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Aspects of the Feeding Ecology of the Little Grass Frog, *Pseudacris ocularis* (Anura: Hylidae)

JEREMY L. MARSHALL[1] and CARLOS D. CAMP
Department of Biology, Piedmont College
Demorest, Georgia 30535

ABSTRACT—We report on the foods of the little grass frog, *Pseudacris ocularis*, from Georgia. Fifty specimens were collected from two isolated wetlands located in Evans and Grady counties, Georgia, during late spring and summer 1993. Analysis of stomach contents determined that the most abundant food items were small arthropods associated with leaf litter and soil. Almost 50% of the food items were collembolans, followed by hymenopterans (17%), acarines (9%), homopterans (8%), and coleopterans (8%). We compared foods of adult males with those of newly metamorphosed juveniles collected at the same time from the Grady County site. Juvenile frogs ate more individual food items and a greater diversity of prey species than did adult males. This difference could be due to adult *Pseudacris* selecting larger, more profitable prey than juveniles select. Lower feeding activity exhibited by breeding males might also be a contributing factor.

Little is known about the feeding ecology of many amphibians, especially intraspecific variability in foods and foraging (Duellman and Trueb 1986). Variation in dietary preferences among population subgroups (e.g., breeding males, non-breeding females, subadults, juveniles, larvae, etc.) has been reported to reflect differences in habitat preference (Lamb 1984), gape (Toft 1980), developmental condition (Brophy 1980, Davic 1991), and other factors.

The little grass frog, *Pseudacris ocularis* (Bosc and Daudin), is the smallest North American anuran (Conant and Collins 1991). It occurs in a wide variety of ephemeral and semi-permanent wetlands in the southeastern Coastal Plain and favors grassy areas in and around cypress ponds and similar sites (Harper 1939, Mount 1975). In spite of its relative abundance in many of these areas, virtually nothing is known of the feeding ecology of this frog. The purpose of our study was to describe the diet of *P. ocularis* and to investigate any potential differences between the feeding of adult frogs and newly metamorphosed juveniles.

[1] Present address: Biology Department, University of Mississippi, University, Mississippi 38677.

MATERIALS AND METHODS

We collected 50 *P. ocularis* for stomach analysis from two localities during May–July 1993. Both sites were ephemeral wetlands in the lower Coastal Plain of Georgia. The first site, located in Grady County, was dominated by black gum (*Nyssa sylvatica*) and was situated in a low pine flatwood having a canopy of slash pine (*Pinus elliottii*) and an understory of saw palmetto (*Serenoa repens*) and gallberry (*Ilex glabra*). The second, in Evans County, was a dome of pond cypress (*Taxodium ascendens*) surrounded by sandhills dominated by longleaf pine (*P. palustris*) and turkey oak (*Quercus laevis*). Areas similar to both sites were described in detail by Wharton (1978).

After collection, all specimens were preserved in 10% formalin, and stored in 35% isopropanol. Each frog was measured for snout-vent length (SVL) and dissected for stomach analysis. Individual food items were counted and identified. Because prey items were too small to use volumetric displacement, relative importance of prey was determined by comparing each individual prey item to a paper grid and visually estimating the number of grid squares occupied (Camp and Bozeman 1981).

Twenty of the Grady County frogs were collected between 2200 and 2400 EDT on 5 June. This sample consisted of 10 mature males and 10 juveniles that had just completed metamorphosis. We used this sample to make comparisons between feeding of adults and juveniles. Because we did not independently test for prey availability, other collections were not used for comparisons because of possible complications arising from temporal or between-site differences in available prey items. In addition, although adult females were included in these samples, small numbers (n = 4) precluded between-sex comparisons. Correlation between the number of prey items eaten and body size was tested using the procedure described by Zar (1984). A comparison of diversity between adult male and juvenile prey species was made using the Shannon-Wiener Index of Diversity (H') (Zar 1984).

RESULTS

One hundred-forty individual prey items were identified and consisted entirely of arthropods, mainly insects (Table 1). Springtails (Collembola) were the most numerous group, making up 47% of the food items eaten and found in 56% of the stomachs. Because they are so small, however, they contributed less than 20% of the area occupied by all prey items. Hymenopterans, especially ants (Formicidae)

Table 1. Stomach contents of 50 *Pseudacris ocularis* from the Coastal Plain of Georgia. Unless otherwise indicated, the smallest taxon in each order is represented by a single species; "i" repreesnts immature instars. Numbers (*n*) for higher taxa also include unidentified food items.

Food Item	(*n*)	Percentage of Total Number	Percentage of Total Area	% Frequency
INSECTA	122	87.1	90.1	82.0
Collembola	66	47.1	19.5	56.0
Isotomidae	26	18.6	5.6	20.0
Poduridae	2	1.4	0.5	4.0
Sminthuridae	37	26.4	13.4	26.0
Coleoptera	11	7.9	9.2	18.0
Carabidae	1	0.7	1.6	2.0
Cleridae	1	0.7	0.3	2.0
Coccinellidae	1	0.7	1.1	2.0
Staphylinidae (3)	5	3.6	4.3	6.0
larvae	1	0.7	0.4	2.0
Dictyoptera	2	1.4	19.1	2.0
Blattidae	2	1.4	19.1	2.0
Diptera (larvae) (3)	3	2.1	1.2	6.0
Homoptera	11	7.9	11.1	16.0
Delphacidae (i)	10	7.1	10.9	14.0
Hymenoptera	24	17.1	14.6	32.0
Diapriidae	1	0.7	2.2	2.0
Dryinidae	1	0.7	0.8	2.0
Encyrtidae	1	0.7	0.1	2.0
Evaniidae	2	1.4	6.4	2.0
Formicidae	7	5.0	1.2	6.0
Scelionidae	7	5.0	1.9	6.0
Orthoptera	2	1.4	4.8	4.0
Acrididae (i)	2	1.4	4.8	4.0
Phasmida	1	0.7	9.6	2.0
Phasmatidae	1	0.7	9.6	2.0
Siphonaptera	1	0.7	0.1	2.0
Thysanoptera	1	0.7	0.1	2.0
Phlaeothripidae	1	0.7	0.1	2.0
ARACHNIDA	18	12.9	9.9	22.0
ACARINA	13	9.3	5.5	16.0
Mesostismata	1	0.7	0.1	2.0
Oribatei (2)	12	8.6	5.4	14.0
Araneida	4	2.9	4.2	6.0
Anyphaenidae	1	0.7	1.6	2.0
Palpigradi	1	0.7	0.2	2.0

and parasitic wasps (Scelionidae), were the second most important group, making up 17% numerically and occurring in 32% of the stomachs. Hymenopterans made up 15% of the relative area. Other important insect groups represented were coleopterans, particularly rove beetles (Staphylinidae), making up 8% of numbers, 9% of area, and occurring in 19% of the stomachs, and delphacid homopterans (7, 11, and 14%, respectively). Although found only occasionally, relatively large roaches (Dictyoptera) and walking sticks (Phasmida) made up a considerable amount of the total quantity of food eaten (19 and 10% of total area, respectively). The only non-insect food items found were arachnids. These consisted primarily of mites (Acarina), which made up 9% numerically, 6% of the area, and occurred in 16% of stomachs.

Juvenile frogs from the 5 June, Grady County sample had a mean SVL of 8.80 mm with a standard error (SE) of 0.21 mm. Adult males from this sample had a mean SVL of 14.87 mm and a SE of 0.23 mm. Food items eaten by these frogs are shown in Table 2. The Shannon-Wiener Index for juvenile prey species diversity ($H' = 1.062$) was significantly larger than that for adults ($H' = 0.739$; $t = 3.27$, df = 45, $P < 0.01$). There was a negative correlation between number of food items eaten and frog size ($r^2 = 0.25$, $t = 2.18$, df = 14, $P < 0.05$).

DISCUSSION

Pseudacris ocularis is commonly found on lower tree trunks and foliage up to a height of 1 m or more (Harper 1939); males prefer these sites as calling perches (Harper 1939, Mount 1975). However, the majority of food items we found were arthropods that are associated with leaf litter and/or soil (e.g., springtails, mites, dipteran larvae, staphylinids, ants, thrips, palpigrades, etc.). In addition, we found a large number of frogs on the ground, particularly during daytime collections. It is apparent, then, that *P. ocularis* spends a considerable amount of its foraging time on the ground.

According to optimal foraging theory (Pyke et al. 1977, Krebs 1978), a predator should choose prey that represent the greatest net energy gain and forage in areas where profitable prey are most frequently encountered. Considering the small size of these frogs, small abundant leaf litter arthropods such as springtails and mites might represent a relatively stable, predictable source of profitable prey. However, amphibians might find larger arthropod prey to be more profitable than small ones due to a proportionately smaller exoskeleton (Jaeger and Barnard 1981). Therefore, little grass frogs should

Table 2.Stomach contents of 10 juvenile and 10 adult *P. ocularis* collected 5 June 1993, Grady County, Georgia; "i" represents immature instars; * indicates two species represented. Numbers for higher taxa also include unidentified food items.

	Juveniles		Adults	
Food Item	*n*	%	*n*	%
Collembola	9	27.3	10	45.5
Isotomidae	4	12.1	9	40.9
Sminthuridae	4	12.1	1	4.5
Coleoptera	2	6.1	2	9.1
Carabidae	1	3.0	0	0.0
Cleridae	1	3.0	0	0.0
Staphylinidae	0	0.0	2*	9.1
Diptera (larvae)	1	3.0	1	4.5
Homoptera	3	9.1	5	22.7
Delphacidae (i)	2	6.1	5	22.7
Hymenoptera	5	15.2	1	4.5
Formicidae	0	0.0	1	4.5
Scelionidae	4	12.1	0	0.0
Orthoptera	0	0.0	2	9.1
Acrididae (1)			2	9.1
Siphonaptera	1	3.0	0	0.0
Thysanoptera	1	3.0	0	0.0
Phlaeothripidae	1	3.0		
Acarina	9	27.3	0	0.0
Meostigmata	1	3.0		
Oribatei	8*	24.2		
Araneida	1	3.0	1	4.5
Anyphaenidae	0	0.0	1	4.5
Palpigradi	1	3.0	0	0.0

feed more on larger prey when available. Our data would, in part, appear to confirm this hypothesis. For instance, relatively large immature delphacids made up < 7% of total food items. However, in the 5 June, Grady County sample of adults (Table 2), delphacids made up 23%, indicating these food items were probably more available at that time, although we do not have independent confirmation of prey abundance.

Newly metamorphosed *P. ocularis* ate more individual food items and a greater diversity of prey species than did adult males. Two factors may explain these results. First, there may be an ontogenetic shift in foraging strategy during post-metamorphic growth of *P. ocularis*. Such a shift has been inferred in *P. triseriata* (Christian 1982) where adults select more optimal (i.e., large) prey than do juveniles, which indiscriminately feed on prey they encounter. This may be the result of larger animals being able to choose from a greater range of prey sizes, whereas smaller individuals are largely restricted to small prey, as is apparent in *P. crucifer* (Oplinger 1967). This shift would account for the lower diversity of prey species taken by adult *P. ocularis*. Second, the adult sample used in our comparisons consisted entirely of males. Several authors have reported a sharp decline in feeding activity by adult male frogs during the breeding season (Jenssen and Klimstra 1966, Lamb 1984). The males in our study were not breeding (the pond was completely dry) and only sporadically calling at the time of collection (5 June), although breeding had been previously observed at this site in March. Mount (1975), however, reported breeding congregations of *P. ocularis* as late as 29 July in nearby Houston County, Alabama, and Harper (1939) recorded vigorous chorusing in the Okefenokee during August and September. Therefore, since *P. ocularis* does breed throughout the summer, we cannot rule out the possibility of lower feeding activity in adult males during the time of our collections.

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Corrections of Records of Occurrence of *Peromyscus polionotus* (Wagner) and *P. gossypinus* (LeConte) (Rodentia: Muridae) in the Blue Ridge Province of Georgia

JOSHUA LAERM AND JAMES L. BOONE
Museum of Natural History and Institute of Ecology
University of Georgia, Athens 30602

ABSTRACT—Reexamination of marginal records of *Peromyscus polionotus* and *P. gossypinus* previously reported from the Blue Ridge Province of Georgia indicate specimens were misidentified. Neither species occurs in the Blue Ridge Province. The distribution of *P. polionotus* is restricted to south of a line from Greenville and Spartanburg counties, South Carolina, southeast to Clarke, County, Georgia and west to Dawson and Cherokee counties, Georgia. The distributional limit of *P. gossypinus* is south of a line from Lincoln and Wilkes counties, Georgia west to Dekalb and Fulton counties and then west and north to Polk, Floyd, and Dade counties.

Mice of the genus *Peromyscus* Gloger are among the most common and broadly studied small mammals in North America. Yet they are often difficult to distinguish on the basis of traditional morphological features, and consequently limits to their distribution are difficult to delineate. This is particularly true within Osgood's (1909) *P. leucopus* and *P. maniculatus* species groups (Hooper 1968, Laerm and Boone 1994). Frequently biologists depend upon range maps to rule out certain species; nevertheless, the correct identification of a taxon should be based upon morphological characteristics.

Numerous regional studies have been undertaken to provide mensural discrimination between species of *Peromyscus* (Choate 1973, Linzey et al. 1976, Choate et al. 1979, Stromberg 1979, Engstrom et al. 1982, Feldhamer et al. 1983, McDaniel et al. 1983). Laerm and Boone (1994) recently used discriminant analysis to maximally distinguish between the four *Peromyscus* species that occur in the southeastern United States: *P. gossypinus*, *leucopus*, *maniculatus*, and *polionotus*. Based upon reexamination and correct identification of specimens representing marginal records of *P. gossypinus* and *P. polionotus* with this discriminant analysis model, we questioned the accuracy of existing range maps and marginal records for *P. polionotus* (Wagner) and *P. gossypinus* (LeConte).

Peromyscus polionotus—A black-eyed, white *Peromyscus* was reported from Tallulah Falls, Rabun County, Georgia by Dice (1934:246) who identified the specimen as *P. polionotus polionotus*. This specimen was noteworthy because the pelage was entirely white, and the feet, toes, and nails lacked any pigment. However, as Dice noted, the eyes, eye-ring, and outer parts of the ears were dark. Tallulah Falls, in the Tallulah River Gorge, is at the southern edge of the Blue Ridge Province in Georgia. While not specifically indicated by Dice, this would have been the northernmost record of the species, from a locality well outside the previously described range (Osgood 1909) and in habitat from which the species had never been reported. Typically, *P. polionotus* is restricted to sandy soils and does not occur north of the middle Piedmont of Georgia.

Schwartz (1954) revised the *Peromyscus polionotus* complex and described several new subspecies. He provided external and cranial measurements of the six subspecies of *polionotus* he recognized and referred populations of *polionotus* in the northern portion of Georgia and South Carolina (essentially north of the Fall Line) to *P. p. colemani*. Schwartz (1954:568) commented on the Dice specimen which he ". . . presumed, on geographical grounds, to be assignable to *P. p. colemani*." Had Schwartz actually examined the Dice specimen, he probably would not have referred it to *P. polionotus*. However, Schwartz did not include the specimen in his mensural analysis. Thus, following Dice (1934) and Schwartz (1954), Hall and Kelson (1959), Golley (1962), and Hall (1981) continued to include the specimen as a marginal record for the species.

We questioned the identification of the Dice specimen because (1) it was collected in quartzite sheer rock walls and talus of the Tallulah River Gorge in the Blue Ridge Province and (2) at a locality some 100 km north of any other specimen record. We compared our measurements of the Dice specimen (University of Michigan Museum of Zoology 68496) to measurements provided by Schwartz (1954) for *P. p. colemani* and subjected it to our discriminant function (Laerm and Boone 1994). For 8 of the 11 characters examined by Schwartz (1954:565), the Dice specimen was larger than the range of the comparable measurements made on 11 *P. p. colemani* by Schwartz.

Visual comparison of means and ranges of measurements of 110 *P. polionotus* and 107 *P. leucopus,* which were used to develop a discriminant function for mensural discrimination between these and other southeastern *Peromyscus* spp. (measurements provided in Laerm and Boone 1994), to the Dice specimen indicates that it generally falls inside the range of measurements available for both *polionotus* and *leucopus*. Our discriminant analysis, however, strongly suggest the Dice specimen to be *P. leucopus* (P = 0.939).

Concern over the correct identification of other northern marginal range records of *P. polionotus* in Georgia, South Carolina, and Alabama (see Schwartz 1954, Golley 1966, Wolfe and Rogers 1969, Hall 1981) prompted an examination of these specimens as well. We are satisfied that specimens reported from Jackson County, in extreme northeastern Alabama (Schwartz 1954, Hall and Kelson 1959, Hall 1981) are *P. polionotus*. Similarly, specimens from Greenville and Spartanburg counties South Carolina referred to by Schwartz (1954), Golley (1966), and Hall (1981) are correctly identified as *P. polionotus*.

Review of currently available distributional records for *P. polionotus* in Georgia now indicates the northernmost limit of its range should be amended to extend from Spartanburg and Greenville counties, South Carolina, southwest to Clarke County, Georgia, and west to Dawson and Cherokee counties, Georgia. Unfortunately, there are no records available for the Ridge and Valley or Cumberland Plateau provinces of Georgia west of Dawson and Cherokee counties (Fig. 1). The next records to the northwest are in Jackson County, Alabama (Hall 1981).

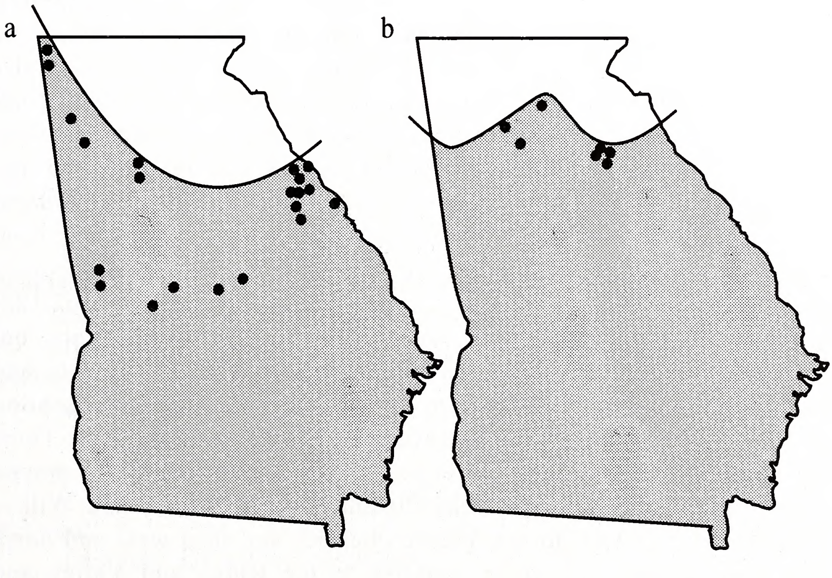

Fig. 1 Distribution of *Peromyscus gossypinus* (a) and *P. polionotus* (b) in Georgia. Dots represent northernmost distributional records only.

Peromyscus gossypinus—Hall and Kelson (1959), apparently following Osgood (1909), indicated the range of *P. gossypinus* in Georgia to be restricted to the Coastal Plain. At that time no specimens were known from the Piedmont, Blue Ridge, Ridge and Valley, or Cumberland Plateau provinces. Golley (1962) published new distributional records for Georgia and indicated (Golley 1962:124) specimens occurring in the southeastern portion of the Piedmont (including Columbia, Lincoln, McDuffie, and Wilkes counties), Ridge and Valley (Floyd, Gordon, and Polk counties), Cumberland Plateau (Dade County), extreme upper Piedmont (Habesham County) as well as the Blue Ridge Province (Rabun County). Subsequently, Wolfe and Linzey (1977) mapped the distribution of the species, apparently following Hall and Kelson (1959). Wolfe and Linzey (1977) do not cite Golley (1962); however, Hall (1981) does cite the Golley (1962) records and maps them accordingly, indicating their range extends into the extreme northeastern Piedmont and Blue Ridge provinces.

We used our discriminant function to examine virtually all *P. gossypinus* records from Georgia. Specimens from Dade County on the Cumberland Plateau and those from Floyd and Polk counties in the Ridge and Valley are *P. gossypinus* as noted by Golley (1962). We were unable to locate any museum specimens referred to by Golley (1962) from Habersham or Rabun counties either in University of Georgia Museum of Natural History collections or those of all other North American mammal collections housing specimens from Georgia. Examination of skin tags and records has not indicated any *P. gossypinus* from those counties to have been re-identified and/or relabeled. We are confident that the specimens of *P. gossypinus* from Ruban and Habersham counties in Golley (1962) were erroneously mapped because, in his verbal description of the range, Golley (1962:128) indicated *P. gossypinus* to be found ". . . on the coastal plain, but extending into the Piedmont on the eastern margin of the state and into the ridge and valley province on the west." He makes no mention of any records in the extreme northern Piedmont or Blue Ridge. Thus, the range of *P. gossypinus* in Georgia should be amended to extend across the middle portion of the Piedmont from Lincoln and Wilkes counties west to Dekalb and Fulton counties and then west and north into Polk, Floyd, and Dade counties in the Ridge and Valley and Cumberland Plateau (Fig. 1). This is essentially the range as previously depicted by Hall and Kelson (1959) and Wolfe and Linzey (1977).

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The Masked Shrew, *Sorex cinereus* (Insectivora: Soricidae), and Red-backed Vole, *Clethrionomys gapperi* (Rodentia: Muridae), in the Blue Ridge Province of South Carolina

JOSHUA LAERM
Museum of Natural History and Institute of Ecology
University of Georgia, Athens, Georgia 30602

ERIC BROWN, MICHAEL A. MENZEL
Daniel B. Warnell School of Forest Resources
University of Georgia, Athens, Georgia 30602

AMANDA WOTJALIK
Museum of Natural History
University of Georgia, Athens, Georgia 30602

WILLIAM MARK FORD
Daniel B. Warnell School of Forest Resources
University of Georgia, Athens, Georgia 30602

AND

MARY STRAYER
Nongame and Heritage Trust Program,
South Carolina Wildlife and Marine Resources Department
P.O. Box 1806, Clemson, South Carolina 29633

ABSTRACT—The first records of *Sorex cinereus* Kerr are documented from South Carolina. Pitfall surveys throughout the Blue Ridge Province resulted in captures from two localities in markedly mesic, relict, boreal habitats. Additional records of *Clethironomys gapperi* (Vigors) were documented including the most southeastern record. Both *S. cinereus* and *C. gapperi* are rare in South Carolina, largely because of limited areas of appropriate habitats.

The masked shrew, *Sorex cinereus* Kerr, has the largest range and exhibits the greatest geographic variation of any North American *Sorex* (Hall 1981, Junge and Hoffmann 1981, van Zyll de Jong and Kirkland 1989). It ranges throughout the transcontinental coniferous forests from the Canadian Arctic south to the extreme northern portions of the United States with significant extensions south into the montane forests of the Rocky and Appalachian mountains. In the southeastern United States including Virginia and West Virginia, eastern Kentucky and Tennessee, North Carolina and Georgia, *S. cinereus* is restricted primarily to high elevation montane communities of the Appalachian Highlands (van Zyll de Jong and Kirkland 1989). To date, however, there have been no records from South Carolina (Golley 1966, Mengak et al. 1987).

Previously, the southernmost records of *S. cinereus* have been reported from Georgia based upon three specimens reported by Wharton (1968) from Beech Creek near its confluence with the Talulla River, Towns County, at an elevation of 807 m. More recently, Ford et al. (In press) have reported *S. cinereus* from numerous, widely scattered localities throughout the Blue Ridge Province of Georgia, including localities in close proximity to the South Carolina state line. Similarly, *S. cinereus* has been reported from several Blue Ridge Province counties in North Carolina (Polk, Henderson, Transylvania, Jackson, Macon, and Clay) which are contiguous to South Carolina (Lee et al. 1982 and unpublished University of Georgia, Museum of Natural History records). Because *S. cinereus* is known to occur in immediately adjacent areas of Georgia and North Carolina and because seemingly appropriate areas of high elevation habitat exist in the Blue Ridge Province of South Carolina, we surveyed the mountainous portions of Oconee, Pickens, and Greenville counties specifically for *S. cinereus*.

METHODS

From 23 January to 1 May 1994 pitfall trap surveys were conducted throughout the Blue Ridge Province of extreme northwestern South Carolina including, from east to west, portions of Greenville, Pickens, and Oconee counties. We totalled 14,000 trap nights at 17 individual sites. At each site twenty, 32-ounce, plastic containers (14-cm lip diameter and 17-cm depth) were placed below ground level adjacent to forest floor debris including stumps, fallen logs, rocks, etc, for a minimum of 60 days. Approximately 0.14L of preservative was placed in the bottom of each pitfall. General habitat features, including dominant overstory and understory vegetation, aspect, and approximate stand age, of each site were recorded and elevations estimated from topographic maps. Traps were checked on a biweekly basis. Specimens were preserved in alcohol for subsequent reproductive and gut content analysis. Standard body measurements were taken, and skulls were prepared for confirmation of identification. All specimens were reposited in the mammal collections of the University of Georgia Museum of Natural History.

RESULTS AND DISCUSSION

We recovered 15 *S. cinereus* at two of 17 Blue Ridge Province sites. Both *S. cinereus* localities were in the northwestern portion of Oconee County. Seven individuals were recovered from the grounds of the Walhala Fish Hatchery in a hemlock (*Tsuga canadensis*) and rhododendron (*Rhododendron maximum*) streamside community which grades upslope into a yellow poplar (*Liriodendron tulipifera*), mixed oak (*Quercus* spp.), hickory (*Carya* spp.), and white pine (*Pinus strobus*) community. Elevation was approximately 760 m. The second *S. cinereus* locality (eight captures) was approximately 1.3 km east of the Walhala Fish Hatchery site in a moderate to mesic mixed oak and yellow poplar hardwood community at approximately 800 m.

Sorex cinereus was the dominant small mammal recovered in the Walhala Fish Hatchery site. Fifteen small mammals were recovered in 1,960 trap nights: seven *S. cinereus*, two *S. fumeus*, one *Sorex hoyi*, one *Blarina brevicauda*, two *Peromyscus maniculatus*, and one *Clethrionomys gapperi*. The recovery of *S. cinereus* was fairly evenly distributed over the trapping period with one or two captured during each sampling period.

At the second site, also with 1,960 trap nights, 12 *S. fumeus*, four *S. hoyi*, two *Peromyscus leucopus*, one *P. maniculatus*, two *Blarina brevicauda*, and one *Clethrionomys gapperi* were captured in addition to the eight *S. cinereus*. Here all the cinereus were captured between 20 March and 3 April; six of which were taken in a single pitfall trap beneath a large, heavily rotted log.

The breadth and intensity of our collection efforts indicate a restricted distribution of *S. cinereus* in South Carolina. *Sorex cinereus* is regarded as having a boreomontane distribution (Junge and Hoffman 1981). In the southern Appalachians it has been documented by Odum (1949), Johnston (1967), Gentry et al. (1968), Linzey and Linzey (1971), Whitaker et al. (1975), and Lee et al. (1982) in western North Carolina; Conaway and Howell (1953), Smith et al. (1974), and Harvey et al. (1991, 1992), in the mountainous regions of eastern Tennessee; and Pagels and Tate (1976), Pagels and Handley (1989), Pagels (1991), Kalko and Handley (1993), and Pagels et al. (1994) in southwestern Virginia. It has not been recorded from elevations below 610 m in southwestern Virginia (Pagels and Handley 1989) or North Carolina (Linzey and Linzey 1971, Lee et al. 1982). Similarly, in Georgia, *S. cinereus* is restricted to high elevation (790–1,370 m) in markedly mesic habitats with northern affinities (Ford et al. 1994).

Kirkland (1985, 1991) indicated that soricids, in general, are most diverse in regions characterized by cool moist forests, possibly by supporting an abundant, stable, and diverse soil invertebrate fauna upon which shrews depend. Pagels et al. (1994) have shown that the presence of *S. cinereus* was significantly correlated with soil moisture holding capacity and total understory vegetation, and that habitat features that promote shaded, moist habitats were particularly important in relict, boreal forest habitats throughout the southern Appalachians.

Although considerable areas of the Blue Ridge Province in South Carolina meet or exceed the minimum elevations at which *S. cinereus* is found elsewhere in the southern Appalachians, boreomontane habitats are limited there. At the southern limit of the Appalachian Mountains, much of the mountain habitat in South Carolina is characterized by south-facing aspects with more xeric, mixed oak and pine communities. Similar xeric south-facing or ridgeline habitats in Georgia yielded few, if any, *S. cinereus* in recent studies (Ford et al. 1994). In Georgia we encountered *S. cinereus* primarily at very high elevations (over 1200 m) or in rich, moist, streamside communities dominated by hemlock and rhododendron on the Rabun Bald Massif. West of the Little Tennessee River in Georgia, *S. cinereus* is restricted to higher (over 1000 m) elevations, and then they only occur in restricted habitats with marked northern affinities such as those described by Wharton (1968).

Our collection site at the Walhala Fish Hatchery is located in a relatively narrow, steep-walled gorge of the East Fork of the Chattooga River. Wharton (1977) noted that similar streamside forest communities on the Georgia side of the Chattooga were kept cool and moist due to complete shading by the hemlock overstory and rhododendron shrub layer as well as by steep-walled gorges. He noted that such areas were refugia of more typical northern forest communities. The Walhala Fish Hatchery, and its associated upslope northern aspect cove hardwood habitat, might represent a limited finger or refugia in South Carolina for boreal species such as *S. cinereus*. The region of the Walhala Fish Hatchery is one of the few sites in South Carolina that has yielded other small mammals with a typical boreal distribution including *Clethrionomys gapperi* (Pivorun et al. 1984) and *Peromyscus maniculatus*. Other high elevation sites in the Blue Ridge Province including Sassafrass Mountain, Jones Gap at Caesar's Head State Park, Saluda Mountain and Hogback Mountain were trapped but yielded no *S. cinereus*. *Peromyscus maniculatus* has been recorded at many of these sites (Golley 1966), and we recovered several specimens at most of these localities. However, *Clethrionomys gapperi* was not reported beyond the Walhalla Fish Hatchery site until we recovered one in the region of Sassafrass Mountain (Pickens County, US Hwy 178, 7.4 m north of State Hwy 11). This is most southeastern record for the species and, like *S. cinereus*, it apparently has a very limited distribution in South Carolina.

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Rediscovery of the Aquatic Gastropod *Helisoma eucosmium* (Bartsch, 1908), (Basommatophora: Planorbidae)

William F. Adams
Environmental Resources Branch
United States Army Corps of Engineers
P.O. Box 1890, Wilmington, North Carolina 28402

and

Susan G. Brady
Department of Biology
University of North Carolina at Wilmington
601 South College Road, Wilmington, North Carolina 28403

ABSTRACT—A population of *Helisoma eucosmium* (Bartsch, 1908), a small freshwater planorbid snail considered to be extinct by some authors, has been discovered in Town Creek, a tidal swamp stream in southeastern North Carolina. This rediscovery will permit a definitive determination of the proper systematic placement of the taxon. In the absence of live specimens, past analysis of this taxon during systematic revisions of the Planorbidae relied only on shell morphology of type material. Under this circumstance, this taxon was variously placed in both tropical and temperate genera and, compounding that problem, was treated as a full species by some authors and a subspecies by others. Its apparently limited range elevates concern for the conservation of planorbid snail diversity in southeastern North Carolina because it is the second taxon with a severely restricted distribution to be found in this rapidly urbanizing region.

Helisoma eucosmium (Bartsch, 1908) is a small, distinctive planorbid snail which was collected and described from Greenfield Lake, a millpond constructed prior to 1750 (Adams 1990*a*). This site is located within the City of Wilmington, New Hanover County, North Carolina, and is on a tributary to the lower Cape Fear River. During the past few decades, repeated attempts to recollect *H. eucosmium* in Greenfield Lake and elsewhere within the region have been unsuccessful (Fuller 1977, Adams 1990*a*). This fact, combined with the water quality degradation in many regional streams, has led many investigators to treat the taxon as extinct (Opler 1976, Imlay 1977, Palmer 1985) or possibly extinct (Fuller 1977, Adams 1990*b*).

During the spring of 1994, while performing a survey of the mollusks of Town Creek, a tidal swamp stream tributary to the lower Cape Fear River in adjacent Brunswick County, SGB discovered a population of *Helisoma eucosmium* approximately 14.5 km (9 mi) SSW of the type locality (Fig. 1). Although much of this stream system remains to be investigated, the taxon is known to occupy at least a 1.75 km (1.1 mi) stretch of the main creek. Five specimens were deposited in the invertebrate research collection at the North Carolina State Museum of Natural Sciences, Raleigh (NCSM). All conform precisely to the original shell description given by Bartsch (1908), particularly in displaying the chestnut-colored bands (Figs. 2 and 3). The largest specimen (NCSM #P1207), collected on 30 April 1994, has a greater diameter of 6.0 mm, a lesser diameter of 4.75 mm, and a height of 3.0 mm. It was probably an adult that overwintered, a likelihood suggested by its size and the minor pitting and corrosion of the shell surface. Three specimens taken in early July 1994 (NCSM #P1208) are smaller; average dimensions of three specimens are maximum diameter 3.8 mm, minimum diameter 3.0 mm, and height 1.9 mm (n = 3). Similarly-sized specimens taken from the same period laid eggs in captivity indicating that sexual maturity had been attained.

The molluscan community in the freshwater part of Town Creek is diverse; species encountered to date are listed in Table 1. Continuing surveys may disclose additional species and most of those historically documented (Adams 1990*a*) from the type locality of *Helisoma eucosmium* may ultimately be found.

In his description, Bartsch (1908) assigned *Helisoma eucosmium* and a subspecies from Louisiana, *H. eucosmium vaughani*, to the genus *Planorbis* Müller 1774. F. C. Baker (1931) restricted that genus to species of European origin and, without examination of soft tissue anatomy, provisionally placed *eucosmium* in the genus *Helisoma* Swainson 1840. In his subsequent monograph on the Planorbidae, Baker (1945) retained this assignment, placing it alone with *Helisoma anceps* (Menke, 1830) in the subgenus *Helisoma* s.s.; however, he made no reference to anatomical examinations supporting this placement. On the strength of unpublished observations by J. P. E. Morrison of live individuals of *H. e. vaughani* from Louisiana, Fuller (1977) tentatively assigned the species to the Central American genus *Taphius* H. & A. Adams 1855. *Taphius* and other planorbid genera of tropical affinity (*Afroplanorbis* Thiele 1931, *Biomphalaria* Preston 1910, *Australorbis* Pilsbry 1934, *Tropicorbis* Pilsbry and Brown 1914, *Planorbina* Haldeman 1842, *Armigerus* Clessin 1884, and *Platytaphius* Pilsbry 1924) have long been the subjects of taxonomic debate and divergent systematic treatment,

Table 1. Freshwater mollusks of upper Town Creek, Brunswick County, North Carolina, 1994.

Gastropods	Bivalves
Viviparidae	Unionidae
Campeloma decisum (Say)	*Pyganodon cataracta* (Say)
Hydrobiidae	*Villosa delumbis* (Conrad)
Amnicola limosus (Say)	*Ligumia nasuta* (Say)
Gillia altilis (Lea)	Unknown taxa of the
Physidae	*Elliptio complanata* and
Physella hendersoni (Clench)	*Elliptio icterina* complexes
Planorbidae	Corbiculidae
Micromenetus dilitatus (Gould)	*Corbicula fluminea* (Müller)
Helisoma eucosmium (Bartsch)	Sphaeriidae
Planorbella trivolvis (Say)	*Eupera cubensis* (Prime)
Ancylidae	*Musculium securis* (Prime)
Laevapex fuscus (C. B. Adams)	Unidentified sphaeriids

a problem generated and sustained by years of inconclusive taxonomic studies resulting from the great similarity in chonchology and anatomy existing within a genus complex of worldwide distribution (Hubendick 1955, H. B. Baker 1960). While taxonomic and systematic problems are common in the freshwater gastropods, the need for nomenclatural stability within the tropical planorbids is a matter of great medical and economic importance because these snails are intermediate hosts of the human parasite *Schistosoma mansoni*.

In response to a petition by Wright (1962), the International Commission on Zoological Nomenclature (1965) issued Opinion 735, ruling that *Biomphalaria* is to be given precedence over the generic names *Taphius*, *Planorbina*, and *Armigera* when any or all of these names are considered to apply to the same genus. Under this ruling, Fuller's (1977) binomen would be valid only if *Taphius* is determined to be separable from *Biomphalaria* at the genus level. Bypassing this issue, Burch (1982, 1989) stated *Helisoma eucosmium* may be a "form or juvenile" of *Helisoma anceps* (Menke, 1930) and, therefore, did not grant it specific status. Based on shell morphology and the reproductive maturity of the material collected from Town Creek, we find no evidence to support this possibility. Although the very oblique aperture of *H. eucosmium* is suggestive of the *Biomphalaria* group, the lack of vertically depressed whorls is not; therefore, we provisionally accept Baker's

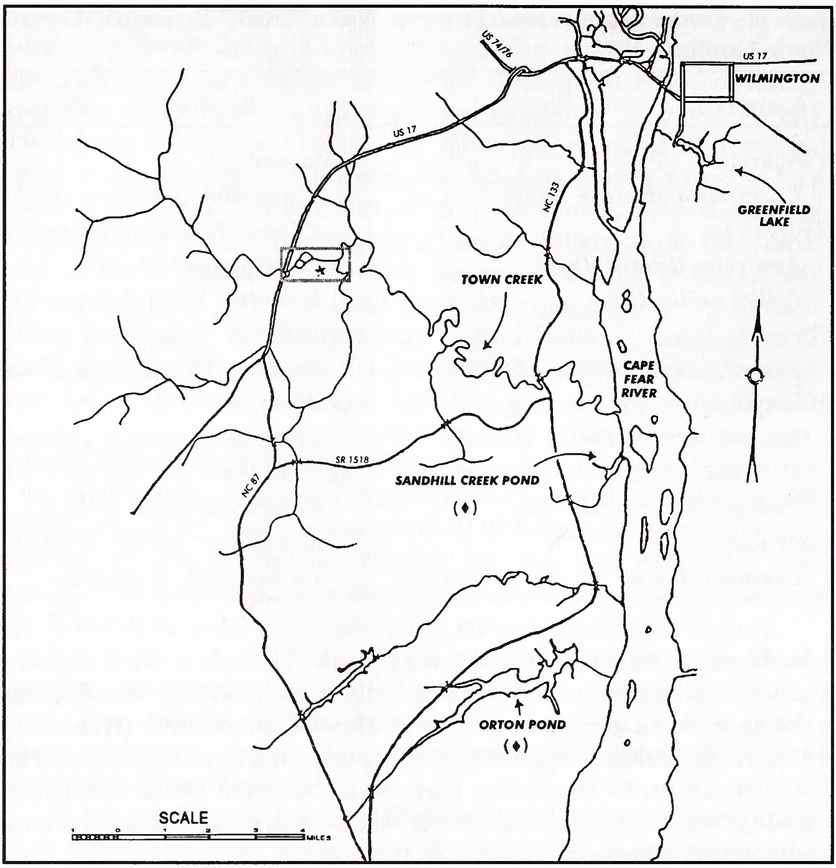
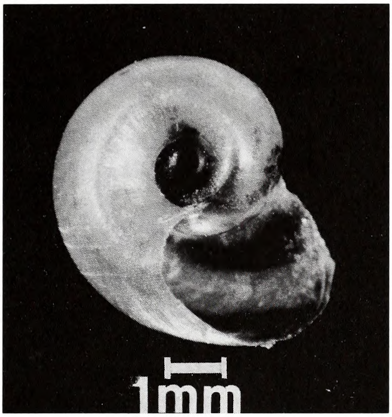


Fig. 1. Town Creek and vicinity (★ = known range of *Helisoma eucosmium*, ♦ = known sites of *Planorbella magnifica*.

(1945) designation pending definitive studies of soft tissue anatomy.

Over much of its length, Town Creek is a tidal system approximately 30–50 m wide with maximum depths varying between 5–7 m. Whereas the lower reaches are brackish, no salinity has been detected in the area where *Helisoma eucosmium* occurs. Physical parameters of the water are pH 5.1–7.0 ($\bar{x}$ = 6.1, n = 3), conductivity 217 μmhos/cm (n = 2), and calcium concentration 107.9 ppm (n = 2). All specimens of *H. eucosmium* came from a littoral community, occurring in less than 3 m of water, consisting of dense continuous mats of Brazilian elodea (*Egeria densa* Planchon), fanwort (*Cabomba caroliniana* Gray), fragrant waterlily (*Nymphaea odorata* Aiton), spatterdock (*Nuphar luteum* (Linnaeus)), and floating-heart (*Nymphoides aquatica* (Walter)).



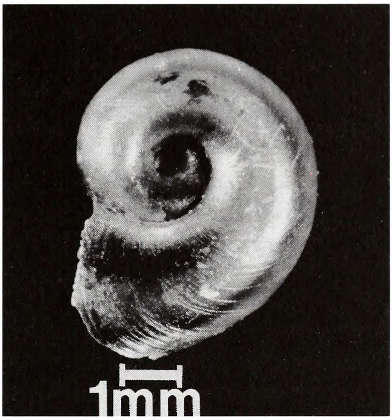
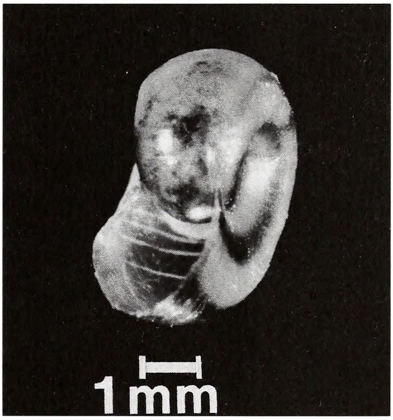


Fig. 2. Dorsal, ventral, and apertural views of *Helisoma eucosmium* (NCSM #P1208). Lip aperture is incomplete.



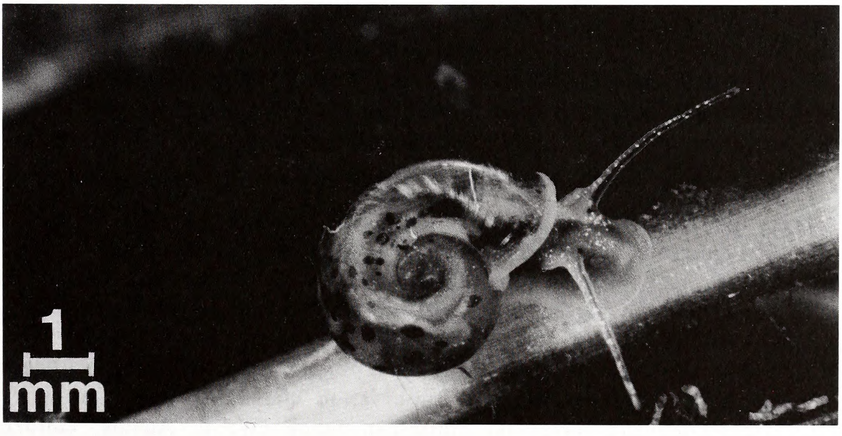


Fig. 3. Foraging *Helisoma eucosmium*.

Streambank forest cover, typical of southern swamps, consists of bald cypress (*Taxodium distichum* (Linnaeus)), tupelo gum (*Nyssa aquatica* Linnaeus), red maple (*Acer rubrum* Linnaeus), and water ash (*Fraxinus caroliniana* Miller).

Our report of *Helisoma eucosmium* constitutes the second recent recollection of a likely "extinct" planorbid snail in the Cape Fear River drainage of southeastern North Carolina, the other being the rediscovery of *Planorbella magnifica* (Pilsbry) in Orton Pond (Adams 1988) and in Sandhill Creek Pond (Adams 1993), approximately 14.5 km (9.0 mi) SE and 12 km (7.5 mi) ESE, respectively (Fig. 1). Because of the heavy residential and industrial development that has occurred in southeastern North Carolina within the past half-century, these waterbodies might hold some of the few remaining populations of the original freshwater molluscan fauna of the lower Cape Fear Basin. If *H. eucosmium* is restricted to Town Creek and systematic research determines that it warrants full species rank, protection under state and federal conservation laws might be warranted. Although the Town Creek watershed is still very rural, covered primarily in crop and forest lands, the surrounding region is urbanizing rapidly, and the stream will surely be impacted by this trend. Consequently, additional surveys to determine the distribution of *H. eucosmium* and resolution of outstanding systematic issues are urgently needed.

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Effects of a Clearcut on the Herpetofauna of a South Carolina Bottomland Swamp

Joseph P. Phelps[1]
North Carolina State University
Hardwood Research Cooperative
Raleigh, North Carolina 27695-8008

AND

Richard A. Lancia
Department of Forestry
North Carolina State University
Raleigh, North Carolina 27695-8002

ABSTRACT—Amphibians and reptiles were trapped during summer in a South Carolina bottomland swamp to assess the impacts of clearcut timber harvesting. Animals were captured using drift fences with pitfall traps, coverboards, and polyvinyl chloride pipes which simulated treefrog habitat. Twenty-nine species (10 amphibians and 19 reptiles) were detected on the site. Some were captured frequently enough to infer microhabitat preferences. Salamanders were much more frequent in the control area than in the clearcut. Other species showing preferences for the control were bronze frogs (*Rana clamitans*), gray treefrogs (*Hyla chrysoscelis*), and box turtles (*Terrapene carolina*). Reptiles generally preferred the clearcut. This was especially true of lizards and large snakes. Diversities showed no significant differences between the control and clearcut. Small clearcuts done on long rotations are recommended. Machinery impact should be kept to a minimum, and down wood and snags should be left on the site.

Bottomland hardwood forests have been recognized for their importance in floodwater and sediment retention, water quality protection, timber production, and wildlife habitat (Brinson et al. 1981, Clark and Benforado 1981, Harris and Gosselink 1986). At the same time, these ecosystems are being lost and degraded rapidly (Turner et al. 1981, Rudis 1993) due in large part to fragmentation. In the Southeast, 75,000 acres of forested wetlands have been lost since 1982 (Cubbage and Flather 1993), not including acreage that was logged and regenerated. These logged wetlands may temporarily lose some functional value, and they contribute to fragmentation.

[1] Present address: Weyerhaeuser Company, Southern Forest Research, P.O. Box 1060, Hot Springs, Arkansas 71902.

The research results presented here were obtained concurrent with other studies (Pavel 1993, Perison In Press) designed to document the impact of timber harvesting on the functional value of a bottomland swamp. Amphibians and reptiles (herpetofauna) were chosen as the appropriate wildlife groups to study because of their abundance in the Southeast (Keister 1971, Vickers et al. 1985, Hairston 1987) and because of their importance in food chains (Pough et al. 1987, Blaustein and Wake 1990). Herpetofaunal species are also influenced by factors that are affected by timber harvest, including hydrology, soil quality, and vegetative structure. Herpetofaunal communities have been shown to be altered by clearcutting (Enge and Marion 1986, Pough et al. 1987, Petranka et al. 1993), ditching of wetlands (Vickers et al. 1985, Enge and Marion 1986), and changing forest cover (Bennett et al. 1980, Pough et al. 1987).

In addition, much attention has been paid to a possible worldwide decline in amphibian diversity (Blaustein and Wake 1990, Pechmann et al. 1991, Hairston and Wiley 1993). Logging has been identified among the many possible causes of such a decline (Wake 1991, Hairston and Wiley 1993). Amphibians may be a good indicator of general environmental degradation, due to their exposure to terrestrial and aquatic toxins, and their sensitivity to habitat changes (Beiswenger 1988, Blaustein and Wake 1990).

The objectives of our research were to evaluate whether clearcutting in a hardwood swamp had any effect on community diversity or abundance of summer-active amphibians and reptiles. We also attempted to identify habitat variables that may have been related to changes in the herpetofaunal community.

METHODS

Study Site

The study site was on the South Fork of the Edisto River, near Norway (Orangeburg County), South Carolina. "The site is representative of blackwater swamps in the Carolinas that have timber management potential" (Perison et al. 1993). Predominant trees in the swamp forest included tupelo gum (*Nyssa* spp.), sweetgum (*Liquidambar styraciflua*), willow/water oak (*Quercus phellos/nigra*), and green ash (*Fraxinus pennsylvanica*) (Pavel 1993). A clearcut of approximately 10 ha was completed in January 1991. Much of the clearcut area was impacted by skidder tire ruts. The adjacent control area was upstream of the clearcut and was a second growth stand approximately 45 years old. Second growth forest surrounded the clearcut. The sampled area of control was comparable to the size of the clearcut. The edge sampled was 650 m long.

HERPETOFAUNA

Sampling—Amphibians and reptiles were captured using three types of traps: drift fences, coverboards, and polyvinyl chloride (PVC) pipe. Nine arrays of drift fences, measuring 270 m in total, were constructed of aluminum flashing (Gibbons and Semlitsch 1981). Each array consisted of two 15-m lengths placed at right angles to one another. Three of the arrays were placed in the clearcut, three in the control, and three along the edge between the clearcut and control. Twelve pitfall traps (19–L plastic paint buckets) were placed along each array, for a total of 108 traps. Arrays were centered in the clearcut, about 75 m from the edge. Control arrays averaged about 75 m from the edge.

Forty-five coverboards were systematically placed across the study site, 30 in the clearcut and 15 in the control. Each coverboard consisted of a piece of plywood or particle-board (about 120 x 60 x 0.625 cm) placed flat on the ground to simulate the type of cover often used by ground-dwelling herpetofauna (DeGraff and Yamasaki 1992, Fitch 1992, Mitchell et al. 1993). Coverboards were placed a minimum of 20 m apart.

Sixty 1.5-m lengths of PVC pipe were driven into the soil to capture treefrogs. The diameters of the pipes were 2.5 and 5 cm. Forty pipes were used in the clearcut, and 20 in the control. These pipes served as refuges for treefrogs, which were easily captured at the open top ends of the pipes. One nocturnal chorus survey (July 1993) was done to compare to habitat use trends indicated by the pipe captures. Frog choruses were monitored from the clearcut, control, and edge for 30 minutes each. Weather was humid, warm, clear, and calm.

Each of the traps was checked daily during the summers of 1992 and 1993. All captured animals were released immediately. Adult anurans were toe-clipped, but no capture-recapture data will be presented here (see below). In 1992, we trapped from 29 May until 13 August, with the exception of 14 days when the swamp was flooded. On those days, only the treefrog pipes were checked. In 1993, four drift fence arrays (one control, two edge, one clearcut) were checked from 20 May to 12 August. The remaining traps were checked from 20 June to 12 August. Again, sampling was impeded due to flooding.

Sampling was replicated within the control, edge, and clearcut site, but not replicated with additional sites because of constraints imposed by the establishment of concurrent studies, which used small replicated treatment blocks within the clearcut (Pavel 1993, Phelps 1993, Perison In Press). These blocks were the reason for unequal sampling effort for coverboards and PVC pipes in the clearcut, edge, and control. Due to the lack of replication, the results and conclusions from this study apply to the particular site we studied. Generalization to other sites is risky.

Data analysis—Capture data were analyzed using the Shannon-Weaver Diversity Index (Poole 1974). This allowed statistical comparisons among drift fence arrays in the clearcut, on the edge, and in the control; and between coverboards in the clearcut and in the control. Variance for each treatment was calculated based on the number of captures in each treatment, and was used to calculate the t-statistic ($\alpha = 0.05$) for each comparison (Poole 1974). The formulas used are as follows:

$$H' = \Sigma_{i=1}^{s} p_i \ln p_i$$

$$\mathrm{Var}(H') = \frac{[\Sigma_{i=1}^{s} p_i \ln^2 p_i] - [\Sigma_{i=1}^{s} p_i \ln p_i]^2}{N} + \frac{s-1}{2N^2}$$

$$t = \frac{H'_1 - H'_2}{[\mathrm{Var}(H'_1) + \mathrm{Var}(H'_2)]^{1/2}}$$

$$\mathrm{d.f.} = \frac{[\mathrm{Var}(H'_1) + \mathrm{Var}(H'_2)]^2}{\frac{[\mathrm{Var}(H'_1)]^2}{N_1} + \frac{[\mathrm{Var}(H'_2)]^2}{N_2}},$$

where i represents each species in the sample, pi = proportion of species i in the sample, s = number of species in the sample, N = number of captures in the sample.

Assumptions of the Shannon-Weaver Index were that all species present were sampled, and all were equally catchable. These assumptions were not met because of the differing ability of the traps to catch various species (Gibbons and Semlitsch 1981). Also, two species caught by hand were never captured in a trap of any kind and were therefore excluded from calculations of H'. These were the brown water snake (*Nerodia taxispilota*) and the timber rattlesnake (*Crotalus horridus*). Their size explains the lack of pitfall captures, as no larger snakes were caught in pitfalls. Other large snakes were captured under coverboards.

Poole (1974) states that "no great error" will occur in calculating Shannon-Weaver as if all the species available are present in the sample, even when, as in this case, some species are not represented. Unequal catchability of species should still allow relative diversity comparisons.

The lack of replication allowed only a rough comparison of capture frequencies, not a statistical test of differences in abundance (Hurlbert 1984). The original intent was to estimate abundances of anurans using mark-recapture methods, but a lack of sufficient recapture prevented this. To make direct comparisons of capture frequencies, we assumed that capture probabilities for each species were the same across habitats. This assumption could not be tested, so habitat preferences should be interpreted with caution.

Habitat Characteristics

Sampling—In an attempt to relate herpetofaunal diversity to microhabitat variability, the percent cover of midstory and overstory trees was measured with a spherical densiometer at five points around each drift fence array. One reading was taken in the center and one at a distance of 15 m in each cardinal direction. Percent cover of vegetation less than 2 m tall was also measured, using a line intercept method (Barbour et al. 1987). There were four 15-m transects at each drift fence array, originating at the middle of the array and extending in each cardinal direction. A complete description of the vegetation of the site is given by Pavel (1993).

The cross-sectional area of coarse woody debris was measured using the same transects. In this case, the transects were thought of as vertical planes that extended from the ground to the highest piece of downed wood. Each piece of wood greater than 8-cm diameter (at the point of intersection) was measured to the nearest centimeter and classified as "sound" or "rotten" (Brown 1974).

Surface soil temperatures and soil densities were measured by Perison (In Press) in the control and clearcut areas. All habitat data were analyzed using *t*-tests at the 0.05 alpha level. Each measurement was considered to be independent, and means and standard errors were calculated for each variable. In the clearcut, soil temperature and density were measured in areas with skidder traffic, but not in skidder ruts. These variables were not measured at the edge.

RESULTS

Herpetofauna

Shannon-Weaver Diversity Indices calculated for the drift fence and coverboard captures are given in Table 1. There was no significant difference between clearcut and control diversity indices for either of the two trapping methods. The diversity of the edge drift fences was lower than either the control (t = 8.70, d.f. = 1,538) or clearcut drift fences (t = 9.70, d.f. = 2,209). The reason for this difference was the

Table 1. Summary of herpetofauna capture data, Edisto River swamp, South Carolina, 1992–1993. *H′* is the value of the Shannon-Weaver diversity index. Values of *H′* with the same letter were not different at 5% alpha level.

	Captures (*N*)	Species (*s*)	*H′*
Control drift fences	930	16	0.9161a
Clearcut drift fences	1,172	16	0.9109a
Edge drift fences	2,647	17	0.4738b
All drift fences	4,749	23	0.7153c
Control coverboards	150	9	1.7077d
Clearcut coverboards	129	16	1.7710e
All coverboards	279	19	1.9832e

heavy weighting toward one species, the southern toad (*Bufo terrestris*), on the edge. Clearcut and control drift fence diversities were not different at the 0.05 alpha level. Coverboard diversities were higher than drift fence diversities (t = 18.5, d.f. = 333). Drift fences captured more species (23) and individuals (4,749) than coverboards (19 and 279, respectively). The inclusion of the clearcut increased the richness of the capture sample. Twenty-three species were captured on the site in drift fences, but only 16 species were captured in the clearcut, and 16 in the control. Nineteen species were captured under coverboards, but only 16 were captured in the clearcut, and nine in the control.

Several species showed clear preferences for either the control or the clearcut (Table 2). All types of salamanders were detected more often in the control area. A total of 112 salamanders was captured in pitfall traps and under coverboards. Ninety-two (82.1%) of these were captured in the control area, with only 9 (8.0%) in the clearcut (Table 2). Bronze frogs (*Rana clamitans*) were captured more frequently in the control (104 control captures to 17 in the clearcut), while southern leopard frogs (*R. utricularia*) were less common in the control (33 drift fence captures compared to 52 on the edge and 51 in the clearcut). Other frog species showing preferences were eastern narrow-mouth toads (*Gastrophryne carolinensis*) and green treefrogs (*Hyla cinerea*), which preferred the clearcut, and gray treefrogs (*H. chrysoscelis*), which preferred the control. Southern toads, most of which were juveniles, were captured most frequently in the edge pitfalls. Southern toads were abundant in all three areas. The data on frog and toad species were supported by the breeding chorus monitoring.

Reptiles generally seemed to prefer the clearcut. Eastern mud turtles (*Kinosternon subrubrum*) were captured 41 times in the clearcut, 35 times on the edge, and only 10 times in the control area. Common musk turtles (*Sternotherus odoratus*) and eastern box turtles (*Terrapene carolina*) showed the opposite trend. Lizards (*Eumeces fasciatus* and *Anolis carolinensis*) and large snakes (chiefly *Agkistrodon piscivorus* and *Nerodia* spp.) were more common in the clearcut. Because they were rarely captured in traps but often seen, habitat preferences of large snakes, lizards, and box turtles are largely inferred from hand captures, rather than trapping data.

Habitat Characteristics

Microhabitat variables measured in each area are given in Table 3. Over- and mid-story canopy cover was highest in the control (95%), followed by the edge (74%), and clearcut (6%). Understory canopy cover followed the reverse trend, being highest in the clearcut (95%), followed by the edge (48%), and the control (5%).

Cross-sectional area of sound coarse woody debris was significantly higher in the clearcut, and not significantly different between the edge and control. The mount of rotten coarse woody debris was not different among the three areas. Soil surface temperature and soil compaction were not measured on the edge, but were not significantly different between the clearcut and the control, or between rutted and non-rutted areas in the clearcut.

DISCUSSION

Habitat Preferences

Fewer salamanders were captured in the clearcut, as compared to the control. High temperatures and insolation, and low relative humidity may all have contributed to this, as these factors increase the risk of desiccation. Salamanders need to keep their skin moist for gas exchange, and their large surface areas to volume ratios make moisture retention difficult (Duellman and Trueb 1986). Moisture is a key factor in determining where salamanders can live (Wyman 1988, Petranka et al. 1993). Petranka et al. (1993) speculated that 75% to 80% of southern Appalachian salamanders die of physiological stress due to desiccation following clearcuts.

Ecological differences may explain the varying preferences of frog species. Southern toads are generalists, and their common occurrence along the edge suggests that individuals were using both habitats. Bronze frogs and southern leopard frogs showed opposing preferences, for the control and clearcut respectively. Bronze frogs

Table 2. Herpetofauna capture data by species, habitat, and trap type, Edisto River swamp, South Carolina, 1992–1993. Clearcut captures for coverboards and treefrog pipes are halved since they represent twice the sampling effort as in the control. For treefrog pipes, bold numbers are for 5-cm-diameter pipes; others are for 2.5-cm-diameter pipes.

Species	Drift fence captures			Coverboard captures		Treefrog pipe captures	
	Control	Edge	Clearcut	Control	Clearcut	Control	Clearcut
Bufo terrestris	725	2,417	894	29	35	0	0
Gastrophryne carolinensis	42	50	146	0	3.5	0	0
Rana clamitans	86	42	6	18	5.5	0	0
Rana utricularia	33	52	51	6	5	0	0
Hyla cinerea	0	0	0	0	0	**10** 29	**418** 311
Hyla chrysoscelis	0	0	0	0	0	**11** 19	**0** 3
Eurycea quadridigitata	2	7	1	57	2.5	0	0
Eurycea longicauda	3	2	0	2	0	0	0
Desmognathus auriculatus	4	1	1	24	0	0	0
Siren intermedia	0	1	0	0	1	0	0
Terrapene carolina	0	1	2	0	0	0	0
Stemotherus odoratus	10	13	5	0	0.5	0	0
Kinosternon subrubrum	10	35	41	0	0	0	0
Clemmys guttata	1	6	6	0	0.5	0	0
Chelydra serpentina	0	7	3	0	0	0	0
Trachemys scripta	1	0	6	0	0	0	0
Anolis carolinensis	0	1	0	0	0	0	0
Eumeces fasciatus	2	10	7	0	2	0	0
Agkistrodon contortix	1	0	0	0	0	0	0
Agkistrodon piscivorus	8	1	0	0	1	0	0

Nerodia erythrogaster	1	0	1	0	2.5	0	0
Nerodia taxispilota	0	0	0	0	0	0	0
Nerodia fasciata	0	0	1	0	0.5	0	0
Storeria dekayi	0	1	0	2	0	0	0
Carphophis amoenus	0	0	0	1	0.5	0	0
Coluber constrictor	0	0	0	0	0.5	0	0
Diadophis punctatus	0	0	0	12	3.5	0	0
Farancia abacura	0	0	1	0	0.5	0	0
Elaphe obsoleta	1	0	0	0	0	0	0

Table 3. Habitat characteristics of Edisto River swamp, South Carolina, 1993. Values in the same row with the same letter were not significantly different at 5% alpha level.

	Clearcut		Edge		Control	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Over/midstory % cover	6a	1.9	74b	7.1	95c	0.5
Understory % cover	95a	1.0	48b	7.7	5c	1.4
Rotten coarse woody debris (m^2 cross-sectional area per 15-m transect)	3.3a	1.62	0.9a	0.41	2.6a	1.81
Sound coarse woody debris (m^2 cross-sectional area per 15-m transect)	8.1a	1.35	1.9b	0.41	1.1b	0.47
Soil surface temperature (C)	31.2a	4.2	No data		27.9a	0.8
Soil density (g/cm^3)	0.59a	0.02	No data		0.67a	0.05

are a forest wetland species, whereas leopard frogs are more ubiquitous (Mount 1975). Enge and Marion (1986) found fewer southern leopard frogs in clearcuts than in control areas in southern pine flatwoods.

Eastern narrowmouth toads emerge from burrows only when ground water is sufficiently pooled for breeding. Reduced evapotranspiration in the clearcut (Perison et al. 1993) may have increased the likelihood of these frogs receiving the cue to emerge. Skidder tire ruts may have had a similar effect on these and the other frog species, as they were a source of fish-free breeding pools (Phelps 1993).

Two species of treefrogs were captured, and these showed opposing preferences. Green treefrogs may have predominated in the clearcut because the traps (treefrog pipes) were level with their habitat (leafy sprouting vegetation). Green treefrogs may have been equally abundant in the control (as suggested by the number of control captures, Table 2), but may have been living higher than the traps were sampling. Gray treefrogs were rarely captured, and the reason again may have been that the traps were too low. The removal of trees in the clearcut may have excluded gray treefrogs because their habitat (tree boles) was removed. In the case of the green treefrogs in the clearcut, their habitat quickly returned, but at a lower height. Overall, the treefrog pipe method showed promise, as it was inexpensive and trapped significant numbers of frogs while causing them no apparent stress.

Reptiles may have preferred the clearcut because of increased temperature and insolation. A basking reptile would be at an advantage in the direct sun of the clearcut because it could achieve active temperatures faster and remain active longer through the day. Bury and Corn (1988), working in the Pacific Northwest, found that "reptiles predominate in clearcuts, most likely responding to increased ambient temperatures in such areas." The presence of a large amount of slash in the clearcut may have provided a valuable habitat component in the form of cover for reptiles or their prey. Reptiles that seemed to prefer the control included ringneck snakes (*Diadophis punctatus*), copperheads (*Agkistrodon contortix*), common musk turtles, and eastern box turtles. The reasons for these preferences are not clear, although ringneck snakes were the smallest and most fossorial reptile species regularly captured, and may have been less dependent on basking and more dependent on an undisturbed forest floor.

Recommendations and Conclusions

Clearcut size is one factor to be considered when planning for natural forest regeneration in forested wetlands. Amphibians and reptiles have relatively small home range sizes (Duellman and Trueb 1986) and, therefore, cannot disperse from or quickly recolonize impacted areas. Hairston (1987) found that salamanders return to their home range even after disturbance and handling. Small clearcuts with undisturbed sources of recolonization nearby were advocated by Buhlmann et al. (1988) and Enge and Marion (1986). A mosaic of small clearcuts, second growth, and undisturbed areas would likely create increased landscape diversity, as compared to a single homogeneous stand.

Recovery times of about 60 years for salamander populations in clearcut areas are given by Petranka et al. (1993) in the southern Appalachian and Pough et al. (1987) in New York. This suggests that long rotation times are needed to avoid a long-term decline of salamander populations over several rotations. Enge and Marion (1986) also recommended long rotation times that allow adequate recovery of herpetofaunal populations.

Controlling certain aspects of the harvest operation can minimize the adverse effects of a clearcut. Most importantly, snags and coarse woody debris should be left on the site (Enge and Marion 1986). Woody debris should be of large size and in an advanced state of decay (Bury and Corn 1988, Welsh and Lind 1988). Aubry et al. (1988) suggested that "the abundance levels of salamanders are more likely a function of the availability of woody debris for cover than age of the overstory." Since suitable woody debris is more abundant in older stands, longer rotation times are important. Leaf litter on the forest floor is another important component of herpetofaunal habitat (Pough et al. 1987, DeGraaf and Rudis 1990, Petranka et al. 1993), and can be destroyed by ground machinery such as skidders (Buhlmann et al. 1988). Skidders should be restricted to small areas, and helicopters should be used when practical. Buhlmann et al. (1988) recommended harvesting in the season of inactivity for the local herpetofauna, but some southern Coastal Plain species are active at all times of the year.

Further studies in which capture probabilities can be estimated would allow direct comparison of capture data among species in the same habitat, and within species across habitats. Remaining research opportunities include determining the fate of salamanders in the face of clearcutting, and monitoring subsequent recovery of populations through recolonization. Also, a study similar to ours, focusing on winter-active amphibians, would be valuable. In addition, the habitat value of skidder ruts should be studied. The possible benefit of extra standing water (Phelps 1993) may mitigate the effects of soil degradation (Buhlmann et al. 1988). Finally, additional work with PVC pipes for capturing treefrogs should be done, including their use in various habitats, with different species, and the possible effect of pipe height on trap efficiency.

The key to expanding knowledge in the area of wildlife habitat/forestry relationships is to replicate treatments. In this case, conclusions could have been strengthened by having several clearcuts and several control areas (Hurlbert 1984). Specific factors such as woody debris, size of clearcuts, and skidder rut impact could be studied with such a design. Ideally, each area would be sampled prior to the installation of the clearcut (Buhlmann et al. 1988). This would allow comparison of data from the clearcut before and after treatment, and from the control. Effects of space, time, and the treatment itself could be separated. Replication and the collection of baseline data could be achieved more easily within the framework of Adaptive Resource Management (Walters 1986). This is a system of research integrated with management, wherein management decisions are treated as hypotheses and tested with replicated trials. After several iterations of hypothesis and experiment, predictions involved with policy can become prescriptions based on hard data.

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First Record of the Water Shrew, *Sorex palustris* Richardson (Insectivora: Soricidae), in Georgia with Comments on its Distribution and Status in the Southern Appalachians

JOSHUA LAERM, CHARLES H. WHARTON
Museum of Natural History and Institute of Ecology

AND

WILLIAM MARK FORD
Daniel B. Warnell School of Forest Resources
University of Georgia, Athens, Georgia 30602

ABSTRACT—The first state record of *Sorex palustris* is reported from Georgia, in a markedly boreal habitat in the upper headwaters of the Tallulah River in Towns County. Records in the southern Appalachians indicate the species to be rare and its distribution characterized by a series of disjunct populations.

On 30 May 1994 one adult male water shrew (*Sorex palustris* Richardson) was recovered from a sunken pitfall trap adjacent to Mare Cove Branch at its junction with Burnt Cabin Branch, a tributary of the Tallulah River in extreme northern portion of Towns County, Georgia, at an elevation of 808 m. The specimen was recovered under a rotting log and other woody debris immediately adjacent to the base of a 25 m waterfall in rocky talus. Standard body measurements were: 138-64-19. This is the first record of the species from Georgia and represents an extension of its range approximately 25 km southeast from its nearest reported locality along a short section of Fires Creek in Clay County, North Carolina, at an elevation of 1,160 m (Whitaker et al. 1975)

During the period 30 October 1993 through 30 May 1994 we established a transect of 20 pitfall traps (a total of 5,420 trap nights) along Burnt Cabin Branch. Pitfalls were 946 cm^3 plastic cups (11-cm lip diameter and 14-cm depth) filled with approximately 0.13–L formalin solution and set flush to the ground adjacent to fallen logs, rocks stumps, or other forest floor debris within 5 m of the stream edge. Traps were checked biweekly. The collection locality, which was selectively logged in the past, is a mature, predominantly northern hardwood forest community dominated by yellow birch

(*Betula lutea*), black birch (*B. lenta*), liden (*Tilia heterophylla*), and hemlock (*Tsuga canadensis*), with a rhododendron (*Rhododendron maximum*) understory.

The mammalian fauna of Burnt Cabin Branch has marked boreal affinities. Wharton (1968) reported the first Georgia records of the masked shrew (*Sorex cinereus*) and pygmy shrew (*S. hoyi*) from Beech Creek, another tributary of the Tallulah River within 500 m of the present locality, and Laerm (1992) reported the first Georgia record of the hairy-tailed mole (*Parascalops brewerii*) from the present locality. Other small mammals recovered in pitfalls and snap traps at Burnt Cabin Branch include *Sorex cinereus*, *S. fumeus*, *Blarina brevicauda*, *Tamiasciurus hudsonicus*, *Peromyscus maniculatus*, *Napaeozapus insignis*, and *Clethrionomys gapperi*.

Sorex palustris is distributed in the transcontinental Canadian boreal forest from Nova Scotia westward to southeastern Alaska and southward throughout much of the Sierra Nevada and Rocky Mountains in the western United States as well as the Appalachian Mountains to Tennessee, North Carolina (Hall 1981, Beneski and Stinson 1987), and now Georgia in the eastern United States. Populations throughout the Appalachian Mountains from southwestern Pennsylvania to Georgia are referable to *S. palustris punctulatus* Hooper 1942, the West Virginia water shrew. Based on available published sources, museum records, and personal communications it appears that *S. p. punctulatus* is rare and its distribution characterized by a series of apparently disjunct populations.

The northernmost record for *S. p. punctulatus* is a single specimen from Cove Run in the Negro Mountains, Somerset County, Pennsylvania (Doutt et al. 1966, Enders 1985). More recently, two additional specimens have been obtained from Somerset County (C. Bier and S. McLaren, personal communication; specimens in Carnegie Museum of Natural History). Apparently, the distribution of this subspecies is disjunct from that of *S. p. albibarbis* which is reported from central and northeastern Pennsylvania and northward (Hall 1981, Beneski and Stinson 1987, Merritt 1987).

Mansuetti (1958), Paradiso (1969), and Feldhamer et al. (1984) discussed the questionable occurrence of *S. palustris* in Maryland. However, seven individuals of *S. p. punctulatus* are now known from seven sites in Maryland, all from Garrett County (E. Thompson, Maryland Natural Heritage Program, personal communication). At least 12 individuals are known from five counties (Pendleton, Pocahantas, Preston, Randolph, and Tucker) in West Virginia (Kellogg 1937, Hooper 1942, McKeever 1952, and records on file with West Virginia

Heritage Inventory Program). Three individuals are known from a single locality in Bath County, Virginia, and five from three localities in Highlands County, Virginia (Pagels and Tate 1976, Pagels 1987, Handley 1991, and J. Pagels, personal communication). Thirteen records are known from the Great Smoky Mountains National Park, Sevier County, Tennessee (Conaway and Pfitzer 1952, Linzey and Linzey 1968), and Harvey et al. (1991) report an additional 18 specimens from four localities in Monroe County, Tennessee. In North Carolina it is known from five individuals from Clay County and one specimen from Great Smoky Mountains National Park in Swain County (Whitaker et al. 1975, Linzey 1983, Webster 1987).

Compared to other soricids in the southeastern United States, *Sorex palustris* appears to be rare. *Sorex p. punctulatus* is considered a Category 2 taxon by the United States Fish and Wildlife Service, is listed as endangered in Virginia (Virginia Department of Game and Inland Fisheries), and is considered a species of special concern in North Carolina (North Carolina Natural Heritage Program) and Tennessee (Tennessee Wildlife Resource Agency). Although other soricids, such a *Sorex hoyi* and *Sorex dispar*, that historically have been considered extremely rare are now known to be more widely distributed and more common than previously believed (Pagels 1987, Handley 1991, Laerm et al 1994), the water shrew appears to be the rarest and most localized shrew in the southeastern United States. Additional surveys for the water shrew are required to assess its true status.

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Florida Manatees, *Trichechus manatus* (Sirenia: Trichechidae), in North Carolina 1919–1994

FRANK J. SCHWARTZ
Institute of Marine Sciences
University of North Carolina
Morehead City, North Carolina 28557

ABSTRACT—Florida manatees, first reported in 1919 from North Carolina, are now known to have frequented 59 sites (68 individuals) during the period of 1919–1994. All but two have been subadults of about 1.8–2.4-m lengths. Only seven deaths have been recorded. Eleven coastal counties have harbored manatees. Four occurrences have been at inlets and six in the open ocean. Pelletier Creek, a Carteret County tributary of Bogue Sound, along with the Atlantic Ocean have been the most frequented sites (6); eight manatees occurred at a lush vegetation site in the Trent River (Craven County), a tributary of the Neuse River. Four records came from Wrightsville Beach and Sound, three manatees entered the state from Chesapeake Bay via the canal and Intracoastal Waterway into Currituck Sound. Farthest inland river penetrations have been 94.4 km, 6.4 km north of Wilmington; 92 km, Neuse River at Fort Barnwell Bridge, 33 km northeast of New Bern (Craven County); and one each penetrated the Tar River at Washington (58 km, Beaufort County) and Greenville (88 km, Pitt County). The increased frequency of occurrences in later years may be the result of an increased public awareness of the federally-protected species rather than a seemingly increasing population.

The Florida manatee, *Trichechus manatus*, can attain a size of 4.1 m, 1,620 kg, and ranges from Maryland (Chester River, Chesapeake Bay) to Louisiana in the northern Gulf of Mexico (C. Beck, National Biological Service, personal communication; Jefferson et al. 1993). Northernmost manatee records in North Carolina have been in Currituck Sound (Dare County) (Brimley 1905, 1946; Brimley 1931; Caldwell and Golley 1965) (Table 1, Fig. 1). My study summarizes early records, adds 44 new records (total 59) and comments on where, when, and what size manatees have occurred in North Carolina.

Table 1. Occurrences of manatees in North Carolina 1919–1994 by year, locality, number, status alive (A) or dead (D), size (meters), literature reference, and county.

	Date	Locality	*N*	Status	Approx. Size	County	Reference or Authority
1919	11 September	Masonboro Sound near Wilmington	1	A	2.2	New Hanover	Brimley 1931, 1946
1934	mid-October	Currituck Sound near Duck (Duck Sound)	1	A	3.0	New Hanover	Brimley 1946
1936	8 October	Cape Lookout	1	D	3.3	Carteret	Rathbun et al. 1981
1952	Summer	Southport	1	A		Brunswick	Rathbun et al. 1981
1960		Wrightsville Beach	1	A		New Hanover	Smith 1960
1970	14 December	Wrightsville Beach	1	D		New Hanover	Rathbun et al. 1981
1972	September	Near Southport	1	A		Brunswick	Rathbun et al. 1981
1972	Fall	Wrightsville Beach	2	D		New Hanover	Rathburn et al. 1981
1975	25 June	Cape Hatteras, Pamlico Sound	1	A		Dare	Rathbun et al. 1981
	25 June	3.2 km north of Cape Lookout in Barden's Inlet	1	A		Carteret	Clark, NCMNS[1]
	Summer	Calabash River	2	A		Brunswick	Rathbun et al. 1981
1976	13 July	Ocean Isle Beach	1	A		Brunswick	Rathbun et al. 1981
	6-9 August	Cape Fear River near CPL Power Plant	1	A		Brunswick	Rathbun et al. 1981
	August	Carolina Beach - Ocean	2	A		New Hanover	Rathbun et al. 1981
	Fall	Wrightsville Beach Jetty	1	A		New Hanover	Rathbun et al. 1981
		Lower Cape Fear River	1	A		New Hanover	Lee 1976
1980	August	Minnesott Beach Yacht Basin, Neuse River	3	A	1.4-2.0	Pamlico	This study
1981		Silver Lake, Ocracoke	1	A	1.5	Hyde	This study
	4 August	Pelletier Creek, tributary to Bogue Sound, Morehead City	1	A	1.6	Carteret	This study
	30 September	Pelletier Creek	1	A		Carteret	This study
1982	29-30 June	Avalon Fishing Pier, Altantic Ocean, Kill Devil Hills	1	A	2.4	Dare	C. Beck[1]
	10 July	Trent River	1	A		Craven	Clark[1]
	August	Ocean off Bogue Banks	1	A	2.0	Carteret	This study
	August	Neuse River near Oriental	1	A	2.0	Pamlico	This study
	9 October	Pelletier Creek	1	A	1.8	Carteret	This study
	18-19 October	Pelletier Creek	1	A	1.8	Carteret	This study

Table 1. Continued.

	Date	Locality	*N*	Status	Approx. Size	County	Reference or Authority
1983	24 June	Ocracoke Island	1	A	2.0	Hyde	This study
	August	Ocean off Shackleford Banks opposite Bottle Run Point in Back Sound	1	A	1.8	Carteret	This study
	10-15 September	10-15 km North of Cape Hatteras near Rodanthe, Pamlico Sound	1	A		Dare	This study
	15 September	8 km North Roanoke Island, Albemarle Sound	1	A	3.0	Dare	This study
	30 September	North end Wanchese Harbor	1	A	3.8	Dare	This study
		Davis Harbor, Core Banks, Davis	1	A	1.5	Carteret	This study
	23 October	Stumpy Point, Pamlico Sound, Later died off Pungo River	1	A-D	S	Dare/Beaufort	This study
	24 October	12.9 km North Roanoke Island	1	A	3.0	Dare	This study
	2 November	Tar River, Greenville	1	A		Pitt	This study
1984	5 January	Wade Point, Pamlico River near Pungo River	1	A	2.75	Beaufort	Beck[1]
	6 January	Pamlico River, Pamlico Beach	1	D		Beaufort	Beck[1]
1985	20 September	Tar River 0.3 km upstream of Washington	1	A	1.4	Pitt	Beck[1]
1986	11 March	Cape Fear River near Marker 50 west side Channel	1	D	2.2	Brunswick	Beck[1] NCMNS5252
	September-October	Collington Bay near Kitty Hawk	1	A	1.8	Dare	This study
1987	9 September	Ft. Macon Coast Guard Harbor, Beaufort Inlet, Morehead City	1	A	2.0	Carteret	This study
	9 September	South side Hatteras Island creek near Rodanthe, South end	1	A	2.1	Dare	This study
	24 September	Ft. Macon Coast Guard Harbor	1	A		Carteret	Clark[1]
1990	22 January	Pamlico Sound 3.2 km NNE of Ocracoke-Gap Point	1	A-D	2.1	Hyde	Beck[1] NCMNS6211
	30 September	Pelletier Creek	1	A	1.6	Carteret	This study
	2 October	Pelletier Creek	1	A	1.6	Carteret	This study

Table 1. Continued.

	Date	Locality	N	Status	Approx. Size	County	Reference or Authority
1992	Summer	Pamlico Sound, Brant Island Shoals	1	A	2.0	Hyde	This study
	29 July	Wrightsville Beach, Airlie Marina & Route U.S. 74	1	A	3.0	New Hanover	This study
	18 November	Back Sound, off Harkers Island	1	A	1.4	Carteret	This study
1993	11 July	Northeast Cape Fear River, 6 km North of NC 210	1	A	1.5	Pender[2]	This study
	24 August	Trent River 1.6 km upstream of U.S. 70, New Bern	1	A	1.5	Craven	This study
	August-September	Elizabeth River - Intracoastal Canal to Currituck Sound	3	A	1.4-1.6	Currituck	This study
	1 September	Davis Harbor, Core Sound, Davis	1	A	1.5	Carteret	This study
1994	7 July	Cape Fear River at south end Wilmington port facility, east side at Wilmington Center Marina	1	A	1.8	New Hanover	This study
	14 July	Trent River 1.6 km west of Trent River Bridge, U.S. 70	1	A	1.8	Craven	This study
	30 August	Trent River, Lawson Park, just north of US 70 Bridge over river	1	A	1.8	Craven	This study
	17 September	Trent River, Sheraton Hotel Marina, New Bern	3	A	1.4-1.8	Craven	This study
	22 September	Trent River, Sheraton Hotel Marina, New Bern	1	A	1.8	Craven	This study

[1] Personal communication. [2] Wilmington Morning Star 7/20/93.

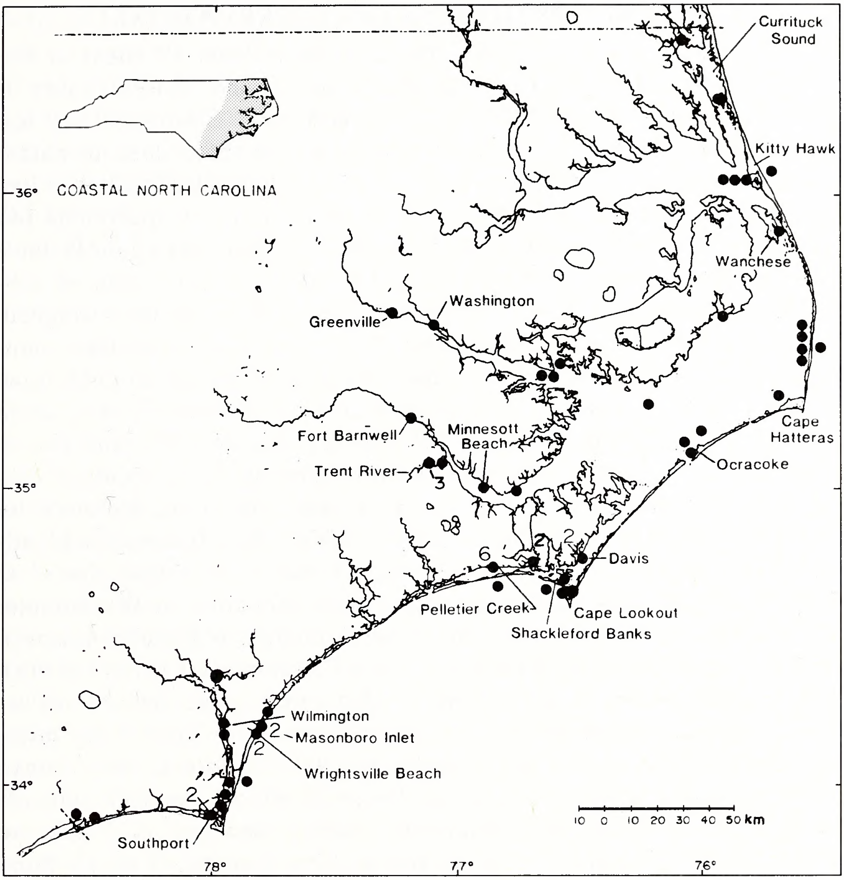

Fig. 1. Locations for 68 manatee sightings in North Carolina during the years 1919-1994.

EARLY LITERATURE OBSERVATIONS

Fifteen live and three dead manatees were reported (16 sites) from North Carolina between 1919 and 1976 by Brimley (1931, 1946), Lee (1976), Rathbun et al. (1981), and Smith et al. (1960). The specimen from Currituck Sound near Duck (Brimley 1946) was about 3 m long. None was weighed, although a Wrightsville Sound specimen and the Currituck specimens were estimated to weigh 450 kg (Brimley 1931, 1946). Clark (National Marine Fisheries Service, personal communication) recorded a live manatee near Cape Lookout 25 June 1975.

RECENT NORTH CAROLINA OBSERVATIONS

Manatees are now known (68 individuals from 59 sites) to frequent nearly all North Carolina ocean and inland waters (Table 1, Fig. 1). From 1977 to 1994, C. Beck (National Biological Service, personal communication) reports three live and three dead manatees from six sites between 1982 and 1990; Clark adds two additional live individuals in 1982 and 1987 and the remaining 42 specimens (41 sites) are from my study (Table 1). All but four occurrences have been of live specimens. Recent manatee sightings have been of subadults or young about 1.8–2.4 m long (Table 1). None has been weighed. Manatees have been recorded from 11 coastal North Carolina counties (Table 1); 15 occurrences have been in Carteret County, nine each in Dare and New Hanover, and eight in Craven County. Most sightings occurred in 1983 and 1994 (nine), five in 1976, and two to four sightings during most other years. Sightings have occurred during nine months of the year, mostly in September (14), followed by eight in August and October (Table 1). Most often frequented localities have been: Pelletier Creek (six), a tributary to Bogue Sound at Morehead City (Carteret County), various localities in the Atlantic Ocean (6), four at Wrightsville Beach and Sound (New Hanover County), and the Trent River near New Bern, North Carolina (8) (Craven County). While Rathbun et al. (1981) noted that open ocean habitat occurrences are rare, four North Carolina records have been from inlet-ocean sites and six in the open ocean. Of the latter, three ocean occurrences were off Shackleford Banks (Carteret County), one off Wrightsville Beach (New Hanover County), and one each off the Outer Banks off Avon and Kitty Hawk (Dare County) (Fig. 1). Most sightings have been of single individuals; the largest groups sighted for several days before disappearing were three at Minnesott Beach Yacht Basin, a tributary to the Neuse River (Pamlico River) in August 1980, and three in the Trent River at the Sheraton Yacht Harbor, New Bern (Craven County) in September 1994.

Although six records are of manatees frequenting Pelletier Creek, the area seems an unlikely manatee habitat as the short 0.8 km creek is plied by many boats, pollution is heavy from numerous boat works and marinas, and considerable runoff occurs from the densely built houses and condominiums lining the shoreline. Yet manatees have spent several days in the creek during each visit. In 1993 to 1994 two (once) to six separate manatees frequented the same general area of the coffee-colored Trent River, tributary to the Neuse River, 2 km southwest of New Bern (Craven County) and fed on dense aquatic vegetation. Three specimens frequented the river 0.2 km west of New

Bern, at Lawson Park or the Sheraton Hotel Yacht Basin in 1994. The 1993 specimen was followed downstream in the Neuse along its western shore for 13 km before vanishing. The July 1994 specimen did not linger in the Trent River prior to its next (presumed) sighting in the lower Neuse River opposite Oriental in late July. August-September 1994 specimens lingered and fed on the lush vegetation of the Trent River even as late as 24 September 1994. Bottom and surface salinities 17 September 1994 were 14 and 7 ppt respectively.

INLAND PENETRATIONS

Manatees are known to penetrate inland freshwater such as the St. John's River of Florida for 224 km to Lake Monroe (Volusia County; D. Odell, Sea World Inc., personal communication). Farthest inland river penetrations by manatees in North Carolina have been: Cape Fear River (one) for 94.4 km-6.4 km above Route 210 and north of Wilmington (Pender County) 11 July 1993, and one for 92 km in the Neuse River to the Fort Barnwell Bridge (Craven County) in October 1980, 33 km northeast of New Bern (Fig. 1). Two other manatees occurred in the Tar River system of the upper Pamlico River, a tributary of Pamlico Sound: one for 88 km to Greenville (Pitt County) in November 1989 and the other for 58 km to just upstream of Washington (Beaufort County) (Fig. 1) in September 1985. The most peculiar movements have been of three manatees that traversed south from the lower Chesapeake Bay in late summer of 1993 via the canal and Intracoastal Waterway into Currituck Sound (Fig. 1). While most manatee sightings have been at localities which could have been reached via the Intracoastal Waterway and sounds, the four inlet and six ocean occurrences also suggest travel north from Florida to North Carolina may have been via those avenues. In any event, observations seem to indicate many more young manatees are expanding their range into North Carolina, perhaps as a result of an increased public awareness of Florida's manatees rather than a real population increase.

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Hanover Public Library (Cape Fear River stories); J. Oakley, Carolina Biological Lab, Burlington (early Brimley references); M. Nabinetts, Washington Daily News (Pamlico River stories), N. Winfrey, Oriental News (comments on lower Neuse River observations); M. Clark provided the three North Carolina State Museum of Natural Sciences records and checked the Museum overall occurrence records. D. Lee of the North Carolina State Museum of Natural Sciences reviewed the paper, as did C. Potter, National Marine Fisheries Service, Division of Mammals (North Carolina data). D. Webster, University of North Carolina, Wilmington, noted the 29 July 1992 record. L. White typed the text; R. Barnes produced Figure 1.

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Recovery of the Cave Crayfish (Decapoda: Cambridae) Population in Peacock Springs, Florida?

W. J. STREEVER
Department of Environmental Engineering Sciences, University of Florida, Gainesville, Florida 32611

ABSTRACT—In 1991, a cave fauna kill was observed within the fully-flooded cave system at Peacock Springs, Suwannee County, Florida. Organisms affected by the kill included the pallid cave crayfish (*Procambarus pallidus*), the yellow bullhead (*Ameiurus natalis*), the American eel (*Anguilla rostrata*), and the Asiatic clam (*Corbicula fluminea*). Following the kill, no crayfish were present along transects, but recently collected census data are not significantly different from data collected before the 1991 kill (Paired *t*-test, $P > 0.1$). However, crayfish numbers have not returned to their pre-1991 levels in the cave passage where the highest crayfish density occurred before the kill. Also, the scarcity of small (<1.5 cm total length) crayfish suggests that the return to pre-1991 levels may reflect dispersal of animals from inaccessible portions of the cave and not replacement of crayfish through reproduction.

The troglobitic pallid cave crayfish, *Procambarus pallidus*, inhabits flooded caves in the Suwannee River drainage in north Florida (Franz and Lee 1982). These caves also are inhabited by other troglobitic and troglophillic species, including several species of catfish (Hale and Streever 1994), ostracods (Walton and Hobbs 1959), the American eel *Anguilla rostrata* (Franz et al. 1994), the Asiatic clam *Corbicula fluminea* (Streever 1992*a*), tubificidae worms (Streever 1992*b*), and the colonial cnidarian *Cordylophora lacustris* (Streever 1992*c*). Franz et al. (1994) provide an extensive review of Florida's cave fauna, emphasizing distributional records for all species reported in association with caves. Little is known about the ecology or population dynamics for most of these species.

The Peacock Springs cave system consists of over 3,300 m of fully-flooded passage, with depths down to about 60 m. Eight openings provide access to the cave system. A surface channel connects openings commonly called Peacock I, II, and III to the Suwannee River. Water from the Floridan aquifer normally flows out of the Peacock I opening and drains into the Peacock III opening and the Suwannee

River. However, during periods of high river levels, water from the Suwannee River overcomes the head of pressure generated by aquifer water. Flow in the surface channel reverses, and Suwannee River water enters the cave system. Following a flow reversal in February 1991, virtually all of the animals in accessible portions of the Peacock Springs cave system were killed. Animals affected by the kill include crayfish, catfish, and Asiatic clams (Streever 1992*b*). The cause of the kill is unknown.

This paper addresses two issues. First, I present 1994 *P. pallidus* census data and subjective observations of other taxa, and second I discuss a possible mechanism for the increase in crayfish population density following the 1991 kill.

METHODS

In 1990, divers established eight belt transects (100 x 4 m) in association with permanent guidelines in the Peacock Springs cave system. Transects were numbered 1–8. Both before and after the fauna kill in February 1991, crayfish were visually censused along transects by divers carrying 50-watt lights. Because cave crayfish roam in the open on the cave floor, visual censusing provides a simple method of estimating population density. After the kill, two additional belt transects, called 2-a (240 m long) and 8-a (350 m long), were established in a tunnel north of the Peacock I opening and north of the Peacock III opening, respectively. Transect 2-a incorporated transect 2, and transect 8-a incorporated transects 7 and 8. All crayfish that were visible from the cave's permanent guidelines were included in censuses along transects 2-a and 8-a, making their width dependent on water clarity and size of the cave passage. In general, the width of transects 2-a and 8-a varied between 4 and 10 m. The large size of the new transects was intended to allow censusing of the smaller crayfish densities occurring after the 1991 kill. A map of the cave showing transect locations was provided by Streever (1992*b*).

The 1994 transect censuses were made between 9 January 1994 and 25 November 1994. During the 1994 censuses, crayfish were recorded as belonging to a size class of less than or greater than 1.5 cm in overall length, estimated from the anterior edge of the rostrum to the posterior edge of the telson. All censuses along each of the original transects were averaged to yield values for each transect before the kill and in 1994. The null hypothesis of no difference between censuses taken before the 1991 kill and those taken in 1994 was tested by a paired *t*-test, with averages of before and after censuses along individual transects comprising pairs (Zar 1984).

RESULTS AND DISCUSSION

Differences in censuses (Table 1) before the 1991 kill and in 1994 are not statistically significant ($P > 0.1$). The increase in crayfish population density immediately after the kill and in 1994 suggests that the population is recovering. However, 1994 censuses in the Peacock III tunnel indicate that populations have not recovered to pre-kill levels along transects 7 and 8. Transect 8a, which encompassed transects 7 and 8 as well as an additional 100 m of cave passage, contained only a fraction of the number of crayfish that were present along transects 7 and 8 before the kill. This indicates that the large crayfish population found in the Peacock III tunnel before the kill is not recovering, nor is the overall population in the cave system.

Of the 138 crayfish censused after the 1991 kill, only one animal was smaller than 1.5 cm. Although animals smaller than 1.5 cm in total length may be missed during censusing, the scarcity of

Table 1. Census data for *Procambarus pallidus* in the Peacock Springs, Florida, cave system before the 1991 kill, immediately after the kill, and in 1994.

	Number of crayfish counted							
	Before 1991 kill			Immediately after 1991 kill		1994		
Transects	$\bar{x}$	S.D.	*n*	$\bar{x}$	*n*	$\bar{x}$	S.D.	*n*
1	1.0	1.0	3	0	1	1.0		1
2	6.5	0.5	2	0	1	1.0		2
2a[1]	not counted			0	1	9.7	5.4	3
3	1.5	0.5	2	0	1	7.0		1
4	4.0	0.0	3	0	1	0.0	0.0	2
5	1.0	0.0	4	0	1	1.0		1
6	6.2	0.8	5	0	1	6.0	1.0	2
7	34.5	2.7	8	0	1	0.0	0.0	8
8	49.5	7.1	8	0	1	0.0	0.0	8
8a[1]	not counted			0	1	10.1	6.6	8

[1] These transects were established after the 1991 kill to cover a larger area than original transects.

small animals suggests that recovery of crayfish population density is not dependent on replacement through reproduction. Cave populations frequently display size distributions with many large individuals and few small individuals, suggesting infrequent reproduction (Poulson 1963, Culver 1982). The fecundity of *P. pallidus* is unknown, but an extensive study of the cave-adapted crayfish *Orconectes australis australis* in Shelta Cave, Alabama, suggests that reproduction in cave crayfishes may be infrequent and that clutch sizes may be small (Cooper 1975). If a similar pattern occurs in *P. pallidus*, crayfish population recovery that depends on reproduction could be slow. Because crayfish population densities in the Peacock Springs cave system do not appear to be recovering through reproduction, the increase in numbers along transects 1 through 6 may not represent a true recovery of the crayfish population. Instead, crayfish density may be the result of colonization by individuals that survived the kill and are now moving into the portion of the cave where transects were located.

Catfish were not counted as part of this study. However, they were common along transects before the 1991 kill, they were absent from transects immediately after the kill, and they were common during the 1994 census dives. An Asiatic clam population near the mouth of Peacock III had an estimated density of 161 individuals/m^2 before the 1991 kill (Streever 1992*a*), but no live Asiatic clams were found immediately after the kill or in 1994. Empty clam shells, presumably remaining from before the kill, were abundant.

The causes of the kill and the factors affecting recovery are unknown. However, intrusion of river water into caves typically full of groundwater appears to be linked to cave kills in the Peacock system. On 19 November 1994, two dead crayfish and a dead catfish were found along transect 6, immediately after a period of flooding during which Suwannee River water entered the cave. However, seven live crayfish were found along the transect on the same day, so this event did not have the intensity of the 1991 kill. Despite this apparent association, the link between river water and crayfish mortality is not clear. *P. pallidus* has been observed in two siphon-spring cave systems flooded by Sante Fe River water throughout the year (personal observation), so intolerance of low temperatures and other environmental factors associated with river water may not be the cause of mortality. Furthermore, kills have been observed in other caves without flooding by river water (Franz et al. 1994). Establishment of the cause of cave crayfish kills requires further investigation.

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Premolar Cementum and Noncementum Lengths As Potential Indicators of Age for Beavers, *Castor canadensis* (Rodentia: Castoridae)

Allan E. Houston
Ames Plantation, Agricultural Experiment Station, The University of Tennessee, P. O. Box 389, Grand Junction, Tennessee 38039-0389

AND

Michael R. Pelton
Department Forestry, Wildlife, and Fisheries, The University of Tennessee, Knoxville, Tennessee 37901-1071

ABSTRACT—Jaws from 28 beavers (*Castor canadensis*), ≥4 years old as determined from cementum annuli on premolars and molars, were collected in west Tennessee. An exponential model predicting age was developed based on the independent variables cementum length and noncementum length as measured along the estimated, maximum longitudinal centerline of cross-sectioned premolars: $AGE = 0 + 6.1784 * e^{(-0.1037*NONCEMEN)} + 2.6513 * e^{(0.1119*CEMENTUM)}$.

Several methods of aging beavers have been attempted with varying degrees of accuracy, including pelt size (Buckley and Libby 1955), tail dimensions, total body mass, skull measurements (Patric and Webb 1960), and baculum size and mass (Friley 1949). Probably the most accurate method was developed by van Nostrand and Stephenson (1964) using tooth eruption and closure of basal openings of premolars and molars for beavers up to 3 years old, and cementum layering in premolars and molars for specimens ≥4 years. Larson and van Nostrand (1968) further refined this technique to include criteria dealing with cementum deposition around basal openings. They noted that age estimations may be complicated by multi-annual cementum layering, but that the ratio of cementum to noncementum on molars and premolars might be used to estimate age in older specimens.

Our objective was to use premolar cementum length (aggregate of all annual cementum depositions) and noncementum length (remains of the original tooth) as independent variables to evaluate a model for estimating age of beavers ≥4 years.

METHODS

This study was conducted in the upper headwater basin of the North Fork of the Wolf River in west Tennessee, largely on the Ames Plantation. From November 1984 through May 1985, beaver jaws from 169 beavers were collected from legal trapping efforts on approximately 1,619 ha of the watershed.

Molars and premolars from lower mandibles were extracted and cleaned. If tooth basal openings indicated a specimen to be $\geq$4 years old, age was determined by grinding the lingual surface of premolars or molars with a 120-grit stone to expose longitudinal cross-sections. Ground surfaces were polished with a 400-grit emery cloth and cementum layers were carefully counted using hand-held magnification (Larson and van Nostrand 1968). Twenty-eight beavers, $\geq$4 years old as aged in this manner (Table 1), provided the samples (i.e., dependent variables) for our study.

Premolar cementum length and noncementum length were measured to the nearest millimeter along the estimated maximum longitudinal cross-sectional centerline of one premolar per specimen (Fig. 1). An exponential model predicting age in years was developed by combining a growth curve for cementum length and a decay curve for noncementum, using nonlinear regression (PROC NLIN) and the multivariate secant method (DUD) to set initial parameters (SAS Institute, Inc. 1985). Intercept was specified at zero to prevent predicted ages from dipping below zero. An "r^2 like" statistic was calculated by taking [1 - (residual SS/corrected total SS)].

RESULTS AND DISCUSSION

The following model was developed using cementum length and noncementum length of premolars as independent variables:

$$AGE = 0 + 6.1784 * e^{(-0.1037*NONCEMEN)} + 2.6513 * e^{(0.1119*CEMENTUM)}.$$

The "r^2 like" statistic was 0.93. The predicted curves are combined to produce a response surface (Fig. 2).

Our data were obtained from specimens on the headwaters of a single watershed. Although beavers can travel considerable distances, we assumed our sample represented only a small region. The study area may not fully represent variation existing range-wide or within adjacent watersheds. It is possible that genetic differences and dietary regimes will yield different tooth size, wear, and cementum accretion

Table 1. Age, as estimated by cementum annuli, cementum and noncementum length, measured to the nearest millimeter along the maximum longitudinal cross-section of one premolar per specimen, and predicted ages and residuals for beavers captured in west Tennessee, November 1984 through May 1985.

Specimen	Age	Cementum	Noncementum	Predicted Age[1]	Residual
1	4	3	22	4.34	-0.34
2	4	3	22	4.34	-0.34
3	4	1	24	3.48	0.52
4	4	3	22	4.34	-0.34
5	4	2	21	4.02	-0.02
6	4	3	21	4.41	-0.41
7	4	3	19	4.57	-0.57
8	4	1	24	3.48	0.52
9	4	1	24	3.48	0.52
10	4	2	20	4.09	-0.09
11	4	1	22	3.60	0.40
12	4	2	22	3.95	0.05
13	4	3	21	4.41	-0.41
14	5	4	14	5.59	-0.59
15	5	6	16	6.36	-1.36
16	5	5	20	5.42	-0.42
17	7	6	19	6.05	0.95
18	8	7	13	7.41	0.59
19	8	9	11	9.23	-1.23
20	9	9	10	9.45	-0.45
21	9	8	13	8.10	0.90
22	9	9	8	9.95	-0.95
23	9	9	9	9.69	-0.68
24	10	8	9	8.92	1.08
25	10	9	11	9.23	0.77
26	10	8	11	8.46	1.54
27	11	10	10	10.31	0.69
28	12	12	10	12.35	-0.35

[1] $AGE = 6.174*e^{(-0.1037*NONCEMEN)} + 2.6513*e^{(0.1119*CEMENTUM)}$.

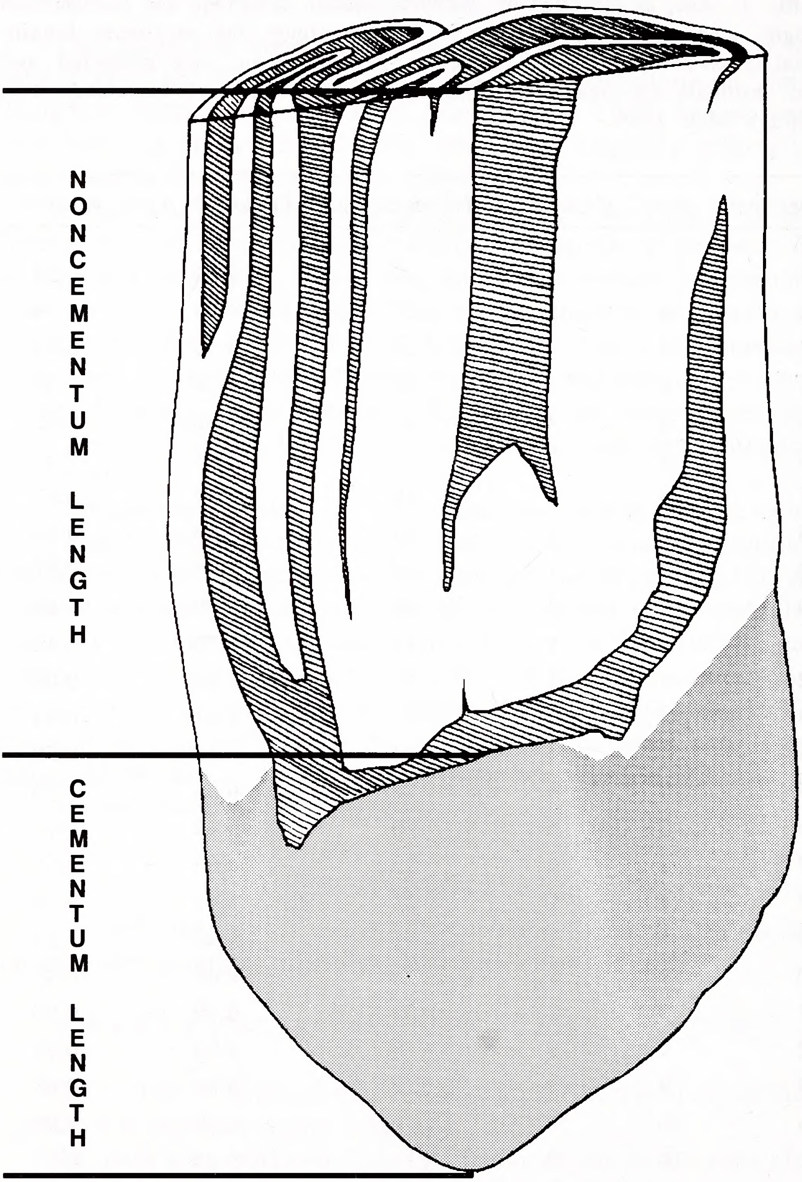

Fig. 1. Schematic representation of cementum length and noncementum length as measured along longitudinal cross-sections of premolars for beaver.

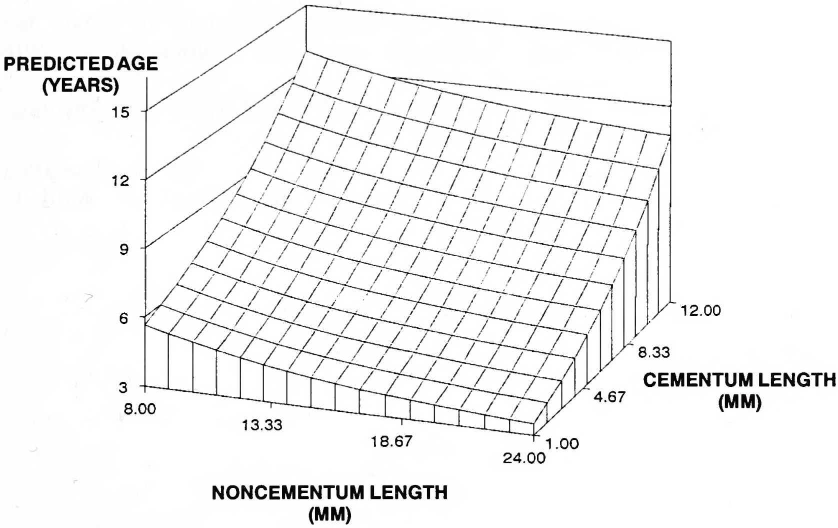

Fig. 2. Response surface of an exponential model predicting age of west Tennessee beaver using cementum length and noncementum length measured along the estimated maximum longitudinal cross-sections of premolars as independent variables.

patterns. Comparative study is needed to document potential variation of these criteria. Also, the method should be validated using known-age specimens. However, these results suggest that this technique could be developed as a reliable method to age beavers.

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Record Clutch Size for *Chelydra serpentina* (Testudines: Chelydridae) in Virginia

JOSEPH C. MITCHELL
Department of Biology
University of Richmond,
Richmond, Virginia 23173

AND

MICHAEL C. ODOM
U.S. Fish and Wildlife Service
11110 Kimages Road
Charles City, Virginia 23030

ABSTRACT—A record clutch size of 67 is reported for a common snapping turtle (*Chelydra serpentina serpentina*) from Charles City County, Virginia, 12 larger than previously reported for this chelonian. The new average for this species in the Commonwealth is 29.9 $\pm$ 16.6 ($\bar{x} \pm$ SD).

The snapping turtle (*Chelydra serpentina*) occurs from Florida north to southern Canada and Nova Scotia in eastern North America and from the Mexican border north to extreme southern Saskatchewan in western North America (Conant and Collins 1991, Iverson 1992, Russell and Bauer 1993). Clutch size varies latitudinally, with the largest sizes reported for northern populations in Canada, South Dakota, and Nebraska (Zug 1993; J. B. Iverson, Earlham College, personal communication). Ash (1951) reported an average clutch size of 28.6 and a range of 13-48 for 85 specimens presumably caught in the Virginia area. However, these data were presented only in an abstract. A complete paper was never published, and no documentation is available for us to determine the source of his specimens. Information provided by the late John T. Wood (formerly a retired medical doctor in Victoria, British Columbia and Virginia in the 1950s, personal communication) indicated that Ash's specimens could have been from multiple locations in and out of Virginia. Mitchell (1994) reported an average clutch size of 27.0 $\pm$ 13.2 (range = 7-55) for 13 females collected from various locations in Virginia.

On 3 June 1994, a gravid female (271-mm carapace length, 201-mm plastron length) was inadvertently killed by a vehicle at Harrison Lake National Fish Hatchery, Charles City County, Virginia. Subsequent dissection revealed 67 shelled eggs. One egg was opened on the date of collection, and the rest were placed in a closed plastic container with a 3:1 mixture of top soil and vermiculite. The soil was kept moist during the incubation period so that the relative humidity was maintained at nearly 100%. Incubation temperatures varied from 25 to 30° C. During the course of incubation, 12 of the 66 eggs died and were discarded; 54 eggs survived. Hatching commenced on 20 August (78 days incubation), and the last egg pipped on 24 August (82 days). Hatchlings showed considerable variation in development, with larger individuals bearing a small yolk sac and smaller individuals bearing a large, cumbersome yolk sac. Of the 54 hatchlings, four failed to survive through yolk sac absorption. The remaining turtles began exogenous feeding as their yolk sac diminished, taking a diet of chopped nightcrawlers and miscellaneous live aquatic macroinvertebrates collected from ponds. The surviving juvenile turtles were released the following spring.

A documented clutch size of 67 eggs is 12 larger than the largest reported for Virginia (Mitchell 1994). Incorporation of the large clutch size reported here yields a new state average of 29.9 ± 16.6 (range = 7-67). The maximum known clutch size for Virginia populations lies between those known for northern populations (83: Quebec (Bleakney 1957); 73: New York and Wisconsin (Yntema 1970); 109: Nebraska (Packard et al. 1990)) and southern populations (43: North Carolina (Brown 1992); 21: Florida (Punzo 1975)).

Reports of average clutch sizes for snapping turtles in different geographic areas based on small sample sizes should be used with caution. Such averages will almost always change with additional data.

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New Distributional Records for the Star-nosed Mole, *Condylura cristata* (Insectivora: Talpidae), in North Carolina, with Comments on its Occurrence in the Piedmont Region

JEFFREY C. BEANE
North Carolina State Museum of Natural Sciences
P.O. Box 29555
Raleigh, North Carolina 27626-0555

ABSTRACT—The distribution of the star-nosed mole (*Condylura cristata*) in North Carolina is updated, including specimen-supported records for seven new counties and sight records for several additional counties. The species is locally common in the Mountains, spottily distributed throughout much of the Coastal Plain, and apparently rare to absent in much of the Piedmont. A specimen from just off the Blue Ridge escarpment in western Surry County represents the first Piedmont record supported by a specimen, although there are additional sight records and unverified reports from that region. This mole is sympatric with the state's other two mole species in many areas, but usually occurs in wetter habitats than either.

INTRODUCTION

The star-nosed mole (*Condylura cristata*) ranges from eastern Manitoba and Minnesota eastward to Labrador and Nova Scotia, and southeastward along the Atlantic coast to southeastern Georgia (Paradiso 1959, Burt and Grossenheider 1976, Petersen and Yates 1980, Hall 1981, Yates and Pedersen 1982). In North Carolina, its distribution has frequently been reported as consisting of two distinct populations—one in the Mountains, where the species is locally common, and one in the Coastal Plain, where it is uncommon to rare—with a conspicuous hiatus in the Piedmont (Lee et al. 1982, Webster et al. 1985, Lee 1987, Webster 1987). The scarcity of records from the Coastal Plain and complete absence of Piedmont records resulted in the species being recommended for listing as status Undetermined by the Nongame Advisory Committee to the North Carolina Wildlife Resources Commission (Webster 1987), and in 1990 the species was granted protection as a species of Special Concern under the North Carolina Endangered Species Act (G.S. 113-331 to 113-337).

I here report on the current known distribution of *Condylura cristata* in North Carolina by providing a list of existing records from the state, and a dot distribution map (Fig. 1) updated from maps provided by Lee et al. (1982) and Webster (1987).

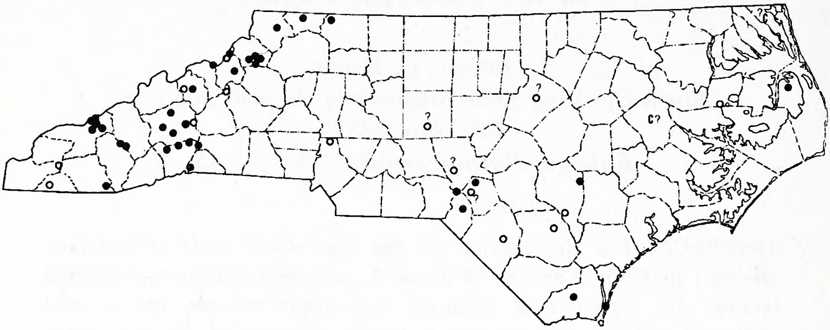

Fig. 1. Known distribution of *Condylura cristata* in North Carolina. Solid dots indicate localities documented by specimens in curated collections. Open circles indicate literature records or sight records not supported by specimens. A single dot or circle may represent two or more records in close proximity. A "C" indicates a literature record, not supported by a specimen, for which only the county and no further information was given. Question marks accompany records for which no specimen was observed, or which are unverifiable or otherwise questionable.

RECORDS OF OCCURRENCE

The following North Carolina localities are supported by voucher specimens, many of them in the North Carolina State Museum of Natural Sciences (NCSM), and are represented by solid dots on the distribution map:

Alleghany Co.: New River, "Sparta" (The New River is actually, at its nearest point, 4 mi. NW of Sparta), 30 May 1968, H. M. Tyus (NCSM 1762). *Ashe Co.*: "¾ mi. from jct. NC 16 and Friendship Church Rd." (= *ca.* 2 mi. ENE Jefferson), 4 Oct. 1991, E. Marsh (Appalachian State University 16731). *Avery Co.*: 2.6 mi. NNE Heaton, Pisgah National Forest, 27 May 1975, R. Jordan and J. Pentecost (Auburn University Museum 1-281); ¾ mi. SE Linville, 24 July 1984, D. S. Lee and J. P. Kumhyr (NCSM 4875). *Brunswick Co.*: *ca.* 6 mi. NNW Supply, Green Swamp Ecological Preserve off NC 211, "Moon Island." 16 May 1993, T. M. Padgett (TMP 511; to be deposited at NCSM). *Buncombe Co.*: W of Asheville (University of Michigan Museum of Zoology); Biltmore (Harvard Museum of Comparative Zoology 6635); *ca.* 2.6 mi. WNW Swannanoa, Warren Wilson College campus, Aug. 1977, D. S. Lee and B. Lee (NCSM 7837); Weaverville, 6 Feb. 1896, Mrs. J. S. Cairns (Harvard Museum of Comparative Zoology 5399). *Dare Co.*: *ca.* 7 mi. SW Manns Harbor, Alligator

River National Wildlife Refuge, Milltail Rd., 20 March 1991, P. R. Trail, M. L. Dunn, et al. (NCSM 6710). *Haywood Co.*: 5 mi. SW Waynesville on U.S. 23, 30 Aug. 1951, F. S. Barkalow, Jr. (North Carolina State University 274). *Henderson Co.*: Hoopers Creek near Fletcher, 8 Oct. 1974, B. A. Sanders (NCSM 4937); 1 mi. S Gerton, Little Bearwallow Mtn., 8 July 1994, P. B. Spivey (to be deposited at NCSM); 1 mi. W. NW Mills River (town), near jct. SR 1336 and SR 1338, 25 May 1993, K. A. Buhlmann, D. W. Herman, and J. L. Warner (NCSM 7868). *Hoke Co.*: 9.2 mi. NE Ashley Heights, Ft. Bragg Military Reservation, 29 May 1992, LCTA survey crew (NCSM 7213). *Jackson Co.*: 0.7 mi. NE Balsam, Blue Ridge Parkway at Balsam Gap, 22 May 1991, A. C. Boynton (NCSM 7528). *Macon Co.*: Highlands, 1 June 1946 (University of Georgia Museum of Natural History 192); Highlands, *ca.* 1 June 1946, R. Bridges (NCSM 6575); *ca.* 0.5 mi. E center Highlands, Highlands Biological Station, 23 Oct. 1982, S. Morrison (University of Georgia Museum of Natural History 7595); 1 mi. E.NE Highlands, SR 1603, 0.3 rdmi. E jct. SR 1604, 20 Sept. 1984, A. L. Braswell and J. E. Cooper (NCSM 7462). *New Hanover Co.*: near Carolina Beach, 16 Nov. 1956, G. Tregembo (NCSM 3243). *Mitchell Co.*: Roan Mtn. (Wake Forest University); Roan Mtn. near Magnetic City, 15 March 1894 (U. S. National Museum 66300); Roan Mtn. near Magnetic City, 15 Aug. 1895 (U. S. National museum 91519). *Polk Co.*: Green River Valley near Saluda, 28 May 1974, G. G. Shaw and M. Bradley (NCSM 1237). *Rutherford Co.*: Chimney Rock, Southside Drive, 19 Dec. 1989, M. Jaeger-Gale (NCSM 6336). *Richmond Co.*: 3.7 mi. NE Hoffman, U.S. 1, 0.1 rdmi. S Lumber River, 18 May 1980, A. L. Braswell (NCSM 3283). *Sampson Co.*: 5.5 km W Faison (Duplin Co.) off SR 1734, 9 June 1994, W. D. Webster (University of North Carolina at Wilmington 3370). *Scotland Co.*: "Laurinburg, Mr. Newton's farm" [the farm referred to was located *ca.* 8 mi. N Laurinburg, or 4.5 mi. W Wagram (NCSM files, W. M. Palmer, pers. comm.)], 12 April 1975, R. B. Julian (NCSM 3047). *Surry Co.*: 0.8 mi. NNW Low Gap near jct. NC 89 and SR 1433, A. B. Somers et al., 7 June 1994 (NCSM 7744). *Swain Co.*: Deep Creek; Kephart Prong Hatchery; Smokemont; Charlies Bunion Mtn. at Sevier Co., TN line; and Appalachian Trail between Newfound Gap and Indian Gap at Sevier Co., TN line; all in Great Smoky Mountains National Park (Great Smoky Mountains National Park collection, Linzey and Linzey 1968); Great Smoky Mountains National Park, Appalachian Trail, ¼ mi. S Boulevard Trail (= *ca.* 6.8 mi. NW Smokemont), 20 Aug. 1961, J. B. Westbrook (University of Georgia Museum of Natural History 3112). *Watauga Co.*: Blowing

Rock (Wake Forest University); Boone (Appalachian State University 7606); Boone, Hidden Valley Circle, 14 March 1981, D. Notrichia (Appalachian State University 7591); Boone, 1987, R. W. Van Devender (Appalachian State University 14633); *ca.* 1 mi. WSW Boone, jct. NC 105 and Poplar Grove Rd., 16 Sept. 1978 (Appalachian State University 5125); *ca.* 3 mi. WSW Boone, Laurel Cr. along NC 105, 13 Sept. 1985, F. Authenreith (Appalachian State University 12086); Blue Ridge TWP, Jakes Mtn. Rd. near jct. SR 1511, Dec. 1986, M. P. Rowe (Appalachian State University 12786); Blue Ridge TWP, SR 1511 along Sand Spit Branch and Blue Ridge Parkway, 27 Sept. 1987, R. W. Van Devender (Appalachian State University 14205); Sugar Grove, jct. U.S. 321 and Edmiston Rd., 24 Nov. 1978, H. Rogers (Appalachian State University 7601); Sugar Grove, Edmiston Rd., 5 Sept. 1985, R. N. Henson (Appalachian State University 12485); Watauga Co., no further data (Appalachian State University 16751). *Yancey Co.*: Burnsville, 3 Feb. 1976, L. P. Hartis (NCSM 2409).

In addition to localities supported by voucher specimens, the following literature and sight records are considered valid, and most are included as open circles on the distribution map:

"Mountains near the border of South Carolina" (Audubon and Bachman 1851). *Avery Co.*: Elk Park (Lee 1987, NCSM files). *Bladen Co.*: *ca.* 2 mi. N.NE White Lake (town) off SR 1517 near jct. U.S. 701, 30 April 1992, T. M. Padgett and R. Rageot (Thomas M. Padgett, pers. comm.). *Buncombe Co.*: 2–3 mi. N Black Mountain at Montreat, *ca.* 1915–1920, E. E. Brown (Elmer E. Brown, pers. comm.); Swannanoa, *ca.* 20 April 1931, C. S. Clapp (Lee 1987, NCSM files). *Cherokee Co.*: Topton, 13 May 1934, E. B. King (Brimley 1944-1946). *Clay Co.*: Hayesville, 3 Aug. 1947, R. G. Vick (Paradiso 1959, NCSM files; specimen formerly at NCSM but apparently lost). *Macon Co.*: Highlands vicinity, specimens "not infrequently" taken by H. C. Harbison prior to May 1908 (Brimley 1944–1946); Highlands vicinity, three specimens reported by Johnston (1967); one of these, formerly in the Highlands Museum, is now NCSM 6575; the same specimen was also reported by Odum (1949). *McDowell Co.*: just N Ashford along U.S. 221, ca. 1800' elev., two specimens taken from the stomach of a black rat snake (*Elaphe obsoleta*), 23 May 1960, E. E. Brown. These specimens were reported by Brown (1979), but their specific locality was not included in that paper (Elmer E. Brown, pers. comm.). *Mecklenburg Co.*: Davidson (east side near golf course branch), ca. 1950–1955, E. E. Brown (Elmer E. Brown, pers. comm.). *New Hanover Co.*: near Carolina Beach, 7 June 1959, G. Tregembo (Lee 1987, NCSM files). *Pitt Co.*: no further data (Lee et al. 1982, Clark et al. 1985, Lee 1987, Webster 1987). The original source of this record seems uncertain, and it is accompanied by a question mark on the distribution map in Fig. 1. *Robeson Co.*: near Lumberton, early Dec. 1943, A. M. Ivey (Brimley 1944–1946). *Sampson Co.*: near Garland, 13 May 1918, J. F. Johnson (Brimley 1923, Brimley 1944–1946, Paradiso 1959). *Washington Co.*: Wenona, early Nov. 1992, E. R. Rainey (Brimley 1923, Brimley 1944–1946, Paradiso 1959). *Watauga Co.*: Boone, four specimens, 19 May 1918, (Brimley 1944–1946). *Yancey Co.*: *ca.* 7 mi. W. Burnsville along Lickskillet Branch, *ca.* 1981. J. McFee (Allen C. Boynton, pers. comm.).

Lee (1987) and Webster (1987) reported *C. cristata* from Moyock in Currituck County, based on a specimen from the digestive tract of a mink obtained from a fur dealer in that town and reported by Wilson (1954). However, Wilson (1954) indicated that some of the mink in his study were taken in Camden and Dare counties, and no specific locality was given for the specimen from which the mole was retrieved. That it was from Currituck County is possibly an erroneous assumption. It is therefore accompanied by a question mark on the distribution map. Regardless, this record affirms the presence of *Condylura* in the northeastern corner of the state.

Clark et al. (1985) suggested the occurrence of *Condylura* in Bladen and Hoke counties (no specific localities given) based on the presence of mole runs "almost certainly made by this species." Lee (1987) reported *C. cristata* from McCain, Hoke County, citing Clark et al. (1985) as the source. That paper does not, however, contain a clear reference to the species' occurrence at McCain. Lee (1987) further reported observation of "burrows and mounds of *Condylura*" from West End, Moore County, in 1980. Since these records did not involve the observation of actual specimens, they are accompanied by question marks on the distribution map.

Lee (1987) also reported *C. cristata* from Green [sic] County, "pre-1950," citing Clark et al. (1985) as the source, but that paper contains no reference to the species occurring in Greene County. Neither are there records from that county in the North Carolina State Museum's files, hence, it is not included on the distribution map.

Two additional reports of *C. cristata* from the Piedmont of North Carolina are as follows.

Randolph Co.: 2.1 mi. SSE Ulah, off SR 2843 < 0.1 rdmi. SE jct. NC 159. John Schneider, a horticulturist with the North Carolina Zoological Park, reported (personal communication) a specimen that was captured and badly mangled by his dog in March or April, 1991. I visited the site in July, 1994, and found no obvious signs of fresh mole activity, but no serious collecting efforts have yet been undertaken there.

Wake Co.: 1.25 mi. SW Millbrook (= 4.0 mi. N.NE center Raleigh), 4001 Quail Hollow Drive along Big Branch. Dr. Wesley E. Kloos, a genetics professor at North Carolina State University, reported (personal communication, NCSM files) having captured two specimens in his back yard between 1989 and 1991, and released both in nearby Eastgate City Park. A photograph sent to the North Carolina State Museum, of Kloos holding one of the captured animals, was too small and blurred for positive identification. Frequent pitfall trapping on the site during 1992–1993 yielded no specimens.

Although neither Kloos nor Schneider is a mammalogist, both are scientifically oriented individuals, and each seemed certain of the animals's identity. The star-nosed mole is certainly a difficult animal to misidentify. Their reports are therefore included here, and are probably valid, although they remain unverified, and are accompanied by question marks on the distribution map. Except for the Surry County record, and the Mecklenburg County sight record by Brown, they represent the only reports from the Piedmont region of the state. However, the records from Polk and Rutherford counties (NCSM 1237 and 6336, respectively) are very near the eastern edge of the escarpment, and the sight record of burrows and mounds from West End in Moore County (Lee 1987) is at the extreme inner edge of the Coastal Plain.

The locality for the Surry County specimen (NCSM 7744) lies just off the Blue Ridge escarpment in the extreme western Piedmont, and is the first specimen-supported record for that geographic province in the state. The specimen was found dead along a bog at the edge of a hayfield. Evidence of considerable mole activity was apparent at this site during 1994 and 1995 (personal observation), and the landowners reported that these moles were commonly killed by house cats on the property, as was possibly the case with this specimen (Ann B. Somers, personal communication).

The specimens from Ashe, Brunswick, Dare, Hoke, Jackson, and Rutherford counties also represent new county records. The sight records for Bladen, McDowell, Mecklenburg, Randolph, and Wake counties, though not supported by specimens, represent previously unpublished county records as well (see Lee et al. 1982, Webster 1987).

DISCUSSION

The range of the star-nosed mole overlaps that of the eastern mole (*Scalopus aquaticus*) throughout North Carolina, and that of the hairy-tailed mole (*Parascalops breweri*) in the Mountains. The hairy-tailed mole is currently known from Avery, Buncombe, Caldwell, Jackson, Haywood, Macon, Mitchell, Swain, Transylvania, Watauga, Wilkes, and Yancey counties in the Mountains (Lee et al. 1982, NCSM files). The late Joseph M. Bauman (personal communication) also reported specimens from Cherokee County. The eastern mole apparently occurs throughout the state (Lee et al. 1982, Webster et al, 1985), and is in most places the most common mole.

Differences in habitat preference by the three have been noted by several authors. Star-nosed moles are known to prefer, if not require, wet areas as habitat (Hamilton 1931, Burt and Grossenheider 1976, Yates and Pedersen 1982, Webster et al. 1985). Nearly all North Carolina specimens for which habitat information is available were collected in such areas. A possible exception is the Bladen County specimen listed above, which was found dead in a dry, sandy area apparently not near a wetland (T. M. Padgett, personal communication). The eastern mole has been reported to avoid "the wet soils preferred by the Star-nosed Mole" (Lee et al. 1982). The hairy-tailed mole reportedly occurs in similar habitats as the eastern mole, but usually at higher elevations, with most specimens being taken at above 2,000 ft. (610 m) (Lee et al. 1982, Webster et al. 1985, NCSM files). Lee et al. (1982) reported the hairy-tailed mole to be "considerably more common than the Star-nosed Mole," but this may not hold true at all montane localities. In Watauga County, for instance, *Condylura* apparently is more frequently encountered than *Parascalops* (R. W. Van Devender, personal communication), and there are overall more *Condylura* than *Parascalops* from the North Carolina mountains in the State Museum's collections.

The ecological niches of the three moles may thus be loosely described as *Parascalops* and *Scalopus* frequenting well-drained soils, often with an altitudinal separation between them, and *Condylura* utilizing wet, low-lying areas at a wide range of elevations. However, some syntopy may occur. All three species may occur at some montane localities, as is the case in the vicinity of Highlands Biological Station in Macon County at *ca.* 3,900 ft. (1,190 m) in elevation (NCSM files). In Ashe County at *ca.* 2,880 ft. (878 m), I found a dead eastern mole (NCSM 7251) in a wet sedge meadow bog, a site which appeared more suitable for a star-nosed mole. Eadie (1939) reported having trapped *Condylura* and *Parascalops* in the same tunnel at a New Hampshire site. Undoubtably, the distributions and interspecific zrelationships of North Carolina's three mole species merit further study.

The possibility that *Condylura cristata* occurs at low densities or at scattered localities throughout the state, and that the Mountain and Coastal Plain populations are not disjunct, should not be ignored. Although Lee et al. (1982) stated that "absence of records from the piedmont is certainly not an artifact of collecting," there have probably been few serious efforts to collect *C. cristata* in the North Carolina Piedmont, other than the recent trapping efforts at the Wake County site. Moreover, specific attempts to collect *Condylura* in the Mountains and Coastal Plain have seldom if ever proven successful, and Clark et al. (1985) commented on the difficulty encountered in trapping the species. Most available specimens for which the method of collection is known were found dead on roads or otherwise accidentally encountered. Even in the Mountains where the species may be fairly common, there are still several counties for which specimens have not been reported. Much of the Piedmont, particularly the western part, has been largely overlooked or ignored by biologists, and its fauna remains poorly documented. Small, fossorial or otherwise secretive vertebrates may long elude detection in any region. As examples, the eastern tiger salamander (*Ambystoma tigrinum*) was first discovered in the Piedmont in Wake County by me in 1982 (NCSM files) after that area had been heavily collected by herpetologists for nearly a century; and the bog turtle (*Clemmys muhlenbergii*) was discovered in three new Piedmont counties during 1992–1993 (Beane 1993). Although some areas, such as the Raleigh vicinity, have been heavily collected by mammalogists and other biologists for more than a century, little effort has been specifically aimed at star-nosed mole trapping.

The North Carolina Piedmont has been heavily altered for agriculture and urbanization—probably more so overall than either the Mountains or the Coastal Plain, and many Piedmont wetlands have been drained or otherwise destroyed in the process. It is possible that wetlands alteration or other human activities may have eliminated the star-nosed mole from many areas of the Piedmont in recent times. If populations of this mole do occur throughout the Piedmont of North Carolina, it is likely that they exist as scattered relicts (either Pleistocene relicts or more recent anthropogenic relicts) and at low densities. It is hoped that this paper will help stimulate biologists working in North Carolina (and other southern states) to make every reasonable effort to collect evidence of *Condylura*, and to photograph or collect specimens wherever they are encountered, especially at undocumented localities.

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Observations on North Carolina Crayfishes (Decapoda: Cambaridae)

John E. Cooper
418 Wayne Drive
Raleigh, North Carolina 27608

AND

Alvin L. Braswell
North Carolina State Museum of Natural Sciences
P.O. Box 29555, Raleigh, North Carolina 27626

ABSTRACT—*Cambarus* (*Tubericambarus*) *acanthura*, *Orconectes* (*Procericambarus*) *spinosus*, and an apparently undescribed species of *Orconectes* (*O.* sp. B), are reported for the first time from North Carolina. Six additional specimens of *Orconectes* (*Crockerinus*) *virginiensis* are reported from the Chowan and Roanoke basins, and its range in North Carolina is clarified. *Orconectes* (*C.*) *erichsonianus*, for which a North Carolina locality has been published, is deleted from the State list. *Cambarus* (*Jugicambarus*) *asperimanus* is reported from the Watauga and New rivers in Watauga County, and localities are provided that expand its known range in the Piedmont Plateau. New locality data, distributional clarifications, or natural history notes are provided for *Cambarus* (*Depressicambarus*) *latimanus*, *C.* (*D.*) *reduncus*, *Cambarus* (*Jugicambarus*) *carolinus*, *C.* (*J.*) *dubius*, *C.* (*J.*) *nodosus*, *Cambarus* (*Puncticambarus*) *georgiae*, *C.* (*P.*) *parrishi*, *C.* (*P.*) *reburrus*, *Procambarus* (*Ortmannicus*) *medialis*, *P.* (*O.*) *pearsei*, and *P.* (*O.*) *plumimanus*. A blue specimen of *C. latimanus* is reported from the Neuse River basin. The North Carolina crayfish fauna is correlated with the State's major river basins and physiographic provinces.

Thanks largely to the efforts of the late Horton H. Hobbs, Jr., U. S. National Museum of Natural History, Smithsonian Institution, with whom the modern era in crayfish studies essentially began, the composition of the crayfish fauna of North Carolina is relatively well known. As indicated in his most recent checklist of the American crayfishes (Hobbs 1989:89), the North Carolina fauna consists of 27 described native species, a putative subspecies of one of them, and one introduced species. Hobbs, sometimes with coworkers, described one of the four genera, six of the 11 native subgenera, and 11 of the 27 native species known to occur in the State at the time of his checklist.

In addition to the described species, at least four and probably five known but undescribed species from North Carolina await description. Hobbs and Peters (1977:8–9) mentioned *Cambarus* (*Cambarus*) sp. A, close to *Cambarus* (*Cambarus*) *bartonii* Fabricius; *Cambarus* (*Depressicambarus*) sp. B, close to *Cambarus* (*Depressicambarus*) *reduncus* Hobbs; and *Cambarus* (*Puncticambarus*) sp. C. The latter, *C.* (*P.*) sp. C, refers not to a single undescribed species but to an undiagnosed species complex that includes *Cambarus* (*Puncticambarus*) *acuminatus* Faxon, which is one of the 27 species listed for North Carolina. In fact, however, Hobbs (1969:135) said that *C.* (*P.*) *acuminatus* (*sensu stricto*) may be "confined to the Saluda drainage" of South Carolina, and later (Hobbs 1989:25) added, "Even in the Santee Cooper basin (of which the Saluda River is a tributary), . . . more than one rather distinct 'variant' is recognizable." We see no reason in our paper to depart from using *C.* (*P.*) sp. C for this complex until a diagnosis has been completed. Considering that the species in the complex range from the mountains to the coast in North Carolina, there probably are several awaiting description. Cooper and Cooper (1977*a*:198–199) and Cooper and Ashton (1985:9) commented on the undescribed *Orconectes* sp. A, and North Carolina localities for another apparently undescribed *Orconectes* (herein designated *O.* sp. B) are presented in our paper. One of us (JEC) is investigating a number of other new species, but further comment on them at this time would be premature. It is a certainty that other undescribed species await discovery in North Carolina.

About another widespread crayfish that occurs in parts of North Carolina, *Procambarus* (*Ortmannicus*) *acutus acutus* (Girard), Hobbs (1989:64) said, "With little doubt, the populations currently assigned to this subspecies constitute a species complex." The complex was under study by Hobbs and Hobbs (1990:608). Hobbs (1989:24) also said that *Cambarus* (*Lacunicambarus*) *diogenes* Girard, a broadly distributed crayfish whose range includes eastern North Carolina, "is a species complex and needs considerable attention." Jezerinac (1993:532) "concluded that the complex consists of two subgenera *Lacunicambarus* and *Tubericambarus*, new subgenus, and at least five additional species or subspecies." Another extremely variable crayfish that occurs in parts of North Carolina, *C.* (*C.*) *bartonii*, is also in dire need of revision. Hobbs (1969:146) referred to "the depauperate state of our knowledge of the relationships of those crayfishes which are currently being tentatively designated as *C. b. bartonii* . . . ." Hobbs (1989:82, 89) included *Cambarus bartonii cavatus* Hay in his list of crayfishes occurring in North Carolina, but

North Carolina was not included in his statement of the range of this putative subspecies (Hobbs 1989:14). We have opted to omit it as a member of the North Carolina cambarid fauna until specific evidence appears to support its inclusion.

Four described species are North Carolina endemics: *Cambarus* (*Depressicambarus*) *catagius* Hobbs and Perkins, of the upper Cape Fear River basin; *Cambarus* (*Puncticambarus*) *reburrus* Prins, of the French Broad and Savannah basins; *Procambarus* (*Ortmannicus*) *medialis* Hobbs, of the Neuse and Tar-Pamlico basins; and *Procambarus* (*Ortmannicus*) *plumimanus* Hobbs and Walton, of the Northeast Cape Fear and New (White Oak) basins, which, as we explain later, may be expanding its range into the lower Neuse basin. The undescribed *Orconectes* sp. A is another North Carolina endemic, found only in the Neuse and Tar-Pamlico basins.

This article adds two described and one undescribed native species to the State list, provides additional distributional and natural history information for them and 13 other species, deletes a species for which a North Carolina locality has been published, correlates the State's crayfish fauna with its major hydrologic units, and summarizes the distribution of this fauna in the State's three major physiographic provinces.

Abbreviations used are as follows. SR = secondary road (formerly CR for county road); NC = North Carolina state highway; US = United States highway (an A after the number means alternate highway); I = interstate highway; FRS = United States Forest Service Road; cntr = center of town or city; NCSM C- = crustacean collections, North Carolina State Museum of Natural Sciences, Raleigh; USNM = collections, U. S. National Museum of Natural History, Smithsonian Institution, Washington, D. C. Collector's names are given in first usage, initials thereafter.

Cambarus (*Depressicambarus*) *latimanus* (LeConte)

Hobbs (1981:120), reporting observations made in a thesis by J. L. Boyce (1969), stated that in Yellow River, Georgia, *C. latimanus* "becomes relatively inactive during December, January, and February," Hobbs (1981:119) also provided monthly capture data for a large number of specimens that suggested the same thing: 77 collected in November, five in December, 21 in January, and none in February, as opposed to 164 in March, 1,079 in April, and relatively high numbers in most other months. These kinds of collecting data, however, can be more a reflection of seasonal activities of the collectors than of the collected. If we can equate "activity" with "catchability," and in the case of animals taken in traps we feel justified in so doing, *C. latimanus* is not inactive during winter months in eastern North Carolina. Intensive sampling was conducted in the Neuse River basin from late December 1978 through May 1979, and in the Tar-Pamlico basin from January through April 1980, most of it part of a study of the distribution and ecology of the salamander, *Necturus lewisi* (Brimley) (Braswell and Ashton 1985). This effort yielded considerable winter and spring capture ("activity") data for 409 adult and 279 juvenile *C. latimanus*, the majority of them caught in traps (Table 1).

Bouchard (1978:37) remarked on a dearth of ovigerous females in collections of this species, saying, "Of the numerous collections of *C. latimanus* that have been made, only three specimens are females with eggs (or young)." One of these females was collected in a tributary of the Neuse River in Wake County, North Carolina, on 16 April 1977, the other two were collected in Alabama on 22 April 1973. Hobbs (1981:119), who examined 2,424 specimens of this species from approximately 400 localities, remarked, "I have no records of ovigerous females or of those carrying young anywhere within its range . . . . This paucity of such females in collections almost certainly reflects inadequate sampling of burrows in the banks of streams." Most of the smallest juveniles collected in the Neuse and Tar-Pamlico surveys were taken in late April and May. This, combined with the few available dates of capture of ovigerous females, Bouchard's (1978:47) report of a copulating pair found on 2 November 1974 in Alabama, and the fact that nearly 50 percent of the males in the January sample reported in Table 1 were form I, leads us to suggest that in eastern North Carolina (1) mating and egg production occur in winter and perhaps late fall, (2) incubation occurs during winter and early spring,

Table 1. Summary of winter and spring captures of *C. latimanus* in the Neuse and Tar-Pamlico river basins, 1978–1980.

Month	♂I	♂II	♀	juv	N
Jan	46	48	81	21	196
Feb	15	20	39	46	120
Mar	14	40	50	22	126
Apr	9	19	23	168	219
May	1	2	2	22	27
Totals	85	129	195	279	688

and (3) the young are produced later in the spring (a time of high water, expanded habitat, and increased availability of food). This supports Thorp's (1978:278) statement that in the lower Savannah River basin of South Carolina this species "enters the reproductive period as temperatures are dropping in fall and winter."

On 17 February 1982, a blue specimen of *C. latimanus* was found by a worker clearing a muddy ditch at the south end of the Wayne Community College campus in Goldsboro, Wayne County (Neuse River basin). It was taken to Gary W. Woodyard of the college biology faculty, who generously donated it to the N. C. State Museum. The animal, a form II male (NCSM C-775), was generally cobalt blue, with the pigment obviously in the exoskeleton since the underlying chromatophore pattern of blotches and abdominal stripes was clearly visible. The right cheliped was missing, but the left cheliped and all pereiopods were whitish on the ventral surfaces, with a pale bluish tint at the base of the coxa of each limb. The lateral margin of the palm and propodus was very light blue, but the entire dactyl was darker except at the ventral tip. The gonopods (first pleopods), eyestalks, antennae, antennules, and antennal scales were pale blue. There was a small white area on the anterolateral carapace just below the suborbital angle and along part of the margin of the carapace. The small tubercles and punctations of the carapace were points of white, as were the small cervical spines. Most of the ventral abdomen was clear, but the transverse ridges between segments were blue.

This is the first blue individual reported for this species, and the first blue crayfish reported for any non-blue species in North Carolina. One North Carolina crayfish, *Cambarus* (*Jugicambarus*) *dubius* Faxon, is known to have a cobalt blue color morph. In the area where the blue *C. latimanus* was found, the species normally is light tan or greenish, with dark brown or green carapace markings and abdominal stripes. Hundreds of normal-colored specimens of this species have been collected in the Neuse River and its tributaries, including a number from Wayne County.

Fitzpatrick (1987) summarized most of the known records for the "blue color phase" in six crayfish genera, and discussed environmental (diet and illumination) versus genetic causes of such color variations. Penn (1951) reported a blue color variant of *Procambarus* (*Scapulicambarus*) *clarkii* (Girard), a normally red species, in Louisiana. Penn later (1959:10) said, "In recent years anomalous bright blue specimens have appeared in several parts of the state . . . ." (That someone may be culturing this obviously genetic variant is indicated by the fact that in April 1984 JEC examined several bright blue specimens of this species, said to be from "Thailand," that were for sale as exotic novelties in a Raleigh tropical fish shop. A form I male was purchased and is in the NCSM collections, C-1295.)

Smiley and Miller (1971:221) estimated the frequency of blue variants in normally non-blue *P. a. acutus* as 1 in 50,000. Black (1975) experimentally demonstrated that blue color in this species is a mutation, in which the gene controlling the chemical composition of a carotenoid pigment in the exoskeleton behaves as a single recessive allele, with complete penetrance of the dominant normal allele. He estimated the ratio of blue to normal crayfish in the pond of origin of his parental stocks at 1:5,600. Anthony D'Agostino has bred cobalt blue *Homarus americanus*, and the F_1 offspring inherit this coloration as a homozygous recessive trait (Porterfield 1982:38), which is what Black found in *P. a. acutus*.

With a nod to William of Occam, we find it considerably more parsimonious to conclude that the Wayne County *C. latimanus* was a genetically blue individual than that its abnormal color was produced by diet or environmental conditions.

In North Carolina, *C. latimanus* is a common, widespread inhabitant of the eastern Piedmont Plateau and much of the Coastal Plain. It is possible, though, that it also occurs in the Hiwassee River basin of the Blue Ridge, as we discuss later.

Cambarus (*Depressicambarus*) *reduncus* Hobbs

Bouchard (1978:40) gave the range of this species as "in the Piedmont province from the Cape Fear River drainage in North Carolina southward to the Santee River basin . . . .," and in the latest American checklist Hobbs (1989:16) gave it as "Piedmont Province from Orange County, North Carolina to Richland County, South Carolina." Concerning the northern terminus of its range, these statements almost certainly were based on specimens from the upper Cape Fear basin in and around Chapel Hill, Orange County, earlier reported by Hobbs (1956:66–67) and Hobbs and Peters (1977:50). Although Cooper and Ashton (1985:9) had reported *C. reduncus* from the Neuse and Tar-Pamlico basins, north of the Cape Fear, they gave no particulars. The following localities extend the known range of this species north into the Piedmont headwaters of these two rivers, very close to the Roanoke River basin.

NEUSE RIVER BASIN. *Durham Co.*—(1) Lick Crk at SR 1905, 10 air mi (16 air km) E Durham; 1 ♂ I (NCSM C–520), 27 Jan 1979, A. P. Capparella. *Granville Co.*—(2) burrow in roadside ditch along

SR 1721, 3.5 air mi (5.6 air km) SE cntr Creedmoor, near Wake Co line; 1 ♂ I (NCSM C–860), 23 Apr 1978, R. E. Ashton, Jr.; (3) swamp at E edge Lake Rogers (on Ledge Crk), 1 air mi (1.6 air km) NW Creedmoor; 1 j ♂, 9 Mar 1991, D. G. Cooper, JEC. *Wake Co.*—(4) burrow in lawn, Morrisville; 1 ♀ (NCSM C–907), 27 Mar 1978, J. Clayton; (5) alive on SR 1300 (Hemlock Bluffs Rd) N of bridge; 1 ♂ I (NCSM C–909), night 3 Nov 1977, R. W. Laney, D. F. Lockwood; (6) alive on road, 0.5 mi (0.8 km) W jct SR 1379 & Kildaire Rd; 1 ♂ I (NCSM C–910), night 3 Nov 1977, RWL, DFL. TAR-PAMLICO RIVER BASIN. *Granville Co.*—(7) alive on road, jct SR 1304 & 1307, 1.8 air mi (2.9 air km) W Hebron; 1 ♂ II (NCSM C–1262), night 23 Apr 1983, J. P. Kumyhr, D. Smith. *Person Co.*—(8) Tar R at SR 1565, 1.7 air mi (2.7 air km) WSW Dennys Store; 1 ♂ I, I ♀ (NCSM C–665), 20 Feb 1980, trap, E. Rawls. *Vance Co.*—(9) Tabbs Crk at SR 1101, 2.3 air mi (3.7 air km) W Kittrell; 1 ♂ I, 1 ♀ (NCSM C–655), 24 Jan 1980, trap, ER.

Hobbs and Peters (1977:18) reported *C. reduncus* from "Montgomery County: (2) Hamer Creek, 3 mi (4.8 km) N Richmond Co line on St Rte 73," assigning the locality to the "CATAWBA BASIN." This locality, though, like nearly all of Montgomery County, is in the Yadkin-Pee Dee basin. The following collections of *C. reduncus*, however, are known from the Catawba basin in North Carolina: *Gaston Co.*—(1) small stream (trib South Crowders Crk) near office Crowders Mountain State Park, off SR 1125, 0.6 rd mi (0.9 rd km) SW jct SR 1106, 5.2 air mi (8.3 air km) S Bessemer City; 1 ♂ II, 1 j ♂, 3 ♀, 4 j ♀ (NCSM C–2300), 22 Apr 1985, ALB. *Mecklenburg Co.*—(2) plowed field along dirt rd at E end SR 3629 (Sixmile Crk dr), ca. 6.3 air mi (10.1 air km) SE cntr Pineville; 1 ♂ II, 4 j ♂, 1 ♀, 2 j ♀ (NCSM C–1043), 19 Apr 1980, from burrows with chimneys, N. L. Elliott; (3) ditch along SR 3629 (Sixmile Crk dr), ca. 5.6 air mi (8.9 air km) SE cntr Pineville; 9 j ♂, 1 ♀, 11 j ♀ (NCSM C–1045), 19 Apr 1980, NLE. *Union Co.*—(4) along SR 1624, 0.5 rd mi (0.8 rd km) NW jct NC 200, 2.0 air mi (3.2 air km) NNE Monroe; 1 ♂ I (NCSM C–311), 15 Jul 1978, J. W. Braswell, Jr., ALB; (5) East Fk Twelve Mile Crk at SR 1329, ca. 2.1 air mi (3.4 air km) SSW Wesley Chapel; 1 j ♂, 3 j ♀ (NCSM C–1031), 18 Apr 1980, in roadside ditch fed by woodland pool; 1 j ♂, 3 j ♀ (NCSM C–1047), 18 Apr 1980, in shallow, temporary floodplain pools; 1 ♂ II, 1 j ♀ (NCSM C–1027), 26 Apr 1980, dug from burrows with chimneys in old-field, NLE; (6) small branch Little Twelve Mile Crk at SR 1329, ca. 2.9 air mi (4.6 air km) SSW Wesley Chapel; 4 j ♂, 7 j ♀ (NCSM C–1037), 18 Apr 1980, NLE; (7) woodland pool off Little Twelve Mile Crk at SR 1328, ca. 3.1 air mi (5.0 air km) SW Wesley Chapel; 3 j ♂, 1 j ♀ (NCSM C–1040), 18 Apr 1980, NLE; (8) damp ditch at East Fk Twelve Mile Crk at SR 1336, ca. 1.6 air mi (2.6 air km) SW Wesley Chapel; 1 j ♂, 1 j ♀ (NCSM C–1038), 20 Apr 1980, from burrows, NLE.

Cambarus (*Jugicambarus*) *asperimanus* Faxon

This crayfish occurs in the Watauga River basin in Tennessee (Hobbs 1989:20), but no localities for the species have been reported from this system in North Carolina. Additionally, no one unequivocally has reported its occurrence anywhere in the New River basin. With respect to the latter, in a discussion of "*Cambarus* (*Cambarus*) *bartoni asperimanus*," Ortmann (1931:138) stated, " I have a male (I) and two females from Blowing Rock (in the headwaters of New River, some distance northeast of Asheville), in which the inner margin of the palm has the tubercles somewhat more strongly developed than is usual in *bartoni*. This indicates a transition toward *asperimanus*. However, I prefer to leave these with *bartoni*; the character being much less distinct here than in the specimens from Asheville and Canton" (Buncombe and Haywood counties, respectively, French Broad River basin). There is one other published locality for *C. asperimanus* that could be in the New River basin, but it was not reported as such. Hobbs and Peters (1977:57) recorded the species from "Watauga County: (8) creek at Deep Gap," but placed this locality in the Pee Dee (Yadkin) basin. This citation does not indicate whether "creek at Deep Gap" refers to the community of Deep Gap, or the mountain gap of the same name. The community is in eastern Watauga County on Deep Gap Creek, a tributary that joins South Fork New River in Ashe County. The mountain gap lies southeast of the Blue Ridge, in the drainage of Stony Fork Creek, a headwater tributary that enters the Yadkin River in western Wilkes County.

On 25 July 1984, we collected *C. asperimanus* in both the Watauga and New River basins at the following localities. WATAUGA RIVER BASIN. *Watauga Co.*—(1) small stream entering N bank Watauga R at NC 105 bridge, jct SR 1112, ca. 2.4 air mi (3.8 air km) SE Valle Crucis; 2 ♀ (NCSM C–1811), from under separate rocks at mouth of stream. NEW RIVER BASIN. *Watauga Co.*—(2) small, shallow creek (South Fk New River dr) in hardwood ravine and meadow on E side Howard Knob, off Hidden Valley Circle, 0.3 rd mi (0.5 rd km) from jct Chestnut Drive in north Boone; 1 ♂ I, 5 j ♂, 1 ♀, 1 j ♀ (NCSM C–1814), 1 ♀ with attached young (NCSM C–1815), 3 ♀, 1 j ♀ (NCSM C–1816), with R. W. VanDevender.

At the Watauga River locality, the only other crayfish collected was *Cambarus* (*Puncticambarus*) *robustus* Girard, all specimens of which were taken from the river itself. At the New River locality, the orangish-tan *C. asperimanus* were "associated" with cobalt blue *C. dubius*. The two species were dug from burrows within a few meters of each other, but their habitats differed. The *C. asperimanus* that came from burrows were in simple, shallow burrows at or just above water level along the banks of the creek, while the *C. dubius* were dug from more complex burrows in a mucky seepage area near the same creek. Some *C. asperimanus* were found under rocks in the creek, but no *C. dubius* were in this habitat, and no *C. asperimanus* were dug from the seep.

The limits of the range of *C. asperimanus* east of the Blue Ridge escarpment in North Carolina are not yet clear, but we made a number of collections of the species at the base of the eastern foothills and in the Piedmont as far east as western Catawba County. Hobbs and Peters (1977:57) first recorded the species in this area, from a locality in the upper Catawba basin in northwestern Burke County. Our collections at the following new localities extend the range of *C. asperimanus* farther east in the Catawba basin, and south and east into the Broad River basin.

CATAWBA RIVER BASIN. *Burke Co.*—(1) Jacob Fk nr office South Mountain State Park, 3.4 air mi (5.4 air km) SW Pleasant Grove; 1 ♂ I, 3 ♂ II, 1 j ♂, 4 ♀ (NCSM C–2281), 23 Apr 1985; (2) Laurel Crk along NC 18, 2.0 rd mi (3.2 rd km) ESE jct SR 1929, 3.2 air mi (5.1 air km) N Pleasant Grove; 2 ♂ I, 5 j♂, 6 j ♀ (NCSM C–2286), 1 ovig ♀ (NCSM C–2309), 26 Apr 1985. *Catawba Co.*—(3) small stream (trib Henry Fk) along I 40 at milepost 120 near Burke Co line, ca. 4.0 air mi (6.4 air km) SW cntr Hickory; 1♂ II, 3 j ♂, 1 ♀, 1 j ♀ (NCSM C–1257), 12 Apr 1983. *McDowell Co.*—(4) trib Swannanoa Crk along SR 1400, 1.3 rd mi (2.1 rd km) W jct E end SR 1407, 2.1 air mi (3.4 air km) WNW cntr Old Fort; 2 ♂ I, 2 ♂ II, 1 j ♂ (NCSM C–807), 20 Aug 1977; (5) trib Catawba R along US 70, 3.1 mi (5.0 km) E Buncombe Co line, 2.3 air mi (3.7 air km) WSW cntr Old Fort; 2 ♀ (NCSM C–949), 24 Nov 1978, with D. L. Stephan; (6) small cascading stream (trib Swannanoa Crk) along SR 1407, ca. 0.4 rd mi (0.6 rd km) NE Buncombe Co line, ca. 5.0 air mi (8.0 air km) W cntr Old Fort; 1 j ♂, 3 ♀, 1 j ♀ (NCSM C–1251), 12 Apr 1983; (7) Long Br (trib Mill Crk) along SR 1407, 0.4 rd mi (0.6 rd km) S railroad crossing, 1.5 air mi (2.4 air km) SE Graphite & 3.2 air mi (5.1 air km) WNW cntr Old Fort; 1♂ II, 1 j ♀ (NCSM C–1258), 12 Apr 1983; (8) Buck Crk at NC 80 bridge, 0.4 rd mi

(0.6 rd km) N jct SR 1437, ca. 0.2 air mi (0.3 air km) E Sunny Vale; 1♀ (NCSM C–2200), 26 Sep 1984. BROAD RIVER BASIN. *Cleveland Co.*—(9) small stream (Buffalo Crk dr) in hardwoods, 0.8 rd mi (1.3 rd km) S Lincoln Co line, 2.3 air mi (3.7 air km) NNE Belwood; 1 ♂ II, 3 j ♂, 3 j ♀ (NCSM C–2283), 22 Apr 1985. *McDowell Co.*—(10) intermittent creek (trib Cane Crk) in hardwood ravine along NC 226, 0.1 rd mi (0.2 rd km) WNW Rutherford Co line, 3.4 air mi (5.4 air km) SE Dysartville; 4 ♂ II (NCSM C–987), 25 Jun 1977, 2 ♂ I, 5 ♂ II, 11 j ♂, 9 ♀, 14 j ♀ (NCSM C–1821), 1 ♀ with attached young (NCSM C–1823), 1 ♂ II, 1 j♂, 2 ♀ (NCSM C–1824), 26 Jul 1984. *Rutherford Co.*—(11) trib Broad R at NC 9, ca. 0.3 air mi (0.5 air km) S town Lake Lure; 1 ♂ II (NCSM C–64), 6 Aug 1976; (12) small stream in steep ravine at NC 9, 0.8 rd mi (1.3 rd km) W cntr town Chimney Rock; 1♀ (NCSM C–959), 3 ♂ II, 1 ♀ (NCSM C–960), 5 Jun 1977, with E. Messersmith. *Polk Co.*—(13) unnamed trib Green R near Raccoon Mountain; 1 ♂ I (NCSM C–2012), summer 1974, G. G. Shaw.

We conclude, based on the apparently broad temporal distribution of ovigerous females and those with young, that *C. asperimanus* either has an extended breeding season or has a long development time for the ova and young. Hobbs (1981:190) reported an ovigerous female taken in Rabun County, Georgia, in April 1977, and said that "elsewhere" such females have been taken in April, June, and December. The latter statement may have been based on Bouchard (1972:47), who reported ovigerous females (presumably in Tennessee) in "April to June and December." As indicated above, we collected a female with attached young in Watauga County on 25 July 1984, and another a day later in McDowell County. David G. Cooper collected a female with three attached young in Jackson County on 10 August 1993. In addition, we found a number of individual females closely associated with groups of tiny young in Macon County on 19 September 1984, and on this same date we found free-living young of the same size.

The Jackson County female collected by DGC on 10 August 1993 is the largest *C. asperimanus* we have seen, with a total carapace length (TCL) of 42.0 mm and a postorbital carapace length (PCL) of 37.0 mm. Another very large specimen, a form I male measuring 38.0 mm TCL (32.5 mm PCL), was collected by DGC at the same site on the same date. We collected a form I male in Macon County that measured 36.0 mm TCL (31.5 mm PCL). The only other size data we know of for this species are those of Hobbs (1981:190). His largest

Georgia specimen, an ovigerous female, measured 30.5 mm TCL (26.7 mm PCL), and his largest form I male was 27.6 mm TCL (24.1 mm PCL).

Cambarus (*Jugicambarus*) *carolinus* (Erichson)

Although Hobbs and Bouchard (1973:42), Bouchard (1976:594), and Hobbs (1989:21) included southwestern North Carolina, south and west of the French Broad River, within the range of this species, no one has yet reported precise locality or natural history data for this primary burrower in North Carolina. Faxon (1890:624) reported a form I male of his *Cambarus dubius*, collected by James Mooney from " 'Among the Cherokees,' Indian Territory," and said, "According to the label accompanying the specimen it is called *Tsisgágili* (red crayfish) by the Cherokee Indians." The same author later (Faxon 1914:396) included this specimen (USNM 14314) under *C. carolinus*, said "I am advised by Mr. Mooney that it was in reality obtained in Swain Co. or in Jackson Co., N. C., " and added (Faxon 1914:397) that "The living color . . . was red . . . ." Ortmann (1931:147) reported Faxon's specimen under "*Cambarus* (*Cambarus*) *carolinus*," and inexplicably indicated that it was from "Cherokee Co.; North Carolina." He added, "I have seen, at Murphy, Cherokee Co., crawfish-chimneys, and tried unsuccessfully to dig out specimens . . . . The owner of the place told me, that these were *red* crawfish, and thus probably this species." Ortmann (1931:147) also recorded the species from "Swampy ground near springs, Marion, McDowell Co. . . . Swamp, Ashville [sic], Buncombe Co., . . .," and "Blowing Rock, Watauga Co., ..." These three localities are outside the range of *C. carolinus* as currently understood, but the last two are within the known range of *C. dubius* (*sensu lato*). The McDowell County locality is in the western Piedmont Plateau, in the headwaters of the Catawba River basin, beyond the known ranges of both *C. carolinus* and *C. dubius*. Brimley (1938) recorded *C. carolinus* at "Judson," and Hobbs and Bouchard (1973:21) called for confirmation of this record. This would have been a reasonable place to find *C. carolinus*, since Judson was a community on the Little Tennessee River in southwestern Swain County, but it is now beneath the waters of Fontana Lake (Powell 1968:259). The reference by Harris (1903:142) to "*C. carolinus*" in the Tar-Pamlico River basin was clearly in error.

We made the following collections of specimens referred to this species at the indicated localities, all within the basin of the Little Tennessee River: *Clay Co.*—(1) boggy spring seep in Riley Cove, off unnumbered dirt road reached from US 64, 3.3 rd mi (5.3 rd km) S jct SR 1359 & 1.2 rd mi (1.9 rd km) W jct FSR 71 (old US 64), Natahala National Forest; 1 ♂ II (NCSM C–948), 16 Aug 1977, 1 ♂ I, 1 ♂ II, 5 j ♂, 4 ♀, 3 j ♀ (NCSM C–2165), 1 ♂ II, 1 ♀ (NCSM C–2166), 21 Sep 1984. *Graham Co.*—(2) dug from muck in Talulah (Tulula) Bog, along US 129, 1.4 rd mi (2.2 rd km) E jct SR 1201, 6.7 air mi (10.7 air km) SE Robbinsville; 1 j ♂, 2 ♀, 1 j ♀ (NCSM C–2290), 25 Apr 1985; (3) small boggy area near Cheoah R along SR 1147, 0.1 rd mi (0.2 rd km) S jct US 129; 1 ovig ♀, 1 j ♀ (NCSM C–2310), 26 Apr 1985. *Macon Co.*—(4) boggy area around flood-plain pond by Nantahala R, off US 19, ca. 0.5 rd mi (0.8 rd km) NE Graham Co line & 5.2 air mi (8.3 air km) NW Kyle; 1 ♂ II, 1 j ♂, 1 ♀, 1 j ♀, remains of decomposed ♂ I, pair of loose chelipeds (NCSM C–2292), 24 Apr 1985, with J. Bauman; (5) dug from sphagnum bog and margin murky stream along Little Choga Crk on SR 1402, 3.3 rd mi (5.3 rd km) SE jct SR 1401, 3.2 air mi (5.1 air km) WSW Aquone; 1 ♂ II, 1 ♀ (NCSM C–2287), 25 Apr 1975, with JB; (6) under rocks in wet roadside ditch along SR 1401, 2.9 rd mi (4.6 rd km) NE jct SR 1402, 2.3 air mi (3.7 air km) WNW Aquone; 2 j ♂ (NCSM C–2289), 25 Apr 1985, with JB.

All the specimens were brick red in color, and all except those from locality (6) were dug from burrows, usually constructed among soil and roots in boggy areas. The bog at locality (1) was about 8 m from a small, rocky stream, tributary to Buck Creek (Nantahala River). Only one other crayfish, a juvenile male *C. b. bartonii*, was dug from this bog. In the nearby stream, under rocks and in substrate under rocks, we found other *C. b. bartonii*, and a female of an unidentified *Cambarus*. The stream was about 1– to 1.5–m wide, 7– to 8–cm deep, and had a low gradient and low velocity current. At locality (4), an unidentified *Cambarus* was found under a rock in wet sand near the bog, and at locality (5) *C. b. bartonii* was found in the stream but not in the boggy area.

Cambarus (*Jugicambarus*) *dubius* Faxon

There are a number of published localities for *C. dubius* in North Carolina, including recent ones in Hobbs and Peters (1977:24, 50; 1989:324). The range of the species in North Carolina, however, is poorly known, both because it is a primary burrower and difficult to find and collect, and because of taxonomic uncertainties. In general, the species occurs in "northwestern North Carolina" (Hobbs 1989: 22), "north and west of the French Broad River basin" (Bouchard 1976:594). Little has been published about its natural history in North Carolina.

The following collections of *C. dubius* are of distributional and natural history interest. NEW RIVER BASIN. *Watauga Co.*—(1) seepage area near small, shallow creek (South Fk New R dr) in hardwood ravine and meadow on E side Howard Knob, off Hidden Valley Circle, 0.3 rd mi (0.5 rd km) from jct Chestnut Drive, in north Boone; 3 ♂ II, 8 j ♂, 2 ♀, 8 j ♀ (NCSM C–1812), 2 ♀ with attached young (NCSM C–1813), 2 j ♀ (NCSM C–1817), 1 ♂ I, 5 ♂ II, 3 j ♂, 2 ♀, 5 j ♀ (NCSM C–1818), 25 Jul 1984, RWV, ALB, JEC. FRENCH BROAD RIVER BASIN. *Haywood Co.*—(2) bog near small stream (trib Cold Springs Crk, Pigeon R dr), in rhododendron thicket in steep ravine along FSR 148, Pisgah National Forest, 3.6 rd mi (5.8 rd km) SW jct SR 1334; 1 ♂ I, 2 ♂ II, 4 j ♀ (NCSM C–2192), 23 Sep 1984, ALB, JEC. YADKIN-PEE DEE RIVER BASIN. *Surry Co.*—(3) Horne Crk Off SR 2072, ca. 8.3 air mi (13.3 air km) S town Pilot Mountain; 1 ♂ II (NCSM C–95), 20 Jul 1976, R. M. Shelley, ALB; (4) open bog Schuyler pasture, ca. 0.6 mi (1.0 km) N Low Gap, between E side NC 89 and Gulley Crk (Fisher R dr); 1 ♀, 19 Aug 1994, A. B. Somers. *Wilkes Co.*—(5) Stone Mountain State Park; 1 ♂ I (NCSM C–1106), 16 Jul 1975, D. S. Lee, P. Hertl; (6) Hunting Crk at SR 2428, 0.3 rd mi (0.5 rd km) S NC 115, ca. 9 air mi (14.4 air km) SE Wilkesboro; 1 ♀ (NCSM C–1234), 15 Jul 1976, F. D. Scott, M. E. Filka.

At the Watauga County site the *C. dubius*, cobalt blue in color, were dug from burrows in a mucky seep near the creek. One of the females (NCSM C–1813) had young attached to its pleopods. Thirteen specimens of *C. asperimanus* also were collected at this site, but occupied a different habitat than the *C. dubius* (see the *C. asperimanus* account). At the Haywood County site the *C. dubius*, this time of a brick red color morph, also were dug from burrows in a boggy area, about 3 to 4 m from a small stream. The form I male, one of the form II males, and two of the juvenile females showed considerable exoskeleton decalcification, and the other form II male was soft. In the stream near this bog, eight *C. b. bartonii* were found under rocks or dug from the stream substrate. The female from site (4) in Surry County was found walking in wet grass at about 1900 hours under rainy conditions.

Cambarus (*Jugicambarus*) *nodosus* Bouchard and Hobbs

Only two specimens of this burrowing crayfish, females from two separate localities in Cherokee County, have been reported from North Carolina (Bouchard and Hobbs 1976:13). We collected 45 specimens of this species from two additional localities in the Hiwassee River basin: *Cherokee Co.*—(1) seepage area on slope above SR 1322 and Shuler Crk, 0.1 rd mi (0.2 rd km) E of Tennessee state line, ca. 4.3 air mi (6.9 air km) WSW Violet; 4 ♂ II, 12 j ♂, 2 ♀, 8 j ♀, 1 j unsexed (NCSM C–1786), 1 ♂ I, 1 ♀ (NCSM C–1787), 21 Jul 1984; (2) seeps and shallow intermittent water on hillside above SR 1323 and trib Shuler Crk, 2.8 rd mi (4.5 rd km) W jct SR 1324, ca. 3.3 air mi (5.3 air km) WSW Violet; 1 ♂ I, 4 ♂ II, 5 j ♂, 3 ♀, 3 j ♀ (NCSM C–1788), 21 Jul 1984.

All specimens were dug or scraped from shallow burrows in dark muck. Some of the burrows were submerged in seepage water, and some specimens were found under rocks in these areas. No other crayfishes were found with *C. nodosus*.

In North Carolina, *C. nodosus* is limited to the Hiwassee River basin, where it appears to be the ecological equivalent of *C. asperimanus*. The two species have never been reported from the same localities or even the same river basins anywhere, and *C. asperimanus*, although common and widespread in other montane (and western Piedmont) river systems, seems to be absent from the Hiwassee River and its tributaries.

Cambarus (*Tubericambarus*) *acanthura* Hobbs

Although known from two localities in Fannin County, Georgia (Hobbs 1981:219–220), this crayfish has never been reported from North Carolina. Three localities in the Hiwassee River basin of North Carolina are now known: *Cherokee Co.*—(1) floodplain pond and ditches along Nottely R off end SR 1404, ca. 1.0 mi (1.6 km) N US 64 and 5.8 air mi (8.0 air km) SW Murphy; 1 ♂ I, 2 j ♀, 1 carapace (NCSM C–529), 24 Nov 1978, DLS ALB, 5 j ♂, 2 j ♀ (NCSM C–2291), 24 Apr 1985, JB, ALB; (2) floodplain Nottely R at US 64 Bridge, 0.8 mi (1.3 km) E Ranger; 5 j ♂, 3 j ♀ (NCSM C–496), 1 ♂ II (NCSM C–497), 2 j ♂ (NCSM C–498), 1 ♂ I (NCSM C–499), 17 Dec 1976, FDS, ALB; (3) small creek (trib Nottely R) in rhododendron thicket off SR 1423, ca. 0.5 mi (0.8 km) N US 64, 5.0 air mi (8.0 air km) SW Murphy; 1 j ♀ (NCSM C–1790), 22 Jul 1984, ALB, JEC.

At locality (3), the only other crayfish found in the creek was a male II *Cambarus* (*Puncticambarus*) *hiwasseensis* Hobbs. Specimens C–497 and C–499 were kept alive in the laboratory after their capture in December 1976; the former died on 13 May 1980, and the latter, which was a juvenile when collected, died a form I male on 22 May 1981. The pond at locality (1) had extensive mats of floating water shield (*Brasenia* sp.) when we visited it on 21–22 July 1984. A trap set there overnight yielded no crayfish.

Cambarus (*Puncticambarus*) *georgiae* Hobbs

This crayfish has been reported from only three localities, one in Rabun County, Georgia (the type locality), and two in Macon County, North Carolina, all in the upper Little Tennessee River basin (Hobbs 1981:255). The second North Carolina locality was given as "Sugar Fork River 8 mi NE of Franklin on US Hwy 64 . . . 26 June 1957, E. A. Crawford." In response to a query about this site, Hobbs (in litt.) said it should be emended to Cullasaja River, US 64 at Gneiss, 8 mi (12.8 km) SE of Franklin. According to Powell (1968:130), "The Cherokee work, *Kul-say-gee*, means 'sugar' or 'sweet,' " and at least one part of the river apparently was known in the 19th century as Sugar Town Creek.

We collected 39 *C. georgiae* at three localities in the Cullasaja River watershed: *Macon Co.*—(1) Buck Crk at culvert under US 64-NC 28, 0.2 rd mi (0.3 rd km) S jct SR 1535, ca. 0.6 air mi (1.0 air km) S Gneiss; 1 ♂ I, 2 ♀, 2 j ♀ (NCSM C–2155), 20 Sep 1984; (2) Cullasaja R at bridge, jct SR 1667 & 1653, ca. 1.0 air mi (1.6 air km) SSE airport in Franklin; 1 j ♂ (NCSM C–2161), 20 Sep 1984; (3) Cullasaja R along US 64-NC 28, 0.2 rd mi (0.3 rd km) N jct SR 1678, ca. 0.2 air mi (0.3 air km) S Gneiss; 6 j ♂, 9 j ♀ (NCSM C–2158), 3 ♂ I, 1 ♂ II, 1 j ♂, 5 ♀ (NCSM C–2159), 4 j ♂, 4 j ♀ (NCSM C–2167), 21 Sep 1984; this locality is either the same as, or very close to, the second North Carolina locality provided by Hobbs (1981:255).

At locality (1), a single female *C. asperimanus* and 22 *C. b. bartonii* were also taken. At site (3), we also found 29 *C. b. bartonii.*

On 19 and 20 September 1984, we made collections at three localities in the Cullasaja drainage above Cullasaja Falls, at elevations near or above 900 m (3,000 ft). At the highest of these sites we found only a large number of *C. asperimanus*, and at the others we found only 46 *C. asperimanus* and 51 *C. b. bartonii*. Thus, *C. georgiae* almost certainty is absent from higher elevation, high-gradient streams in the Cullasaja watershed.

We can add a second Georgia locality to the range of the species: *Rabun Co.*—Little Tennessee R at Hwy 246, ca. 0.3 mi (0.5 km) E jct US 441, NNE of Dillard; 3 ♂ I, 1 j ♂ (NCSM C–626), 20 Oct 1979, REA, Jr, J. Perry.

Cambarus (*Puncticambarus*) *parrishi* Hobbs

This species, which is endemic to the Hiwassee River basin, previously was known in North Carolina from two collections made in Clay County in 1959 and 1960 (Hobbs 1981:267). On 22 September 1984, we collected 21 specimens at two additional sites: *Clay Co.*—(1) Fires Crk along FSR 340, 2.3 rd mi (3.7 rd km) NE of end SR 1344 (which becomes FSR 340), Nantahala National Forest, ca. 4.3 air mi (6.9 air km) NNW cntr Hayesville; 1 ♂ I, 2 ♀, 1 j ♀ (NCSM C–2174); (2) trib Fires Crk (likely Rockhouse Crk) along FSR 340A, ca. 0.8 rd mi (1.3 rd km) N jct FSR 340 and 2.9 rd mi (4.6 rd km) NE SR 1344, Nantahala National Forest; 1 ♂ I, 1 ♂ II, 3 j ♂, 4 ♀, 1 j ♀ (NCSM C–2175), 2 j ♀, part of adult exuvium (NCSM C–2178), 2 j ♂, 3 j ♀ (NCSM C–2180).

Cambarus parrishi was the only crayfish found at site (1), but at site (2) nine *C. b. bartonii* also were collected. Of the four *C. parrishi* taken at site (1), one of the females exhibited exoskeleton decalcification and the male was very soft. At site (2), two males and one female showed decalcification, two of the females were soft, and part of an adult exuvium was found.

Cambarus (*Puncticambarus*) *reburrus* Prins

This species is endemic to headwater streams of the Savannah and French Broad river basins, in Buncombe, Henderson, Jackson, and Transylvania counties in the Blue Ridge province of North Carolina (Cooper and Cooper 1977*b*:214). There is some confusion, however, about the precise distribution of the species. Its type locality is a "Small tributary to the Horsepasture River from Sapphire (= Fairfield) Lake off U. S. 64, 5.5 miles east of Cashiers, Jackson County, North Carolina. Sapphire Lake is an impoundment from which the tributary . . . flows several hundred yards into the Horsepasture River (upper Savannah River drainage)" (Prins 1968:459). It should be noted that Fairfield Lake, although also on a tributary of the Horsepasture River (Long Branch), is about 1.0 air mi (1.6 air km) northwest of Sapphire Lake.

The type locality was the only known site for the species at the time of its description, but four years later Prins and Hobbs (1972: 412) added the French Broad River basin to its range and suggested that the "population described by Prins in the headwaters of the Savannah River is an introduced one." Ross (1971:29–32), however, had earlier discussed evidence for a probable Pleistocene breach of the Blue Ridge by Savannah basin headwaters, and "an obvious encroachment of Toxaway River of the Savannah River system upon the headwaters of the French Broad River of the Tennessee River basin." Ross further commented that "Toxaway Creek has not only breached the Blue Ridge but it has also begun to drain some of the 2900 to 3000-foot surface around Lake Toxaway, which once must have been part of the French Broad basin." Later, Hobbs and Peters (1977:11) provided evidence, based on the distributions of fishes and entocytherid ostracods, that "the possibility of a former connection between parts of the two basins exists." Despite these analyses, however, current evidence indicates that Prins and Hobbs (1972:412) may have been correct in suggesting that *C. reburrus* is not native to the Savannah River basin.

The following additional collections of this species are all from the same locality in the general area of the type locality. *Jackson Co.*—pond in floodplain Horsepasture R along US 64, 1.2 rd mi (1.9 rd km) W jct SR 1119; 1 ♀ with young (NCSM C-890), 1 ovig ♀ (NCSM C–891), 5 Jun 1977, ALB, 3 ♀ with young (NCSM C–253, 258, 259), 1 j ♀, 1 ♂ II (NCSM C–260), 4 ♂ II, 1 ♀ 1 j ♀ (NCSM C–912), 27 Jun 1977, DLS, ALB. Several collections made elsewhere in the Horsepasture watershed yielded only *C. b. bartonii*.

At all localities where *C. reburrus* has been taken, it has proved to be a creature of slack or slow-moving waters of low gradient and generally with considerable organic debris. To our knowledge, it has not been taken in swift, high-gradient streams devoid of detritus. Collections we made in September 1984 in two such headwater streams of the Chatooga River south of Highlands, Macon County, streams that in North Carolina are independent of the more eastern headwaters of the Savannah, produced only *C. asperimanus*. Suitable *C. reburrus* habitat is unlikely in the lower Horsepasture and Toxaway rivers, and in the Thompson River. It almost certainly exists, however, in those parts of the Horsepasture watershed between Sapphire and Fairfield lakes and the northern limits of Cashiers, in the headwaters of the Chatooga River in and around Cashiers, in the floodplain of the Toxaway River around Lake Toxaway above Toxaway Falls, and in the Whitewater watershed above Whitewater Falls. We can find no evidence that *C. reburrus* has been taken from any of these areas, but perhaps more field work will reveal its presence in one or more of them.

Although fairly common and widespread in the upper reaches of the French Broad River basin, *C. reburrus* has yet to be verified any farther downriver in this system than eastcentral Buncombe

County (see Prins and Hobbs 1972:412 for localities near Black Mountain and Swannanoa, and the additional Buncombe County locality listed below). Prins and Hobbs (1972:412) reported the species from "Madison County—3.5 mi. west of Old Fort in Pisgah National Forest on U. S. Hwy. 70, . . . 17 June 1940, J. C. Moore, coll.," and added, "These specimens are somewhat atypical and are thus tentatively assigned to this species." Hobbs (1989:27) included Madison County in the range of the species. The locality in question, however, is in McDowell County and in the headwaters of the Catawba River basin, not the French Broad. Old Fort is over 5 air mi (8 air km) east of the Buncombe County line and the nearest headwater creeks of the Swannanoa River (French Broad). The Madison County line is some 24 air mi (38 air km) west of Old Fort, so Madison County is in error. Hobbs very kindly loaned us the specimens collected over 50 years ago at this site (USNM 131904; 1 j ♂, 3 j ♀). Comparison with *C. reburrus* of similar sizes and sexes showed that the questionable specimens did not belong to this species. Hobbs later pointed out (in litt.) that they may belong to an undescribed *Puncticambarus* that occurs in the Catawba River basin, one of those subsumed under *C.* (*P.*) sp. C.

Further doubt is cast on the occurrence of *C. reburrus* in lower parts of the French Broad basin by collections we made in July and September 1984. We collected over 300 specimens at 11 sites of various kinds in the Pisgah National Forest in Madison County, and 78 specimens at 4 sites in the Pigeon River drainage in Haywood County, but found no *C. reburrus*. Our current knowledge, then, indicates that this species is absent from the Pigeon (and probably Nolichucky) hydrologic units of the French Broad, and from the main French Broad and its tributaries northwest of the Asheville area.

Hobbs and Peters (1977:36) reported the ostracod, *Dactylocythere megadactylus* Hart and Hart, an ectocommensal of several crayfish species, from 37 localities in North Carolina, "in which it is confined to the Piedmont Plateau." They inadvertently listed *C. reburrus* among the ostracod's hosts, but their distribution map for *D. megadactylus* (Hobbs and Peters 1977:71) showed no localities within the range of this Blue Ridge crayfish.

So many additional collections of *C. reburrus* have been made from Henderson County, particularly from the French Broad and Mills rivers, that we see no reason to list them. The following localities, however, are of sufficient interest to be specified: *Buncombe Co.*—(1) Swannanoa R at SR 2416, 0.1 rd mi (0.2 rd km) S jct SR 2002, ca. 1.5 air mi (2.4 air km) NW Wilson; numbers and sexes not available (NCSM C–2194), 25 Sep 1984, ALB, JEC. *Transylvania Co.*—(2) French Broad R at River Mile (RM) 195.8 along Wilson Rd at head Elm Bend; no other data available, M. Ford; (3) French Broad R at mouth Williamston Crk (RM 192.8) at US 276; 1 ♀ (NCSM C–1686), 23 Jun 1977, MF; (4) West Fk French Broad R near jct SR 1309 & 1312, ca. 4.2 air mi (6.7 air km) NW Rosman; 1 ♀ (NCSM C–2221), 18 Oct 1984, V. Schneider; (5) Davidson R at US 276, 0.2 rd mi (0.3 rd km) SE of FSR to Pisgah Forest National Fish Hatchery, ca. 4.3 air mi (6.9 air km) NNW cntr Brevard; 1 ♀, 13 Aug 1993, J. Weems.

Orconectes (*Crockerinus*) *erichsonianus* (Faxon)

Hobbs (1981:263) listed this species and *C. latimanus* as associates of *C. hiwasseensis* at a locality in the Hiwassee River system of North Carolina. This is the only published record for *O. erichsonianus* in North Carolina. Hobbs (in litt.) said, "the locality is 1.6 miles west of the junction of U. S. Hwy. 64 on State Route 60, Cherokee County—Nottely River, collected on June 12, 1960, by K. W. Simonds . . . ." He added, "the whereabouts of the specimens is a puzzle. They were never catalogued and perhaps are still shelved with the uncatalogued material here [at the U. S. National Museum of Natural History]."

On 21 July 1984, we collected 47 crayfish at a site that must have been the same as, or very close to, the one in question — the Nottely River at NC 60, 2 air mi (3.2 air km) SSW of Ranger. This collection contained only *C. b. bartonii*, *C. hiwasseensis*, and an unidentified *Cambarus*. Collections that we made on several occasions elsewhere in the Hiwassee River basin in Cherokee and Clay counties also failed to yield any *Orconectes*, and the species is not known from this system in Georgia (Hobbs 1981:21, 287). Hobbs later (1989:35, 84, 89) did not include North Carolina in the general range of *O. erichsonianus*, and we are convinced that the species does not occur here. It could have been extirpated from the State, but its historic range just west of North Carolina is limited to the Appalachian Plateau and the Ridge and Valley physiographic provinces, no elements of which are found in North Carolina.

Orconectes (*Crockerinus*) *virginiensis* Hobbs

This is one of only two species of *Orconectes* known to occur on the Atlantic versant in North Carolina, where it reaches the southern limits of its range. It is also the only member of subgenus *Crockerinus* in the State. Its type locality is a tributary of the Nottoway River, which is a major trunk of the Meherrin River, in southeastern Virginia (Hobbs 1951:124–125). The Meherrin River joins the Chowan River at the Gates County, North Carolina, line. *Orconectes virginiensis* originally was known in the Chowan basin of North Carolina from five specimens collected at a single locality in Hertford County: Cutawhiskie Creek (Swamp), a tributary of Potecasi Creek, 1 air mi (1.6 air km) southwest of Menola (Cooper and Cooper 1977*c*: 215). The collection, made on 13 August 1974 by Chris Ellis, consisted of a form I and two form II males (NCSM C–33), and two females (NCSM C–31, 32). A sixth Chowan basin specimen, an adult female, was collected on 24 July 1985 from a submerged log in the Meherrin River at CR 1175 (Parkers Ferry), downstream from the confluence of Potecasi Creek, about 3.2 air mi (5.1 air km) north-northwest of the center of Winton, Hertford County, by David R. Lenat.

Although Hobbs (1989:38) gave the general range of *O. virginiensis* as "Chowan drainage system in North Carolina and Virginia," Cooper and Cooper (1977*c*:215) had reported it earlier from the lower Roanoke River basin in Martin County. A form I male (USNM 116979) was collected in Ready Branch, a tributary of Sweetwater Creek, 4.5 air mi (7.2 air km) south of Williamston, on 28 March 1949 by E. C. Raney. This species is now known from the following additional localities in the Roanoke River basin: *Bertie Co.*—(1) Roanoke R at NC 45/308 at Washington Co line, 5.6 air mi (9.0 air km) ENE cntr Sans Souci; 1 ♀, 2 j ♀, 6 Jul 1986, DRL. *Halifax Co.*—(2) Roanoke R at NC 258 at Northampton Co line, 2.9 air mi (4.6 air km) E cntr Spring Hill; 1 j ♂, 9 Jul 1987, DRL. *Martin Co.*—(3) Ready Br at US 17 bridge, ca. 5.5 air mi (8.8 air km) S Williamston; 1 j ♀ (NCSM C–363), 17 Jun 1980, JP.

The adult female collected at the Bertie County site was found in a submerged log. About this locality, which is not far west of Batchelor Bay, a brackish estuary of Albemarle Sound, Lenat (in litt.) said that the water there was about 200 m wide, slow-moving, and "may be slightly brackish." He added, "The shore areas have abundant growths of water lily, with many pieces of dead wood on the bottom. Prolific algal growths suggested some enrichment this year. The fauna is primarily freshwater, but also contains some estuarine taxa." At the Martin County site, a form I male and two female *P. a. acutus* were collected with the *O. virginiensis*.

Occurrence of this species in both the Chowan and lower Roanoke basins is not surprising, since during the Pleistocene the Chowan "would have been a tributary of the Greater Roanoke

River" (Lachner and Jenkins 1971:62). Little has been reported on the distribution and natural history of this species, especially in North Carolina, and it remains one of the State's least known and ostensibly rarest crayfishes.

Orconectes (*Procericambarus*) *spinosus* (Bundy)

There are no published localities for the occurrence of any member of subgenus *Procericambarus*, and specifically for *O.* (*P.*) *spinosus*, in North Carolina. Hobbs (1981:297) indicated its general range as "Streams in the Coosa and Tennessee river basins in Alabama, Georgia, North Carolina, Tennessee, and Virginia," but later (Hobbs 1989:50, 85, 89) did not include North Carolina within the range of the species. Prior references to *Cambarus* (= *Orconectes*) *spinosus* in the Tar River (Faxon 1890:632; Harris 1903: 130, 142; Ortmann 1905:115, 1931:87, 88), all apparently based on specimens reported by Bundy (1877) from Rocky Mount, refer to the undescribed *Orconectes* sp. A.

North Carolina specimens assigned to *O. spinosus* have been collected at the following localities in the Cheoah River watershed of the Little Tennessee River basin: *Graham Co.*—(1) Tulula (Talula, Talulah) Crk at SR 1211, ca. 0.3 air mi (0.5 air km) E Robbinsville; 1 ♂ II, 1 ♀ (NCSM C–252), 25 Nov 1978, DLS, ALB; (2) Cheoah R just upstream from sewage treatment plant outfall Robbinsville; 5 ♂ II, 3 ♀ (NCSM C–389), 8 Oct 1980, J. H. Davies; (3) Tulula Crk at NC 143, 0.3 air mi (0.5 air km) E cntr Robbinsville; 2 ♂ I, 2 ♂ II, 4 ♀ (NCSM C–1213), 23 Oct 1982, RWV, ALB, D. Sever, 5 ovig ♀ (NCSM C–2302), 2 ♂ I, 1 ♂ II, 19 j ♂, 9 j ♀ (NCSM C–2303), 25 Apr 1985, ALB; (4) Tulula Crk at SR 1138, just N Robbinsville; 7 ♂ I, 1 ♂ II, 5 j ♂, 3 j ♀ (NCSM C–2306), 2 ovig ♀ (NCSM C–2312), 2 ovig ♀ (NCSM C–2313), 4 ♂ I (NCSM C–2352), 26 Apr 1985, ALB.

At locality (2), three of the form II males showed considerable exoskeleton decalcification, and one of them and another form II male and one female were soft. The specimens taken at locality (3) were found under rocks in the creek, and the species appeared to be more abundant than the only other crayfish found there, *C. b. bartonii*. The two species also occurred together at locality (4).

Orconectes (*Procericambarus*) sp. B

A large species of *Orconectes*, previously considered to be introduced *Orconectes juvenilis* (Hagen) [= *Orconectes* (*Proceri-*

cambarus) *rusticus* (Girard)] by Hobbs and Walton (1966) and Hobbs et al. (1967), occurs in the New-Kanawha basin of Virginia (Hobbs, in litt.). This animal also has been taken in New River headwaters at the following North Carolina localities: *Alleghany Co.*—(1) small stream entering New R just E US 21-221, ca. 0.2 air mi (0.3 air km) S Virginia state line, 3.0 air mi (4.8 air km) NNE jct US 21 & 221 at Twin Oaks; 1 ovig ♀ (NCSM C–284), 20 May 1978, REA, Jr, JEC. *Ashe Co.*—(2) South Fk New R at SR 1602, ca. 0.6 air mi (1.0 air km) SE jct US 221, 2.6 air mi (4.2 air km) ENE town Nathans Creek & 7.8 air mi (12.4 air km) NE cntr Jefferson; 3 ♂ II, 2 j ♂, 4 ♀ (NCSM C–257), 20 Jul 1978, DSL; (3) South Fk New R at E side NC 88 bridge and along SR 1588, ca. 0.5 rd mi (0.8 rd km) NE Orion & 4.8 air mi (7.6 air km) E West Jefferson; 2 ♂ I, 1 ♂ II (NCSM C–276), 1 ovig ♀ (NCSM C–277), 1 ♂ II (NCSM C–256), 21 May 1978, REA, Jr, JEC; (4) South Fk New R along CR 1566, 0.3 rd mi (0.5 rd km) S jct SR 1567; 2 ovig ♀ (NCSM C–803, 804), 4 ♂ II (NCSM C–805), 20 May 1978, REA, Jr, JEC; (5) South Fk New R at NC 221, ca. 1.7 air mi (2.7 air km) WSW Scottsville; 1 j ♂, 2 ♀ (NCSM C–2358), 27 May 1985, F. Winborne, DRL; (6) Buffalo Crk near confluence Little Buffalo Crk, ca. 2.5 mi (4.0 km) W cntr West Jefferson; 1 j ♂ (NCSM C–2355), 30 May 1985, DRL, FW; (7) Dog Crk at SR 1592, 4.0 mi (6.4 km) E Jefferson; 1 j ♀ (NCSM C–508), 6 Aug 1978, J. R. Clamp, M. Dennis.

This species was very common at locality (3), where it occurred in close association with another large crayfish, *Cambarus* (*Hiaticambarus*) *chasmodactylus* James. The two often were found under the same cover, usually medium-size to large rocks in cold, fast-moving water, and in the same gravel riffles. Both species also occurred together at locality (2). At locality (4), the *Orconectes* was collected with *C. chasmodactylus* and *C. robustus*.

Procambarus (*Ortmannicus*) *medialis* Hobbs
Procambarus (*Ortmannicus*) *pearsei* (Creaser)
Procambarus (*Ortmannicus*) *plumimanus* Hobbs and Walton

These three species comprise a "disjunct" enclave at the northern periphery of the range of the Planirostris Group of the genus *Procambarus*, a fact that is of considerable importance in understanding the evolutionary history of the group. Hobbs (1975:15) summarized their distributions: "The Neuse River basin appears to mark the southern limit of the range of *P. medialis*, the northern [Northeast] Cape Fear River basin marks the southwestern limit of the range of *P. plumimanus*, and the range of *P. pearsei* encompasses most of the coastal plain lying in the Cape Fear River basin (excluding the Northern [Northeast] Cape Fear) southward through the Little Pee Dee River basin." The following records and discussions support this statement, slightly expand and clarify the known ranges of these species, add some information on their natural history, and help explain a distributional anomaly for *P. plumimanus*.

Procambarus medialis

As mentioned by Cooper and Ashton (1985:10), although the type locality of *P. medialis* is in the Tar-Pamlico basin in Halifax County (Hobbs 1975:13), this and one other site near it in the drainage of Deep Creek are the only places within this basin where the species currently is known to occur. All other collection sites are within the Neuse River basin. Eleven specimens were captured in wire minnow traps at three localities in the Neuse basin during the *N. lewisi* study (Braswell and Ashton 1985), and one of them was in the mainstem Neuse River in Lenoir County. Identical traps were employed at over 180 stations in the Tar-Pamlico basin, from its headwaters in Person County to central and southern Beaufort County, but yielded no additional *P. medialis*. One of these stations was in Beech Swamp, less than 5 air mi (8 air km) west of Deep Creek, and another was in the Tar River near its confluence with Deep Creek in Edgecombe County. There are no obvious ecological, edaphic, or physiographic reasons, however, for this apparent severe restriction of the known range of *P. medialis* in the Tar-Pamlico basin. During the *N. lewisi* survey, little collecting was done in roadside ditches or isolated lentic waters, and no digging of burrows was attempted. More thorough sampling of these possibly preferred habitats might reveal a wider distribution pattern for *P. medialis* in this river basin, although it also inhabits larger, flowing waters in the Neuse basin.

The following additional localities are in the Neuse River basin: *Johnston Co.*—(1) Black Crk at NC 50, 5.5 air mi (8.8 air km) NNE Benson; 1 ♀ (NCSM C–144), 27 Jan 1979, trap, K. Everett; 1 ♀ (NCSM C–230), 30 Jan 1979, trap, KE; 1 ♀ (NCSM C–140), 10 Feb 1979, trap, KE; (2) Hannah Crk at US 701, 10 air mi (16 air km) E Benson; 4 ♀ (NCSM C–1079), 22 Apr 1979, trap, P. S. Freed, 1 ♂ II, 1 ♀, 1 j ♀ (NCSM C–1097), 23 Apr 1979, trap, PSF; (3) dry roadside ditch, Truck Lane and East Rose St, Smithfield; 1 ♂ I, 1 ♂ II, 1 ♀ (NCSM C–2270), 17 Apr 1985, W. M. Palmer, ALB. *Lenoir Co.*—(4) Neuse R at NC 55, 1.1 rd mi (1.8 rd km) E jct SR 1809, 5.2 air mi (8.3 air km) NE Kinston; 1 ♂ II (NCSM C–231), 29 Jan 1979, trap, PSF.

At locality (3), each of the three specimens was found under a separate railroad crosstie along the dry ditch, near entrances to burrows that could be seen to reach water. The ditch normally contains water, but this area was in the midst of a prolonged drought that had been broken only by some rainfall on the previous night. Other ditches had some water. In captivity, the form I male, collected in April, molted and died on 29 September 1985, but remained form I.

Procambarus pearsei

Hobbs (1975:14) mapped 22 unspecified localities for *P. pearsei* in the Cape Fear, Lumber, and Waccamaw basins in Bladen, Brunswick, Columbus, Cumberland, Robeson, and Sampson counties. This same map inadvertently indicated an additional locality for *P. pearsei* in the Neuse River drainage of Johnston County. This should have been for *P. medialis*; the position of the dot corresponds to a locality for this species given by Hobbs (1975:13), ". . . 5.3 miles south of Smithfield on U. S. Highway 706." The nearest headwater stream of the Cape Fear basin, Mingo Swamp, rises at the extreme western edge of Johnston County, about 2.5 air mi (4.0 air km) SSW of site (1) above. Thus, the range of *P. pearsei* given by Hobbs (1989:70) as "Johnston and Sampson counties, North Carolina, south to . . . .," currently requires the deletion of Johnston County.

The following localities add *P. pearsei* to the Cape Fear basin in Bladen County, and extend the known range slightly west in the Lumber River basin into Hoke and Scotland counties. CAPE FEAR RIVER BASIN. *Bladen Co.*—(1) pond along SR 1327, 1.6 rd mi (2.6 rd km) NW jct SR 1325, 5.7 air mi (9.1 air km) W Ammon, in vicinity Little Singletary and Horseshoe (Suggs Mill Pond) lakes; 1 ♂ I, 1 j ♂ (NCSM C–304), 17 Mar 1979, P. S. Ashton, REA, Jr., ALB; (2) Horseshoe Lake, 0.7 rd mi (1.1 rd km) NE SR 1327; 1 ♂ I, 8 j ♂, 1 ♀, 6 j ♀ (NCSM C–1602), 23 Feb 1980, PSA, REA, Jr, NCSM Jr Curators. LUMBER RIVER BASIN. *Hoke Co.*—(3) Antioch Bay off NC 211, 1.7 air mi (2.7 air km) SSE Antioch; 4 ♂ I, 3 ♀, parts of ♀ (NCSM C–2240), 1 Feb 1985, RWL, DLS, DFL; (4) pools in powerline cut Antioch Church Bay, E side NC 211, 0.6 rd mi (1.0 rd km) SSE jct SR 1447, 2 air mi (3.2 air km) SSE Antioch; 1 ♂ II, 2 ♀ (NCSM C–2241), 23 Feb 1985, DLS, RWL, DFL. *Scotland Co.*—(5) borrow pit near jct SR 1400 & 1413, ca. 3.5 air mi (5.6 air km) NW Wagram; 1 ♂ I, 1 j ♂, 2 j ♀ (NCSM C–2011), 8 Oct 1974, MRC, WMP, ALB, JEC.

The remains of a form I male and at least one other *P. pearsei* (NCSM C–1277) were removed from the stomach of a redtailed hawk, *Buteo jamaicensis*, found dead near Hallsboro, Columbus County, on 8 April 1983, and prepared as a museum specimen by Gilbert Grant. Seven females carrying late-instar young (NCSM C–2242-2244, 2246-2249) were found at a site in Robeson County on 23 February 1985 by DLS, RWL, and DFL. A female (NCSM C–1951) was found alive on NC 211, about 3 air mi (4.8 air km) south of Bolton, Columbus County, at night on 24 March 1975.

Procambarus plumimanus

Hobbs and Walton (1958:10–11) provided a locality for *P. plumimanus* in Craven County and two in Duplin County, and Hobbs (1975:14) mapped two localities in Duplin County, three in Craven County, one in Carteret County, and one apparently on the Craven-Carteret line. Hobbs (1989:70) added Jones County to the range of the species, but gave no specifics since this was a general checklist. The following localities add to our knowledge of the distribution of this crayfish. NORTHEAST CAPE FEAR RIVER BASIN. *Pender Co.*—(1) borrow pit "Back Island," Holly Shelter Game Lands, 0.3 mi (0.5 km) N Lodge Rd; 1 ♂ II, 4 j ♂, 1 ♀, 1 j ♀ (NCSM C–870), 4 j ♂, 5 j ♀ (NCSM C–871), 3 Oct 1981, REA, Jr; (2) borrow pit Lodge Rd, Holly Shelter Game Lands, ca. 2 air mi (3.2 air km) NW US 17, 5.8 air mi (9.3 air km) SW Edgecombe; 3 ♂ I, 2 j ♂, 1 ♀ (NCSM C–872), 24 Jul 1981, REA, Jr; (3) dr of Harrisons Crk off NC 210, ca. 1 rd mi (1.6 rd km) N jct SR 1574, 4.2 air mi (6.7 air km) NW Hampstead; 1 ♂ I, 1 j ♂, 2 ♀ (NCSM C–933), 13 Mar 1977, E. Flowers, DLS. NEW (WHITE OAK) RIVER BASIN. *Carteret Co.*—(4) borrow pit along SR 1125, 5.3 mi (8.5 km) NW Newport (vicinity Northwest Prong Newport R); 1 ♀ (NCSM C–1942), 25 Mar 1975, MRC, JEC; (5) slough along Millis Rd (SR 1112 extended), 0.7 mi (1.1 km) W jct SR 1124, 5.5 air mi (8.8 air km) WSW Newport (Jason Br of Southwest Prong Newport R); 2 ♂ I, 1 ♂ II, 1 j ♂, 1 ♀, 1 j ♀ (NCSM C–2097), 25 Mar 1975, MRC, ALB, JEC. *Jones Co.*—(6) drainage ditch along FSR 152 (Black Swamp Rd), ca. 7 mi (11.2 km) ESE Maysville, 1 ♂ I (NCSM C–294), 7 Apr 1979, DSL; (7) slough on Great Lake Rd (SR 1101 extended as FSR 126), ca. 10 air mi (16 air km) SE Maysville (Hunter Crk dr); 2 ♂ I, 1 ♂ II, 1 j ♂, 1 j ♀ (NCSM C–2069), 26 Mar 1975, MRC, JEC. *New Hanover Co.*—(8) cypress pond at Carolina Beach State Park; 1 ♂ I, 1 ♀ (NCSM C–850), 3 May 1980, PSA, REA, Jr; this locality is on a narrow peninsula between the Cape Fear River and Onslow Bay. *Onslow Co.*—(9) permanent ditch and pools along US 17, 0.4 mi (0.6 km) N jct SR 1103, ca. 3.7 air mi (5.9 air km) S Verona; 1 ♂ I, 1 ♂ II, 4 ♀ (NCSM C–70), 10 Aug 1976, M. M. Browne.

Although the natural range of *P. plumimanus* appears to be limited to the Northeast Cape Fear and New (White Oak) basins, and this species did not appear at any of the *N. lewisi* survey stations sampled in the Neuse basin (Cooper and Ashton 1985:10), two localities for the species within the lower Neuse basin are known. The type locality, "Roadside ditch 2.2 miles southeast of Havelock, Craven County, North Carolina on Hwy. 70" (Hobbs and Walton 1958: 10) apparently lies close to East Prong Slocum Creek and not far from the head of Hancock Creek, both north-flowing streams that drain into the Neuse River on either side of the Cherry Point Naval Reservation. Only swamps separate this area from nearby headwaters of the Newport River not far to the south. The second locality, also in the Neuse basin in Craven County, is a ditch along Catfish Lake Road (SR 1100), 3.0 air mi (4.8 air km) southwest of the town of Croatan, in the drainage of East Prong Brice Creek.

This apparent expansion of the range of *P. plumimanus* into the lower Neuse basin possibly can be explained by the fact that in Carteret, southern and eastern Craven, and southern Jones counties, as in much of the poorly drained outer (tidewater) Coastal Plain, contemporary drainage distinctions have become blurred. The drainage divides, very low to begin with, have been breached by stream channelization, a vast system of man-made drainage canals, and the Intracoastal Waterway. Drainage canals along SR 1100 east and southeast of Catfish Lake provide access from the White Oak River basin to West Prong Brice Creek of the Neuse basin. Farther east, the Harlowe (Clubfoot), Adams Creek, and other canals, link elements of the Neuse River with the Newport and North rivers. Precisely what roles the easternmost of these interbasin waterways might play in crayfish distributions will not become clear until we have an understanding of the tolerance that various species display for the physicochemical features of their waters. Some crayfishes, notably *P. a. acutus* and *Fallicambarus* (*Creaserinus*) *fodiens* (Cottle), and even *C. diogenes*, are widely distributed in tidewater North Carolina. They often occur in close proximity to saline estuaries and tidal creeks, and there is a population of *F. fodiens* across Croatan Sound on Roanoke Island. Interbasin connectors also are present in other coastal river basins (see below).

THE HYDROLOGIC UNITS AND THEIR CRAYFISH FAUNAS

Seventeen major river basins generally are recognized within North Carolina (Heath et al. 1975:152). All of them include smaller hydrologic units, some of which are autonomous drainage systems within the State. All but five of the major river basins lie within the huge drainage of the Atlantic Ocean, and flow generally east and south to empty into broad, saline estuaries and sounds of the ocean. The exceptions are (1) the Hiwassee, Little Tennessee, French Broad, and Watauga rivers, which drain north and west into the Tennessee River, and (2) the New River, which drains north and west via the Kanawha River into the Ohio River. These western North Carolina waters ultimately flow into the Mississippi River drainage of the Gulf of Mexico. In North Carolina, the west-flowing and east-flowing montane headwaters of river systems are separated by the Appalachian (Eastern Continental) Drainage Divide, represented in the State by the Blue Ridge physiographic province.

The Waccamaw River and its tributaries, along with Lake Waccamaw, are recognized as a hydrologically and faunistically distinctive drainage unit by some biologists (see Bailey 1977: 269, 273; Shute et al. 1981:18–22), and are so treated here. Another hydrologic unit, the Northeast Cape Fear River, probably also should be considered an autonomous drainage system, because it does not join the Cape Fear River until it reaches the estuary at Wilmington. In addition, the Northeast Cape Fear is faunistically distinct, apparently lacking over a dozen species of lowland freshwater fishes found in the Coastal Plain portions of the Cape Fear itself (Rohde et al. 1979:114–115: Menhinick 1991). The Northeast Cape Fear also lacks two crayfish species found in the lower Cape Fear, but has one species that is absent from the Cape Fear (see below). Historically as well as faunistically, the Northeast Cape Fear appears to have more in common with the New (White Oak) drainage system than with the Cape Fear. During the Pleistocene, when sea level attained its highest stand (as indicated by the Surry Scarp, which marks the marine terrace formed by the Wicomico Sea), much of the southeastern Coastal Plain of North Carolina was covered by the ocean (Rohde et al. 1979:113, 116). This inundated area included today's New (White Oak) River drainage, most of the Northeast Cape Fear, and part of the lower Cape Fear. The early coastal Cape Fear and Northeast Cape Fear basins were at that time broadly separated, and they are still separate systems today.

TENNESSEE-OHIO-MISSISSIPPI

Hiwassee River—The Hiwassee River system rises in the Blue Ridge of northcentral Georgia, and in Clay and Cherokee counties, North Carolina. It flows generally north and west across the southwest corner of the State and into Tennessee, where it merges with the Tennessee River. Two streams of this system head in the southwest corner of Cherokee County and flow south into the Toccoa River in Georgia, part of the Ocoee River system. The Ocoee then joins the Hiwassee in Tennessee.

Cambarus hiwasseensis and *C. parrishi* are upper Hiwassee endemics, occurring in both Georgia and North Carolina. The type locality of *C. hiwasseensis* is a tributary to Peachtree Creek, 0.8 mi (1.3 km) north of Peachtree School on US 64A, Cherokee County, North Carolina (Hobbs 1981:260–261). Other species that occur in the Hiwassee system in North Carolina but have broader ranges are *C. b. bartonii*, *C. nodosus*, and *C. acanthura*. The latter two species are known in North Carolina only from the Hiwassee. Hobbs (1981: 20, 22) reported *C. latimanus* in this system in Georgia, and said (Hobbs 1981:263) that it was found with *C. hiwasseensis* and *O. erichsonianus* at a locality on the Nottely River in North Carolina. In addition, his range map for *C. latimanus* (Hobbs 1981:115) showed Georgia localities west of Nottely Lake in Union County, and in Fannin County just west of the North Carolina state line. Furthermore, Bouchard (1972:36) recorded the species "downstream in the Ocoee (Tennessee) River drainage to the Little Frog Mountains in Polk County, Tennessee." This area is in the Hiwassee basin just west (downriver) of North Carolina. Thus, *C. latimanus*, which in North Carolina is a species of the eastern Piedmont Plateau and the Coastal Plain, also may occur in the Hiwassee basin of the Blue Ridge in at least Cherokee County. It did not turn up, however, in our Hiwassee field work, which included the Nottely River. Hobbs and Peters (1977:27) cited a record for *Cambarus* (*Hiaticambarus*) *longirostris* Faxon in the Hiwassee basin in Cherokee County, "Valley River at Andrews . . . (Crawford 1961:244)," and Hobbs (1981:171–172) found this species in the headwaters of the Nottely River in Union County, Georgia, which is a considerable distance upriver from North Carolina. The distribution maps in James (1966:12–13), however, showed no localities for this species within the Hiwassee basin in North Carolina. In July and September 1984, we failed to collect this crayfish at any site within the system, including the Valley River near Andrews. Nevertheless, *C. longirostris* could occur in the Hiwassee basin in North Carolina. *Cambarus carolinus* also may occur there, but specific records are lacking. There is a small, forest-green *Cambarus* in Cherokee County that is as yet unidentified.

Little Tennessee River—The main artery of the Little Tennessee River originates in the Blue Ridge of Rabun County, Georgia. Its tributaries drain most of Macon County, and parts of Swain and Graham counties, North Carolina. Its major eastern tributary, the Tuckasegee River, heads in Jackson County and flows northwest into Fontana Lake. Another eastern tributary, the Cullasaja River, begins in southeastern Macon County and joins the Little Tennessee River south of Franklin. A western tributary, the Cheoah River, heads in southern Graham County and flows northwest through Santeetlah Lake, to merge with the Little Tennessee River at Cheoah Dam near the state line. A second major western tributary, the Nantahala River, rises in western Macon County and along the eastern border of Clay County, and flows primarily north into Fontana Lake. Beyond this lake the Little Tennessee flows west into Tennessee, joining the Tennessee River near Lenoir City.

One crayfish, *C. georgiae*, is endemic to the Little Tennessee, where currently it is known from two sites along the main river in Rabun County, Georgia, and several lower elevation sites in the Cullasaja River watershed of North Carolina. More wide-ranging species of this system are *C. b. bartonii*, *C. longirostris*, and *C. asperimanus*. Specific localities for *C. carolinus* are reported here, and Hobbs and Peters (1977:56) referred to a *C.* (*J.*) sp. in Jackson County (Tuckasegee watershed), which may turn out to be *C. carolinus* or an undescribed species. *Orconectes spinosus* is herein reported from the Cheoah River watershed of this basin.

French Broad River—The uppermost tributaries of the French Broad River rise on the western slopes of the Blue Ridge in Transylvania, Henderson, and Buncombe counties. Its major western tributary, the Pigeon River, heads in western Haywood County and is an autonomous unit in North Carolina. However, it joins the French Broad near Newport, Cocke County, Tennessee. The main eastern tributaries, the Cane, Nolichucky, and Toe rivers, rise in Avery, Mitchell, and Yancey counties. They, too, form an independent unit that flows northwest and enters Tennessee as the Nolichucky. This river then turns west and merges with the French Broad at the upper end of Douglas Lake. The French Broad River initially flows northeast in North Carolina, then turns northwest and enters Tennessee about 5.5 air mi (8.8 air km) downriver from Hot Springs, Madison County. It joins the Holston River at Knoxville to form the Tennessee River.

The endemic North Carolina crayfish, *C. reburrus*, is distributed throughout the upper French Broad, but appears to be absent from the Pigeon (and probably Nolichucky) watersheds, and from the main French Broad system northwest of Asheville. The other species of this river basin are *C. b. bartonii*, *C. longirostris*, *C. asperimanus*, *C. dubius*, *C. robustus* (Hobbs and Peters 1977:30), and *C.* sp. C. The type locality of *C. asperimanus* is Flat Creek, Montreat, Buncombe County (Faxon 1914:391). We collected many specimens of what may be an undescribed *Puncticambarus* in three streams in Madison County, but for now these are assigned to *C.* sp. C. Bouchard (1978:36) reported a specimen of *C. latimanus* from the French Broad in North Carolina, extralimital to any part of the known range of the species, but considered it probably an introduction.

Watauga River—The Watauga River rises in western Watauga County west of Grandfather Mountain and flows north and west into Tennessee. A southwestern tributary, the Elk River, heads in northern Avery County. It is a minor independent subdrainage in North Carolina, but joins the Watauga in Tennessee. The Watauga is impounded just beyond North Carolina's borders, but eventually merges with the Holston River of the Tennessee River system.

The crayfish fauna of the Watauga River basin in North Carolina is not well known, but consists of *C. b. bartonii*, *C. longirostris*, *C. asperimanus*, *C. dubius*, and *C. robustus*.

New River—The two major western tributaries of New River—North Fork New River and South Fork New River—head in Ashe and Watauga counties, respectively. They flow northeast and merge at the northern Ashe-Alleghany county line to form the New River just before it enters Virginia. Eastern tributaries, Little River and Brush Creek, rise in central and eastern Alleghany County, and flow northward into Virginia to join the New River. The New River merges with the Kanawha River near Charleston, West Virginia.

Cambarus chasmodactylus and probably *Orconectes* sp. B are endemic to the New-Kanawha system, and in North Carolina they are limited to, and close associates in, fast-flowing tributaries of the New River. Records for these common species in the eastern tributaries in Alleghany County, however, are sparse. The other members of the New River crayfish fauna in North Carolina are *C. b. bartonii*, *C. asperimanus* (Watauga County), *C. dubius*, and *C. robustus*.

ATLANTIC

Savannah River—The Savannah River begins as fast-flowing streams in deep ravines on the eastern slopes of the Blue Ridge in southeastern Macon, southern Jackson, and southwestern

Transylania counties. In North Carolina, its easternmost tributaries—the Toxaway, Horsepasture, Thompson, and Whitewater rivers—flow south as independent streams, entering Lake Jocassee and the Keowee River system of the Savannah basin not far into South Carolina. West of these rivers, the Chatooga River and several even more western tributaries of that river head in Macon County and flow independently south. The Chatooga River forms part of the upper boundary between Rabun County, Georgia, and Oconee County, South Carolina. The Tallulah River, which rises in the southeastern corner of Clay County on the slopes of Standing Indian Mountin, flows south into Towns and Rabun counties, Georgia, where it joins the Tugaloo River of the upper Savannah system.

The crayfish fauna of the Savannah River basin in North Carolina consists of the endemic *C. reburrus* (currently known in this system only from the floodplain of the Horsepasture River in Jackson County), *C. b. bartonii*, *C. asperimanus*, and *Cambarus* sp. (Hobbs and Peters 1977:38). The type locality of *C. reburrus* is in the Savannah basin (see the preceding account for this species). Little is known of the crayfish fauna of the Tallulah River in North Carolina, but *C. asperimanus* and *C. b. bartonii* undoubtedly occur there.

Broad River—This system rises in the west as headwater streams in southern and eastern Henderson, western Polk, and eastern Buncombe counties, and in the north in southern McDowell and northern Rutherford and Cleveland counties. A western tributary, the North Pacolet River, heads in southern Polk and Henderson counties, and flows independently into the Pacolet River of South Carolina. The Pacolet and Broad rivers merge at the juncture of Cherokee, Union, and Chester counties, South Carolina. Eastern tributaries head in eastern Cleveland and western Lincoln and Gaston counties, flow independently into South Carolina, then soon join the Broad River at the line between Cherokee and York counties. The Broad flows through the eastern foothills and western Piedmont of North Carolina, across South Carolina, and merges with the Saluda River at Columbia to form the Congaree River. The Congaree joins the Wateree River (continuation of the Catawba River), and the Wateree flows into the Santee system via Lake Marion.

The crayfish fauna of the Broad River basin in North Carolina consists of *C. b. bartonii* (the eastern and southern limits of its range here are unclear, but it is known from Cane Creek, McDowell County, and Green River, Henderson County), *C.* sp. A (Hobbs and Peters 1977:52), *C. asperimanus* (in southeastern McDowell and northeastern Cleveland counties), and *C.* sp. C (which is probably throughout the system). The ubiquitous *P. a. acutus* may turn up in the eastern reaches of the basin, and it is not inconceivable that exhaustive effort could reveal *C. carolinus* along the border with South Carolina. The latter species occurs in the upper Tyger River watershed of the Broad-Congaree basin, in Greenville and Pickens counties, South Carolina (Hobbs and Bouchard 1973:60–61). A juvenile male crayfish (NCSM C–2229) that strongly resembles *Cambarus* (*Puncticambarus*) *spicatus* Hobbs was collected in the North Pacolet River of the lower Broad basin in Polk County, but it would be premature to add this species to the North Carolina fauna on the basis of this specimen. The species is known with certainty only from a tributary of the Broad River in Fairfield and Richland counties, South Carolina (Hobbs 1989:27).

Catawba River—This heavily impounded system rises in North Carolina, with its headwaters on the Blue Ridge escarpment in southeastern Avery, Caldwell, McDowell, and Burke counties. The streams flow into and through the Piedmont Plateau. Tributaries that head in southern Mecklenburg and western Union counties flow independently south-southwest into South Carolina, where they join the Catawba River in York County. The Catawba flows south into South Carolina, where it enters the Wateree basin of the Santee drainage.

Cambarus b. bartonii and *C. asperimanus* appear to be limited to the foothills and upper Piedmont sections of the Catawba River basin. The former may occur as far south and east as Catawba County at the Alexander County line (Hobbs and Peters 1977:45–46), unless the population there is revealed to be *C.* sp. A. *Cambarus asperimanus* has been found in streams in Burke, Catawba, and McDowell counties. *Cambarus dubius* has been reported from Avery County in the upper Catawba basin (Hobbs and Peters 1977:24). *Cambarus* sp. A and *C.* sp. C may occur throughout the system, and *C.* sp. B currently is known only from Catawba County. *Cambarus reduncus* is known from Gaston, Mecklenburg, and Union counties. *Procambarus a. acutus* has been collected in Lincoln and Gaston counties. Hobbs and Peters (1977:45) recorded *Cambarus* (*Hiaticambarus*) *longulus* from a locality in the Catawba basin in northern Caldwell County, but there is evidence that the specimens from that site either came from a tributary of the nearby Yadkin-Pee Dee River, or belong to what appears to be an undescribed species under investigation by JEC. James (1966:13) did not show *C. longulus* in the Catawba basin, and Hobbs later (1989:20) wrote that it ranges "south to the Yadkin basin in North Carolina . . . ."

Yadkin-Pee Dee River—The headwaters of the Yadkin-Pee Dee basin rise in the eastern Blue Ridge of Virginia, in western Surry, Wilkes, and southeastern Watauga counties, North Carolina, and in the western Piedmont in southwestern Stokes and western Forsyth counties, North Carolina. The main trunk of the Yadkin River begins in Watauga County east of Blowing Rock, flows southeast to northcentral Caldwell County, then makes an abrupt turn and flows northeast to the juncture of Surry, Stokes, Yadkin, and Forsyth counties. There it turns south and, at the Stanly-Montgomery county line southeast of Badin Lake, joins the Uwharrie River, a major eastern tributary that rises in northwestern Randolph County. This merger forms the Pee Dee River. A major western tributary, the Rocky River, heads in southern Iredell and northern Mecklenburg counties, flows east, and joins the Pee Dee at the Anson County line below Lake Tillery. Several creeks that drain southcentral Union County flow south directly into the Lynches River, South Carolina, a major western trunk of the Pee Dee River. Southeastern tributaries of the Pee Dee drain southern Anson and Richmond counties, flowing directly into South Carolina to join the Pee Dee River in Chesterfield County. The Pee Dee flows across northern South Carolina and merges with the Little Pee Dee River at the tip of Britton Neck. The Pee Dee then continues into Winyah Bay.

In the uppermost sections of the Yadkin-Pee Dee basin occur *C. asperimanus*, *C. longulus*, and *C. dubius*. The southern limits of their distributions are unknown, but all three appear to be restricted to higher elevations within this basin. Specimens tentatively identified as *C. b. bartonii* have also been collected in the upper reaches of this basin. *Cambarus reduncus* occurs in the Piedmont, and *C.* sp. C apparently occurs throughout. Hobbs and Peters (1977: 18) reported *C.* sp. A from Mongtomery County, collected with *C.* sp. C and *P. a. acutus*, inadvertently placing the locality ("creek, 4.6 mi . . . W Mt Gilead on SR 73") in the Catawba River basin. Holt and Weigl (1979:24) described the ectocommensal branchiobdellid, *Xironodrilus bashaviae*, from several creeks in Forsyth County, including "Bashavia" (Barshavia = Bechewa) Creek, with *C. b. bartonii* its host. This crayfish could turn out to be *C.* sp. A. *Procambarus a. acutus* has been collected in Anson, Cabarrus, Davidson, Montgomery, and Union counties. *Fallicambarus fodiens* and *C. diogenes* may occur in that part of the basin draining the southeastern Piedmont and Sandhills.

Lumber River—To the west this Coastal Plain system heads in the Sandhills of southern Moore, eastern Montgomery, and Richmond, Scotland, and Hoke counties. Some of the streams drain directly into the Little Pee Dee River just across the South Carolina line. Eastern tributaries rise in western Bladen and Columbus counties. The Lumber River flows primarily east and south into South Carolina, where it joins the Little Pee Dee River on the Marion-Horry county line south of Nichols.

The crayfish fauna of the Lumber basin consists of *C. diogenes*, *C.* sp. C, *F. fodiens*, *P. a. acutus*, *Procambarus* (*Ortmannicus*) *ancylus* Hobbs, *Procambarus* (*Ortmannicus*) *blandingii* (Harlan), and *P. pearsei*. A locality for the latter species, given as "CAPE FEAR BASIN. Bladen County: (2) 3.7 mi (6 km) S Dublin on St Rte 41" (Hobbs and Peters 1977:52), actually is in the Lumber River basin. An unidentified *Procambarus*, currently represented in collections by only juveniles and one female, has been found in the Lumber River basin in Robeson and Scotland counties. When form I males become available, this species may prove to be *Procambarus* (*Ortmannicus*) *lepidodactylus* Hobbs, which is known from the system in South Carolina, or an undescribed species of the Pictus Group currently known only from the Waccamaw River basin (see below).

Waccamaw River—The northernmost headwaters of the Waccamaw River drain southcentral Bladen and northern Columbus counties, and its eastern tributaries drain western and northern Brunswick County. Some of the northern tributaries enter Lake Waccamaw, the largest of the natural Carolina Bay lakes, and the Waccamaw River flows from the south shore of the lake. East of the lake there is an extensive system of man-made drainage canals that "connects Honey Island Swamp (Juniper Creek tributary) with Dans Creek of the Cape Fear drainage and Big Creek which drains into Lake Waccamaw, ..." (Shute et al. 1981:21). South of the lake, the Waccamaw River forms part of the line between western Brunswick and southeastern Columbus counties, then flows southwest into South Carolina and enters Winyah Bay. The Shallotte, Lockwood Folly, and Calabash rivers, which drain most of southern Brunswick County, are here included in this system. The Calabash River flows west into Little River in Horry County, South Carolina, and is connected to the Waccamaw River through the Intracoastal Waterway.

The crayfish fauna of the Waccamaw basin consists of *C. diogenes*, *C. latimanus* (known from two localities in Brunswick County), *F. fodiens*, *P. a. acutus*, *P. ancylus*, *P. blandingii*, and *P. pearsei*. Specimens from this basin previously assigned to *P. lepidodactylus* actually represent a new species being described by

JEC. Current evidence indicates that *C.* sp. C, which occurs in the adjacent Lumber River basin, is absent from the Waccamaw basin.

Cape Fear River—The Cape Fear River, which begins in the Piedmont Plateau and drains the largest watershed in the State, is confined to North Carolina. Its major northern tributary, the Haw River, heads in northwestern Guilford, southern Rockingham, Orange, and Durham counties. A large southern tributary, the Deep River, begins in southwestern Guilford and eastern Randolph counties, flows southeast to northern Moore County, then turns east and north, forming the northwestern boundary of Lee County. The Haw and Deep rivers then merge in eastern Chatham County at the Lee County line, forming the Cape Fear River. A central tributary, the Rocky River, heads in northeastern Randolph County, flows southeast through Chatham County, and joins the Deep River at the Lee County line. A major central tributary in the Coastal Plain, the Black River, drains Sampson County and the western part of Duplin County. Another Coastal Plain tributary, the South River, divides Cumberland and Bladen counties to the west from Sampson and Pender counties to the east. The Black River merges with the South River in southern Sampson County at the Bladen County line, and the South enters the Cape Fear at the line between Pender and Bladen counties. The Cape Fear then empties into the estuary at Wilmington, New Hanover County.

Until recently, the endemic North Carolina crayfish, *C. catagius*, was known only from its type locality, burrows in a lawn at East Whittington Street in the southeastern section of Greensboro, Guilford County (Hobbs and Perkins 1967:145), which is in the Haw River subdrainage. Other colonies of this primary burrower have now been discovered, and efforts are being made to more accurately determine its range (Davis 1992:29). *Cambarus reduncus* is restricted to the Piedmont and Fall Line zone, while *C. latimanus*, *C. diogenes*, and *C.* sp. C are found in both the Piedmont and Coastal Plain. *Procambarus a. acutus* appears to be common throughout the system, even into its headwaters. Faxon's (1914:367) report of "*Cambarus blandingii*" from Reedy Creek, near Greensboro, must have been based on *P. a. acutus*, which D. G. Cooper collected from Lake Reidsville and a small lake south of Reidsville, Rockingham County, in the Haw River subdrainage. *Fallicambarus fodiens* apparently has made inroads into the Piedmont of the Cape Fear basin; Hobbs and Peters (1977:46) recorded it from the Rocky River in Chatham County. *Procambarus ancylus* is known from White and Singletary lakes, Bladen County (Hobbs 1958:167), and has been collected from a borrow pit near Colly Creek (NCSM

C–1949), which has a tributary stream entering it from Singletary Lake. *Procambarus pearsei* is known from as far north in the system as northern Sampson County, and might occur in extreme southwestern Johnston County. Its type locality, a pond and ditch on NC 22 south of Fayetteville, Cumberland County (Creaser 1934:4), is in this river basin. *Procambarus blandingii*, which occurs in the Lumber and Waccamaw basins, appears to be absent from the lower Cape Fear, but this needs investigation.

The northern tributaries of the Northeast Cape Fear River originate in the Coastal Plain in southern Wayne and northeastern Sampson counties. The system drains almost all of Duplin, most of Pender, western Onslow, and northern New Hanover counties. The Northeast Cape Fear generally is considered an eastern trunk of the Cape Fear River, but it flows into saline waters at Wilmington, independent of the Cape Fear. As alluded to in the previous discussion of the Northeast Cape Fear as a hydrologically and faunistically autonomous unit, there are differences in the crayfish faunas of the two systems. Since the Northeast Cape Fear is confined to the Coastal Plain, it is not surprising that it does not harbor *C. catagius* or *C. reduncus*, both Piedmont species. It does have *P. plumimanus*, however, which is absent from the Cape Fear but present in the New (White Oak), and lacks *P. ancylus* and *P. pearsei*, both of which occur in the Cape Fear, Lumber, and Waccamaw. The rest of the crayfish fauna of the Northeast Cape Fear is that of the coastal Cape Fear, i.e., *C. latimanus*, *C. diogenes*, *C.* sp. C, *F. fodiens*, and *P. a. acutus*.

New (*White Oak*) *River*—The major hydrologic units of the New (White Oak) drainage basin are the autonomous New, White Oak, Newport, and North rivers and their tributaries. All are small and all empty into saline coastal waters behind barrier islands in Onslow Bay, and Bogue and Back sounds. The New River drains the center of Onslow County, and extreme eastern Pender and New Hanover counties. The White Oak drains eastern Onslow County and forms part of the boundary between southeastern Jones and eastern Onslow counties. Included in the White Oak unit are Catfish and Great lakes of Croatan National Forest, southwestern Craven County. The Newport and New rivers both drain southern Carteret County, and both, like the White Oak, are artificially connected with the lower Neuse River basin to the north (see the *P. plumimanus* account).

The crayfish fauna of the New (White Oak) basin consists of *C. diogenes*, *C. latimanus*, *F. fodiens*, *P. a. acutus*, *P. plumimanus*, and probably *C.* sp. C.

Neuse River—The Neuse is a second major drainage system that heads and debouches in North Carolina (for a brief description see Cooper and Ashton 1985:6–7). It includes Long, Little, and Ellis lakes of Croatan National Forest, Craven County. Ellis Lake has a direct connection with Southwest Prong Slocum Creek.

Cambarus reduncus is confined to the Piedmont Plateau and Fall Line zone of this basin, where the southeasternmost known localities are in central Wake County. *Cambarus latimanus*, *C. diogenes*, *C.* sp. C, and *P. a. acutus* occur throughout the system. *Procambarus medialis*, *F. fodiens*, and *O.* sp. A are essentially Coastal Plain species, with *F. fodiens* and *O.* sp. A both edging into the Fall Line zone at least as far west as southern Wake County. Two localities for *P. plumimanus*, including the type locality, are known in the lower Neuse basin. The listing by Harris (1903:56) of *C. b. bartonii* in the Neuse was in error, and was probably based on Faxon's (1885:61) erroneous report of the species from Kinston, Lenoir County, which also was repeated by Ortmann (1931:131).

Tar-Pamlico River—Like the Cape Fear and Neuse rivers, the Tar-Pamlico is confined to North Carolina (for a brief description see Cooper and Ashton 1985:6–9). Lake Mattamuskeet, part of this system in Hyde County, connects with the Alligator River of the Pasquotank basin through drainage canals and the Intracoastal Waterway, which also forms a direct connection between the Alligator and Pungo rivers. Drainage canals also connect Pungo Lake of the Tar-Pamlico basin, Washington and Hyde counties, with canals from New (Alligator) Lake in the Pasquotank drainage of Hyde County.

The crayfish fauna of the Tar-Pamlico is the same as that of the Neuse basin, except for the apparent expansion into the latter of *P. plumimanus*. During the Pleistocene, these drainages "would have been conjoined to form the Greater Pamlico River" (Lachner and Jenkins 1971:62). In the Tar-Pamlico, however, *P. medialis* appears to be limited to the immediate area of the type locality, a pool in a roadside ditch, 0.6 mi (1 km) south of Scotland Neck, on US 258, in southeastern Halifax County (Hobbs 1975:13). In the Neuse basin its known range is more extensive, occupying an area from Johnston County downriver to Lenoir and Pitt counties. In addition, the Tar-Pamlico range of *Orconectes* sp. A extends from headwaters in Granville County to eastern Pitt County, whereas in the Neuse, despite intensive sampling, this species has not been found any farther upriver than southern Wake County. The report by Faxon (1914:367) of "*Cambarus blandingii*" from Lake Mattamuskeet was undoubtedly based upon *P. a. acutus*.

Roanoke River—The Roanoke is another heavily impounded river. Its major western tributary, the Dan River, begins in the Blue Ridge in Virginia, and in northeastern Surry, Stokes, and Forsyth counties, North Carolina. The Dan flows essentially east and north, moving in and out of North Carolina in northern Rockingham and Caswell counties, and acquiring tributaries in both. It joins the Roanoke at Buggs Island Reservoir in Virginia. The Roanoke then flows southeast into North Carolina, adding tributaries in northern Granville and Vance counties and feeding into John H. Kerr Reservoir and Lake Gaston. The river flows southeast from Lake Gaston, drains southwestern Northampton, northern Halifax, and most of Bertie and Martin counties, then empties into the western arm of Albemarle Sound at Batchelor Bay.

Cambarus longulus and *C. b. bartonii* occur in the upper Dan River watershed, where *C. longulus* is known from no farther east than Rockingham County, and the eastern limits of the range of *C. b. bartonii* are unknown. *Cambarus* sp. C apparently occurs throughout the system. *Cambarus diogenes* and *F. fodiens* occur in the Coastal Plain, but encroach on the Piedmont Plateau, where the western limits of their ranges are uncertain. *Procambarus a. acutus* is found in all of the Coastal Plain, and as far west in the Piedmont as eastern Caswell County. *Orconectes virginiensis* is known from Bertie, Halifax, and Martin counties.

Chowan River—The Chowan River basin is confined to the northeastern Coastal Plain, rising at the confluence of the Nottoway and Blackwater rivers just south of the Virginia state line. The southeast-flowing Meherrin River heads in Virginia, enters North Carolina to form part of the northern boundary between Northampton and Hertford counties, then turns east across Hertford County to join the Chowan at the Gates County line. The system drains northern and eastern Northampton, Hertford, and most of southern and western Gates, western Chowan, and northeastern Bertie counties, then empties into the western arm of Albemarle Sound.

The crayfishes of the Chowan basin are *C. diogenes*, *F. fodiens*, *P. a. acutus*, *O. virginiensis*, and possibly *C.* sp. C. The listing by Harris (1903:53) of *C. b. bartonii* in the Chowan basin (in Virginia) was in error, and was probably based on Faxon's (1885:61) erroneous report of the species from Southampton and Lunenburg counties, which also was repeated by Ortmann (1931:131)

Pasquotank River—North of Albemarle Sound, the streams that form the northern part of this Coastal Plain system rise in the southeastern tip of Virginia and in eastern Gates County, North Carolina. This part of the basin includes the Pasquotank River that drains northeastern Gates, northern Pasquotank, and the northern half of Camden counties; the Perquimans River of Perquimans County; the Little River that rises in the Dismal Swamp in central Pasquotank County and forms part of the lower Pasquotank-Perquimans county line; the North River that rises in the Dismal Swamp in Currituck and Camden counties; the Northwest River, which begins in Norfolk County, Virginia, and flows southeast into Tull Bay, Currituck County; and the North Landing River, which begins in Princess Anne County, Virginia, flows south into Currituck Sound, and connects with the lower James River of Virginia via the Intracoastal Waterway. All these rivers except the Northwest and North Landing flow into Albemarle Sound.

South of Albemarle Sound the Pasquotank system includes the north-flowing Alligator River, which drains parts of northern Hyde, much of Tyrrell, and most of Dare counties; the Scuppernong River that drains eastern Washington and northwestern Tyrrell counties; and Phelps and New (Alligator) lakes. Both an immense system of man-made drainage canals in the Dismal Swamp west of Phelps and Pungo lakes, and the Intracoastal Waterway, link parts of the Pasquotank basin with the Pungo River, Lake Mattamuskeet, and other parts of the Tar-Pamlico basin in Beaufort and Hyde counties.

The crayfish fauna of the Pasquotank basin consists of *C. diogenes*, *F. fodiens*, and *P. a. acutus*. *Fallicambarus fodiens* has been found across Croatan Sound, near Manteo on Roanoke Island, Dare County.

CRAYFISH DISTRIBUTIONS BY PHYSIOGRAPHIC PROVINCES

Cambarus is the dominant crayfish genus in North Carolina, with 18 described species (not including *C.* "*acuminatus*") and at least three known but undescribed species. Nine of these species are limited to the Blue Ridge, three are limited to the Piedmont Plateau, and two overlap the Piedmont and Coastal Plain (one of these two also may be found in all three provinces). Distributions of the taxa now subsumed under *Cambarus* sp. C, which includes *C.* "*acuminatus*," will not be clarified until this complex has been diagnosed. Suffice it to say that they occur in all three physiographic provinces. The sole North Carolina species of *Fallicambarus* is primarily Coastal Plain in distribution, but also has invaded the eastern Piedmont Plateau. One of the two described *Orconectes* in North Carolina occurs only in the Blue Ridge, as does an apparently undescribed member of the genus. The other described *Orconectes* is limited to the northeastern Coastal Plain, and a second undescribed

Table 2. Summary of crayfish distributions in major physiographic provinces of North Carolina. X = present.

Species	Blue Ridge	Piedmont Plateau	Coastal Plain
Cambarus			
(*C.*) *b. bartonii*	X	X	
(*C.*) sp. A	?	X	
(*D.*) *catagius*		X	
(*D.*) *latimanus*	?	X	X
(*D.*) *reduncus*		X	
(*D.*) sp. B		X	
(*H.*) *chasmodactylus*	X		
(*H.*) *longirostris*	X		
(*H.*) *longulus*	X	X	
(*J.*) *asperimanus*	X	X	
(*J.*) *carolinus*	X		
(*J.*) *dubius*	X	?[1]	
(*J.*) *nodosus*	X		
(*L.*) *diogenes*		X	X
(*P.*) *georgiae*	X		
(*P.*) *hiwasseensis*	X		
(*P.*) *parrishi*	X		
(*P.*) *reburrus*	X		
(*P.*) *robustus*	X	?	
(*P.*) sp. C[2]	X	X	X
(*T.*) *acanthura*	X		
Fallicambarus			
(*C.*) *fodiens*		X	X
Orconectes			
(*C.*) *virginiensis*			X
(*P.*) *spinosus*	X		
(*P.*) sp. A		X	X
(*P.*) sp. B	X		
Procambarus			
(*O.*) *a. acutus*		X	X
(*O.*) *ancylus*			X
(*O.*) *blandingii*			X
(*O.*) *lepidodactylus*			?
(*O.*) *medialis*			X
(*O.*) *pearsei*			X
(*O.*) *plumimanus*			X

[1] Known from east of the Blue Ridge in Avery, Surry, and Wilkes counties, but eastern limits of range unknown.

[2] Includes *C.* (*P.*) *acuminatus* (*s. l.*).

species of the genus is essentially Coastal Plain but occurs also at the eastern edge of the Piedmont Plateau. Genus *Procambarus*, with six, and probably seven, described native species, dominates the Coastal Plain. Six of these species are limited to this province, but the seventh also occurs deeply into the Piedmont. Table 2 is a summary of species distributions by physiographic provinces.

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Finally, we express our deepest gratitude to and for the late Horton H. Hobbs, Jr., whose death was a great personal tragedy and an incalculable loss to decapod research. His kindness and generosity, his knowledge and insights, and his total integrity, shall never be forgotten.

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ADDENDUM

After this paper went to press, V. Schneider and D. R. Lenat collected the first *Cambarus spicatus* adults from North Carolina: Cleveland Co., First Broad R at SR 1530, 6.1 air mi (9.8 air km) WSW cntr Casar; 2 ♂ II, 3 ♀ (NCSM C–2487), 20 Jun 1995.

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NEW PUBLICATION

Reptiles of North Carolina by William M. Palmer and Alvin L. Braswell was released by the University of North Carolina Press in August 1995. It contains 428 pages, 76 color plates, 68 range maps, 170 tables, and 126 drawings by scientific illustrator Renaldo Kuhler. The hardcover book is available from the publisher for $39.95 plus shipping charges and N.C. sales tax (if applicable). Orders may be placed toll free by calling (800) 848-6224. MasterCard and Visa charges are accepted.

ERRATA

The authors of "Atlantic Ocean Occurrences of the Sea Lamprey, *Petromyzon marinus* (Petromyzontiformes: Petromyzontidae), Parasitizing Sandbar, *Carcharhinus plumbeus*, and Dusky, *C. obscurus* (Carcharhiniformes: Carcharhinidae), Sharks off North and South Carolina" (*Brimleyana* 21:69-72) have requested that the following corrections be published:

Page 70: North Carolina paragraph, line 4, should have been *1.5*-m-FL, not 3.

Page 71: Footnote[1] to Table 1 should be host *male*, not female.

DATE OF MAILING

Brimleyana 21 was mailed on 25 April 1995.

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