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Seasonal Changes in Nocturnal Activity of the Hellbender, *Cryptobranchus alleganiensis,* in West Virginia

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Widespread declines in the distribution and abundance of the hellbender, *Cryptobranchus alleganiensis,* have been attributed to habitat loss and degradation (Smith and Minton, 1957; Dundee, 1971; Nickerson and Mays, 1973a; Bury et al., 1980; Williams et al., 1981; McCoy, 1982; Gates et al., 1985; Trauth et al., 1992). Thus, it has become important to implement censuses for hellbenders, an important first step for conserving the species.

Several methods for locating hellbenders have been described (Nickerson and Mays, 1973a, b; Williams et al., 1981) and the relative effectiveness of some methods has been tested (Williams et al., 1981). These techniques include electroshocking, electroshocking coupled with a seine, lifting rocks, scuba diving, and passive nocturnal searches with spotlights. Turning rocks during daylight has been the most commonly used technique for conducting studies to determine relative abundance and general life history patterns (Hillis and Bellis, 1971; Nickerson and Mays, 1973a, b; Taber et al., 1975; Noeske and Nickerson, 1979; Peterson et al., 1983; Peterson, 1987; Peterson et al., 1988; Peterson and Wilkinson, 1996). This technique is effective in uncovering many individuals within a stream section and is appropriate for abundance studies. However, in some streams nocturnal surveys can be used in addition to or as an alternative to turning rocks to determine presence/ absence.

The effectiveness of nocturnal searches during different times of the year has not been addressed. Several researchers have reported nocturnal activity by hellbenders (Townsend, 1882; Noeske and Nickerson, 1979; Coatney, 1982; Blais, 1996). In some populations maximum activity of hellbenders was reported to occur approximately two hours after dark (Noeske and Nickerson, 1979; Coatney, 1982), with a second, smaller period of activity at dawn (Noeske and Nickerson, 1979), though the activity peak at dawn was observed in the lab and may not occur in nature. In contrast, Blais (1996) witnessed very little nocturnal activity in hellbenders in southcentral New York. In this paper, we examined the effectiveness of nocturnal surveys in the central Appalachians and provide data to indicate when surveys should be conducted to increase accuracy of nocturnal surveys in documenting presence or absence of hellbenders.

During May-October of 1998, we studied hellbenders inhabiting the West Fork of the Greenbrier River, Pocahontas County, West Virginia (elev. 838 m), in a 215 x 20 m section of stream. The substrate was made of limestone and shale cobble, sand, and many large, flattened rocks. The study site consisted of two areas of riffles and three slower flowing, deeper areas. Water depths ranged from 10-15 cm in the riffles to 1 min the deepest pools. The stream reached its greatest depth in March, April, and May, and its lowest depth in August and September. Hellbenders were found most often in water less than 30 cm deep. Water temperatures from April through October ranged from 12-23 C.

Just after the onset of darkness, between two and four researchers walked the stream bottom using flashlights to search for hellbenders. When an individual was located it was captured by hand, placed into a dipnet, and tagged, measured, and weighed. Within the study section, 29 individuals were marked with 14 mm passive integrated transponder (PIT) tags for a mark-recapture study (Humphries, 1999). PIT tags were injected subcutaneously into the dorsal region of the base of the tail. Hellbenders were immediately returned to the exact capture site after processing; if

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they were captured under a rock, they were replaced near the entrance hole.

Searching usually took place between 2100 and 2400 h. Nocturnal searches encompassed 2.5–4 person-hours, but the site was always searched thoroughly until all visible hellbenders had been captured. Surveys were conducted during 17 nights, from 16 May to 10 October 1998 with approximately 1–2 wks between searches. The results of two nights (26 and 27 June) were combined because searching was halted due to adverse weather conditions each night, forcing us to search the upper half and lower half of the site on consecutive nights. Number of surveys conducted by month were as follows: May (2), June (2), July (2), August (5), September (4), October (2).

Individual hellbenders were categorized as either active or hidden, based on their location at the time of capture. Hellbenders observed walking on the streambed were scored as active, and those with only their heads protruding from under a rock were scored as hidden. To capture hidden individuals, the rocks were lifted and the hellbenders were removed. If a rock could not be lifted because of its size, the hidden hellbender was counted in the census, but the gender was not recorded unless the individual could be identified by distinct markings.

All hellbenders observed during this study appeared to be sexually mature adults, based on size (Peterson et al., 1988) (mean TL = 45.3 cm, range = 29.5–56.5 cm) and secondary sexual characteristics of males. The male to female sex ratio for all hellbenders captured within the stream during the summer (N = 41) was 1.01:1 and within the study site it was 1:1.1 (N = 29). The male to female sex ratio during May and June was 1:1.8. Reproduction was not observed, but maximum cloacal swelling in males and information from other researchers (Green, 1934; S. Blackburn, pers. comm., 1998) suggested that the breeding season was late August to early September.

Fifty-nine captures of hellbenders were made during nocturnal surveys in 1998, and an additional 12 individuals were observed hidden under rocks too large to lift. Nocturnal activity of hellbenders was highest in early summer, with up to 10 individuals active per night during May and June, but no more than four active per night from July through October (Fig. 1A). Several differences existed in the nocturnal activity of females (Fig. 1B) and males (Fig. 1C). The shift in nocturnal activity of females was more pronounced than that of males. Twenty-three active females and 18 active males were observed during the study, though only three nocturnally hidden females were observed compared with 15 hidden males. Nocturnal activity in males decreased slightly in late summer, though their activity was relatively low during all times of the year. Only 33% of the nocturnally active males observed during the summer were found during May and June. Females were highly active early in the year (May and June), but were rarely encountered from July through October. Sixty-five percent of the nocturnally active females were observed in May and June.

Pearson-Product moment tests indicated that stream depth was positively correlated with nocturnal activity of all hellbenders combined (r = 0.56, P = 0.02).

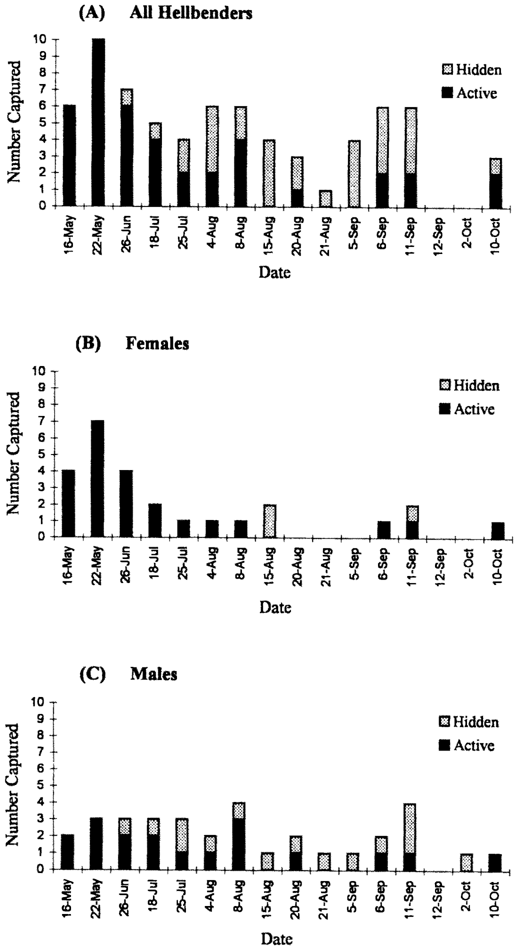

FIG. 1. Number of (A) all hellbenders, (B) females, and (C) males active or hidden during nocturnal surveys conducted from May through October 1998 in a 215 × 20 m section of the West Fork of the Greenbrier River, Pocahontas Co., West Virginia. Note: the gender of some hidden individuals could not be determined, but they were included in the "all hellbenders" group.

Water temperature was not significantly correlated with hellbender activity (r = 0.18, P = 0.51).

A peak in nocturnal activity early in the summer and a virtual lack of nocturnal activity in later months has not been reported by other researchers. The only other mention of a similar trend was by Townsend (1882) who observed considerable numbers of hellbenders in early summer. The reasons for seasonal shifts in nocturnal activity remain unclear, however. Water depth was highest during months of greatest nocturnal activity. It is possible that hellbenders remain hidden at night during periods of low water to avoid being preyed upon by bears or raccoons taking advantage of the clear and shallow water. Future studies should examine this relationship in other streams.

Surprisingly, we observed the lowest incidence of nocturnal activity during the breeding season. In contrast, other researchers have reported that many hellbenders may be seen walking the stream bottom during the breeding season, even during the day (Green, 1934; Bishop, 1941; D. Madison, pers. comm., 1999). During late summer, Madison (pers. comm.) observed many hellbenders active both day and night within a 30 m stretch of stream that contained a nesting site; however, he stated that it was difficult to locate any hellbenders shortly after this event was over. Since hellbenders typically congregate during the breeding season, it is possible that our study area did not contain a nesting site and that individuals in our site migrated to other parts of the stream in late summer.

Smith (1912) noted that the sex ratio in a Pennsylvania stream varied with time of year and with location within the stream. The sex ratio at our study site, though 1:1 overall, was highly biased toward females during the spring (1:1.8). Though our data suggest that females moved out of the study site late in the season, we still observed greater activity early in the year in general. Similar trends were noticed in areas outside of the study site; nocturnal activity appeared highest early in the summer.

Behavior related to reproduction may have also influenced the nocturnal activity of males. Hellbenders are known to defend rocks, even outside of the breeding season (Smith, 1907; Bishop, 1941; Hillis and Bellis, 1971; Peterson, 1988; Peterson and Wilkinson, 1996) and rarely has more than one individual been found beneath the same rock (Smith, 1907; Hillis and Bellis, 1971; Nickerson and Mays, 1973a). Peterson and Wilkinson (1996) observed defense of shelters by both sexes in aquaria, but only males tend to defend shelters when nests are present (Smith, 1907). We observed fewer active males, but similar numbers of inactive males under rocks during nocturnal surveys later in the summer. At least two males in our site remained within the vicinity of their respective rocks the entire summer and displayed minimal nocturnal activity. Perhaps some rocks provide better shelters or nest sites than others and males stay at these sites to deter potential invaders, thereby reducing nocturnal activity in males in the late part of the summer.

Nocturnal activity in spring and early summer also could be driven by food consumption and changing energy requirements. Energy demands may be high early in the year as yolk deposition and testes enlargement are most dramatic from May until July (Ingersol, 1982). Active foraging for crayfish at night may be used in addition to or instead of a sit-and-wait strategy during times of high energy requirements. Nocturnally active hellbenders in our study stayed within a relatively small area during a given night (<100 m^2), and we observed one active female swallowing a crayfish on 22 May 1998. Detailed studies on feeding activity have not been completed, but Minton (1972) mentioned that an adult male captured in March ceased feeding by early June, just as its cloaca began to enlarge. Minton (1972) also reported that hellbenders in a southern Indiana stream were caught on baited hooks both day and night in greatest numbers from early March to late May. Though anecdotal, these reports suggest a relationship between feeding and activity. Further studies on nocturnal behavior and on the stomach contents of hellbenders at various times of the year would be useful in determining whether activity cycles relate to feeding.

In summary, a seasonal trend in nocturnal activity is apparent in high-elevation streams in West Virginia. Nocturnal activity was positively correlated with higher water levels, but additional factors likely contributed to seasonal activity shifts. Nocturnal surveys were very useful for documentation of presence/ absence in May and June, but could not be relied upon in later months. We stress, however, that nocturnal activity may vary with geographic location, location of nest sites within streams, prey availability, timing of the breeding season, or other factors. Studies on the seasonal activity cycles of hellbenders in other locations must be conducted before relying on the results of presence/ absence surveys using this method.

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Does the Aquatic Salamander, *Siren intermedia,* Respond to Chemical Cues from Prey?

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Early detection of prey can be an important factor in determining whether a predation event is ultimately successful {Lima and Dill, 1990). In aquatic amphibians prey detection could involve a number_ of sensory modalities, including vision, 0emo_recept on {smell and taste), tactile/mechanorecept10n{mcludmg the lateral line), and electroreception {see Heatwole and Dawley, 1998). Most experimental studies of prey detection in amphibians have focused on use of e1t er visual {overview in Roth et al., 1998) or chemical {overview in Dawley, 1998) cues. In general, visual cues appear to play a central role in well-lit habitats with active prey, and chemical cues are more imp r-tant if prey are cryptic or if habitats have r duced visibility because they are dark, cloudy, or highly vegetated {Dodson et al., 1994; Dawley, 1998).

Siren intermedia is a paedomorphic salamander whose habitat ranges from shallow ditches and ponds to permanent swamps or sloughs {Petranka, 1998). Because sirens tend to burrow in sediments or occupy vegetated areas or underwater crayfish burrows, they can be difficult to locate and capture {Carr, 1940; Cockrum, 1941; Freeman, 1958). Despite their cryptic existence, sirens may be important as both predators and competitors in some wetland communities {Fauth and Resetarits, 1991; Resetarits and Fauth, 1998; Fauth, 1999; Snodgrass et al., 1999). Their contribu on to the biomass of the community can be substantial: Gehlbach and Kennedy (1978) found siren density and standing crop biomass to be as high as 1.3 siren $/m^2$ and 56.6 g/m^2, respectively, and Frese (2000) e hmat: ed siren density and biomass in southeastern Missouri to be 1.7 $sirens/m^2$ and 58 g/m^2.

Sirens prey on a wide range of taxa. Stomach contents have revealed snails, bivalve shells, aquatic insects, algae, and mud {Dunn, 1924; Noble and Marshall, 1932; Carr, 1940; Collette and Gehlbach, 1961). In addition to invertebrate prey, sirens rely on amphibian larvae and small fish as seasonally important food items {Altig, 1967; Sullivan, 1999). Sirens are believed to forage at night {Davis and Knapp, 1953; Asquith and Altig, 1987) by consuming orpanisms closely associated with the substrate {Hanlm and Mount, 1978).

Because sirens have small eyes and typically are active under conditions of restricted visibility {at night

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