Issues in Species Recovery: An Example Based on the Wyoming Toad

VICTORIA J. DREITZ

*The identification and recovery of endangered species is difficult because of their rarity, the continuing threats to their survival, and inadequate funding for research and conservation. There have been some success stories, but also a number of failures. Have biologists learned from our failures, or are we repeating the same mistakes? While habitat availability and cost are important limitations to species recovery, other, more easily addressed issues also hamper recovery programs. The Wyoming toad (*Bufo baxteri*) is an endangered species whose recovery has been stalled by problems that are common to species recovery efforts, especially for animals without significant "charisma." I summarize the research undertaken on the Wyoming toad since its listing, highlight the difficulties in building a scientifically based recovery program, and identify some of the unmet challenges impeding recovery. Although specific to the Wyoming toad, these recommendations are relevant to recovery programs facing similar issues.*

Keywords: Bufo baxteri*, endangered species, reintroduction, recovery, Wyoming toad*

In a perfect world, recovery programs would have adequate funding, with public and scientific support, and would be built on a foundation of reliable data. In reality, many of these essential ingredients are missing from most recovery programs. For example, the lack of ongoing training to help workers remain abreast of new methods and ideas (Anderson et al. 2003), the appointment of inexperienced personnel to key positions (Reading and Miller 1994), and the lack of coordination among agencies may particularly affect recovery programs. Because recovery programs are often carried out with a thin margin for error, they require strong, qualified leadership with up-to-date knowledge on species and conservation methods.

Suggested modifications to the Endangered Species Act, as well as critiques and assessments of recovery plans, have been published since the early 1990s (Tear et al. 1993, Hoekstra et al. 2002). The recovery program for the Wyoming toad (*Bufo baxteri*) lacks many of the essential ingredients. Because these deficiencies are commonplace, the case of the Wyoming toad provides perspective on other species recovery efforts. I examine the recovery efforts for the Wyoming toad using the framework of critical elements associated with recovery plans for aquatic-breeding amphibians (Semlitsch 2002). I summarize the research undertaken since the toad's listing, highlight the difficulties in building a scientifically based recovery program, and identify unmet challenges in hopes of illuminating some of the problems that arise in species recovery efforts.

Recognizing a species in trouble

The Wyoming toad is endemic to the Laramie Plain and was first described by George Baxter in 1946 (Porter 1968, Baxter and Stone 1985). This toad, a relic from the retreat of Pleistocene glaciation, has been considered a subspecies of the Canadian toad, *Bufo hemiophrys* (Porter 1968, Baxter and Stone 1985). However, Wyoming toads are separated from the range of Canadian toads by at least 750 kilometers (km) and are considered a distinct species by Packard (1971), Smith and colleagues (1998), and Crother and colleagues (2000). From their discovery through the early 1970s, Wyoming toads were considered common and abundant within their restricted range (Baxter and Stone 1985), but rapid declines (Baxter and Meyer 1982, Baxter et al. 1984) presaged their likely extinction by the mid-1980s (Lewis et al. 1985). In 1984, the Wyoming toad was listed as endangered (USFWS 1984).

A single population of Wyoming toads was discovered in 1987 at Mortenson Lake, in Albany County, Wyoming (Odum and Corn 2005). This location was purchased by The Nature Conservancy, and Mortenson Lake National Wildlife Refuge (MLNWR) was established in 1993. The refuge, an im-

Victoria J. Dreitz (e-mail: Victoria.Dreitz@state.co.us) is a research associate–zoologist at Colorado State University, Colorado Natural Heritage Program, 8002 Campus Delivery, Fort Collins, CO 80523. She can be reached at the Colorado Division of Wildlife, 317 W. Prospect Road, Fort Collins, CO 80526.

poundment in a complex of lakes and irrigation canals about 6 km north of the Laramie River, was originally a private ranch leased to a fishing club. Reproduction by Wyoming toads was recorded at MLNWR in 1988 (Freda et al. 1988), but the number of egg masses declined until no reproduction was observed after 1991 (Parker 2000, Parker and Anderson 2003, Odum and Corn 2005). By 1993, the few toads that could be found were collected from MLNWR for captive breeding, and the Wyoming toad was considered extinct in the wild (Odum and Corn 2005). Between 1995 and 1999, more than 9500 postmetamorphic toads were reintroduced at MLNWR (Odum and Corn 2005). Egg masses were reported in 1998 and 1999, presumably from toads reintroduced in 1995 or later (Parker 2000). At least one egg mass, which later hatched, was observed at MLNWR in 2002, and at least three, which also hatched, in 2004 (Michelle Geraud, US Fish and Wildlife Service [USFWS], Cheyenne, WY, personal communication, 21 December 2005).

The Wyoming toad is currently found at MLNWR and at one new reintroduction site (2005) between Laramie and Centennial, Wyoming. Genetic diversity is low (Jennings et al. 2001), and chytrid fungus (*Batrachochytrium dendrobatidis*) has been identified as contributing to mortality of individuals (Jennings et al. 2001; Allen P. Pessier, Zoological Society of San Diego, San Diego, CA, personal communication, 29 December 2005). The population at MLNWR is not currently self-sustaining, relying on annual supplementation with captive-reared animals (Odum and Corn 2005).

Although the Wyoming toad was listed in 1984, it was its rediscovery in 1987 that stimulated the formation of an *ad hoc* recovery group by USFWS and the Wyoming Game and Fish Department (WGFD), which also included regular participants from the University of Wyoming, The Nature Conservancy, and various zoos (Ronald E. Beiswenger, University of Wyoming, Laramie, WY, personal communication, 12 February 2006). A recovery plan was adopted in 1991 (USFWS 1991). The plan outlined basic goals but did not include specific objectives or methods to meet those goals. In 1992, the Albany County Wyoming Toad Task Force was convened as requested by the governor of Wyoming, with the support of the Environmental Protection Agency. The objective was to resolve conflicts between the mosquito control program subscribers and protection measures for the Wyoming toad. This group was active only between 1993 and 1995 (Ronald E. Beiswenger, University of Wyoming, Laramie, WY, personal communication, 12 February 2006). Captive breeding was initiated in 1993, and the American Zoo and Aquarium Association (AZA) approved a species survival plan in 1996 (Spencer 1999).

The Wyoming Toad Recovery Team was appointed in 2001, 17 years after the Wyoming toad was listed. That same year, the IUCN (World Conservation Union) Species Survival Commission Conservation Breeding Specialist Group (CBSG) facilitated a workshop including the recovery team, scientists, and interested citizens. The goal of the workshop was to "better understand the factors leading to the precipitous decline of the Wyoming toad, and to develop a set of alternative population management options" (Jennings et al. 2001). The workshop focused on disease, anthropogenic impacts, and population modeling, all within the context of a "shared vision" to "prevent extinction of the species in the wild" (Jennings et al. 2001). The formation of two recovery groups (the *ad hoc* group and the formal recovery team) and the CBSG workshop paralleled recovery actions for the endangered Houston toad (*Bufo houstonensis*) (Brown and Mesrobian 2005).

Monitoring

The success of recovery efforts since 1992 has been measured by monitoring activities that are limited to one or two surveys a year (early summer and fall) conducted by a variable number of untrained observers (P. Stephen Corn, US Geological Survey, Missoula, MT, personal communication, 21 December 2005). The semiannual surveys entail volunteers walking around Mortenson Lake through areas with saturated soils (habitats preferred by toads). If a toad is sighted, it is noted. Toads are not handled. Because observers are continuously moving through the search area, it is assumed that animals were not previously sighted during the survey (Ronald E. Beiswenger, University of Wyoming, Laramie, WY, personal communication, 12 February 2006; Erin Muths, US Geological Survey, Fort Collins, CO, personal communication, 13 December 2005). The results of these surveys are limited to counts of toads observed, categorized by life history stage (juvenile or adult). Although this information provides a minimum bound on the number of toads present, inferences from this type of count-based survey are biased because detection rate (i.e., percentage of animals seen, heard, or trapped) varies among counts (Nichols 1992, Williams et al. 2002). This survey provides quantitative information neither on breeding success nor on the fraction of the population sampled (i.e., there is no estimate of detection probability).

Use of methods lacking scientific rigor can lead to erroneous conclusions (Anderson et al. 2003), with potentially disastrous effects on species persistence (Steidl et al. 2000). For example, overestimating population size can lead to a false sense of security and a subsequent reduction of recovery efforts, and underestimating a population can precipitate hurried or unsuitable actions. Appropriate use of data, and a clear recognition of the inferences drawn from those data, is critical. Available data on the Wyoming toad are limited in scope (see below), and the only available population estimates use closed-population models from a study conducted in the period 1990–1992 (Withers 1992, Odum and Corn 2005).

Research on Wyoming toads

Research undertaken on the Wyoming toad includes field studies, captive breeding efforts, and disease identification. The most positive and numerous research activities have been in the veterinary and zoological communities, where endocrinologists and pathologists have worked successfully to breed Wyoming toads and identify diseases.

Field studies. Field research on Wyoming toads has missed the mark. The few studies conducted to date have been hampered by the scarcity of animals and by flawed methods. Both research and monitoring have been constrained by the reluctance of the *ad hoc* recovery group and regulatory agencies (USFWS, WGFD) to allow methods that involve more than minimal handling of animals (P. Stephen Corn, US Geological Survey, Missoula, MT, personal communication, 21 December 2005).

Two master's theses dominate the field research. Withers (1992) described the general natural history of Wyoming toads, in collaboration with Corn (1993), and compared habitats used by toads with habitats available in the immediate vicinity of Mortenson Lake. These data suggested that Wyoming toads mature earlier (males at two years and females at three years) than other, higher-elevation bufonids in the region (Withers 1992, Corn 1993, Carey et al. 2005, Odum and Corn 2005). Few Wyoming toads were observed to survive more than one to two years after reaching adult size, but this was most likely due to mortality from chytrid fungus (Withers 1992, Odum and Corn 2005). The interpretation of habitat use was hampered by significant differences in habitat measures between the years of the study (1991 and 1992).

Parker (2000) and Parker and Anderson (2003) compared the use of habitat by adult wild Wyoming toads and captive-reared Wyoming toads using radio telemetry in 1998 and 1999. Because there was no reproduction at MLNWR from 1992 to 1998, toads described as "wild" were most likely individuals reintroduced in 1996 or 1997. Thus, a comparison is misleading. The determination of habitat use and preference is fraught with difficulties such as spatial and serial autocorrelation, nonindependence of proportions, and definitions of habitat availability (e.g., Aebischer et al. 1993, Arthur et al. 1996). These concerns call into question many of the conclusions drawn from this study regarding preferred habitat (Parker 2000, Parker and Anderson 2003).

It is inappropriate to base management actions for a critically endangered species on unpublished and non-peer-reviewed reports (Reading and Miller 1994). The collection of accurate demographic data on Wyoming toads has long been recognized as essential to understanding the population dynamics of the species (USFWS 1991, Jennings et al. 2001). An overarching research agenda, including a well-designed monitoring program, is necessary (Boersma et al. 2001, Semlitsch 2002, Dodd 2005). Monitoring can provide reliable information from which important data gaps can be addressed, often in discrete, manageable, and affordable units. While the information mentioned above may be useful within the appropriate context, the rigorous evaluation of reintroduction efforts will go further toward developing a successful recovery program. This is especially important because reintroductions are necessary to sustain the Wyoming toad population in the wild.

Captive breeding. Maintaining animals in an unnatural environment, facilitating breeding, performing genetic screening, and investigating causes of disease in the field and in captivity are both challenging and critical to the success of the recovery program. The captive breeding effort for the Wyoming toad is the most successful aspect of the recovery program. Captive populations are maintained at eight AZA institutions following the AZA species survival plan (Spencer 1999). The development of captive husbandry protocols (Spencer 1999, Jennings et al. 2001) and the recognition of disease (Jennings et al. 2001, Pessier et al. 2002) in the Wyoming toad provide a sound basis for continued research and the provision of animals for reintroduction purposes. However, the captive breeding program should not be viewed as a panacea (Snyder et al. 1996). Simply adding animals to an area is unlikely to result in recovery (Dodd 2005). The captive breeding program for the Wyoming toad still faces unresolved issues. Most captive animals do not live longer than three years, but breeding success is highest in toads that are more than three years old (Jennings et al. 2001). This may indicate a difference between metabolic and chronological age in captive animals, but whether this difference is due to disease, nutrition, or other factors requires further investigation.

Disease identification. The Wyoming toad is afflicted by disease, both in captivity and in the wild. Bacterial infections ("red leg"), fungal infections (chytrid fungus), edema syndrome (Jennings et al. 2001), and short tongue syndrome (Jennings et al. 2001, Pessier et al. 2002) are documented, ongoing problems. Mycotic dermatitis (*Basidiobolus ranarum*) was identified as the cause of mortality in toads (104 of 147, or 71 percent; Taylor et al. 1999), but the pathogen was later determined to be chytrid fungus (Odum and Corn 2005). This disease is implicated in the decline of the boreal toad in the Rocky Mountains (Muths et al. 2003) and has most likely played a prominent role in the decline of Wyoming toads (Corn 2003).

Evaluation of reintroduction

For most amphibians, especially those that are endangered, reintroduction results are bleak (Dodd 2005). The amphibian reintroduction programs that have enjoyed the most success have followed the steps outlined by Dodd and Seigel (1991). These steps include knowing the causes of decline, committing to long-term monitoring, and adhering to the critical elements presented by Semlitsch (2002). Dodd (2005) notes, "Long-term research and monitoring, absolutely essential in any conservation program, are doubly important to ensure the success of HS/RRT [reintroduction] projects" (p. 270).

Efforts to reintroduce Wyoming toads to MLNWR have focused on releasing postmetamorphic toads (Odum and Corn 2005). Although the number of animals reintroduced has been documented, the success of reintroductions has not been evaluated. In response to the continued scarcity of toads in the wild and the proven ability to rear toads in captivity, in 2001 the USFWS requested quantitative information on the potential for reintroduction of captive-reared postmetamorphic toads to MLNWR. A one-year pilot study (Muths and

Dreitz 2003) was financially supported to estimate oversummer survival of reintroduced postmetamorphs and provide guidelines for a long-term monitoring program. The goal was not to provide specific answers, but rather to elucidate an avenue to address questions such as "What is the minimum yearly release number needed to sustain a viable population of Wyoming toads at a reintroduction site?" and "What is the appropriate monitoring protocol to detect trends in a population of Wyoming toads?" The pilot study was designed to follow a sampling approach accounting for imperfect detection based on mark–release–recapture procedures of the robust design (Kendall et al. 1997). Muths and Dreitz (2003) followed standard protocols (Heyer et al. 1994, Williams et al. 2002), including a priori simulations to estimate the number of animals to be released. Although survival was low, postmetamorphs did survive through the summer (Muths and Dreitz 2003). The pilot study field-tested protocols and methods and documented modifications to those protocols necessary to provide data for a long-term monitoring program for the Wyoming toad (Muths and Dreitz 2003).

Considerations for recovery

More than 25 years have passed since the Wyoming toad was recognized as critically imperiled, and 21 years since it was listed as an endangered species. Biological problems, including a precipitous decline in population numbers in the early 1990s and the presence of a lethal fungus (Jennings et al. 2001), have made study difficult and reintroduction an equivocal proposition. Since listing, there have been only four formal studies of the Wyoming toad: two theses (Withers 1992, Parker 2000, Parker and Anderson 2003), a three-year (1990–1992) project by the USFWS (Corn 1993, Odum and Corn 2005), and a pilot study (Muths and Dreitz 2003). Only the study by Muths and Dreitz (2003) provided guidelines for monitoring the reintroduction of captive-reared toads.

Semlitsch (2002) identified critical elements associated with successful recovery programs. He first discussed spatial and temporal scales. Defining the spatial scale for the Wyoming toad recovery effort is straightforward because of the toad's limited historical range. The temporal scale will most likely be dictated by the production of animals from captive husbandry, the development of disease identification tools, and the development of remedial actions in the face of disease. Below we address three additional points identified by Semlitsch (2002) in the context of the Wyoming toad.

Location of translocation sites relative to historical range and quality of habitat. Chytrid fungus (Jennings et al. 2001), pesticides, herbicides, and nonnative predators (e.g., stocked brown trout, *Salmo trutta*) are potential threats to Wyoming toads at MLNWR. Sites other than MLNWR should be identified using a priori criteria such as appropriate habitat characteristics, food availability, and predator and disease factors. Results from the pilot study at MLNWR (Muths and Dreitz 2003) can be used to evaluate candidate reintroduction sites where limitations are likely to be similar, that is, where few, if any, wild individuals are present and where released animals have low genetic diversity. New sites should be surveyed thoroughly for the presence of amphibians and of diseases such as chytrid fungus.

At least two applications for "safe harbor" agreements have been submitted (USFWS 2004), and one reintroduction site has been established on private property (R. Andrew Odum, Toledo Zoological Society, Toledo, OH, personal communication, 21 December 2005). Wyoming toads, including both adults and tadpoles, were released at the reintroduction site in 2005 (Jodi Bush, USFWS, Cheyenne, WY, personal communication, 22 September 2005), although the extent to which these sites were surveyed before the release is unknown. Postrelease surveys, which follow the field protocols of the semiannual sampling at MLNWR (i.e., no handling, toads sighted, no estimate of detection rate), are conducted only semiweekly (summer 2005) because of staffing limitations (Jodi Bush, USFWS, Cheyenne, WY, personal communication, 22 September 2005).

Translocation and reintroduction procedures. Given the assumption that captive rearing and reintroduction are the most practical recovery options for the Wyoming toad, we should examine both the methods and other associated elements carefully. For the Wyoming toad, the questions of where to gather animals to reintroduce into depopulated areas and whether to use captive or wild-caught animals are moot—there are no known extant populations in the wild. The genetic issues inherent in small, captive populations are being addressed by members of the Wyoming Toad Recovery Team (R. Andrew Odum, Toledo Zoological Society, Toledo, OH, personal communication, 21 December 2005).

Eggs collected in the wild are the first choice for translocation (Semlitsch 2002). Griffith and colleagues (1989) showed that wild-collected stock survived at twice the rate of captive-reared animals. Successful toad introductions involve translocations of eggs or juveniles at several sites, with releases in multiple years boosting the chances of success (Denton et al. 1997). Although documentation is limited, unsuccessful translocations of other bufonids have used postmetamorphic animals (Dodd and Seigel 1991, Muths et al. 2001).

Important population parameters (survival and reproduction) can be estimated and a monitoring program can be implemented that accounts for detection rate. Without such a monitoring scheme, an assessment of life history parameters is limited to imprecise and most likely unreliable estimates. Reintroducing egg masses provides an estimate of recovery effort needed to produce breeding animals, but cannot provide estimates for specific population parameters, such as survival. For example, if 1000 egg masses are reintroduced and 50 adult toads return to breed, we know the magnitude of effort necessary to produce 50 breeding adults. Accounting for detection rate using individually identifiable animals will yield useful data sooner than releasing eggs and waiting until toads mature and return to breed. Moreover, it provides an opportunity to quantify the success of the efforts in biologically meaningful terms. A two-pronged approach, using both eggs and individually identifiable juveniles, may be the most effective. This approach puts toads on the ground through the release of egg masses, and it reliably estimates population parameters that are necessary to build, maintain, and eventually complete such a reintroduction program.

Although reintroduction appears to be the tool of choice for recovery of the Wyoming toad, I highlight the recommendations of Dodd and Seigel (1991) and Dodd (2005). The motivation to employ reintroduction should be examined carefully. For example, is the reintroduction program attractive because it provides good publicity? If breeding in the wild occurs soon after the reintroduction, will success be declared, regardless of the long-term outlook? Sometimes reintroduction is chosen without adequately addressing the factors that put the species at risk in the first place. Often these factors, such as disease, are not obvious and require significant investment to elucidate properly (Dodd 2005).

Measuring success and long-term management. According to Boersma and colleagues (2001), "One cannot possibly know whether management is working and whether it needs to be adaptively altered unless its effects are monitored" (p. 648). It follows that it is impossible to declare a reintroduction successful without long-term monitoring to determine the ability of the population to sustain itself through time (Semlitsch 2002). It is impossible, using current data, to infer the status of the population, project the population's long-term viability, or evaluate the Wyoming toad recovery effort. Although new releases occurred in 2005, follow-up observations of the reintroduction effort rely on field surveys that cannot adequately evaluate the success of the reintroduction.

Communication. Measuring success and accomplishing short- and long-term management goals depends on clear articulation of the goals. It is likely that logistical stumbling blocks and miscommunication are not unusual and are, in fact, symptomatic of collaborative recovery efforts (Reading and Miller 1994). Miscommunication can undermine the success of a conservation program (e.g., Saterson et al. 2004). The case of the Wyoming toad is instructive. A critical misunderstanding occurred because of lack of dialogue regarding the goals of the Wyoming toad pilot project (Muths and Dreitz 2003). Specifically, there was a disparity between the questions addressed in the pilot project (Muths and Dreitz 2003), as requested by the USFWS, and the questions to which the recovery team expected answers. Agreement among management agencies on priorities is of paramount importance for acquiring adequate support and targeting success (Reading and Miller 1994). In addition, miscommunication regarding the number of animals available for release probably jeopardized the results of the pilot study (Muths and Dreitz 2003).

The assignment of inexperienced personnel to key positions has been noted as a substantive problem in endangered species recovery (Reading and Miller 1994) and may be particularly applicable to the recovery of the Wyoming toad, the most endangered amphibian in the United States. The problem of inadequate experience or expertise is not unique to endangered species recovery, but is symptomatic in the wildlife profession. Anderson and colleagues (2003) noted, "Perhaps our greatest failure as a profession has been the near total lack of meaningful science education.... [P]rofessionals must be given the opportunity to keep abreast of a large array of general technical advances" (p. 302). The Wyoming Toad Recovery Team also suffers from gaps in leadership: The coordinator resigned in 2004, and as of December 2005, no new coordinator had been designated. Strong leadership is essential for project direction and communication (Reading and Miller 1994).

The original recovery plan was completed in 1991. Although a revision is currently under way, there have been no revisions in 15 years, in spite of considerable advances in statistical modeling of population parameters (Williams et al. 2002) and molecular techniques (Wayne and Morin 2004). Available drafts of the revised recovery plan for the Wyoming toad (the last available draft was dated 2001) list several goals under "Part II Recovery," including "identify scientific criteria needed for population estimates" and "collect accurate demographic and ecological data." However, recently proposed and field-tested methods accounting for detection rate have been questioned in terms of their statistical efficacy and their field techniques for handling animals (Erin Muths, US Geological Survey, Fort Collins, CO, personal communication, 13 December 2005). Recovery plans need to be dynamic and responsive to advances in all relevant fields. Boersma and colleagues (2001), however, suggest that revised recovery plans may be no more effective than those without revision.

A second aspect of communication concerns informing the public. Miscommunication in the form of overly optimistic progress reports can mislead the recovery team or the public. Examples of this can be found in recovery efforts for other species, such as the black-footed ferret (*Mustela nigripes*) (Reading and Miller 1994) and the Houston toad (Yaffee 1982). Recent press releases about the recovery program for Wyoming toads focus on captive husbandry and the release of postmetamorphs, but no mention is made of the lack of data on the survival of released animals or the difficulty of obtaining such estimates.

Conclusions

Reintroducing a species is a separate exercise from monitoring its status. However, reintroduction without monitoring contributes little to the long-term success of recovery efforts and the persistence of the species (Dodd and Seigel 1991, Dodd 2005). An effective reintroduction and monitoring program for Wyoming toads is likely to be accomplished by a two-pronged approach focusing on the reintroduction of eggs and of individually identified postmetamorphic toads. According to Semlitsch (2002), "Monitoring procedures that do not distinguish between translocated [reintroduced] and wildproduced animals or between generations *through some mark-release-recapture procedures* will not be good measures of success" (p. 626; italics added). A program that releases eggs and individually identifiable juvenile toads can address immediate concerns over the use of captive-bred progeny and can address longer-term goals of providing information on life history parameters for management needs and program assessment.

A successful amphibian recovery program must attend to critical elements (*sensu* Semlitsch 2002), including the collection and use of defensible data. The most positive actions for Wyoming toads have been in the fields of veterinary science and husbandry. Endocrinologists and pathologists have worked successfully to identify the physiological processes that govern breeding in Wyoming toads and to investigate disease, nutritional problems, and other challenges involved in captive husbandry. While this aspect of toad recovery work has excelled, however, field research has faltered. Two pertinent issues are a general lack of funding for "noncharismatic" microfauna and an excessive concern over the fate of individual animals (e.g., as a result of handling), as opposed to the species as a whole, both of which have interfered with the development and implementation of necessary research. Unfortunately, many research opportunities are no longer available because of the decline in Wyoming toad numbers between 1993 and 2003.

The Wyoming toad has faced political and resource problems less severe than those that have hampered conservation of the Houston toad (Brown and Mesrobian 2005), but it still provides a good example of the fine-scale difficulties that can plague a recovery program. The example of the Wyoming toad demonstrates that listing a species is no guarantee that sufficient recovery efforts will be implemented or that communication among cooperating entities will occur. Seventeen years is too long a gap between the identification of an endangered species and the organization of a recovery team. Nearly 15 years have elapsed since revisions were made to the recovery plan for the Wyoming toad (more revisions are currently in preparation; Ronald E. Beiswenger, University of Wyoming, Laramie, WY, personal communication, 12 February 2006). In recovery planning, more attention should be focused on communication and on the timely production of adequate and achievable recovery goals and criteria, including the use of research to determine the direction and success of recovery plans. The Wyoming toad provides one more case that emphasizes the dire need to improve recovery efforts of endangered species.

Acknowledgments

I am indebted to Erin Muths of the US Geological Survey–Fort Collins Science Center, who participated in the development of this manuscript and in the monitoring pilot study conducted on Wyoming toads. She provided expertise on amphibians, particularly on historical and current perspectives of Wyoming toad ecology and conservation efforts, and many hours of discussion on recovery efforts of threatened and endangered amphibians. I thank Ronald E. Beiswenger, P. Stephen Corn, Michelle Geraud VanAcker, Andy Kouba, R. Andrew Odum, Allen P. Pessier, G. Brint Spencer, and Bill Turner for sharing unpublished information about the Wyoming toad recovery program. Erin Muths, Paul M. Lukacs, P. Stephen Corn, Paul F. Doherty Jr., B. Lee Lamb, Barry Noon, Kenneth Wilson, and three anonymous reviewers provided helpful comments on earlier drafts of the manuscript.

References cited

Aebischer NJ, Robertson A, Kenward RE. 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74: 1313–1325.

Anderson DR, Cooch EG, Gutierrez RJ, Krebs CJ, Lindberg MS, Pollock KH, Ribic CA, Shenk TM. 2003. Rigorous science: Suggestions on how to raise the bar. Wildlife Society Bulletin 31: 296–305.

Arthur SM, Manly BFJ, McDonald LL, Garner GW. 1996. Assessing habitat selection when availability changes. Ecology 77: 215–227.

Baxter GT, Meyer JS. 1982. Progress Report: An Investigation of the Status of the Wyoming Toad in Albany County, Wyoming, and Possible Causes of the Decline in Numbers of Wyoming Populations of Anuran Amphibians. Laramie (WY): Department of Zoology, University of Wyoming.

Baxter GT, Stone MD. 1985. Amphibians and Reptiles of Wyoming. 2nd ed. Cheyenne (WY): Wyoming Game and Fish Department.

Baxter GT, Stromberg MR, Dodd CK Jr. 1984. The status of the Wyoming toad (*Bufo hemiophrys baxteri*). Environmental Conservation 9: 338, 348.

Boersma PD, Kareiva P, Fagan WF, Clark JA, Hoekstra JM. 2001. How good are endangered species recovery plans? BioScience 51: 643–649.

Brown LE, Mesrobian A. 2005. Houston toads and Texas politics. Pages 150–167 in Lannoo MJ, ed. Amphibian Declines: The Conservation Status of United States Species. Berkeley: University of California Press.

Carey C, Corn PS, Jones MS, Livo LJ, Muths E, Loeffler CW. 2005. Environmental and life history factors that limit recovery in southern Rocky Mountain populations of boreal toads (*Bufo boreas*). Pages 222–236 in Lannoo MJ, ed. Amphibian Declines: The Conservation Status of United States Species. Berkeley: University of California Press.

Corn PS. 1993. Population Ecology of the Endangered Wyoming Toad (*Bufo hemiophyrs baxteri*): 1992 Results. Fort Collins (CO): US Fish and Wildlife Service.

———. 2003. Deteriorating status of western amphibians: Can we generalize about causes? Pages 249–255 in Linder G, Krest SK, Sparling DW, eds. Amphibian Decline: An Integrated Analysis of Multiple Stressor Effects. Pensacola (FL): Society of Environmental Toxicology and Chemistry.

Crother BI, et al. 2000. Scientific and Standard English Names of Amphibians and Reptiles of North America North of Mexico, with Comments Regarding Confidence in Our Understanding. St. Louis (MO): Society for the Study of Amphibians and Reptiles. Herpetological Circular no. 29.

Denton JS, Hitchings SP, Beebee TJC, Gent A. 1997. A recovery program for the natterjack toad (*Bufo calamita*) in Britain. Conservation Biology 11: 1329–1338.

Dodd CK Jr. 2005. Population manipulation. Pages 265–270 in Lannoo MJ, ed. Amphibian Declines: The Conservation Status of United States Species. Berkeley: University of California Press.

Dodd CK Jr, Seigel RA. 1991. Relocations, repatriations, and translocations of amphibians and reptiles: Are they conservation strategies that work? Herpetologica 47: 336–350.

Freda J, Gern B, McLeary D, Baxter G. 1988. 1988 Recovery Efforts for the Endangered Wyoming Toad, *Bufo hemiophrys* baxteri. Laramie (WY): Department of Zoology, University of Wyoming.

Griffith B, Scott JM, Carpenter JW, Reed C. 1989. Translocation as a species conservation tool: Status and strategy. Science 245: 477–480.

Heyer WR, Donnelly MA, McDiarmid RW, Hayek LC, Foster MS. 1994. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Washington (DC): Smithsonian Institution Press.

Hoekstra JM, Clark JA, Fagan WF, Boersma PD. 2002. A comprehensive review of endangered species act recovery plans. Ecological Applications 12: 630–640.

Jennings M, Beiswenger R, Corn PS, Parker M, Pessier A, Spencer B, Miller P, eds. 2001. Population and Habitat Viability Assessment for the Wyoming Toad (*Bufo baxteri*). Final Workshop Report. Apple Valley (MN): IUCN/SSC Conservation Breeding Specialist Group.

Kendall WL, Nichols JD, Hines JE. 1997. Estimating temporary emigration using capture–recapture data with Pollock's robust design. Ecology 78: 563–578.

Lewis DL, Baxter GT, Johnson KM, Stone MD. 1985. Possible extinction of the Wyoming toad, *Bufo hemiophrys baxteri*. Journal of Herpetology 19: 166–168.

Muths E, Dreitz VJ. 2003. Preliminary Development of a Monitoring Program for Wyoming Toad Populations. Fort Collins (CO): US Geological Survey–Fort Collins Science Center.

Muths E, Johnson TL, Corn PS. 2001. Experimental repatriation of boreal toad (*Bufo boreas*) eggs, metamorphs, and adults in Rocky Mountain National Park. Southwestern Naturalist 46: 106–113.

Muths E, Corn PS, Pessier AP, Green DE. 2003. Evidence for disease-related amphibian decline in Colorado. Biological Conservation 110: 357–365.

Nichols JD. 1992. Capture–recapture models. BioScience 42: 94–102.

Odum RA, Corn PS. 2005. *Bufo baxteri* Porter, 1968, Wyoming toad. Pages 390–392 in Lannoo MJ, ed. Amphibian Declines: The Conservation Status of United States Species. Berkeley: University of California Press.

Packard GC. 1971. Inconsistency in application of the biological species concept to disjunct populations of anurans in southeastern Wyoming and north-central Colorado. Journal of Herpetology 5: 191–193.

Parker J. 2000. Habitat use and movements of the Wyoming toad, *Bufo baxteri:* A study of wild juvenile, adult, and released captive-raised toads. Master's thesis. University of Wyoming, Laramie, WY.

Parker JM, Anderson SH. 2003. Habitat use and movements of repatriated Wyoming toads. Journal of Wildlife Management 67: 439–446.

Pessier AP, Roberts DR, Linn M. 2002. Short tongue syndrome, lingual squamous metaplasia and suspected hypovitaminosis A in captive Wyoming toads, *Bufo baxteri*. Pages 151–153 in Bradley T, ed. Proceedings, Association of Reptilian and Amphibian Veterinarians: Ninth Annual Conference, October 9–12, 2002, Reno, Nevada. N.p.: The Associations.

Porter KR. 1968. Evolutionary status of a relict population of *Bufo hemiophrys* Cope. Evolution 22: 583–594.

Reading RP, Miller BJ. 1994. The black-footed ferret recovery program: Unmasking professional and organizational weaknesses. Pages 73–100 in Clark TW, Reading RP, Clarke AL, eds. Endangered Species Recovery: Finding the Lessons, Improving the Process. Washington (DC): Island Press.

Saterson KA, Christensen NL, Jackson RB, Kramer RA, Pimm SL, Smith MD, Wiener JB. 2004. Disconnects in evaluating the relative effectiveness of conservation strategies. Conservation Biology 18: 597–599.

Semlitsch RD. 2002. Critical elements for biologically based recovery plans of aquatic-breeding amphibians. Conservation Biology 16: 619–629.

Smith HM, Chiszar D, Collins JT, van Breukelen F. 1998. The taxonomic status of the Wyoming toad, *Bufo baxteri* Porter. Contemporary Herpetology 1998 (1). (22 June 2006; *www.cnah.org/ch/ch/1998/1/index.htm*)

Snyder NFR, Derrickson SR, Beissinger SR, Wiley JW, Smith TB, Toone WD, Miller B. 1996. Limitations of captive breeding in endangered species recovery. Conservation Biology 10: 338–348.

Spencer GB. 1999. The Wyoming toad SSP. Endangered Species Bulletin 24: 18–19.

Steidl RJ, DeStefano S, Matter WJ. 2000. On increasing the quality, reliability and rigor of wildlife science. Wildlife Society Bulletin 28: 518–521.

Taylor SK, Williams ES, Thorne ET, Mills KW, Withers DI, Pier AC. 1999. Causes of mortality of the Wyoming toad. Journal of Wildlife Disease 35: 49–57.

Tear TH, Scott JM, Hayward PH, Griffith B. 1993. Status and prospects for success of the Endangered Species Act—a look at recovery plans. Science 262: 976–977.

[USFWS] US Fish and Wildlife Service. 1984. Endangered and threatened wildlife and plants; determination that *Bufo hemiophrys baxteri* (Wyoming toad) is an endangered species. Federal Register 49 (11): 1992–1994.

———. 1991. Wyoming Toad Recovery Plan. Denver (CO): US Fish and Wildlife Service, Region 6.

———. 2004. Programmatic Safe Harbor Agreement and receipt of an application for an enhancement of survival permit associated with proposed restoration and reintroduction activities for Wyoming toads within suitable wetland habitat of Albany County, WY. Federal Register 69 (94): 26878–26879.

Wayne RK, Morin PA. 2004. Conservation genetics in a new molecular age. Frontiers in Ecology and the Environment 2: 89–97.

Williams BK, Nichols JD, Conroy MJ. 2002. Analysis and management of animal populations. San Diego (CA): Academic Press.

Withers DI. 1992. The Wyoming toad (*Bufo hemiophrys baxteri*): An analysis of habitat use and life history. Master's thesis. University of Wyoming, Laramie.

Yaffee SL. 1982. Prohibitive Policy: Implementing the Federal Endangered Species Act. Cambridge (MA): MIT Press.