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Structured decision making as a conservation tool for recovery planning of two endangered salamanders

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ABSTRACT

At least one-third of all amphibian species face the threat of extinction, and current amphibian extinction rates are four orders of magnitude greater than background rates. Preventing extirpation often requires both ex situ (i.e., conservation breeding programs) and in situ strategies (i.e., protecting natural habitats). Flatwoods salamanders (*Ambystoma bishopi* and *A. cingulatum*) are protected under the U.S. Endangered Species Act. The two species have decreased from 476 historical locations to 63 recently extant locations (86.8% loss). We suggest that recovery efforts are needed to increase populations and prevent extinction, but uncertainty regarding optimal actions in both ex situ and in situ realms hinders recovery planning. We used structured decision making (SDM) to address key uncertainties regarding both captive breeding and habitat restoration, and we developed short-, medium-, and long-term goals to achieve recovery objectives. By promoting a transparent, logical approach, SDM has proven vital to recovery plan development for flatwoods salamanders. The SDM approach has clear advantages over other previous approaches to recovery efforts, and we suggest that it should be considered for other complex decisions regarding endangered species.

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1. Introduction

Globally, amphibians are among the most imperiled taxa—at least one-third of all species face the threat of extinction (Stuart et al., 2004; Wake & Vredenburg, 2008). Scientists conservatively estimate that current amphibian extinction rates are four orders of magnitude greater than background rates, supporting the hypothesis that a sixth mass extinction is underway (Alroy, 2015; Wake & Vredenburg, 2008). There are currently 35 amphibian species or populations listed as threatened (n = 15) or endangered

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(n = 20) in the United States by the U.S. Fish and Wildlife Service (USFWS) under the Endangered Species Act (ESA); 22 of these have active recovery plans (USFWS, 2016a), though some have not been updated to reflect current knowledge (Walls et al., 2017). These plans are developed by the USFWS to provide guidance regarding management actions needed to achieve recovery of protected species. Preventing the extinction of endangered species often requires both in situ actions (i.e., protecting species in their natural habitats) and ex situ strategies (i.e., establishing conservation breeding programs). The decision to establish ex situ populations requires careful thought—as a last resort, captive breeding may be necessary to prevent extinction, but its ultimate success depends on having high quality habitat into which captive-bred individuals can be reintroduced (Dolman, Collar, Scotland, & Burnside, 2015). Decisions about in situ and ex situ actions for federally-protected species are especially complex because managers must address regulatory burdens in addition to complicated biological issues (Runge, 2011). Thus, effectively evaluating the costs, risks, and benefits of both in situ and ex situ approaches requires input from various types of stakeholders, including scientists, zoo collaborators, agency personnel, non-governmental organizations, and land managers.

The flatwoods salamanders (*Ambystoma cingulatum* and *A. bishopi*; Fig. 1) are federally-protected species native to the southeastern United States, but these species lack complete recovery plans. In 2013, the informal Flatwoods Salamander Working Group was established to coordinate conservation actions among research and management groups (see author affiliations). For flatwoods salamanders, substantial uncertainty regarding the effectiveness of possible conservation actions in both in situ and ex situ realms is a hindrance to recovery planning. Uncertainty concerning in situ actions stems from an inadequate understanding of necessary habitat characteristics, as well as the particular management actions required to properly restore flatwoods salamander habitat. On the ex situ front, considerable uncertainty remains about the capacity to establish captive breeding populations, because there has been very little success thus far in breeding bi-phasic (i.e., those with both aquatic and terrestrial life history stages) ambystomatid salamanders in captivity; in some cases, efforts have failed due to unknown diseases.

In general, recovery plans have faced criticism for their static nature, lack of scientific rigor, and failure to adequately address threats (Clark, Hoekstra, Boersma, & Kareiva, 2002; Wolf, Hartl, Carroll, Neel, & Greenwald, 2015). Additionally, recovery planning processes may stall due to data deficiencies and disagreements about optimal management actions (Gregory, Long, Colligan, Geiger, & Laser, 2012). Leaders within the Flatwoods Salamander Working Group opted to formally confront the complexity and uncertainty about potential recovery actions using decision analysis. Structured decision making (SDM) is a process that decomposes a decision into key components: problem identification, management objectives, potential actions, system models that project consequences of actions, and optimization processes that reconcile tradeoffs (Gregory et al., 2012; Williams, Szaro, & Shapiro, 2007; Fig. 2). Here, we present our approach to addressing both in situ and ex situ efforts through two related SDM workshops, discuss the major decision outcomes, and highlight current efforts toward recovery planning. First, however, we illustrate the motivation for the decision processes with a description of flatwoods salamander declines.

2. Flatwoods salamander declines

Flatwoods salamanders (Fig. 1) occurred historically throughout the Coastal Plain of the southeastern U.S., across South Carolina, Georgia, Alabama, and the panhandle of Florida (Lannoo, 2005; Fig. 3). The species was initially designated as threatened in 1999, but in 2007, it was split into the federally-threatened frosted flatwoods salamander, *A. cingulatum*, and the federally-endangered reticulated flatwoods salamander, *A. bishopi* (Pauly, Piskurek, & Shaffer, 2007). Both species have complex life cycles—they depend on seasonal ponds for breeding and larval development, and juveniles metamorphose and disperse into terrestrial habitats. In other ambystomatid species, most juvenile salamanders are recruited into natal populations, but some disperse to new breeding sites (Gamble, McGarigal, & Compton, 2007; Semlitsch, 2008). Like many other amphibians with complex life cycles, detection of larval flatwoods salamanders requires appropriate rainfall in a given year (to provide suitable breeding conditions), intense and standardized effort to sample aquatic larvae, and coordination

Fig. 1. Flatwoods salamander life stages and habitat: (a) reticulated flatwoods salamander larva, (b) suitable flatwoods upland habitat, (c) adult frosted flatwoods salamander in wiregrass, (d) adult frosted flatwoods salamander, and (e) prescribed burning to restore flatwoods salamander habitat. [Photos a, c, d: P. Hill; b, e: KMO].