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ECOLOGICAL STATUS OF THE HELLBENDER (*Cryptobranchus alleganiensis*) AND THE MUDPUPPY (*Necturus maculosus*) SALAMANDERS IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

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Abstract: Diurnal skin-diving surveys of streams in the Great Smoky Mountains National Park revealed low density populations of hellbenders (*Cryptobranchus alleganiensis*) in Little River, Deep Creek, and Oconoluftee River. The Little River population included well-developed eggs, gilled larvae, larvae and adults, with an almost 50% larval composition. Little River was the only stream where mudpuppies (*Necturus maculosus*), consisting of two or three age classes, were found. Water quality profiles revealed acidic conditions for Little River and Noland Creek, indicating that monitoring efforts should be continued. The use of electroshocking during late summer and early fall and any chemical treatments for rough fish elimination is strongly discouraged in those streams with *C. alleganiensis* populations. Appropriately sized *C. alleganiensis* and *N. maculosus* were PIT tagged for future monitoring which should use the same diurnal skin diving method.

Key Words; *Cryptobranchus alleganiensis*, *Necturus maculosus*, Great Smoky Mountains National Park, ecology.

INTRODUCTION

The biological significance of the Great Smoky Mountains National Park (GSMNP) is reflected by its designation as an International Biosphere Reserve (Dodd et al., 1998), and many herpetologists consider it to be the most important amphibian reserve in eastern North America. This is especially true of scientists who study salamanders. Worldwide amphibian declines and limited knowledge of the current population status of many species has led to the prioritization of inventories coupled with population monitoring. Most of the studies within the GSMNP have centered on plethodontid salamanders (Smith and Petranka, 2000; Welsh and Droege, 2001). We initiated this study to assess the distribution and ecological status of two large paedomorphic salamanders: the hellbender, *Cryptobranchus alleganiensis* (Daudin) (Cryptobranchidae) and mudpuppy, *Necturus maculosus* (Rafinesque) (Proteidae), within the GSMNP. Secondary goals involved tagging salamanders with Passive Integrated Transponder (PIT) tags for long term monitoring, as well as addressing potential threats to these populations,

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and making recommendations for future research. This study is a component of the GSMNP, Tennessee and North Carolina, U.S. Geological Survey (USGS) Herpetology Project under the auspices of the USGS, Florida Caribbean Science Center (Dodd et al., 1998; Dodd et al., 1999; Irwin, 1999).

MATERIALS AND METHODS

We conducted diurnal skin-diving surveys of the GSMNP streams considered potential habitat for *C. alleganiensis* and *N. maculosus* between 21 August and 15 October 2000. These surveys included low elevation sections (269-652 m) of the Little River, Little Pigeon River, Cosby Creek, Big Creek, Middle Prong of Little River, Abrams Creek, Fighting Creek, West Prong of Little Pigeon River, Oconaluftee River, Noland Creek, Deep Creek, and Cataloochee Creek. Portions of these streams were also surveyed with heavy-duty dip nets (55 x 45 cm, 0.6 cm mesh), raking through leaf beds, as well as by setting these nets within riffle channels and by raking the rocky areas upstream from these sets. Surveys were conducted between 1015 and 1805 hrs and typically involved four individuals, three of whom were in the water surveying and one providing support by recording data, carrying equipment, and tagging. Underwater surveys were accomplished by direct observation coupled with turning rocks and other objects. Salamanders were weighed with an Ohaus CS-2000 compact scale, measured using a standard meter stick for total (TL) and snout-vent lengths (SVL), and PIT tagged with a 10 ml syringe coupled with a 12 gauge needle. PIT tags were inserted within connective tissue adjacent to the vertebral column just caudad and lateral to the posterior limb attachment. Needles were sterilized in 95% ethanol before use. After tagging and data collection, salamanders were released at their capture site. Dissolved oxygen (DO) was measured with a Hanna Hi 9142 oxygen meter. Conductivity and pH were obtained with a Hanna Watercheck pH and TDS reader, and measurements were standardized between site readings using Orion perpHect buffers. Elevations, latitudes, and longitudes were taken with a Garmin GPS 12.

RESULTS

All *C. alleganiensis* and *N. maculosus* were captured via skin-diving. Five adult *C. alleganiensis* were found in Deep Creek, NC (35°27.564’N, 83°26.261’W to 35°27.586’N, 83°26.232’W), and one adult was found in Oconaluftee River (35°31.400’N, 83°18.335’W). Thirty-three adults and larvae, plus a nest with about 200 eggs (containing larvae near hatching), were found in Little River, TN (35°39.965’N, W 83°42.488’W to N 35°39.971’N, W 83°41.206’W; Fig. 1). We also found four *N. maculosus* in Little River (35°40.081’N, 83°41.856’W; Fig. 1).

Given the low population densities of *C. alleganiensis* and *N. maculosus* in many GSMNP streams, only limited comments can be made of the population of *C. alleganiensis* in Little River. *Cryptobranchus alleganiensis* were found at all Little River survey sites from near the western GSMNP border (near Townsend, TN) to about 7 km upstream (Fig. 1). The Little River survey found at least three larval age classes (including larvae in egg membranes within a nest), and several age classes of subadult and adult *C. alleganiensis* (Figs. 2, 3). The collection effort for *C. alleganiensis* captured in GSMNP was 0.25-0.65 individuals/hr or 2.98 individuals/hr including the 200 well-developed larvae in egg membranes. Water quality data within GSMNP surveyed habitats were: pH from 6.7 to 7.8,

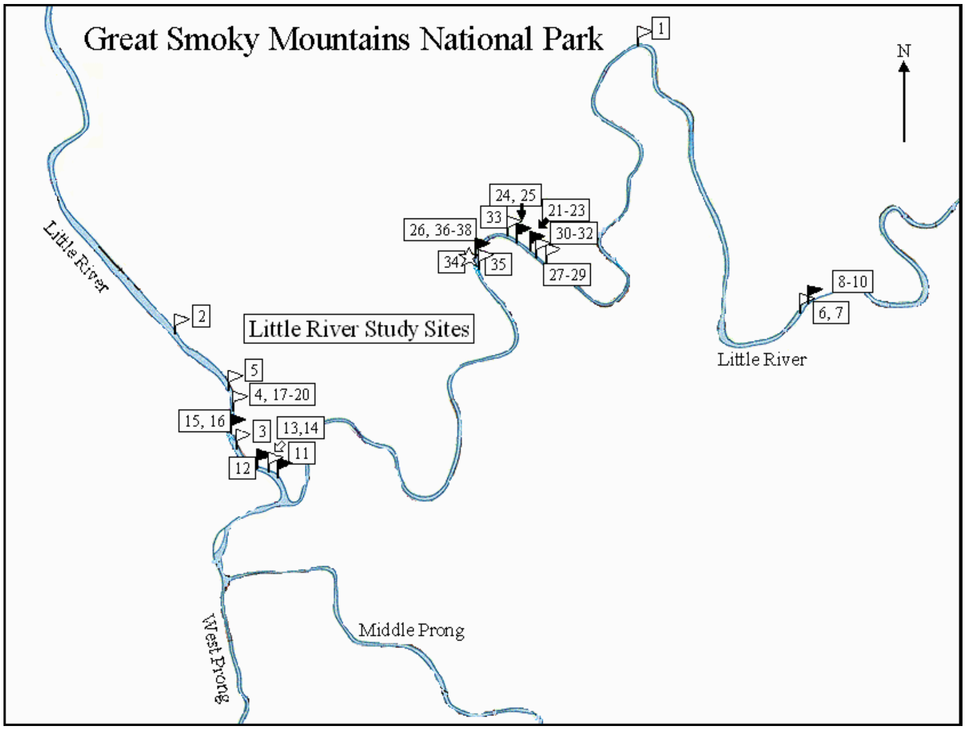

FIG. 1. Locations of hellbender (*Cryptobranchus alleganiensis*) and mudpuppy (*Necturus maculosus*) salamanders at Little River study sites, GSMNP. Black flag = PIT tagged animal, white flag = non-PIT tagged animal, star = *Cryptobranchus* nest, number = individual salamanders and the nest.

DO from 6.5 to 10.4 ppm, and water temperatures from 8.5° to 20.8°C. GSMNP streams had substantial relief within the many surveyed stream sections, sometimes more than 60 m in short sections (Table 1). GSMNP streams typically had metamorphic rock streambeds with scattered piles of dense metamorphic rock and some accumulation of sand, gravel, and igneous rock. We were unable to survey Hazel and Eagle creeks because of transportation problems caused by low water levels in Fontana Lake.

DISCUSSION

Distribution.—*Cryptobranchus alleganiensis* were first recorded in 1936 from the GSMNP of Tennessee in Little River near Elkmont, West Prong of Little Pigeon River near Gatlinburg, and Abrams Creek (King, 1939). Additionally, *C. alleganiensis* were also observed in Hazel Creek and Deep Creek in North Carolina (King, 1939). A gravid *C. alleganiensis* was collected in 1945 in Oconaluftee River at Smokemont (Huheey and Stupka, 1967), and in 1958, an individual was found in Forney Creek (Irwin, 1999). A brief rock turning/nocturnal spotlighting survey discovered seven *C. alleganiensis* in 1999 in Little River near the western GSMNP boundry and Townsend, TN, but none in Abrams Creek, Cataloochee Creek, nor Oconaluftee River (Irwin, 1999).

Larval and adult *N. maculosus* were collected in 1937 in Abrams Creek, just above the junction with Little Tennessee River (King, 1939) Additional *N. ma-*

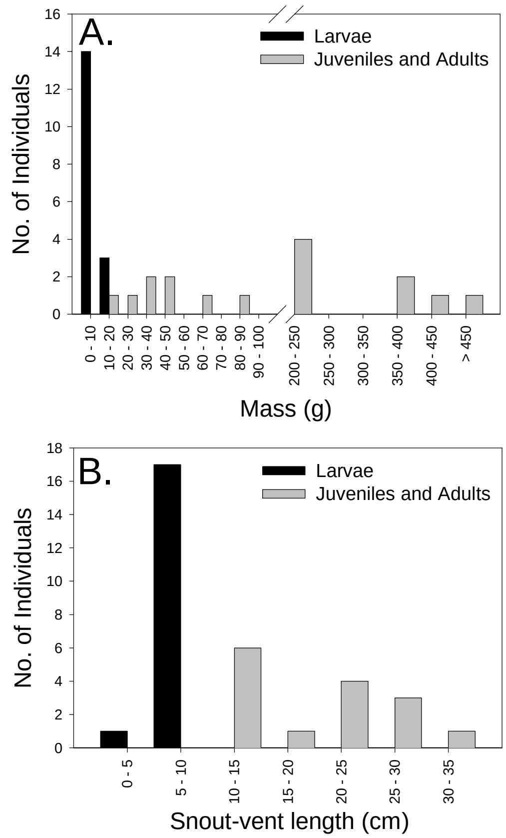

FIG. 2. Size distributions of *Cryptobranchus alleganiensis* at Little River study sites in GSMNP. Note that the larvae in egg membranes (n = 200) are not included in the graphs.

culosus specimens were found in 1940 and 1957 in Abrams Creek (Huheey and Stupka, 1967). The first *N. maculosus* recorded from Little River was found just inside the park boundary near Townsend, TN (Merkle and Kovack, 1974). Although *N. maculosus* sightings were reported in the same section of Little River in 1998, none were found in 1999 (Irwin, 1999).

Little River was the only lengthy GSMNP stream surveyed where *C. alleganiensis* were found throughout the areas sampled and where a substantial population existed (Fig.1). Our GSMNP capture data per hour (0.25-0.65 or 2.98 individuals/hr) for *C. alleganiensis* was low as compared to the North Fork of White River (NFWR), Missouri, where 8.0-12.0 individuals/hr were captured (Nickerson and Mays, 1973a, b; Nickerson, unpubl. data). However, Little River population structure has numerous larval and adult age classes, which indicate successive years of reproductive success (Figs. 2, 3). A unique feature of the Little River *C. alleganiensis* population is the high ratio of larvae to adults captured (16 larvae and 17 adults), as *C. alleganiensis* larvae are rarely found in NFWR and other Ozark populations (Nickerson and Mays, 1973a). Thus, the Little River seems to possess a low density *C. alleganiensis* population, which appears stable within the constraints of the habitat.

The distribution and ecological status of *N. maculosus* in GSMNP continues to

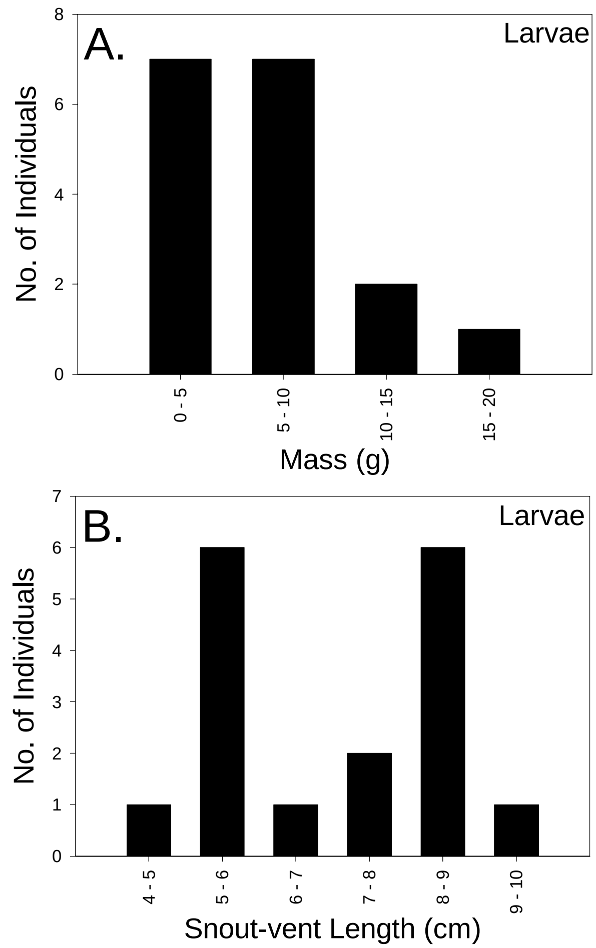

FIG. 3. Size distributions of larval *Cryptobranchus alleganiensis* at Little River study sites in GSMNP. Note that the larvae in egg membranes (n = 200) are not included in the graphs.

Table 1. Abiotic data from Great Smoky Mountains National Park research sites.

Site	Ambient Air Temp. (°C)	Water Temp. (°C)	pH	DO (ppm)	Con-duc-tivity	Elevation (m)
Little River (sites)	12.3-22	8.5-20	6.9-7.4	7.1-10.4	10.0	330-394
Little Pigeon River	23	18.3	N/A	N/A	N/A	373
Cosby Creek	21.1	17.7	N/A	N/A	N/A	506-567
Big Creek	24.7	17.8	N/A	N/A	N/A	472-494
Middle Prong of Little River	21.2	18.8	N/A	N/A	N/A	269
Abrams Creek	26.7	20.8	N/A	N/A	N/A	341
Fighting Creek	13.4	12.5	7.3	7.3	N/A	424-431
West Prong of Little Pigeon River	20.2	13.4	7.8	8.9	10.0	424-461
Oconoluftee River (Smokemont)	22.5	13.5	7.8	6.6	10.0	626
Noland Creek	25	14	6.7	6.7	10.0	518
Deep Creek	18-24	8.8-15.1	7.3	6.5-10.3	10.0	547-557
Cataloochee Creek	11	12.4	7.4	7.8	10.0	606

be an enigma. However, our sample of four Little River *N. maculosus* (9.0 - 20.3 cm TL) extends their known geographic distribution several km, and indicates that two or perhaps three age classes are present. During this study, other investigators found *N. maculosus* larvae in Abram's Creek (K.G. Smith and W.J. Barichivich, pers. comm.). However, seasonal movement of these salamanders may be partially responsible for our dearth of data (R. Sajdak, pers. comm.).

Threats.—Factors implicated in threatening or destroying populations of *C. alleganiensis* include damming, increased siltation from clearing riparian habitats, building bridges, roads and culverts, over-collecting, pollution from acid mine activities, agricultural, industrial practices and eutrophication (Nickerson and Mays, 1973a; Trauth et al., 1993). Salamander populations have been eliminated within GSMNP streams downstream from road building and areas where road fill was utilized in projects near streams (Huckabee et al., 1975). These salamander kills were associated with lowered pH (4.5-5.9) and increased sulfate and metal concentrations, which occur naturally via leaching of pyritiferous phyllite from geological formations within GSMNP (Huckabee et al., 1975). Disturbances that expose the Anakeesta rock formations eliminate nearly all of a stream's macroinvertebrates as well as aquatic salamander populations (Kucken et al., 1994). The slightly acidic readings within Little River and Noland Creek (Table1), suggest that water quality should be routinely monitored at those and other GSMNP sites. *Cryptobranchus alleganiensis* have unique respiratory components, including a single hemoglobin that does not show a Bohr effect (Taketa and Nickerson, 1973a, b), therefore, a shift toward a more acidic habitat might negatively affect populations.

Crayfish are the major diet of *C. alleganiensis* throughout their range (Nickerson and Mays, 1973a; Nickerson and Ashton, 1983). The GSMNP streams surveyed had low populations of crayfishes when compared to Ozark streams with high populations of *Cryptobranchus* (Nickerson, unpubl. data). Several otters (*Lutra canadensis*) were observed within Little River, and large populations of otters could significantly reduce crayfish populations.

Some aspects of fish population management may also be hazardous to *Cryptobranchus* and *Necturus* survival. Use of chemicals to reduce "competitive and rough fish" populations are implicated in *Cryptobranchus* and *Necturus* declines (Matson, 1990; C J. McCoy, pers. comm). In the past, Pro-noxfish (liquid rotenone) has been used to eliminate fishes from Abrams and Indian Creeks and their tributaries (Lennon and Parker, 1957, 1959). Rotenone undoubtedly affected salamander and macroinvertebrate populations, the latter of which may have been part of the salamander food base. We do not know the effects of electro-shocking on gravid *Cryptobranchus*, their eggs or larvae. However, if electro-shocking surveys must take place, we suggest that this technique should not be conducted during the late summer or fall reproductive season where *C. alleganiensis* populations exist.

Future monitoring and research.—Little River populations of *C. alleganiensis*, perhaps coupled with *N. maculosus*, should be monitored. We strongly recommend diurnal skin-diving surveys of this habitat because it is currently the only proven method for sampling all age classes of *Cryptobranchus* (Nickerson et al., submitted). PIT tagging, coupled with branding of larvae, could be utilized to study both species simultaneously. Some sections of Little River and smaller streams could be surveyed nocturnally. Nocturnal surveys may allow access to typically nocturnal salamanders that have chosen very secure lodging in crevices or under rocks too large to turn. However, the effectiveness of nocturnal surveys varies with gender and season (Humphries and Pauley, 2000), and also requires more equipment and may be more hazardous to the surveyors.

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