	T	S/T	S	T	S/T
1971-72	0	16	0.00	6	16	0.38	9	30	0.30
1972-73	7	25	0.28	5	36	0.14	3	44	0.07
1973-74	12	27	0.44	6	26	0.23	2	36	0.06
1974-75	16	27	0.59	3	33	0.09	1	39	0.02
1975-76	12	18	0.67	3	16	0.19	1	22	0.04

Table 3. Number of alligator sightings made at various salinities and temperatures in the Dutchman Creek estuary from September 1971 through August 1976.

Salinity (ppt)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	30	32	Totals
1971-72	1		1		2		2	2	2	1		1	1					1			1													15
1972-73						1	4		1				2		1		1	1	2		1													14
1973-74	2		1							1			1	1	2	1		2	2					1		1		1	2	1	1			20
1974-75					1		2	1		4	1		1	1			3			2	1		1		1			1	1					21
1975-76	2		2	1		1			1								1		1			2	4			1								16
Totals	5		4	1	3	2	8	3	4	5	2	1	4	2	2	2	6	4	5	2	3	2	5	1	1	2		2	3	1	1			86

Temperature (°C)

	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Totals
Totals	1		2	2	3	3	3	9	1	1	1	7	5	10	8	2	7	8	8	3		2	86

Table 4. Estimated lengths of alligators sighted in Dutchman Creek estuary from September 1971 through August 1976.

	Length				
	<1 m	1-2 m	>2 m	Undetermined	Totals
1971-72		7		8	15
1972-73		10	2	3	15
1973-74	1	17		2	20
1974-75	2	13		6	21
1975-76		7	3	6	16
Totals	3	54	5	25	87

fish and shellfish are relatively high. In keeping with this hypothesis, the alligators that we observed in the lower reaches of the Dutchman Creek estuary in the first year of study (1971-72) may have been only temporary inhabitants whose presence was due to a plentiful food supply.

Another reason for the distributional shift may be related to nesting requirements. Joanen (1969) found that most alligators on the Rockefeller Refuge in coastal Louisiana nested in natural marsh consisting primarily of wiregrass, *Spartina patens.* Salinities in these marshes averaged 3.8 ppt. No nests were transected in the more saline marsh type (Joanen et al. 1971). When questioned as to where estuarine-inhabiting alligators in the vicinity of Southport nested, long-time residents invariably stated that nesting occurred along the upper reaches of estuarine tributaries in a narrow zone characterized by freshwater marsh vegetation. Because this type of habitat was not sampled in our study in the Dutchman Creek estuary, such statements could not be verified for North Carolina. This kind of marsh, although limited in extent, would seem to be a more favorable nesting habitat than the salt marsh proper, where the danger of inundation during storm tides would undoubtedly be greater. In support of this belief is the observation that nearly all juvenile (< 1 m) alligators seen in the vicinity of Southport were in freshwater habitats. At one locality in particular, one of us (WSB) repeatedly saw several alligators as small as 0.5 m long in a shallow freshwater impoundment created by diking off approximately 10 ha of saltmarsh adjacent to a tidal creek about 6 km north-northeast of Southport.

The number of alligators sighted in the Dutchman Creek estuary during the 5-year study remained relatively constant from year to year despite a major alteration in their habitat. However, continued survival of individuals now inhabiting the freshwater drainage canal could be jeopardized because this canal has made their habitat more accessible to humans.

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A Key to the Tadpoles of North Carolina

JOSEPH TRAVIS[1]

Department of Zoology,
Duke University, Durham, North Carolina 27706

ABSTRACT.— A dichotomous key for identifying the tadpoles of North Carolina and a guide for their field identification with a hand lens are offered. Problems in identifying tadpoles are discussed. The key should be useful throughout the southeastern United States, because it treats most of the species present in this area.

INTRODUCTION

Although anuran larvae are excellent subjects for various types of field and laboratory research, the difficulty of correctly identifying tadpoles is well known. Early keys were either difficult to use (e.g., Wright and Wright 1949) or restricted in taxonomic (e.g., Orton 1952) or geographic (e.g., Smith 1934) coverage. Altig (1970) provided a key to all of the tadpoles found in the continental United States and Canada, and proposed a standard terminology for use in identifying tadpoles. Later references to Altig will be to this 1970 paper. A complete key to variable animals such as anuran larvae can prove difficult to use. Geographic variation can produce ambiguities in identification, and characters that may be diagnostical at a local level may prove impossible to integrate into a more thorough treatment.

North Carolina, with 30 species of anurans (Martof et al. 1980), provides an excellent situation for the development of a more restricted key. The extensive phenotypic variability seen in some species, such as *Hyla crucifer* and *Rana clamitans*, often precludes the effective use of Altig's key in the state. A North Carolina key should also be useful in the southeastern United States, because it includes most of the species found in this area.

My local key was constructed from Altig's and others in the literature, specimens collected by me and others during my four years in North Carolina, and laboratory rearings of unidentified tadpoles. Some key characters used by other workers subsequently proved unreliable and have been deleted. I examined many specimens of 27 of the 30 North Carolina species, including living individuals. *Pseudacris brimleyi, P. brachyphona*, and *Rana heckscheri* were not personally examined. *Hyla versicolor* was obtained from Giles County, Virginia, and specific identity was verified by karyotype analysis. The occurrence of *H. versicolor* in North Carolina remains problematic (Martof et al. 1980).

[1] Present address: Department of Biological Science, Florida State University, Tallahassee, Florida 32306

USE OF THE KEY

This contribution should prove useful for live or preserved animals in development stages 25 through 40 (Gosner 1960). The key is not arranged phylogenetically. General arrangement and terminology follow Altig's.

Altig discussed some of the major sources of difficulty in tadpole identification, beginning with the problem of poor preservation. Coloration, useful in identifying live material, will fade in preserved specimens. Labial teeth can fall out, and keratinized skin layers can be dislodged from their underlying structures.

Larval anurans are highly susceptible to environmental influences on morphology. For example, food type can affect mouthpart morphology, causing some distortions of the normal appearance, as is evident in a comparison of laboratory-reared and field-collected tadpoles. Ambient temperatures will affect development rates, and may influence allometric growth patterns (see below). The tails of many tadpoles are damaged by predators, particularly nymphal dragonflies (Caldwell et al. 1980). This may affect comparisons based on length ratios, either because of the tail's abbreviated length or because of a change in its overall shape as regeneration occurs. In addition, a regenerated tail often has a blackened tip or large blotches or large blotches on the fin, marks that may not be part of the normal pattern. Color of a live animal can vary with background. *Rana clamitans* larvae developing in a pond that contains a high level of gray clay in suspension (as in some ponds in the Sandhills region) will be very pale, while larvae in other situations may range from green to dark brown.

Many characters vary ontogenetically. The most obvious of these is color. The clear belly of young *Rana clamitans* larvae will become an opaque, cream color as the animals develop. The number of rows of labial teeth and the length of the rows change with tadpole age and size. The most subtle ontogenetic variations are the allometric shape changes exhibited by some species. The notable flagellum of a *Hyla femoralis* tadpole is not present in a young larva, but becomes increasingly well developed as the tadpole grows. Many species with broad fins, like *Hyla gratiosa* and *H. chrysoscelis,* have more streamlined profiles as small larvae. All these sources of phenotypic variation should be kept in mind when using any key to tadpoles.

KEY TO THE TADPOLES OF NORTH CAROLINA

1. Jaws without keratinized sheaths; oral disc and labial teeth absent (Microhylidae) .... *Gastrophryne carolinensis*
   Jaws with keratinized sheaths; oral disc and labial teeth present (Fig. 2).. 2
2. Anus medial (Fig. 4A).. 3
   Anus dextral (Fig. 4B).. 4
3. Oral disc emarginate (Fig. 2); tooth row formula 1-2/3; spiracle distinctly on left side of body (Fig. 3A) (Bufonidae) 5
   Oral disc not emarginate (Fig. 2); tooth row formula 2/4 or more; spiracle ventrolateral (Pelobatidae) .... *Scaphiopus holbrooki*
4. Oral disc emarginate (Ranidae) 33
   Oral disc not emarginate (Hylidae) 8
5. P-2 (see Fig. 2) with distinct median gap; P-3 less than 0.50 P-1; papillary border extends to lateral tips of P-2; light color in life.. *Bufo quercicus*
   P-1 with no median gap; P-3 greater than 0.50 P-1; papillary border extends *distinctly* around P-2; dark color in life 6
6. Substantial submarginal papillae (Fig. 2), particularly around emarginate areas of oral disc; dorsal tail fin height equal to musculature height (Fig. 1); dorsal fin may be higher than ventral fin .... *Bufo terrestris*
   Few if any submarginal papillae; dorsal tail fin height lower than musculature height; fins subequal in height 7
7. Dorsum unicolored; snout sloping in lateral view; tail musculature distinctly bicolored; tail fin height/musculature height 2.0 or less .... *Bufo americanus*
   Dorsum often slightly mottled in life; snout rounded in lateral view; tail musculature often not distinctly bicolored; tail fin height/musculature height greater than 2.0 .... *Bufo woodhousei fowleri*
8. Two rows of posterior labial teeth (Fig. 2)................................ 9
   Three or more rows of posterial labial teeth 13
9. A-2 gap (Fig. 2) wide; spiracular tube at least partly free from body wall; body slightly depressed; tail tip often solid black *(Acris)*..................... 10
   A-2 gap narrow to moderate; spiracular tube fully attached to body wall; body globular; tail tip, if black, with mottle or blotched black edges............ 11
10. Free section of spiracular tube long, almost entire length of tube; throat dark; tail musculature finely flecked; Coastal Plain .... *Acris gryllus*
    Free section of spiracular tube short, less than or equal to half the length of tube; throat light; tail musculature mottled or reticulated; Piedmont and mountain valleys .... *Acris crepitans*
11. Tail musculature distinctly striped in lateral view; light stripe extends from dorsal tail musculature stripe to eye; throat and chest may be mottled; dorsum of tail musculature often banded or with saddles.................................. *Limnaoedus ocularis* (part)
    Tail musculature not or only faintly striped, but without extension to eye; throat and chest light; dorsum of tail musculature not banded............ 12

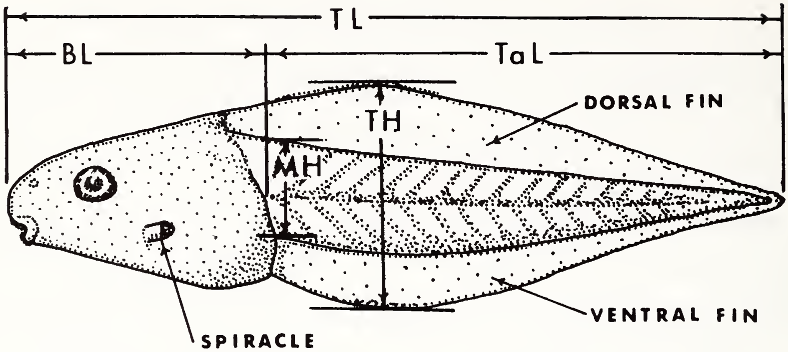

Fig. 1. Left lateral aspect of a tadpole. TL = total length; BL = body length; TaL = tail length; MH = musculature height; TH = tail height. Redrafted from Altig (1970).

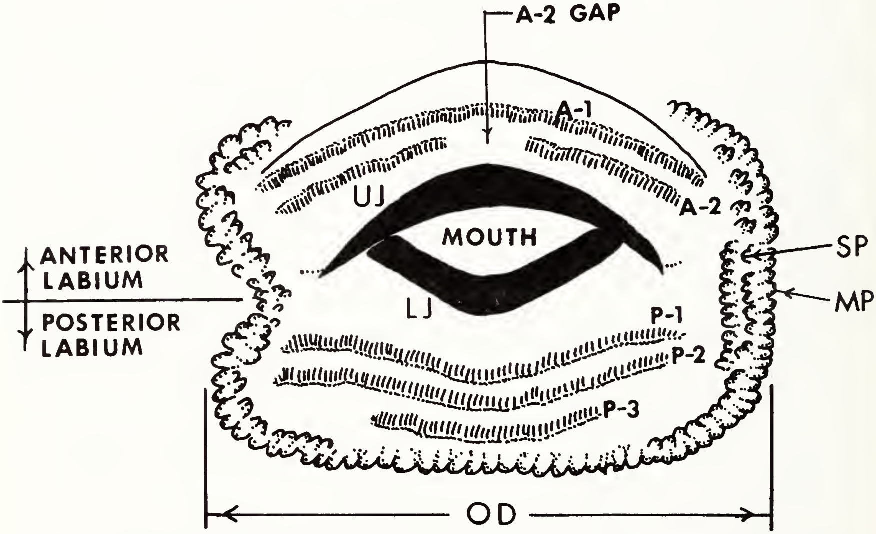

Fig. 2. Tadpole mouth parts, schematic. UJ = upper jaw (mandible); LJ = lower jaw (mandible); A-1,2 = first and second anterior tooth rows; P-1,2,3 = first, second and third posterior tooth rows; SP = submarginal papilla; MP = marginal papilla; OD = oral disc (shown emarginate on viewer's left, marginate on right). Redrafted from Altig (1970).

12. Tail musculature unicolored or bicolored; fins clear or with stellate melanophores; small black dots often present on body; A-2 subequal to A-1; one row of marginal papillae (see Fig. 2); snout round when viewed dorsally . . . . *Pseudacris triseriata* (part)
Tail musculature mottled; fins clear or with large blotches; no dots on body; A-2 longer than A-1; two rows of marginal papillae; snout square when viewed dorsally . . . . *Hyla crucifer* (part)

13. Posterior gap in papillary border 14
No posterior gap in papillary border 16
14. Tail musculature distinctly striped and stripe may extend forward to eye; snout rounded or pointed in dorsal view 15
Tail musculature mottled or indistinctly striped, but in no case does a light stripe extend forward to eye; snout square in dorsal view .... *Hyla crucifer* (part)
15. Tail musculature stripe extends to eye; snout round when viewed dorsally; posterior gap in papillary border greater than or equal to length of P-3; interocular distance wide, only slightly less than maximal head width .... *Limnaoedus ocularis* (part)
No extension of tail musculature stripe to eye; snout tapered or slightly pointed in dorsal view; posterior gap in papillary border less than length of P-3; interocular distance narrow, substantially less than maximal head width .... *Hyla andersoni* (part)
16. P-3 length 0.50 or more times length of P-2; P-3 longer than upper jaw 17
P-3 length very short, less than 0.50 times length of P-2; P-3 subequal to upper jaw 20
17. Submarginal papillae absent or few; dorsum of tail musculature usually with one black saddle slightly anterior to midlength .... *Hyla gratiosa* (part)
Substantial submarginal papillae; no black saddle on dorsum of tail musculature 18
18. Tail musculature distinctly striped; well developed flagellum at tip of tail; reddish color in life .... *Hyla femoralis*
Tail musculature not striped; flagellum absent; golden to brown or bluish color in life 19
19. Dorsal fin height equal to or greater than musculature height; throat seldom pigmented; dorsal fin never extends anterior to midway between spiracle and eye .... *Hyla chrysoscelis, Hyla versicolor*
Dorsal fin height less than musculature height; throat pigmented in life; dorsal fin extends to posterior border of the eye .... *Hyla squirella*
20. Tail musculature striped 21
Tail musculature not striped 26
21. A-2 gap wide .... *Pseudacris brimleyi*
A-2 gap narrow 22
22. Light dorsal stripe on tail extends to eye; fins clear or with a few stellate melanophores; dorsum of tail musculature banded or marked with saddles .... *Limnaoedus ocularis* (part)
Dorsal stripe does not extend to eye; fins clear or mottled; dorsum of tail musculature not banded 23
23. Tail stripe distinct; snout rounded when viewed dorsally; body slightly depressed 24
Tail stripe may or may not be distinct; snout squarish or tapering in dorsal view; body not depressed 25
24. Dorsal fin originates anterior to spiracle .... *Pseudacris ornata* (part)
Dorsal fin originates posterior to spiracle .... *Pseudacris triseriata* (part)

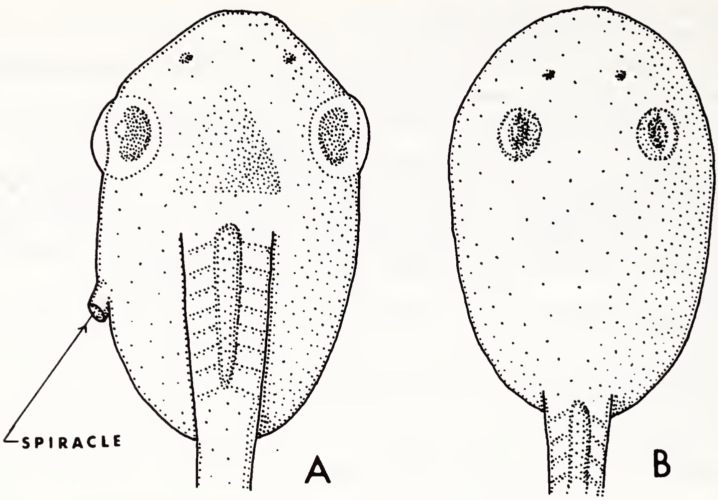

Fig. 3. Eye positions, dorsal aspect. A. Lateral eyes (and spiracle). B. Dorsal eyes. Redrafted from Altig (1970).

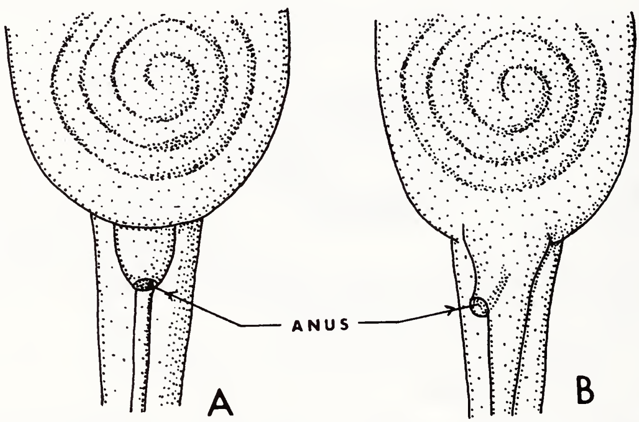

Fig. 4. Anus positions, ventral aspect. A. medial. B. dextral. Redrafted from Altig (1970).

25. Tail stripe faint; snout square when viewed dorsally; snout-spiracle distance/body length greater than 0.60; spiracle just below eye level; dorsal fin higher than ventral fin; interocular distance only slightly less than maximum head width .... *Hyla crucifer* (part)
    Tail stripe distinct; snout tapering in dorsal view; snout-spiracle distance/body length less than 0.60; spiracle well below eye level; fins equal in height; interocular distance markedly less than maximum head width .... *Hyla andersoni* (part)
26. Total length (Fig. 1) greater than 45 27
    Total length less than 45 mm 28

27. Jaws wide and rounded; tail musculature unicolored .... *Hyla gratiosa* (part)
Jaws narrow and angular; tail musculature bicolored .... *Pseudacris ornata* (part)
28. Dorsal fin originates anterior to spiracle 29
Dorsal fin originates at or posterior to spiracle 31
29. Fins clear or with few stellate melanophores; fins rounded; dorsal fin higher than ventral fin.. 30
Fins and tail musculature mottled or reticulated; fins tapering toward the tail tip; dorsal and ventral fins equal in height .... *Hyla cinerea*
30. Jaws wide and rounded; dorsum of tail musculature usually with black saddle slightly anterior to midlength; tail musculature unicolored.................................... *Hyla gratiosa* (part)
Jaws narrow and angled; no black saddle on dorsum of tail musculature; tail musculature bicolored.......................... *Pseudacris ornata* (part)
31. Fins and tail musculature mottled or reticulated; body somewhat globular; snout square when viewed dorsally .... *Hyla crucifer* (part)
Fins and tail musculature clear or with a few stellate melanophores; body somewhat depressed; snout round when viewed dorsally................. 32
32. Body dark brassy in life; dorsal fin terminates far posterior to spiracle .... *Pseudacris brachyphona*
Body color not dark brassy; dorsal fin terminates at or slightly posterior to spiracle 33
33. Dorsal fin higher than ventral fin and equal to tail musculature height.................................... *Pseudacris triseriata* (part)
Fins subequal and both lower than musculature height.. *Pseudacris nigrita*
34. Four or more rows of teeth on anterior or posterior labium .... *Rana sylvatica* (part)
Less than four rows of teeth on both anterior and posterior labium 35
35. A-2 gap ratio greater than 1.5; dorsal fin originates at or only slightly posterior to spiracle .... *Rana sylvatica* (part)
A-2 gap ratio variable; dorsal fin originates far posterior to spiracle 36
36. Lower jaw wide; nostrils medium to large; skin thin, gut visible, with weakly pigmented belly in larger specimens; small animals uniform in color, even when preserved................................ *Rana pipiens* group: 37
Lower jaw narrow; nostrils small; skin thick; gut usually not visible, with strongly pigmented belly in larger animals; small animals with gold transverse bands on anterior part of body, appearing unevenly pigmented when preserved............................ *Rana catesbeiana* group: 39
37. A-2 gap ratio 2 or more; P-1/P-3 length ratio 1.3 or greater... *Rana palustris*
A-2 gap ratio less than 2; P-1/P-3 length ratio less than 1.5 38
38. No keratinized areas at medial tips of P-1; A-2 gap ratio often greater than 1.0; color variable .... *Rana sphenocephala*
Keratinized areas present at medial tips of P-1; A-2 gap ratio always less than 1.0; color usually dark................................ *Rana areolata*
39. Tail musculature unicolored or mottled, but not striped; fins clear or mottled, but not in any particular pattern 41
Tail musculature distinctly bicolored or striped; fins either striped (or with a row of dots) or marked around edges 40

40. Tail musculature distinctly bicolored; fins without stripe; larger specimens have prominent black edging around a clear or speckled fin ..... *Rana heckscheri*
Tail musculature distinctly striped; stripe or row of dots (formed by pigment around the lateral line pores) present on dorsal fin; no black edging on tail fins .... *Rana virgatipes*
41. A-2 gap ratio greater than 0.50; body and tail patterned with distinct black dots; belly light green, white, or yellow in life .... *Rana catesbeiana*
A-2 gap ratio less than 0.50; body and tail lacking distinct black dots; belly of larger individuals is cream or white in life .... *Rana clamitans*

NOTES ON FIELD IDENTIFICATION

Many animals can be diagnosed to genus or species in the field with the use of a hand lens. Small tadpoles are always difficult to identify, but the following notes should allow larger individuals to be placed into one of five principal groups.

Hylidae: body square in dorsal view, eyes lateral; nostrils small compared to eyes; dextral anus; oral disc not emarginate; never black in color, but can range from bluish to brown.

Rana: body oval or round in dorsal view, eyes dorsal or dorsolateral; nostrils small compared to eyes; dextral anus; oral disc emarginate; color diagnostically unreliable.

Bufo: body round or oval in dorsal view, eyes dorsal and with a "cross-eyed" aspect; nostrils large, and head appears to have a "snout"; median anus; oral disc emarginate; color may be dark or light *(Bufo quercicus).*

Scaphiopus holbrooki: body round or oval in dorsal view, eyes close-set and dorsal; head wide relative to body width; entire body moves from side to side while swimming; median anus; oral disc not emarginate; color black.

Gastrophryne carolinensis: body round in dorsal view, distinctly depressed; eyes wide-set and lateral; median anus; no oral disc; color dark, although larger individuals have mottled venters and a stripe on the tail musculature.

ACKNOWLEDGMENTS.— Many people helped collect tadpoles, but I owe a particular debt of gratitude to Mr. Jack Longino, Mr. Peter Morin, and Dr. Henry Wilbur. Professor Joseph Bailey allowed me to use the Duke Vertebrate Collection, and Alvin Braswell, North Carolina State Museum of Natural History, graciously provided specimens of preserved tadpoles. Professor Henry Wilbur generously provided me with the time, funding, and encouragement to construct this key and to refine it from 1977 to 1980 while I was at Duke University. Drs. Ronald

Altig and John Cooper, and an anonymous reviewer, improved the manuscript considerably through their conscientious suggestions, and Dr. Cooper drafted the figures.

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New Distributional Records of Eastern Kentucky Fishes

MELVIN L. WARREN, JR.

Kentucky Nature Preserves Commission, Frankfort, Kentucky 40601

ABSTRACT.— A two year survey of the major river drainages of eastern Kentucky resulted in new records and range extensions of several rare or poorly known fish species. *Ichthyomyzon fossor* is reported for the first time in the Little Sandy River and South Fork of the Kentucky River, and *Notropis galacturus* from the Big Sandy, Laurel and upper Cumberland (above the falls) rivers. The range of *Phoxinus cumberlandensis* is extended to include Laurel and Rockcastle rivers. *Etheostoma tippecanoe* is noted for the first time in the Cumberland River within Kentucky, and the most upstream record of *Percina phoxocephala* in the Ohio River valley of the state is reported. Additional localities and range extensions are noted for eight rare or poorly known Kentucky fishes. Notes on distribution, habitat, and associates are included.

INTRODUCTION

During 1978 and 1979, the Kentucky Nature Preserves Commission conducted aquatic biota surveys of selected streams in four major river drainages of eastern Kentucky (Harker et al. 1979, 1980). Considering past and projected growth of the coal mining industry in this region and the concomitant impacts on stream ichthyofauna, it is apparent that documentation of the existing fauna is both necessary and timely. Much of the distributional information concerning this region is from scattered collections without proper documentation (e.g., locality data, voucher material). The stream fishes of the Big Sandy, Licking, and upper Cumberland rivers are particularly poorly known in terms of substantiated collections (Burr 1980). Collecting efforts of the Kentucky Nature Preserves Commission resulted in distributional information for several poorly known or rare species in the state and suggest that our knowledge of the eastern Kentucky ichthyofauna is far from complete.

Several of the records reported are included in both Burr (1980) and Lee et al. (1980), although not in the detail covered here. The following accounts of species are presented for the purpose of enriching and elucidating knowledge of the varied Kentucky ichthyofauna.

SPECIES ACCOUNTS

The following accounts extend the range of several fish species within and across drainages of eastern Kentucky. The majority of reported specimens were collected during field work conducted by the Kentucky Nature Preserves Commission, although several records were taken from collections examined by the author at the Kentucky

Department of Fish and Wildlife Resources (KFW). A detailed account of methodology and a discussion of most collecting stations, including macrobenthic, periphyton, substrate, and water quality analyses, was presented in Harker et al. (1979, 1980). The bulk of the collections are housed at the Kentucky Nature Preserves Commission (KNP). Other material as noted is deposited at Auburn University (AU), Eastern Kentucky University (EKU), Tulane University (TU), University of New Orleans (UNO), University of Tennessee (UT), and in the collection of Wayne C. Starnes (WCS).

Species accounts include the catalog numbers, followed in parentheses by the number of specimens, the stream and major drainage, the locality, county, and date of collection. All scientific and common names follow Robins et al. (1980), except in the case of undescribed taxa.

Ichthyomyzon fossor Reighard and Cummins. Northern brook lamprey. KNP SO1CAR (2), UT 2.81 (2), WCS 1010-01 (2), Big Sinking Cr. (Little Sandy R. dr.), 1.7 km above mouth, Carter Co., 31 May 1978; KNP K01CLA (1), Goose Cr. (S. Fk. Kentucky R. dr.), at Lipps, Clay Co., 9 May 1978.

Bauer and Branson (1979) recently reported this nonparasitic lamprey from the Middle Fork of the Kentucky River. Previously it was reported from the upper Big Sandy and Barren rivers (Clay 1975), but Burr (1980) did not recognize the latter record. The present collections constitute a new record for the Little Sandy River and an extension of the known distribution in the Kentucky River to the South Fork. All specimens were adults and were taken from areas of swift current over substrates of rubble interspersed with sand and gravel. Both the Ozarkian and Ohio Valley populations of *I. fossor* are relatively isolated from the widely distributed orthern populations (Pflieger 1971; Rohde and Lanteigne-Courchene 1980). The Kentucky distribution of *I. fossor* strongly suggests that former tributaries of the ancient Teays River (e.g., Big Sandy, Little Sandy and Kentucky rivers) (Hocutt et al. 1978) served as refugia and redispersal points during and after Pleistocene glaciation. Although its rarity in Kentucky is partly attributable to the difficulty of collecting adults in preferred habitats (Bauer and Branson 1979), the Kentucky Academy of Science considers the species to be threatened (Branson et al. 1981).

Notropis galacturus (Cope). Whitetail shiner. UT 44.1757 (3), Russell Fk. (Big Sandy R. dr.), below Chesapeake and Ohio Railroad bridge at KY 80, Pike Co., 23 May 1978; KFW 1526 (38), Russell Fk. (Big Sandy R. dr.), at mouth of Grassy Br., Pike Co., 30 August 1961; KNP BO1PIK (70), Elkhorn Cr. (Russell Fk. Big Sandy R. dr.), 3.3 km W of jct KY 80 and KY 197, Pike Co., 11 October 1978; KFW 1521 (7), same locality, 29 August 1961; KFW 1643 (37), Clover Fk. (Cumberland R. dr.), KY 38 bridge, Harlan Co., 27 September 1961; KFW 1508 (4), Laurel R. (Cumberland R.

dr.), at mouth of Spruce Cr., Whitley Co., 23 August 1961; KNP CO7LAU (13), Laurel R. (Cumberland R. dr.), 3.1 km above the mouth of Adams Br., Laurel Co., 11 October 1979.

In Kentucky this distinctive cyprinid is relatively common in clear streams in the Cumberland River below Cumberland Falls. Although noted by Clay (1975) from the Big Sandy River and upper Cumberland River (above the falls), locality data were not given. Gilbert and Burgess (1980a) did not include the Big Sandy, upper Cumberland, or Laurel rivers in their depiction of the Kentucky range. The collections noted here are apparently the only formally published localities of the whitetail shiner in these drainages. It is also known from the upper Tennessee and New rivers of Virginia (Gibbs 1961), which closely abut the headwaters of the Big Sandy and Cumberland rivers. The presence of the species in the four adjacent drainages suggests stream capture as the means of dispersal, and Gibbs (1961) interpreted the presence of *N. galacturus* in the New River as the result of piracies between the New and upper Tennessee rivers. Subsequent workers regarded the New River populations as probably native (Jenkins et al. 1971) or introduced (Gilbert and Burgess 1980a). Limited distribution such as that observed in the New and Big Sandy rivers may be the result of first entry during recent times, reentry after extirpation, or introduction rather than natural factors (Jenkins et al. 1971). In light of the apparent absence of other species indicative of stream capture with adjacent drainages, populations of *N. galacturus* in the Big Sandy River are most likely the result of introduction.

The only historical reference to *N. galacturus* in the Cumberland River above the falls was by Evermann (1918), who apparently erroneously cited Woolman's (1892) Rockcastle River locality. The rarity of *N. galacturus* in surveys above the falls may be in part related to the extensive habitat destruction associated with coal mining. Its apparent rarity in the Laurel River is attributable to habitat destruction and the lack of systematic surveys before the impoundment of Laurel River Reservoir. Interpretation of the native or non-native status above Cumberland Falls invokes reasoning similar to the interpretation of the populations in the New and Big Sandy rivers, although there is strong faunal evidence of lateral stream transfer between the Cumberland and upper Tennessee (Clinch-Powell) rivers (Starnes et al. 1977). Additional collections, comparison, and analyses of populations in the Big Sandy, Cumberland, New, and Tennessee rivers may further enlighten the enigmatic dispersal history and distribution of *N. galacturus*.

Notropis sp. Undescribed. Sawfin shiner. AU 18680 (4), KNP CO1MCY (13), EKU uncat. (4), Rock Cr. (Big S. Fk. Cumberland R. dr.), 6.7 km SW of Bell Farm at Great Meadows Camp Site, McCreary Co., 19 September 1978; AU uncat. (1), KNP uncat. (4), Pitman Cr. (Cumberland R. dr.), Co. Rd. 1247 bridge in Somerset, Pulaski Co., 25 October 1979.

This undescribed relative of the mirror shiner, *Notropis spectrunculus*, was previously known in Kentucky from a single record in the Little South Fork of the Cumberland River (Comiskey and Etnier 1972; John S. Ramsey, pers. comm.). The two additional localities noted above indicate a wider but sporadic distribution in the Big South Fork and middle Cumberland rivers of eastern Kentucky. The rarity of the sawfin shiner in Kentucky may be related in part to lack of recognition by early workers and to the embayment of tributaries by Cumberland River Reservoir. Additional Kentucky collections are anticipated in other medium-to-large streams of the drainage. The species is considered threatened in Kentucky by the Kentucky Academy of Science (Branson et al. 1981).

Phoxinus cumberlandensis Starnes and Starnes. Blackside dace. WCS 883-01 (1), Marsh Cr. (Cumberland R. dr.), 1.8 km S of Co. Rd. 1470 on Marsh Cr. Rd., McCreary Co., 4 May 1978; KNP CO2MCY (3), same locality, 19 September 1978; WCS 1163-01 (1), Craig Cr. (Laurel R. dr.), at KY 312 bridge, Laurel Co., 9 October 1979; KNP CO2LAU (2), Ned Branch (Rockcastle R. dr.), 0.6 km N of terminus of Co. Rd. 1193 and 50 m above the impounded mouth, Laurel Co., 25 July 1979; KNP CO1LET (1), Colliers Branch (Poor Fk. Cumberland R. dr.), 4.2 km E of jct US 119 and Colliers Br. Rd., Letcher Co., 22 April 1980; KNP uncat. (2), Poor Fk. (Cumberland R. dr.), 5.5 km ENE of jct US 119 and KY 932, Letcher Co., 1 June 1979; KNP CO2WHI (15), Bunches Cr. (Cumberland R. dr.), 1.5 km above the mouth, Whitley Co., 22 August 1979.

Previously, *P. cumberlandensis* was known in Kentucky from 12 extant and 2 apparently extirpated populations (Starnes and Starnes 1978). The addition of the six localities reported above indicates the species occurs from the extreme headwaters of the Poor Fork of the Cumberland River downstream to and including the Laurel River, lower Rockcastle River, and Beaver Creek systems. The species was collected in pool areas of headwater streams in association with undercut banks and/or rubble, boulder, and sand substrates. Most seine hauls yielded only one or two individuals. The general habitat description presented by Starnes and Starnes (1978) agrees well with my observations.

Phoxinus cumberlandensis apparently evolved in isolation in the Cumberland River drainage above Cumberland Falls, which represents the major part of the known range (Starnes and Starnes 1978). The discovery of populations in the Laurel and lower Rockcastle rivers below Cumberland Falls represents the first records for these drainages and raises questions concerning the circumvention of the falls. In order to explain the presence of *P. cumberlandensis* immediately below Cumberland Falls, Starnes and Starnes (1978) postulated lateral stream capture or the relatively rapid regression of the falls in recent geologic time.

McGrain (1966) placed the downstream origin of the falls near the present location of Burnside, Kentucky, which is well downstream of the present mouths of both the Laurel and Rockcastle rivers. The presence of *P. cumberlandensis* in these river systems suggests the relatively rapid regression of Cumberland Falls as the most likely explanation for the present distribution. Further faunal evidence is implied by the Cumberland River distribution of *Etheostoma kennicotti* as presented by Page and Smith (1976). Unfortunately, the dispersal and distribution of *P. cumberlandensis* is obscured and fragmented by man's activities in the area (i.e., mining, impoundments, etc.). In addition, there is apparently no geological record of the regression of Cumberland Falls (McGrain 1966). The blackside dace is listed as threatened by the Kentucky Academy of Science (Branson et al. 1981).

Percopsis omiscomaycus (Walbaum). Trout-perch. KNP BO1LAW (3), Little Blaine Cr. (Big Sandy R. dr.), 3.5 km NW of the jct KY 32 and Little Blaine Cr. Rd., Lawrence Co., 3 October 1978; UT 79.4 (4), KNP SO1CAR (2), Big Sinking Cr. (Little Sandy R. dr.), 1.7 km above mouth, Carter Co., 13 September 1978.

Although primarily a northern species, the trout-perch is widely but discontinuously distributed in Kentucky, with most records from the extreme northeastern section of the state (Clay 1975; Burr 1980). The Little Blaine Creek collections were believed to represent the most upstream locality in the Big Sandy River; however, material recently examined from Right Fork Beaver Creek (Levisa Fork Big Sandy R. dr.) indicates a much wider distribution in the Big Sandy than was previously known. The specimens are housed at the Kentucky Department of Transportation, Frankfort, Kentucky (Steve P. Rice, pers. comm.). Additional records in the middle and upper reaches of the Big Sandy River may be expected. *Percopsis omiscomaycus* is listed as of special concern in Kentucky by the Kentucky Academy of Science (Branson et al. 1981).

Ammocrypta pellucida (Putnam). Eastern sand darter. KNP uncat. (1), N. Fk. Red R. (Kentucky R. dr.), below KY 715 bridge at Menifee-Wolfe county line, 17 June 1978; KFW 1745 (4), Greasy Cr. (Middle Fk. Ky. R. dr.), no locality, Leslie Co., 15 August 1962; KFW 1160 (1), Middle Fk. (Kentucky R. dr.), no locality, Leslie Co., 15 June 1960.

Ammocrypta pellucida is known from few localities in the Kentucky River drainage (Williams 1975; Hocutt 1980). The species was previously reported from localities in the lower reaches of the Red River (Branson and Batch 1974) and in the North and South Forks of the Kentucky River (Williams 1975). The above collection extends the known range in the Red River approximately 33 km upstream and indicates a broader distribution in this system than was previously reported. The specimens from Middle Fork of the Kentucky River constitute a new record for this drainage and indicate that *A. pellucida* occurred throughout the upper Kentucky River. The Red River specimen was taken at the margin of a deep (1.0 m), gently flowing pool underlain by clean sand. Repeated efforts to secure additional specimens were unsuccessful. The specimen was taken with *Etheostoma nigrum*, another psammophilic species. Burr (1980) observed that the once relatively common eastern sand darter is rapidly declining in numbers in Kentucky. The Kentucky Academy of Science lists the species as threatened (Branson et al. 1981).

Etheostoma cinereum Storer. Ashy darter. KNP CO5ROC (2), Rockcastle R. (Cumberland R. dr.), at mouth of Eagle Cr., Rockcastle Co., 23 October 1979; KNP CO9MCY (1), Big S. Fk. (Cumberland R. dr.), 3.0 km N of Tennessee state line at mouth of Troublesome Cr., McCreary Co., 24 October 1979.

The ashy darter is confined to the Cumberland River in Kentucky and is known from six substantiated collections, including those shown above (Burr 1980 and pers. comm.). Although Saylor (1980) and Branson (1977) noted the species in the Rockcastle River, no exact localities were given. The above collection is considered the first formal report of the species from this river. Subsequent collections in upstream segments of the Rockcastle River have yielded a number of additional specimens (Brooks M. Burr, pers. comm.). At both sites, *E. cinereum* was collected in sluggish current adjacent to swift shoals over rubble-gravel substrate mixed with detritus and/or dead *Justicia americana* in areas 0.45-0.75 m deep. No fishes were associated with *E. cinereum* on the substrate; however, *Notropis ariommus*, *N. chrysocephalus*, and *N. rubellus* occurred in the water column directly above.

Etheostoma nigrum susanae (Jordan and Swain). Johnny darter. KNP CO5MCY (2), Bridge Fk. Laurel Cr. (Cumberland R. dr.), directly above mouth on KY 478, McCreary Co., 12 September 1979; KNP CO2WHI (5), Bunches Cr. (Cumberland R. dr.), 1.5 km above mouth, Whitley Co., 22 August 1979.

In a recent taxonomic evaluation of this rare subspecies, Starnes and Starnes (1979) reported extant populations above Cumberland Falls within Whitley and McCreary counties. The collections reported above represent new localities from the same general area. Both collections were made in small streams with well-forested watersheds and excellent water quality. Individuals were generally collected over clean-swept sand and bedrock at the base of gentle riffles or in shallow pools. *Etheostoma nigrum susanae* is the only endemic fish above Cumberland Falls and is currently listed by the Kentucky Academy of Science as threatened (Branson et al. 1981).

Etheostoma tippecanoe Jordan and Evermann. Tippecanoe darter. KNP uncat. (1), Big S. Fk. (Cumberland R. dr.), 3.2 km N of Tennessee state line at mouth of Oilwell Br., McCreary Co., 24 October 1979.

In Kentucky, the Tippecanoe darter was formerly known from localized populations in the Licking, Green, and Kentucky rivers (Burr 1980; Clay 1975; Hocutt 1980). Although known from the Big South Fork of the

Cumberland River in Tennessee (Comiskey and Etnier 1972), this record, included in Burr (1980), is the first reported occurrence in the Cumberland River of Kentucky. One adult female was collected in a large, swift, rubble-gravel shoal approximately 0.3-0.5 m deep. Other members of the subgenus *Nothonotus* associated with *E. tippecanoe* were *E. maculatum sanguifluum* and *E. camurum*. The collection of one individual precludes evaluation of the status of the species in this segment of the river; however, *E. tippecanoe* is listed by the Kentucky Academy of Science as endangered (Branson et al. 1981).

Percina copelandi (Jordan). Channel darter. TU 120014 (3), Buckhorn Cr. (N. Fk. Kentucky R. dr.), 0.7 km NE of KY 476, Breathitt Co., 19 June 1978; KNP C09MCY (4), Big S. Fk. (Cumberland R. dr.), 3.0 km N of Tennessee state line at mouth of Troublesome Cr., McCreary Co., 29 August 1979; UT 91.1790 (22), WCS 1009-02 (5), KNP uncat. (6), Russell Fk. (Big Sandy R. dr.), below Chesapeake and Ohio Railroad bridge at KY 80, Pike Co., 23 May 1978.

Burr (1980) regarded the channel darter as uncommon in Kentucky. The presence of the species in Buckhorn Creek represents the first formal record from the North Fork of the Kentucky River. Its occurrence in this relatively small system is surprising in light of its reported preference for big river habitats (Gilbert and Burgess 1980b). The population in the Big South Fork of the Cumberland River apparently represents the second reported locality from this system in Kentucky, although others have noted it from the same drainage in Tennessee (Comiskey and Etnier 1972; Page 1974; Gilbert and Burgess 1980b). An examination of the University of Louisville and KFW museum records revealed that all the collections reported by Clay (1975) from the Russell and Levisa Forks of the Big Sandy River pre-date 1960. The channel darter is apparently persisting in good numbers in Russell Fork as indicated by the present collections. Habitat and species associates are presented under the *Percina oxyrhyncha* account. The channel darter is considered of special concern in Kentucky by the Kentucky Academy of Science (Branson et al. 1981).

Percina oxyrhyncha (Hubbs and Raney). Sharpnose darter. KNP B01JOH (5), Levisa Fk. (Big Sandy R. dr.), 1 km N of River, Johnson Co., 2 October 1978; WCS 1009-03 (4), UT 91.1789 (7), Russell Fk. (Big Sandy R. dr.), below Chesapeake and Ohio Railroad bridge at KY 80, Pike Co., 23 May 1978; KFW 1533 (49), Russell Fk. (Big Sandy R. dr.), mouth of Grassy Br. at Kentucky-Virginia line, Pike Co., 30 August 1961; KFW 1225 (5), Levisa Fk. (Big Sandy R. dr.), mouth of Morgans Cr., Pike Co., 27 September 1960; KFW 1803 (34), N. Fk. (Kentucky R. dr.), Rocklick, Breathitt Co., 19 September 1972.

The darter subgenus *Swainia* is represented in Kentucky by three morphologically similar species, *P.oxyrhyncha*, *P. squamata*, and *P. phoxocephala* (see following accounts). Because of morphological similarities, much confusion has resulted concerning assignment to species within the subgenus. *Percina oxyrhyncha* was unknown in Kentucky until Denoncourt et al. (1977) reported specimens from the upper Kentucky River, and others later noted the species from the upper Big Sandy, Licking, and Green rivers (Thompson 1978; Bauer and Branson 1979; Burr 1980; Thompson 1980a). Thompson (1980a) depicted the range in the Big Sandy River as the extreme headwaters of Levisa and Russell Forks near the Kentucky-Virginia line. The collections of my report indicate that the species is common in Russell Fork, and that the range extends downstream in Levisa Fork at least 80 km from the Kentucky-Virginia line.

The Levisa Fork specimens were adults and were taken in a swift, boulder strewn shoal (0.8-1.0 m deep) directly adjacent to a dense bed of *Justicia americana*. The only directly associated percid was *Percina sciera*. In contrast, the series of juveniles from Russell Fork was collected from a shallow (0.15 m), rubble-gravel shoreline area with moderate current. Species associates included juvenile *Percina evides*, *P. copelandi*, *P. sciera*, and *P. caprodes*. Denoncourt et al. (1977) noted a correlation of specimen size with both substrate and gradient; the above observations support their findings. The rarity of *P. oxyrhyncha* in Kentucky is no doubt partly attributable to taxonomic confusion and the difficulty of collecting adults in the preferred big river habitats. The status of the species is currently listed as undetermined by the Kentucky Academy of Science (Branson et al. 1981).

Percina phoxocephala (Nelson). Slenderhead darter. UNO 3346 (1), Tygarts Cr. (Ohio R. dr.), Bennetts Covered Bridge at jct KY 7 and Co. Rd. 1215, Greenup Co., 31 May 1978.

Percina phoxocephala is most easily confused with *P. oxyrhyncha*. It differs in having lower meristics, a more robust body, and less elongate head and snout (Bruce A. Thompson, pers. comm). Hubbs and Raney (1939) regarded the snout length as diagnostic in separating the two species. The slenderhead darter is the most widely distributed member of the subgenus *Swainia* and has been previously reported in Kentucky from the Green, lower Kentucky (Eagle Creek), Tennessee and Cumberland rivers (Burr 1980; Thompson 1980b). The specimen from Tygarts Creek represents the most upstream record in the Ohio River valley of Kentucky. Its presence in this stream is not unexpected in light of the proximity to populations in northern tributaries of the Ohio River (e.g., Scioto River).

The single adult male was near breeding condition, supporting the April to early June spawning period postulated by Thompson (1980b). The specimen was taken in a moderately fast sand and gravel riffle that supported a dense growth of *Justicia americana*. Personal observations in this and Green River collections suggest that adult *P. phoxocephala* occur most often over gravel and/or finer substrates, whereas adult *P. oxyrhyncha* prefer coarser material such as rubble and boulders. Page and Smith (1971) and Denoncourt et al. (1977) made similar observations on substrate preferences of *P. phoxocephala* and *P. oxyrhyncha*, respectively. Acquisition of additional material may change current views of the complex distributional patterns of both *P. phoxocephala* and *P. oxyrhyncha* (Bruce A. Thompson, pers. comm.). Previous comments concerning the status of the sharpnose darter in Kentucky are also applicable to the slenderhead darter. The Kentucky Academy of Science presently lists *P. phoxocephala* as of special concern in Kentucky (Branson et al. 1981).

Percina squamata (Gilbert and Swain). Olive darter. KNP C04JAC (2), Middle Fk. (Rockcastle R. dr.), 4.5 km W of jct KY 89 and Co. Rd. 2002, Jackson Co., 23 August 1979.

According to Burr (1980), *P. squamata* is known in Kentucky only from the Rockcastle and Big South Fork Cumberland rivers. Although previously reported from the Rockcastle River (Bauer and Branson 1979; Thompson 1980c), the above collections represent the most upstream occurrence. The specimens were secured from below a swift, deep (0.8-1.0 m) riffle over a rubble and boulder substrate. Thompson (1978) stated that until recently the olive darter was the poorest known member of the subgenus *Swainia*, and one of the least known members of the genus *Percina*. The olive darter is listed by the Kentucky Academy of Science as endangered (Branson et al. 1981).

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Systematic Status of the Cumberland Island Pocket Gopher, *Geomys cumberlandius*

Joshua Laerm

Museum of Natural History and Department of Zoology, University of Georgia, Athen, Georgia 30602

ABSTRACT.— The Cumberland Island pocket gopher, *Geomys cumberlandius,* is known only from its type locality on Cumberland Island, Camden County, Georgia. Statistical analyses of 21 morphometric characters of *G. cumberlandius* and 5 mainland populations of *G. pinetis* indicate that coastal populations of *G. pinetis* are more similar to *G. cumberlandius* than they are to more inland populations of *G. pinetis*. These data, coupled with the Recent connection of Cumberland Island to the mainland, argue against taxonomic recognition of *G. cumberlandius*, which is therefore regarded as a synonym of *G. pinetis.*

INTRODUCTION

Until the recent work of Williams and Genoways (1980), *Geomys cumberlandius* Bangs was recognized as one of four nominal species of pocket gophers occurring in Georgia (Hall and Kelson 1959; see also Hall 1981). It has been considered monotypic and known only from its type locality on Cumberland Island, Camden County, Georgia (Fig. 1). *Geomys colonus* Bangs and *Geomys fontanelus* Sherman were also considered monotypic and known only from their type localities in Camden and Chatham counties, Georgia, respectively. *Geomys pinetis* Rafinesque was considered polytypic and widespread throughout Alabama, Florida and Georgia.

Geomys cumberlandius was described in 1898. Specimens were taken on Cumberland Island as late as 1956 but no subsequent specimens were found and the species had been thought extinct. Recently, however, a small population has been reported on the island (H. Neuhauser, pers. comm).

Williams and Genoways (1980) reviewed the systematics of southeastern pocket gophers and concluded, based on morphometrics, that of the four named species only *G. pinetis* is valid. They recognized only two subspecies, *G. p. pinetis* and *G. p. fontanelus*, and synontmized *G. cumberlandius* and *G. colonus* with *G. p. pinetis.*

This manuscript was in preparation when the Williams and Genoways results were published. Because they employed only a portion (77%) of available *G. cumberlandius* specimens, and did not include in their study several characters upon which *cumberlandius* was originally described, an independent corroboration of the systematic status of the species is appropriate. The characters they omitted were: width of nasals, breadth of ascending ramus of maxillary, and measurements of

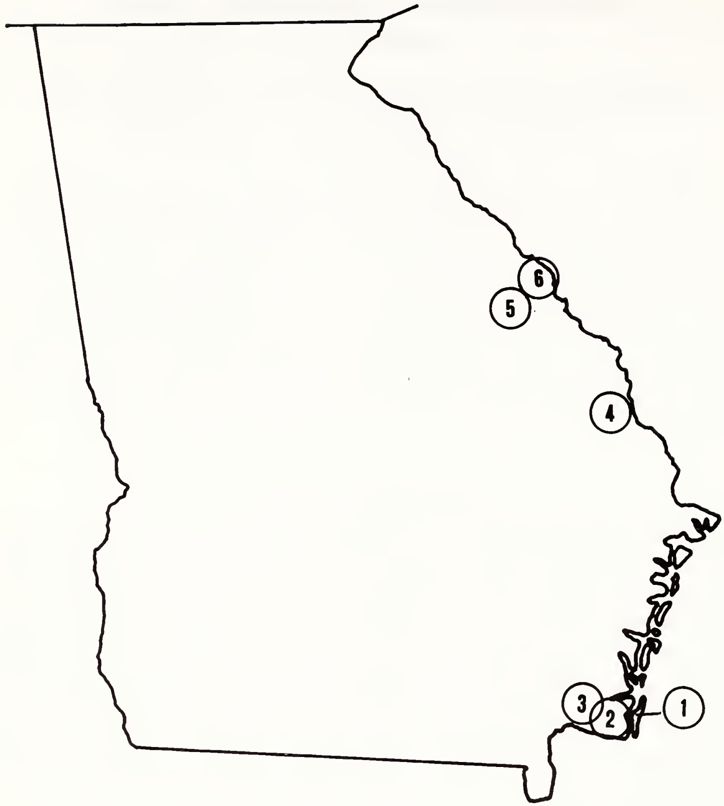

Fig. 1. Location of populations of Georgia pocket gophers examined. 1 = Cumberland Island; 2 = Scotchville, Camden Co.; 3 = Kingsland, Camden Co.; 4 = Hursman's Lake, Screven Co.; 5 = Adam, Richmond Co.; 6= Augusta, Richmond Co.

the auditory bullae. Another reason for corroborating the taxonomic status of *G. cumberlandius* is the current political sensitivity of the Cumberland Island population, which is a possible candidate for state and/or federal endandered status.

MATERIALS AND METHODS

All available specimens of *G. cumberlandius* (N = 73) were examined: Cumberland Island (8, AMNH; 5, CMNH; 1, CU; 13, DMNH; 26, MCZ; 11, NMNH; 9, UGAMNH). These were compared to 157 specimens of mainland *G. pinetis* from the following five populations in east Georgia: Adam (41, MCZ), and Augusta (4, FSM; 11, NMNH), Richmond County; Hursman's Lake (25, MCZ), Screven County; Kingsland (6, FSM; 35, NMNH), and Scotchville (8, AMNH; 10, MCZ; 17, NMNH), Camden County. Acronyms are defined in ACKNOWLEDGMENTS. The Scotchville population, previously recognized as *G.*

colonus has been shown by Laerm et al. (in press) and Williams and Genoways (1980), on the basis of morphometrics, electrophoresis, karyology, and mitochondrial DNA sequence relatedness, to be synonymous with *G. pinetis.* Twenty-one body and cranial measurements were taken to the nearest 0.01 mm with dial calipers. These included: (1) total body length, (2) tail length, (3) hind foot length, (4) condylobasilar length, (5) zygomatic breadth, (6) mastoid breadth, (7) palatal length, (8) palatal depth, (9) rostral breadth, (10) maxillary tooth row length, (11) least interorbital constriction, (12) braincase breadth, (13) nasal length, (14) greatest anterior nasal breadth, (15) breadth of nasals at narrowest point, (16) greatest posterior nasal breadth, (17) interpterygoid fossa length, (18) auditory bulla length, (19) breadth of ascending ramus of maxillary, (20) anterior palatal breadth, and (21) posterior palatal breadth. All measurements except variable 20 were made using the methods of Williams and Genoways (1977) and DeBlase and Martin (1974). Variable 20 was measured across the greatest width of the ascending arm of the maxillary.

It has been well established that body and cranial measurements change during the growth of an individual, but usually not at a constant rate. It is, therefore, frequently desirable to compensate for size variation due to sex and age before comparisons are made. This is particularly true in cases where small sample sizes limit the value of assigning each individual to separate sex and age classes as in the present case. This has commonly been done with proportions or transformation of proportions; however, controversy has recently arisen over the use of these techniques (Atchley et al. 1976; Albrecht 1978; Atchley and Anderson 1978; Dodson 1978; Hill 1978). Fortunately, a number of statistical techniques are available that permit compensation for the effects of size without using proportions. We chose Analysis of Covariance using SAS procedures (Barr et al. 1976) to determine if significant differences could be detected between *G. cumberlandius* and widely separated populations of *G. pinetis.* Males and females were treated separately because of obvious sexual dimorphism. A Multiple Discriminant Function Analysis (SAS) was performed on raw data, separated into male and female groups to obtain generalized distances between populations. These were then clustered by UPGMA (Sokal and Sneath 1973) into distance phenograms to graphically illustrate phenetic distances between populations.

RESULTS

Initial tests of equal slope in the Analysis of Covariance used the following model:

V4 (condylobasilar length)
population
V4 × population.

Results indicate that the interaction term was not significant for the characters examined. Therefore, the intercept (the differences between populations) for the covariate was tested under the following model;

V4
population.

The results of this model (Table 1) indicate significant differences between populations for most characters. For these characters the difference in least squares adjusted means for each population was determined by the Scheffé Test (Morrison 1967) (Table 2).

No significant differences for any of the characters examined can be seen between females of *G. cumberlandius* and other populations of female *G. pinetis*. Males of *G. cumberlandius* can be distinquished from males of other *G. pinetis* populations on the basis of a single character — total length.

Results of the Multiple Discriminant Function Analysis (Fig. 2) similarly indicate low levels of morphological distinction between *G. cumberlandius* and mainland populations of *G. pinetis*. Two assemblages are indicated in both males and females: an upland assemblage consisting of the populations from Adam, Augusta, and Hursman's Lake, and a coastal assemblage consisting of the two Camden County populations and *G. cumberlandius.*The only inconsistency in clustering in both males and females occurs in the apparent relatedness of the coastal Camden County assemblage. Female *G. cumberlandius* and Kingsland *G. pinetis* appear more closely related than either is to the Scotchville *G. pinetis* population, while males from both Camden County populations appear more closely related to each other than either does to the Cumberland Island population. The important point is, of course, that *G. cumberlandius* appears more closely related to coastal Camden County *G. pinetis* than do these *G. pinetis* to their upland conspecifics.

DISCUSSION

Bangs' (1898) description of the insular *G. cumberlandius* was based on a small series of specimens (N = 13) collected at "Stafford Place." He distinquished it from adjacent mainland Georgia and Florida populations of *G. pinetis* on the basis of the very large size and slight pelage and cranial differences. I find that his pelage and cranial features are generally unsatisfactory to permit the distinction of *G. cumberlandius* from other populations of southeastern pocket gophers. Pelage in the *G. pinetis* complex is extremely variable and tends to be correlated with local soil color (Williams and Genoways 1980; Laerm et al., in press). Hence, it has little value in taxonomy. The results of cranial morphometry reported by Williams and Genoways (1980) and herein indicate that cranial differences between *G. cumberlandius* and mainland populations of *G. pinetis* are not sufficient to warrant species level recognition for *G. cumberlandius.*

Table 1. Results of Analysis of Covariance. V4 = condylobasilar length, loc = population, r^2 = correlation coefficient, N = sample size. Asterisks indicate significant (.05 level) figures, NS = nonsignificant figures. See text for discussion.

Males	V1	V2	V3	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17	V18	V19	V20	V21
V4	*	*	*	*	*	*	*	*	*	NS	*	*	*	NS	NS	*	NS	NS	*	*
loc.	*	*	*	NS	*	*	*	*	*	*	NS	*	*	*	*	*	*	*	*	*
r^2	.814	.500	.518	.776	.803	.986	.885	.851	.585	.276	.320	.755	.707	.700	.715	.553	.597	.837	.597	.462
N	102	100	97	102	102	105	105	105	105	105	104	95	103	105	105	96	85	82	105	105
Females	**V1**	**V2**	**V3**	**V5**	**V6**	**V7**	**V8**	**V9**	**V10**	**V11**	**V12**	**V13**	**V14**	**V15**	**V16**	**V17**	**V18**	**V19**	**V20**	**V21**
V4	*	*	*	*	*	*	*	*	*	NS	*	*	*	NS	*	*	NS	*	*	*
loc.	*	*	NS	NS	NS	NS	*	NS	*	*	*	*	*	*	*	*	*	*	*	*
r^2	.656	.384	.367	.907	.451	.981	.880	.803	.527	.303	.556	.790	.763	.338	.657	.477	.790	.594	.524	.543
N	100	100	95	104	97	97	97	101	101	101	103	92	100	100	99	81	87	81	98	98

Table 2. Intrapopulation variation in adjusted means for characters examined for *G. cumberlandius* (1) and other populations of *G. pinetis* as determined by Sheffé Test. See Figure 1 for location legend. Nonsignificant subsets derived from Scheffé Test are indicated by lines below the locality numbers and ranked adjusted means.

Characters	Males						Females					
	1	3	5	6	2	4	1	6	5	3	4	2
1. Total body length	293.68	283.95	279.94	274.87	272.37	247.11	259.67	252.67	251.66	248.71	248.06	244.02
	1	3	6	5	4	2	1	6	5	4	3	2
2. Tail length	101.31	96.75	93.81	91.79	88.46	88.09	87.06	85.90	83.39	83.07	82.54	76.37

Table 2, Continued.

Characters	Males						Females					
3. Hind foot length	1	6	3	4	2	5	6	5	3	4	2	1
	34.88	34.83	34.50	34.01	33.79	33.54	32.24	31.79	31.78	31.77	31.42	31.36
5. Zygomatic breadth	2	4	5	6	3	1	4	1	2	5	6	3
	31.52	31.31	30.95	30.72	30.65	30.30	27.02	26.89	26.76	26.75	26.71	26.57
6. Mastoid breadth	6	5	2	1	4	3	5	6	4	2	1	3
	26.97	26.54	26.39	26.26	25.98	25.95	24.25	23.88	23.81	23.59	23.58	23.38
7. Palatal length	3	4	1	2	5	6	3	4	5	2	1	6
	34.10	34.09	34.02	34.01	33.84	33.67	29.60	29.57	29.49	29.47	29.45	29.41
8. Palatal depth	5	6	4	2	1	3	4	5	6	3	2	1
	18.37	18.31	18.21	18.09	17.97	17.76	16.75	16.48	16.46	16.41	16.31	16.14
9. Rostral breadth	5	3	1	3	6	4	1	3	2	5	4	6
	11.03	10.99	10.94	11.03	10.76	10.70	9.87	9.78	9.71	9.67	9.65	9.58
10. Maxillary tooth row length	5	3	4	6	1	2	6	4	5	3	1	2
	10.25	10.20	10.13	10.09	9.86	9.80	9.74	9.65	9.61	9.55	9.39	9.15

Table 2, Continued.

Characters	Males						Females					
	1	2	3	5	4	6	2	1	3	4	5	6
11. Interorbital constriction	7.26	7.25	7.04	6.93	6.79	6.78	7.18	7.12	7.08	6.88	6.85	6.52
	4	6	1	5	2	3	4	5	6	1	3	2
12. Braincase breadth	20.65	20.39	20.24	20.08	19.87	19.80	19.64	19.31	19.18	19.08	18.95	18.81
	6	5	2	1	3	4	2	1	6	5	4	3
13. Nasal length	19.94	19.20	19.07	18.95	18.89	18.79	16.47	16.40	16.33	16.21	15.88	15.72
	3	2	1	6	5	4	3	2	1	6	4	5
14. Greatest anterior nasal breadth	5.52	5.33	5.17	5.02	5.00	4.92	4.74	4.59	4.58	4.47	4.42	4.31
	3	6	2	5	1	4	6	3	5	2	4	1
15. Midnasal breadth	2.55	2.54	2.50	2.48	2.43	2.14	2.70	2.64	2.56	2.45	2.42	2.24
	5	6	4	3	1	2	6	5	4	3	1	2
16. Greatest posterior nasal breadth	3.67	3.51	3.27	2.92	2.82	2.69	3.51	3.33	3.19	2.87	2.65	2.60
	1	5	4	6	3	2	1	3	5	4	2	6
17. Interpterygoid fossa length	5.48	5.33	5.29	5.29	5.27	5.12	5.09	4.88	4.85	4.72	4.55	4.54

Table 2, Continued.

Characters	Males						Females					
18. Auditory bulla length	3 10.22	1 10.18	2 10.12	5 10.00	6 9.98	4 9.97	3 9.57	4 9.52	2 9.48	1 9.40	6 9.39	5 9.36
19. Maxillary ramus width	1 12.41	5 12.38	3 12.33	2 12.27	6 12.24	4 12.23	10.53	10.47	10.44	10.39	10.37	10.35
20. Anterior palatal breadth	1 2.35	2 2.34	6 2.15	3 2.14	5 2.09	4 1.94	1 2.10	22 2.06	3 1.96	5 1.93	6 1.82	4 1.70
21. Posterior palatal breadth	2 4.32	3 4.06	6 3.97	1 3.97	5 3.79	4 3.75	2 4.26	6 3.92	3 3.90	1 3.83	4 3.64	5 3.59

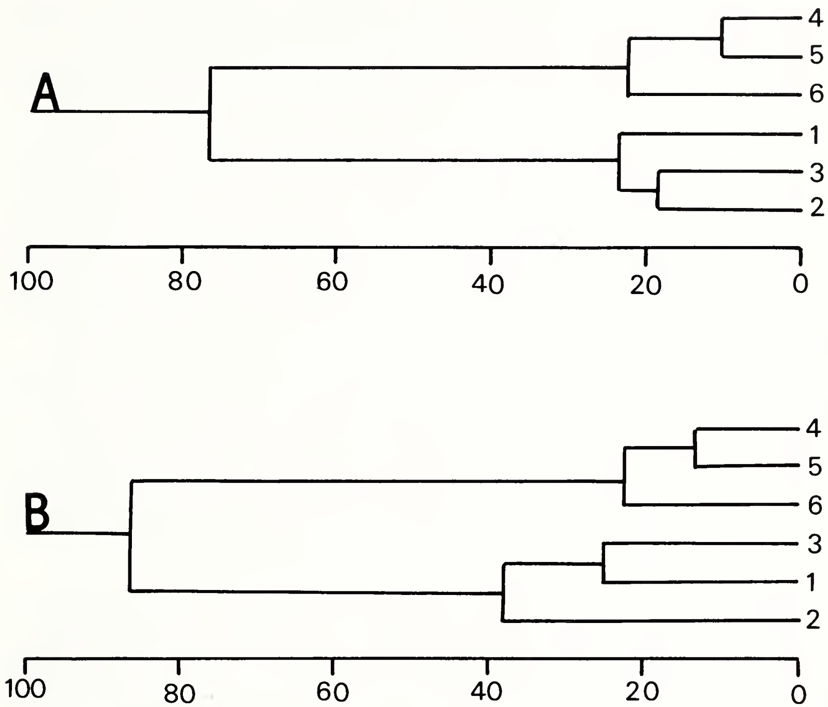

Fig. 2. Distance phenogram for males (A) and females (B). Generalized squared Euclidean distances derived from Discriminant Function Analysis of raw data. Ordinate numbers refer to population locations given in Figure 1; abscissa numbers are generalized squared distances.

The very large size of Cumberland Island gophers in comparison to mainland forms was the chief criterion for Bangs' recognition of *G. cumberlandius.* The data in Table 2 support his observation only in part, because only total length of males is seen to differ significantly in comparison to other populations. However, significant size difference between mainland and insular populations of the same species is not an uncommon phenomenon in vertebrates, particularly mammals (see Case 1978; Heaney 1978). While insular populations of rodents and other small mammals are generally larger than mainland forms, the insular populations are rarely regarded as representing distinct taxa. The large body size of Cumberland Island gophers is consistent with this general observation in other small mammals. Thus, body size alone would not be strong support for species level recognition for Cumberland Island pocket gophers.

Other indirect evidence also argues against such recognition. First, Avise et al. (1979) and Laerm et al. (in press) have shown that populations of pocket gophers throughout eastern Georgia and northeastern Florida show no detectable protein heterozygosity for 25 loci examined, and no karyological differences; based on mitochondrial DNA sequence relatedness, they share a common lineage. Second, based on archaeological evidence it is believed that Cumberland Island was connected to mainland Georgia as recently as 5000-7000 years Before Present (R. Frey, pers. comm.).

Most species and subspecies groups of Recent mammals are, at the youngest, of Pleistocene origin (Hibbard et al. 1965). Russel (1968) suggested that *G. pinetis* differentiated from *Geomys bursarius* by the Sangamon, and *G. pinetis* is recorded from Irvingtonian to Recent deposits in Florida (Webb 1974). Isolation of a population of pocket gophers on Cumberland Island for 5000-7000 years would, in general, be recognized as too short a period for speciation.

I conclude that the most parsimonious interpretation consistent with available data is that *G. cumberlandius* cannot be shown to be distinct from mainland populations of *G. pinetis*. I therefore agree with the conclusions of Williams and Genoways (1980) that pocket gophers on Cumberland Island be synonymized with adjacent mainland *G. pinetis*.

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New Records and Habitat Observations of *Hyla andersoni* Baird (Anura: Hylidae) in Chesterfield and Marlboro Counties, South Carolina

JANICE HEARD TARDELL, RICHARD C. YATES,

AND

DAVID H. SCHILLER

Carolina Power and Light Company,
Harris Energy and Environmental Center,
Route 1, Box 327, New Hill, North Carolina 27562

ABSTRACT.— Sixty-seven *Hyla andersoni* localities were found in Marlboro (56) and Chesterfield (11) counties, South Carolina in 1978 (41) and 1979 (26). Eight sites were in electrical transmission line or gas pipeline rights-of-way, fifteen in recent clearcuts, and forty-four in shrub bog habitats. *Hyla andersoni* apparently is more widely distributed in South Carolina than was previously known. There seems to be potential for maintaining or increasing suitable habitat through appropriate management techniques.

INTRODUCTION

The Pine Barrens Treefrog, *Hyla andersoni*, was described by Baird (1854) on the basis of a specimen received at the U.S. National Museum from Anderson, South Carolina. The origin of the type specimen has been questioned by several authors (Neill 1947, 1957; Wright and Wright 1949; Brown 1980). After the original South Carolina record, *H. andersoni* was not found again in the state until 1950, when specimens were collected in Chesterfield County near the town of Patrick and a population was discovered in Kershaw County (Brown 1980). A 1975 survey of the Carolina Sandhills National Wildlife Refuge in Chesterfield County found *H. andersoni* to be present at 16 localities (Garton and Sill 1979).

The breeding habitat of *H. andersoni* was described by Means and Longden (1976) as occurring where water seeps laterally from sand-capped hills, causing a sharp separation between the moisture requiring shrubby-herbaceous communities in stream bottoms and the dry, pine-oak-wiregrass communities of the hills and slopes. The plant communities developing in such seepages have been described variously as pocosins (Wells 1928), dismals (Kerr 1875), and bays or evergreen shrub bogs (Kologiski 1977). Means and Moler (1978) differentiated between adult and larval habitat of *H. andersoni*; shrub bogs constitute adult habitat and herb bogs are appropriate larval habitat. They reported that herb bogs typically occur on sandy soils upland of shrub bogs and are dominated by grasses, sedges, and forbs. Herb bogs are usually wetter on the surface than their shrub bog counterparts and are a transitional stage to shrub bogs. Apparently, *H. andersoni* populations thrive where these two habitat components occur together.

In this paper we report new information on the distribution and habitat of *H. andersoni* in Chesterfield and Marlboro counties. During the study we found the species inhabiting seepages in shrub and herb bogs, a predictable habitat, but also found it in seeps of electrical transmission line and gas pipeline rights-of-way, clearcut areas, and in a broomsedge field.

METHODS AND MATERIALS

Study Area

We discovered *Hyla andersoni* in Marlboro County during a power plant feasibility study for Carolina Power and Light Company. We then investigated its occurrence along the drainages of Whites, Wolfs, Hicks, Marks, and Phils creeks in northwestern Marlboro County and along the Juniper Creek drainage in Chesterfield County.

Most of the area investigated lies in the northern part of South Carolina's sandhill region and is located east of the dividing line between the Piedmont and Coastal Plain physiographic provinces. The dominant vegetation of the area is the longleaf pine-turkey oak-wiregrass *(Pinus palustris-Quercus laevis-Aristida stricta)* association. Loblolly pine, *P. taeda*, becomes codominant with longleaf, especially in moister areas. In the drier areas post oak, *Quercus stellata*; and black-jack oak, *Q. marilandica*; become more numerous. In several large areas south of Whites Creek the natural forests have been logged, cleared, and replaced with monocultures of slash pine, *P. elliottii*, or left to regenerate naturally. Some of these areas were in the first or second season of growth. Along the small stream basins that drain the sandhills, the vegetation is composed of "pocosin" or "evergreen shrub" species. The dominants are sweet bay, *Magnolia virginiana*; titi, *Cyrilla racemiflora*; various members of the heath family (Ericaceae); and other evergreen shrubs, along with poison sumac, *Rhus vernix*. In many places the vegetation is covered with a tangle of greenbriers, *Smilax* spp.

Methods

United States Geological Survey 7.5 minute series topographic maps were used to locate stream headwaters and intermittent streams. These and other likely areas were inspected during the day to identify appropriate habitat. We returned to the preidentified sites during the evening to listen for the call of *H. andersoni*. Voice identifications were verified by following the sounds to their source and observing calling males, whose numbers were then estimated. For our purposes, a locality where *H. andersoni* was found is one that is separated from another locality by an area where the frogs do not call. The localities were widely separated and generally were located along different tributary streams or seepages.

During 1978 we searched appropriate habitats from 11 through 22 July and from 25 through 27 July. Most effort at that time was directed at the shrub bog habitat. We began our 1979 searches in May and continued them through the summer. During this time we discovered that *H. andersoni* occurred in some clearcuts and transmission line rights-of-way, so emphasis was placed on searching for and surveying these areas. However, this did not preclude searches in the typical shrub bogs. All Marlboro County localities found in 1978 were rechecked in 1979 to investigate the continued presence of *H. andersoni*, but the Chesterfield County locations were not revisited.

RESULTS AND DISCUSSION

Locations

Hyla andersoni was first found in Marlboro County on 20 June 1978 in a shrub bog located in the headwaters of a tributary of Whites Creek. In all, 67 localities were identified in Marlboro (56) and Chesterfield (11) counties during the summer of 1978 (41) and 1979 (26) (Figure 1). The continued presence in 1979 of *H. andersoni* was verified at 24 of the 30 1978 localities in Marlboro County. At the six sites (all well-developed shrub bogs) where *H. andersoni* was not found again in 1979, the habitat was undisturbed. No human activities were evident.

Habitat

Plant species composition at most of the 67 sites was similar to that reported by Means and Moler (1978). The dominant species are listed in Table 1.

Of the 26 localities found in 1979, 8 were located along transmission line or gas pipeline rights-of-way. These areas were similar in structure to the shrub bog-herb bog habitat depicted by Means and Moler. The herb bogs developed where the actual clearing for the rights-of-way crossed a wet area, and the shrub bogs developed to both sides where canopy trees had been removed. Since the rights-of-way are periodically maintained, they would not undergo succession to a closed canopy forest that would preclude *H. andersoni*.

Fifteen of the localities found in 1979 were in clearcuts to the east of U.S. 1 and south of Whites Creek. These areas had been cut little more than a year prior to our finding *H. andersoni* in them. We do not know if the species inhabited these areas before the logging occurred, but cursory checks in 1978 did not reveal their presence. The clearcuts had herbaceous seepages surrounded by small shrubby stands at slightly higher elevations; the shrub species were typical of older shrub bogs.

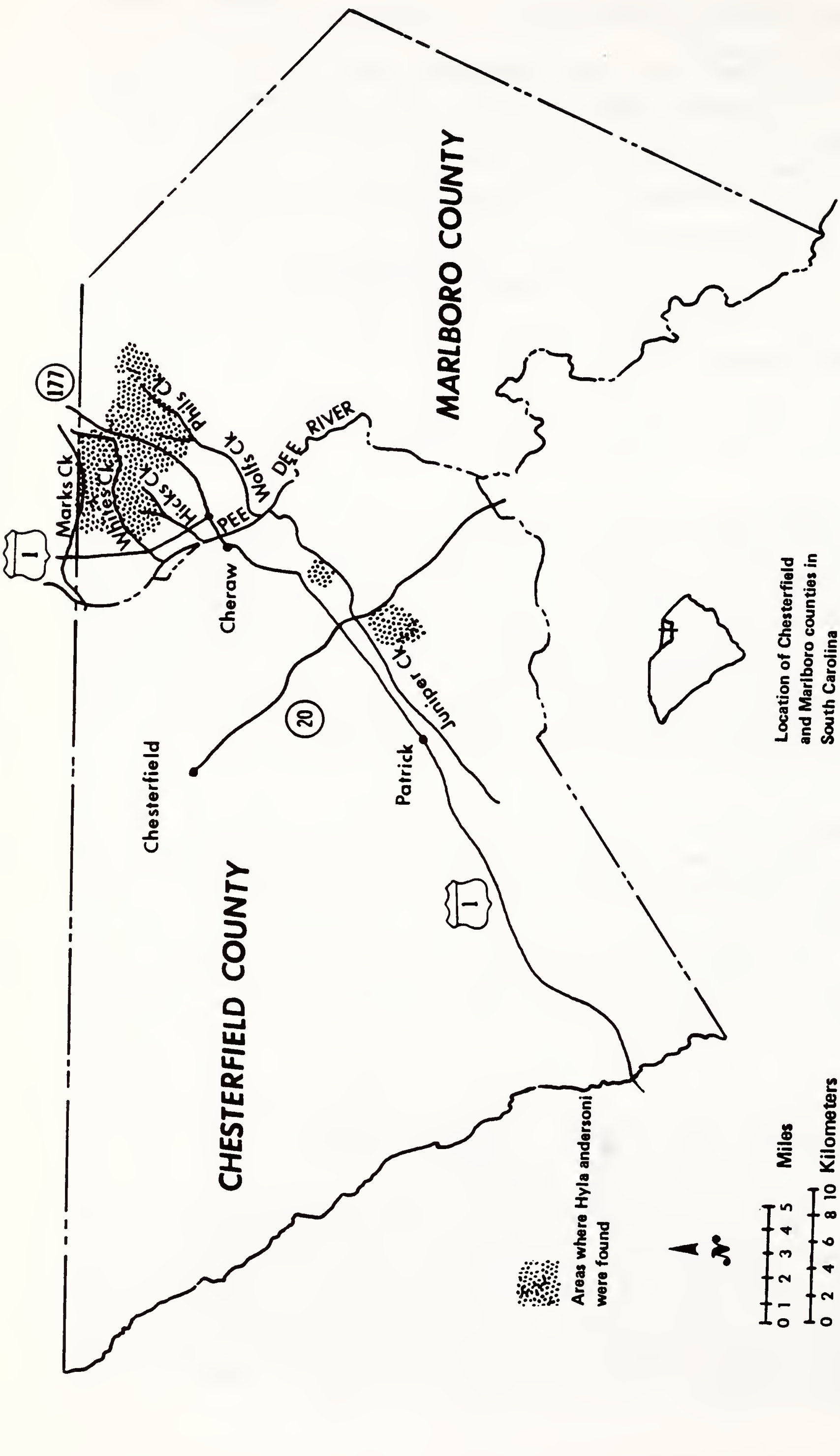

Fig. 1. Area map for *H. andersoni* localities in Marlboro and Chesterfield counties.

The herbaceous species consisted of various grasses, sedges and forbs, and in most cases *Sphagnum* spp. were present. One large clearcut had developed into a broomsedge field uncharacteristic of the other clearcuts in the area. However, it had much relief and seepage and we found *H. andersoni* at two localities there.

Table 1. Dominant plant species in herb and shrub bogs where Pine Barrens Treefrogs were found.

Clethra alnifolia, sweet pepperbush	*Osmunda cinnamomea*, cinnamon fern
Smilax laurifolia, bamboo smilax	*Cyrilla racemiflora*, titi (cyrilla)
Magnolia virginiana, sweet bay	*Sphagnum* spp., sphagnum moss
Pinus taeda, loblolly pine	*Nyssa sylvatica*, black gum
Rhus vernix, poison sumac	*Liriodendron tulipifera*, yellow poplar
Arundinaria gigantea, switch cane	*Oxydendrum arboreum*, sourwood
Rhus copallina, winged sumac	*Acer rubrum*, red maple
Persea borbonia, red bay	*Ilex coriacea*, sweet gallberry

Calling Males

In 1978 the number of calling males ranged from 1 to an estimated 100, with an estimated mean of 12 per locality. However, of the 41 localities, only 4 were estimated to have greater than 15 calling males. During 1979 the range at the 26 sites was from 1 to an estimated 25, with an estimated mean of 6 per locality.

CONCLUSIONS

Apparently *H. andersoni*, although restricted in range, is more widely distributed in South Carolina than previously known. The area we searched was only a small part of the total area of similar habitat in South Carolina, and further research may reveal the presence of *H. andersoni* in other counties where it is now unknown.

Our observations suggest that *H. andersoni* quickly colonizes areas of appropriate new habitat (clearcuts with seepages). Means and Moler (1978) reported that clearcuts constitute good *H. andersoni* habitat, as long as succession to a closed canopy is prohibited and pine monocultures are not planted. Thus, as they suggested, there seems to be a potential for maintaining, or even increasing suitable habitat for *H. andersoni* in areas where suitable soil, topography, and groundwater seepage exists. By applying habitat management practices such as prescribed burning and selective logging and clearing, it is probable that the open shrubby vegetative communities required by *H. andersoni* could be sustained where currently existing, or restored where succession has progressed beyond the favorable stage.

ACKNOWLEDGMENTS.— Many biologists at Carolina Power and Light Company participated in this study. We would like to especially thank Dr. B. J. Ward, Ms. C. W. Anderson and Mr. R. L. Corpening for their help in the field work. Our thanks also are extended to Dr. Paul Feaver and to two anonymous reviewers for their helpful comments on this manuscript.

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Observations on Some Maritime Forest Spiders of Four South Carolina Barrier Islands

L.L. Gaddy

Route 1, Box 223, Walhalla, South Carolina 29691

ABSTRACT.— Quantitative observations on the seasonal abundance of 22 species of araneid orb weavers and general observations on five non-orb weaver species were made on four South Carolina barrier islands. Data collected along transects revealed that 5 of 22 orb weaver species matured in spring, 8 in early summer, 7 in late summer, and 2 in autumn. The greatest number of mature individuals of all orb weaver species was found in early summer, but the greatest number of species matured in late summer. *Araneus bicentenarius*, thought to be rare, was found on all four islands.

INTRODUCTION

The spider fauna of the outer coastal plain of the Carolinas is relatively unknown. Barnes (1953) and Barnes and Barnes (1954) studied the ecology and species composition of spider communities in non-forested maritime communities near Beaufort, North Carolina but did not deal with the maritime forest. Berry (1971) discussed the seasonal distribution of many of the species found on barrier islands, but his field work was done in the Piedmont of North Carolina, an area climatically different from the barrier islands of South Carolina.

Maritime forest is the dominant vegetation cover type on the barrier islands of South Carolina, where live oak, *Quercus virginiana;* laurel oak, *Quercus laurifolia;* palmetto, *Sabal palmetto;* southern magnolia, *Magnolia grandiflora;* and various pines (notably *Pinus taeda* and *Pinus elliottii*) dominate the canopy. Red bay, *Persea borbonia;* yaupon holly, *Ilex vomitoria;* American holly, *Ilex opaca;* and palmetto are the most commonly encountered species in the understory and shrub layers. The canopy and understory are extremely dense, with nearly 100 percent coverage; the shrub layer's average coverage, on the other hand, is low, varying from 10 to 50 percent. The coverage in the herbaceous layer is usually less than 10 percent.

From February to November 1979, monthly observations and collections were made along transects on each of four South Carolina barrier islands—Bulls, Kiawah, Capers, and Hunting islands. These transects, which averaged approximately one kilometer long, were walked at least once a month between the hours of 0800 and 1700. All orb webs and retreats between ground level and 2.7 meters high were checked for adult spiders. The total number of individuals of each sex was recorded.

The data here are based primarily on field identification. Because of the large number of spiders handled, only taxonomically difficult species and representative specimens of common species were collected. Voucher specimens are in the author's personal collection. General notes were taken on the presence of non-araneid orb weavers and non-orb weavers.

RESULTS AND DISCUSSION

Twenty-two species of araneids were found on the four islands. Table 1 lists the number of adults recorded per transect in winter (February), spring (March and April), early summer (May and June), late summer (July and August), and autumn (September and October). No perceptible differences in population or species number were found among the four islands. Most species, however, did exhibit some degree of seasonality, as seen in Table 1.

Of the 22 araneid species, the genus *Araneus* was represented by 4 species, *Mangora* by 3, and *Neoscona, Micrathena,* and *Argiope* by 2 species each. As seen in Table 1, only *Araneus pegnia* was found to be in the adult stage in winter. *Araneus miniatus,* another small *Araneus,* was observed in the spring, along with additional *A. pegnia. Araneus pratensis,* the third small *Araneus* found on the islands, occurred in forest openings only in late summer.

The spring dominants were *Mangora placida* and *Acanthepeira* spp. (Because of the difficulties of field identification of the large number of *Acanthepeira* individuals encountered, these spiders were identified only to genus.) *Mangora maculata* and *M. gibberosa* did not mature until early summer, confirming the observations of Berry (1971). The third most frequent species found mature in the spring was *Araneus bicentenarius.* Levi (1971) thought this species rare in North America, but its giant webs were seen frequently from early March through May on the four islands studied. One individual seen in March was over 20 mm long, possibly having overwintered as an adult (however, no subadults were seen on the transects in February). The retreat of *A. bicentenarius* was usually made in Spanish moss, *Tillandsia usneoides,* on the four study islands.

In early summer, *Acanthepeira* individuals became the dominant adults, reaching a peak in early June. *Neoscona arabesca* matured in early June and continued to be common into October. *Leucage venusta* individuals were common from late May to July. *Argiope trifasciata* peaked in abundance in late summer in shrubby areas. In late July, females of *Nephila clavipes* were undergoing their final molt with males beginning to appear in their webs. Mating frequently took place during the final molt while the female hung defenseless in her web (see Robinson and Robinson 1973, 1976). *Nephila,* however, did not become the most abundant spider until August. In late summer and autumn, *Neoscona domiciliorum* began to appear in the wetter areas of the maritime

Table 1. Frequency (number of adults per transect) of orb weavers on four South Carolina barrier islands.

Species	Feb.	Mar.-Apr.	May-June	July-Aug.	Sept.-Oct.
Araneus pegnia	.3	.5			
Araneus miniatus		.5			
Araneus bicentenarius		3.5	3.0		
Cyclosa sp.		.2	.5		
Acanthepeira spp.		7.1	20.5	2.0	
Mangora placida		7.9		.2	
Eustala anastera		.5		.2	
Leucage venusta		.8	5.5	4.7	1.0
Mangora maculata			1.0		
Mecynogea lemniscata			.5		
Micrathena gracilis			1.0	.7	
Micrathena sagittata			.5	1.2	
Mangora gibberosa			.5	.3	
Neoscona arabesca			18.5	6.5	2.0
Argiope trifasciata			2.0	4.5	2.0
Araneus pratensis				.3	
Gasteracantha cancriformis				.7	
Gea heptagon				.2	
Acacesia hamata				.2	
Nephila clavipes				13.7	31.5
Argiope aurantia				.2	.1
Neoscona domiciliorum				.3	2.0
Totals	.3	21.2	57.5	31.4	43.0

forests. By this time, *Nephila clavipes* was the overwhelmingly dominant species (see Table 1).

The spiny-bodied orb weavers, *Micrathena gracilis, Micrathena sagittata,* and *Gasteracantha cancriformis,* were not as common in the maritime forest as they are on the adjacent mainland. It must be pointed out, however, that *G. cancriformis* was more common than Table 1 indicates, being frequently seen in its web above 2.7 meters (spiders in webs more than 2.7 meters above the ground were not counted due to the difficulty of collecting and identifying these individuals).

Nephila clavipes, Acanthepeira spp., and *Neoscona arabesca* were the most numerous of the 22 orb weaver species. More orb weaver individuals matured in early summer; however, more species of orb weavers matured in late summer (see Table 1). The autumn totals in Table 1 are artificially high because of the large number of *Nephila clavipes,* a visually and numerically dominant species.

General observations on non-orb weavers indicate that *Latrodectus mactans* is common under debris in dunes dominated by sea oats, *Uniola paniculata.* Large males (7 mm body length) of *L. mactans* were found in the maritime forest. Three species of the inquilinous *Argyrodes* were found on the four islands: *Argyrodes fictilium* (Hentz) [=*Rhomphaea lacerta* (Walckenaer)], *Argyrodes furcatus* (O.P.-Cambridge), and *Argyrodes nephilae* Taczanowski. *Argyrodes nephilae* was found in the webs of *Acanthepeira* spp. and *Tidarren sisyphoides,* as well as those of *Nephila clavipes.*

Carico (1973) noted that the genus *Dolomedes* was absent from "most islands off the coast of the southeastern United States," salt water being a barrier to their dispersal. However, during my study *Dolomedes triton* (Walckenaer) was found in a freshwater wetland less than 50 m from the beach front.

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Foods of Two Species of *Plethodon* (Caudata: Plethodontidae) from Georgia and Alabama

CARLOS D. CAMP

Department of Zoology, University of Georgia, Athens, Georgia 30602

AND

LUKE L. BOZEMAN

Department of Zoology-Entomology, Auburn University, Auburn, Alabama 36830

ABSTRACT.— The stomachs of 34 *Plethodon websteri* and 55 *P. serratus* from Georgia and Alabama were examined for food. Acarines and Collembola were major food items in stomachs of smaller *P. websteri* whereas ants were predominant in the stomachs of larger individuals. Ants were the dominant food item in the stomachs of *P. serratus*.

Very little is known concerning the ecology of the Southern Redback Salamander, *Plethodon serratus* Grobman, which was recently taxonomically separated from the Redback Salamander, *Plethodon cinereus* (Highton and Webster 1976). Several reports exist on the foods of *P. cinereus* (Blanchard 1928; Hamilton 1932; Jameson 1944; Jaeger 1972; Caldwell and Jones 1973; Fraser 1976), but the only report concerning the prey of *P. serratus* is a single statement by Johnson (1977) that it feeds on arthropods. The foods of the recently described Webster's Salamander, *Plethodon websteri* Highton (formerly considered *Plethodon dorsalis*), have also not been reported, although Holman (1955) discussed the foods of *P. dorsalis* in Indiana. We present here an account of the foods of *P. serratus* and *P. websteri* in Georgia and Alabama.

Fifty-five *P. serratus* were collected from Fulton and Harris counties, Georgia, during March and April of 1980. During the same period, 34 *P. websteri* were collected from Upson County, Georgia, and Lee County, Alabama. Specimens were sacrificed in the field in chloretone and preserved in 10% formalin to terminate digestion. In the laboratory, stomach contents were placed in a petri dish lined with a paper grid (2.5 mm x 2.5 mm) and examined under a dissecting microscope. In order to determine relative prey proportion in the diet, visual estimates of relative area occupied by prey items were made by comparing each prey item to the grid and estimating the number of grid squares it occupied. Snout-vent length (SVL) was recorded for each specimen. The foods of different size classes were compared when appropriate.

Nineteen specimens of *P. websteri* had SVLs of 22-27 mm; the remaining 15 specimens each has a SVL greater than 30 mm. Smaller

Table 1. Stomach contents of 19 small and 15 large *P. websteri* and 55 *P. serratus* from Georgia and Alabama. N = number of prey items; % st = percent of stomachs in which prey item was found; % area = percent of total area occupied by prey items on grid.

	P. websteri 22-27 mm SVL			*P. websteri* >30 mm SVL			*P. serratus*		
Prey Item	N	%st	%area	N	%st	%area	N	%st	%area
Gastropoda	3	10.5	2.2	3	13.3	3.2	3	5.5	0.8
Annelida	3	10.5	6.7				1	1.8	3.2
Arachnida									
Acarina (mites)	176	89.5	40.1	82	80.0	12.4	110	60.0	4.0
Araneae	3	15.8	1.0	3	20.0	3.2	28	34.5	3.8
Pseudoscorpionida	1	5.3	1.0	2	13.3	1.5			
Chilopoda	2	10.5	3.2	1	6.7	1.4	4	5.5	2.3
Diplopoda							7	12.7	1.6
Isopoda	1	5.3	2.0				39	10.9	8.6
Insecta									
Collembola	52	42.1	24.3	5	20.0	0.7	146	50.9	4.3
Thysanura							2	3.6	0.7
Isoptera				38	13.3	24.4	24	7.2	3.8
Diptera				1	6.7	2.9	11	12.7	3.8
Lepidoptera				1	6.7	1.8	3	5.5	1.9
Orthoptera							2	1.8	0.1
Thysanoptura	1	5.2	0.3	1	6.7	0.1			
Hemiptera							1	1.8	0.1
Coleoptera	8	26.3	5.9	5	33.3	7.7	50	47.3	19.0
Hymenoptera									
Ants	8	36.8	7.2	51	60.0	32.4	270	63.6	32.6
Wasps				2	13.3	3.3			
Unidentified larvae	15	10.5	6.0	2	6.7	5.0	39	16.4	7.8
Unidentified adults							14	3.6	1.4

individuals differed noticeably from larger ones in prey selected (Table 1). Acarines (mites) were the dominant prey in the stomachs of small *P. websteri*, both in numbers and percent area. Their next most important food item was Collembola (springtails). Acarines were frequently encountered in the stomachs of the larger *P. websteri* but did not contribute much to percent area. Ants, however, were important in their diet. Isoptera (termites) were important in both area and numbers in larger *P. websteri*; however, they were not preyed upon frequently as shown by the low percentage of stomachs containing them. These results show that larger salamanders feed on larger prey (e.g., ants and termites), and smaller salamanders feed on smaller prey (e.g., springtails and mites).

Only one *P. serratus* had a SVL less than 30 mm, the remaining 54 being comparable in size to the larger *P. websteri*. Therefore, the food data for *P. serratus* are not reported for separate size groups. Ants were the most important prey of *P. serratus* in area and total numbers. Acarines were common in the stomachs but contributed little to percent area. Beetles, spiders, and isopods also were frequently eaten by this species.

Most of the apparent differences in feeding between the two species of salamanders can be attributed to the large number of smaller *P. websteri* in the samples and the predominance of larger specimens in the *P. serratus* samples. Although the foods of both species appear to be similar, further work is needed on the feeding as well as other aspects of the ecology of these salamanders before conclusions can be drawn concerning their respective feeding strategies.

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