STATUS OF THE OZARK HELLBENDER (CRYPTOBRANCHUS ALLEGANIENSIS BISHOPI): A LONG-TERM ASSESSMENT

A Thesis
Presented to
The Graduate College
Southwest Missouri State University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

By
Benjamin Arik Wheeler
July 1999
STATUS OF THE OZARK HELLBENDER (CRYPTOBANCHUS ALLEGANIENSIS BISHOPI): A LONG-TERM ASSESSMENT

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Master of Science
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Abstract

A global decline in amphibian populations has been noted by biologists since the early 1970’s. There are two problems with documenting the decline of amphibian populations: natural fluctuations in population numbers and lack of long-term data. I censused populations of the long-lived Ozark hellbender, Cryptobranchus alleganiensis bishop, in three rivers in Missouri, and compared the 1998 data to data from previous studies from the 1970’s and 1980’s. Ozark hellbenders appear to have declined in numbers. This decline is characterized by an increase in average body size, due to an apparent lack of recruitment of young into the population. Hellbenders from at least one of the rivers tended to be in better condition in the 1998 samples than they were in the past. It is not known whether the population decline for hellbenders has a single cause or whether each population has experienced independent declines.

This abstract is approved as to form and content

Chairman, Advisory Committee
Southwest Missouri State University
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Approved:

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Member

Member

Associate Vice President for Academic
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Introduction

The health and status of an ecosystem is often determined by monitoring a particular species or group of species. For example, macro-invertebrate surveys are used to infer water quality in streams because they are susceptible to changes in the environment (McDonald et al. 1991). Organisms that are sensitive to environmental changes are called indicator organisms. Because indicator species often are affected in the early stages of environmental decay, they provide an important weapon in the arsenal of conservation biologists.

Historically, amphibians have been overlooked as key players in conservation biology (Pierce 1985). However, amphibians are an important part of many aquatic and terrestrial ecosystems and thus are good candidates for indicator species (Barinaga 1990). For example, the biomass of salamanders in the Hubbard Brook Research Forest is twice that of birds in the peak season, and is about equal to that of small mammals (Burton & Likens 1975). Amphibians play an important role in the food web, serving both as predators (Peterson et al. 1989a; Nickerson & Braswell 1983) and prey (Blaustein & Margalit 1994) in many ecosystems.

The general life cycle of amphibians also makes them useful as bioindicators. In most amphibians, eggs are laid in the water and aquatic larvae metamorphose into terrestrial adults. Amphibian larvae play an important role in recycling nutrients that are lost from terrestrial habitats due to run-off, and terrestrial adults transfer the stored energy from the aquatic system to the terrestrial system (Wassersug 1975). This basic life history has been modified in some species to include direct development (no aquatic stage) and neoteny (no terrestrial stage). The highly glandular skin of amphibians is
permeable and susceptible to water loss, so even terrestrial stages are restricted to moist microhabitats.

Amphibian populations apparently began to decline in the early to mid 1970's (Blaustein & Wake 1990). The use of two major habitat types (aquatic and terrestrial) coupled with highly permeable skin makes amphibians susceptible to a wide range of perturbations (Barinaga 1990; Blaustein & Wake 1990; Duellman & Trueb 1986; Wyman 1990). Many possible anthropogenic causes for these apparent declines have been suggested, including loss of habitat, introduction of exotic predators, agricultural run-off, and over-collecting (Blaustein & Wake 1990; Bradford et al. 1994, Delis et al. 1996; Hecnar 1995). The disappearance of amphibians from areas that were heavily affected by human activities was not surprising. However, the loss of entire populations from areas that have had little or no disturbance by humans (Pechmann & Wilbur 1994, Richards et al. 1993; Trenerry et al. 1994) prompted the National Research Council to sponsor a meeting to discuss possible explanations for the decline (Blaustein & Wake 1990). Side effects from anthropogenic factors such as acid rain (Pierce 1985; Pierce & Montgomery 1989; Wyman 1990) and increased UV radiation (Blaustein et al. 1994, Blaustein et al. 1995; Licht & Grant 1997) are potential reasons for amphibian declines in pristine areas. Natural catastrophic events such as global climatic changes, droughts, floods, parasites, and disease also have been suggested as causes of declines in pristine areas (Blaustein et al., 1994; Blaustein et al., 1995; Bradford et al., 1994; Crump et al. 1992; Johnson et al. 1999; Lips 1999; Richards et al. 1993; Sessions et al. 1999; Trenerry et al. 1994; Wyman 1990). A brief overview of the recommendations of the committee (Wake & Morowitz 1991) is shown in Table 1.
Table 1. A brief summary of selected recommendations from the workshop “Declining amphibian populations—a global phenomenon” (Wake & Morowitz, 1991).

I. Long-term studies of amphibian populations are needed, with special emphasis on:
   - The significance of amphibians in ecosystems
   - The population biology of amphibians
   - The relationship of chemical and physical factors to individual organisms and populations

II. Historical data should be:
   - Derived from museum records and published literature
   - Evaluated to determine suitability for use as a base for comparative studies

III. Investigate the feasibility and desirability of establishment of a new organization, which would be focused on issues of maintenance of biodiversity

IV. Design and develop educational programs to keep the public informed concerning the status of populations and species of critical taxa (such as amphibians) and the importance of these species
The conclusion that there is a global decline of amphibian populations has been controversial (Pechmann & Wilbur 1994; Blaustein 1994, McCoy 1994). One group of researchers believes that there is a general global decline in amphibian populations, and intensive efforts should be centered on finding the cause (Wake, 1991). A second group feels that the observed declines are natural fluctuations in populations and that there is no cause for a general alarm until long term data sets confirm declining trends (Pechmann et al. 1991; Pechmann & Wilbur 1994; Hairston & Wiley, 1993). A third group feels that if a decline exists, then it is a part of a general decline of biodiversity worldwide, and that amphibians are no more influenced than any other groups (Beebee, 1992).

Certain characteristics make some populations especially vulnerable to extinction. First, a species with specialized resource requirements is vulnerable if the resource becomes limited. Second, populations with a restricted range or habitat type have a low probability of rebounding following perturbations. Lastly, species with small local population sizes also are unlikely to rebound after environmental perturbations. One amphibian that exhibits all of the above characteristics is Cryptobranchus alleganiensis, the hellbender.

The hellbender is the largest salamander in the United States. This permanently aquatic species is composed of two sub-species, Cryptobranchus a. alleganiensis, the eastern hellbender and Cryptobranchus a. bishopi, the Ozark hellbender. There are several ways to distinguish between the two sub-species (Dundee & Dundee 1965). The dorsal markings of bishopi are splotches whereas those in alleganiensis are definitive spots. Cryptobranchus a. bishopi also has dark mottling on the lower labial
surface, and a rough patch of skin is present in the pectoral region of C. a. alleganiensis, but absent in C. a. bishopi.

Hellbenders occupy fast-flowing streams and range from southern New York to northern Georgia and west to Arkansas and Missouri. The alleganiensis subspecies is widespread throughout its range, whereas the bishopi subspecies is found only in four rivers along the Missouri-Arkansas border (Routman et al. 1994). In Missouri, C. a. bishopi can be found only in the White River drainage system, which includes the Current River, the Eleven Point River, and the North Fork River. These rivers have spring-fed headwaters that are cool, clear, with rocky bottoms that provide ample diurnal cover.

Hellbenders require swift, cool, well-oxygenated water because of their heavy reliance on cutaneous respiration (Guimond & Hutchinson 1973; Guimond & Hutchinson 1976). Hellbenders are nocturnal and use large rocks or logs for diurnal cover (Nickerson & Mays 1973). Dispersal or migration between rivers of the same river drainage system is limited because downstream stretches do not provide appropriate habitat (Routman et al. 1994). As the rivers deepen downstream, the silt load increases and the cracks between rocks are filled. Moreover, downstream stretches are warmer and thus have a lower oxygen holding capacity.

The species typically breeds in the fall, with the exception of the Spring River population of C. a. bishopi in Arkansas which breeds in winter (Peterson et al. 1989b). Egg masses are deposited under logs, rocks or in holes in mud banks, and it is believed that an adult hellbender then guards the nest until the young hatch (Dundee & Dundee 1965). Larvae are rarely found and are presumed to be subject to heavy predation.
Figure 2. The number of animals captured per day in the North Fork River for historical and 1998 samples.
Larvae undergo metamorphosis around 18 months of age, become sexually mature at about 3-4 years of age, and can live over thirty years (Bishop 1941).

The hellbender was assigned a Federal G4 Rank under the old ranking system, which means they are widespread, abundant and apparently secure globally, although it may be rare in parts of its range (United State Fish & Wildlife Service 1999). Currently, they are not listed under the new federal classification system. However, many governmental organizations have listed the hellbender as rare or threatened across most of its range. The U.S. Fish & Wildlife Service lists the hellbender as a species for concern in Region 3 (Minnesota-Ohio-Missouri and all states in this region); species of concern "might be in need of concentrated conservation actions" (United States Fish & Wildlife Service 1999). State agencies in Virginia, North Carolina and New York also list the hellbender as a species of concern (Redmond 1999; New York 1999; Virginia 1999). Alabama lists the hellbender as threatened (Redmond 1999). The Tennessee Wildlife Resources Agency feels that hellbenders need management (Redmond 1999). Georgia considers the hellbender rare (Georgia Wildlife Federation 1999), and Illinois has listed them as endangered (Phillips 1999). Mississippi has the hellbender on the state watch list, but no status has been assigned (Redmond 1999). The status of the hellbender in Kentucky, Maryland, Pennsylvania, Indiana, and Ohio is unknown to the author at the time of publication.

The Spring River population of Ozark Hellbenders appears to be declining (Shopen 1998; Trauth & Wilhide 1997). Peterson et al. (1988) marked 370 hellbenders along two sites in the Spring River from 1980-1982. Ten years later, Trauth et al. (1992) were only able to capture and mark (PIT tags) 20 hellbenders in the Spring River, and recommended that they be put on Arkansas' endangered species list. A continued effort
only resulted in 33 more animals being marked (Trauth & Wilhide 1997). This prompted the United States Fish & Wildlife Service to call for a survey of Missouri’s Rivers that were known to or potentially harbor populations of C. a. bishopi (see Ziehmer & Johnson 1992). The Missouri Department of Conservation surveyed the Current, Jack’s Fork, and North Fork Rivers and Bryant Creek, and concluded that Missouri populations were healthy and stable (Ziehmer & Johnson 1992).

The purpose of this study is to perform a systematic survey of Missouri’s hellbenders and to compare my data to data from previous studies of Cryptobranchus a. bishopi. Previous studies of C. a. bishopi have examined fecundity (Peterson et al., 1988), ecology (Dundee & Dundee, 1965), reintroduction of captive individuals to the wild (Nickerson, 1980); food habits (Peterson et al., 1989a), and home range (Coatney, 1982; Hillis & Bellis 1971). Data from these and other studies provide a valuable historical record of size distributions of C. a. bishopi. Two researchers (Robert F. Wilkinson & Chris Peterson) agreed to provide their original data from the 1970’s and 1980’s for comparison with data from current populations. Comparison of size distributions and body condition scores are the focus of the project. Due to the increased use and subsequent degradation of hellbender habitat in these rivers, I hypothesize that their status has declined since the last studies were performed. This decline should be characterized by fewer young animals and lower body condition scores.

Information on the current status of C. a. bishopi is important for proper conservation efforts by the Missouri Department of Conservation. Hellbenders do not migrate, so in order to protect this species of concern, separate conservation efforts must be initiated for each of the rivers.
Figure 3. The mean (± 1 SE) of mass and total length of hellbenders from the Eleven Point River (Mann-Whitney U Test, p<0.00005 for both comparisons).
Methods and Materials

Data were collected from May to September of 1998. An attempt was made to collect every hellbender located at sampling sites in each of the three rivers (Current, Eleven Point, and the North Fork). Hellbenders were located by snorkeling, lifting large rocks, and capturing the exposed salamanders by hand. This is the same method used by Peterson and Wilkinson in the historical censuses of the rivers (Wilkinson & Peterson, Personal Communication). Each animal was measured for total length (TL, to the nearest mm) and mass (to the nearest g), and sexed when possible. The cloacal gland of male hellbenders swells at the onset of the breeding season, forming a cloacal ring. All animals were released immediately after the measurements were recorded. A Global Positioning System (GPS, UTM coordinates) reading was taken at each capture site. These readings were given to the Missouri Department of Conservation, but are not reported here due to concerns about unauthorized collecting.

The historical data provided by Robert Wilkinson and Chris Peterson were entered into a spreadsheet (Microsoft Excel 97) and edited so only animals captured during the same months as our study (May to September) and only one entry per animal were included. The first capture record in the historical study period was used (i.e. data on recaptures were not used) for the historical record.

Statistical Analysis

Mean body sizes (both mass and TL) were compared for historical and 1998 data using a Mann-Whitney U-Test. The length frequency distributions of the historical and 1998 populations were compared with a Komolgorov-Smirnov test (Sokal & Rolf,
1997, \( \alpha = 0.05 \). Only historical data collected in the same time period as our study (May through September) were used in these comparisons to control for seasonal differences.

The number of animals captured per day was used to roughly estimate hellbender density for each river. The number of collectors in this survey ranged from 3-5. Catch per unit effort is unknown for the historical data, but the number of collectors ranged from 2-7. Data comparing the number of individuals captured per day for historical and 1998 censuses are presented graphically, but are not analyzed statistically.

Body condition was estimated based on a regression of mass and total length. The resulting residuals were compared using a Mann-Whitney U-test (Minitab 12.21, \( \alpha = 0.05 \)) to determine differences in body condition between historical and 1998 populations.

Historical and 1998 body conditions were compared using adult males only. Females were excluded from the analysis because gravid females introduce additional variability not related to body condition. Males were indistinguishable at the time we collected data in the North Fork River, so this analysis was omitted.
102-543 g. The mean total length and mass for the 1998 males were 398.7 mm (SE=6.61) and 443.8 g (SE=23.7), respectively.

**North Fork River**

Individuals from the 1998 survey (n=50) were, on average, longer (Mann-Whitney U-test, \( W = 28425.5, p<0.00005 \)) and more massive (Mann-Whitney U-test, \( W = 27731.0, p<0.00005 \)) than the animals from the late 1970's (n=641, Fig. 4). The historical population ranged in total length from 136-551 mm and weighed between 20 and 1128 g. The animals captured in 1998 were between 200 and 507 mm in total length and weighed between 59 and 846 g. Comparisons involving only males were not done, since only one male was found in 1998.

**Length Frequency Distributions**

**Current River**

The length distribution of the 1998 sample fell between the 350 to 549 mm size classes. The largest proportion of animals was in the 450-499 mm size class (Fig. 5). No comparisons were made due to the lack of historical data for the Current River.

**Eleven Point River**

Length distributions of the historical and 1998 populations were significantly different (D=0.9958; \( p<0.0001, \) Fig. 6), with relatively fewer individuals in the smaller size classes in the 1998 sample. The largest proportion of animals in the historical records was in the 300-349 mm size class. The majority of animals recorded in 1998
Results

Density

Current River

There were no historical data available for the Current River at the time of this publication. There were 14 animals captured over three collection days (7, 4, and 3) in 1998. Six of the animals collected were considered males and seven were thought to be females.

Eleven Point River

There were 87 hellbender captures recorded for 3 collection days in 1978 (data provided by Peterson). Nine collection days from 1980 to 1982 yielded 314 captures (permanently branded), including 82 recaptures (data provided by Peterson). Only 36 animals were collected during 4 days in 1998, one of which was branded during the 1980-82 study period.

The number of captures per day ranged from 19-50 in the 1978-1982 samples. The number of animals captured per day in 1998 was lower, ranging from 2-20 (Fig. 1).

North Fork River

The 18 collections made from 1978 to 1980 yielded 934 (permanently branded) hellbenders, with 180 of those being recaptures (data provided by Peterson). There were 46 individuals identified as males and 46 individuals that were believed to be females captured in this study period. The three collections made in 1998 yielded 50
Figure 1. The number of animals captured per day in the Eleven Point River for the historical and 1998 samples.
Figure 4. The mean mass and total length of hellbenders from the North Fork River historically (1977-1980) and in 1998 (Mann-Whitney U-test, p<0.00005 for both comparisons).
animals, two of which had been branded during the 1978-80 sample period. Only one animal could be positively identified as male.

The samples from 1998 indicate a relatively low number of animals captured per day (average = 16). The samples from 1977-80 tended to yield higher numbers (average = 51, Fig. 2).

**Mean Mass and Total Length Comparisons**

**Current River**

The 1998 animals (n=14) ranged in length from 375 to 515 mm with a mean ± 1SD of 450.7 ± 46.6 mm. The mass varied from 373 to 852 g with a mean ± 1SD of 625.4g ± 171.4g. There were no historical data available for comparisons.

**Eleven Point River**

The population from the 1998 survey (n=36) was on average longer (Mann-Whitney U-test, W = 29532.5, p<0.00005) and more massive (Mann-Whitney U-test, W = 29905.5, p<0.00005) than the population from previous samples (n=240) (Fig. 3). For the historical population, total lengths ranged from 119-451mm and masses ranged from 11-766 g. For the 1998 sample, total lengths ranged from 324-457 mm and mass ranged between 222-770g.

When only males were considered, males from the 1998 sample (n=20) also were longer (Mann-Whitney U-test, W = 2513.5, p<0.00005) and more massive (Mann-Whitney U-test, W = 2637.0, p<0.00005) than the historical males (n=69). The historical males ranged between 189-444 mm in total length and weighed between
North Fork River

We were not able to determine the sex of the animals from the North Fork River at the time of capture. Therefore the conservative analysis of body condition of males only was not conducted. Instead, we conducted an analysis of males and females combined.

For animals in the same size range (200-551mm), hellbenders from the population sampled in 1998 (n=50, mean=560.6 ± 25.8 g) were more massive than those in the historical population (n=612, mean=323.07 ± 2.88 g) (Mann-Whitney U-test, W = 193172.0, p<0.00005). These data suggest that 1998 hellbenders were in better condition than the historical samples.
Figure 5. The length frequency distribution of the hellbender population in the Current River for the 1998 sample.
fell into the 400-449 mm size class, with the next largest proportion being in the 350-399 mm size class. No animals in the 1998 sample were smaller than 300 mm.

North Fork River

The historical length frequency distributions differed from 1998 distributions (D=0.2916; p<0.005, Fig. 7) with relatively fewer individuals in the smaller size classes. In historical samples, lengths ranged from <200 mm to over 550 mm, with the most animals between 250 and 449 mm in length. The 1998 data included animals ranging from 200 mm in length to less than 549 mm, with the most animals between 400 and 500 mm.

Body Conditions

Current River

No comparisons of body condition were made for hellbenders from the Current River due to the lack of historical data for the river.

Eleven Point River

The males from the 1998 sample (n=20) were more massive (mean=443.8 ± 23.7 g) than the males from the historical samples (n=69, mean=258.6 ± 12.4 g) (Mann-Whitney U-test, W = 2577.0, p<0.00005). This suggests that 1998 males were in better condition than males from the historical samples (Fig. 8,9). However, there was no statistical differences between the past and 1998 body condition estimates (Mann-Whitney U-test, W = 3062.0, p=0.6761).
Discussion

Density

Based on the number of individuals captured per day, the density of hellbenders in the Eleven Point River appears to have declined substantially since the late 1970's and 1980's. Data from the North Fork River are harder to interpret. The 1998 population numbers are clearly less than in the late 1970's and early 1980's. The number of animals captured per day provide rough estimates of the number of animals in the populations. There are no data available for most of the collection days concerning catch per unit effort and there sometimes may have been more animals located because there were more people looking for them. However, it is unlikely that the 1998 sample represents an underestimate in comparison to historical samples. The entire river (excluding the Current River) was censused during the 1998 survey, whereas only a few specific sites were included in the historical censuses. Every likely spot (Fobes 1995) and many that were considered less than optimum were checked for hellbenders. The known historical study sites were especially censused, but in many cases are now poor habitat for hellbenders.

Body Size

In both the Eleven Point and the North Fork Rivers hellbenders were larger in the 1998 samples than in historical samples. One possible explanation is that the 1998 animals grew to larger sizes than in previous years. However, this is not the case. The largest animals captured in 1998 are about the same length (TL) as the largest recorded historical animals. The difference in mean total length appears to be in the minimum
Figure 6. The length frequency distribution of the hellbender populations in the Eleven Point River for historical (1980-1982) and 1998 samples (Kolmogorov-Smirnov test, p<0.00001)
Figure 7. The length frequency distributions of hellbender populations in the North Fork River taken from historical (1977-1980) and 1998 censuses (Kolmogorov-Smirnov test, p<0.005)
size rather than the maximum size. There were fewer small hellbenders in the 1998 samples.

One possible explanation for the lack of small animals is that the collectors were inefficient at finding small animals. However, the 1998 collectors used the same techniques as in historical surveys, and one of the previous researchers (RFW) assisted in a number of the 1998 samples. Moreover, some small animals were collected in 1998 (North Fork River). If small size classes have indeed declined, this decline may indicate problems with reproduction and/or recruitment in the Ozark hellbender populations in Missouri.

**Body Condition**

The trend of Ozark Hellbenders in the 1998 populations weighing significantly more at a given size than in the historical populations could be simply a consequence of the correlation between length and mass: larger animals also are heavier. However, when comparisons were limited to animals of the same size range, the difference in mass was still present. This may indicate differences in body condition. If there has been a decline in the number of Ozark Hellbenders inhabiting the rivers of Missouri, then a consequence would be an increased allotment of food for the remaining animals. Also, if fewer animals are in the river, than there would be decreased competition for shelter rocks. Thus, an animal would be able to store energy rather than use it to search for shelter. This is not necessarily the case. The body condition data in the Eleven Point River shows a trend of better body condition, but the difference is not significant. Reduced densities have been shown to have a positive effect on growth in a
Figure 8. Regression of total length and mass \((1/3)\) for males from the Eleven Point River. The line represents the combined regression for historical and 1998 samples.
Figure 9. The mean (± 1 SE) residuals of mass/TL regression for Eleven Point hellbenders from historical and 1998 samples.
number of species of amphibians (e.g., Wilber 1976; Walls & Jaeger 1987; Scott 1990; Buskirk & Smith). It is unfortunate there is a lack of historical data for the Current River and lack of male hellbenders in the 1998 North Fork River collection. Comparisons between these rivers may have given some insight to interpretation of these results.

Summary

This study found an apparent decrease in the number of hellbenders inhabiting the streams of Missouri. This decrease is characterized by an overall increase in length and mass of hellbenders in the 1998 sample compared to historical populations. The longer average total length of the population is due to a low proportion of individuals in the small size classes.

Natural cycles

Other studies have indicated that some populations of amphibians experience extreme fluctuations in population size (Pechmann et al. 1991; Pechmann & Wilbur 1994). The differences that were found in our study also may represent part of a natural cycle. Hellbenders can live 30+ years, so our relatively long-term study does not span multiple generations.

Lack of Reproduction and/or Recruitment

The decreased number of hellbenders found in the 1998 census could indicate a decline in reproductive success. Groups of hellbenders were observed during the
breeding season in the 1990's (Wilkinson personal communication), but it is not known whether these breeding events led to production of viable offspring.

If successful reproduction is occurring, small individuals may be failing to survive past some critical body size or life stage. There have been few observations of larval hellbenders, so it is difficult to determine whether problems exist with this stage.

Placing this study in the larger context of amphibian declines is difficult. There has been a decline in the number of Ozark hellbenders in at least three of the four rivers that were historically know to contain C. a. bishopi, supporting the hypothesis of a single causative agent affecting all these rivers. Further evidence to support this hypothesis is the close proximity of these rivers to each other. However, several different factors may potentially be affecting each these river. Therefore, final decisions regarding the conservation efforts for the Ozark Hellbender should not be made until there is better understanding of the reason for the lack of small animals in the populations.

**Future Studies**

Future studies could provide additional information about the apparent decline of the Ozark hellbender in Missouri. Efforts should be made to secure additional historical data. If data were available for the early 1960's, then comparisons across multiple generations could be made. Historical data for the Current River populations are especially important, so that similar comparisons can be made as for other rivers. Efforts also should be made to locate male hellbenders in the North Fork River to complete the body condition analysis. The Spring River in Arkansas was the only other confirmed population of Cryptobranchus alleganiensis bishopi. Current data should be


collected from the Arkansas populations. Furthermore, other rivers in the Ozark Mountains should be surveyed for Ozark Hellbenders and similar data recorded. These studies combined with the data presented here could clarify trends in the changes of the Ozark hellbender populations.

Another potential area of research is an intensive investigation into the life history of the hellbender. This study should also include studying the natural history of the larvae. If the Cryptobranchus alleganiensis bishopi populations of Missouri need help recovering from the apparent decline in numbers, this knowledge could enhance conservation efforts.

Environmental toxicologists have investigated the possible endocrine disrupting effects of various commercial chemicals that are released into the environment. Crisp et al. (1998) gives a thorough review of the current knowledge concerning these hormone-mimics and reports adverse effects to the reproductive systems of invertebrates, fish, mammals, birds, and reptiles. Little is known about the effects that these chemicals may have on amphibian physiology. Bioaccumulation of these and other chemicals would be especially harmful to long-lived amphibian species, such as the hellbender. Investigations into the effects of endocrine disrupting agents and other toxicants on amphibians could shed new light on the decline of amphibians.
Literature Cited


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