Title

Endangered Species of the Edwards Aquifer, Texas; A Case Study from the Structured Decision Making Workshop.
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Decision Problem

The challenge for our team is to develop an iterative process that will be used to analyze jeopardy and contribute to the recovery for the Texas wild rice (*Zizania texana*) and Comal Springs dryopid beetle (*Stygoparnus comalensis*) in light of scientific uncertainty and political controversy surrounding water management of the Edwards Aquifer. This process will be used in the development of a Recovery Implementation Program Plan and development of a Habitat Conservation Plan with a 20-year permit. Our group focused on these species because the available information for each of the species spans the range from very little known about the beetle to very good understanding of the biology and ecology of the wild-rice. Our intent is to develop a conceptual model for these two species that can be easily adapted to the remaining threatened and endangered species of the Edwards Aquifer.

Background

Take and Jeopardy / Adverse Modification

The Edwards Aquifer is one of the most prolific artesian aquifers in the world. Located on the eastern edge of the Edwards Plateau in Texas, it discharges about 900,000 acre-feet (af) of water a year and directly serves about two million people. In May 1991, the Sierra Club filed a lawsuit the Service was not adequately protecting endangered species that depend on the Edwards aquifer. The Sierra Club argued that Comal and San Marcos Springs could dry up if unrestricted pumping continued and that would constitute a "taking" as defined by the ESA. In January 1993, Federal Judge Lucius Bunton of the U.S. District Court in Midland ruled in favor of the Sierra Club. The court found that if unrestricted withdrawals continued, endangered and threatened

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species would be "taken" as defined by the ESA. The court also found the Service had failed to implement a recovery plan for San Marcos and Comal Springs and had caused risk or jeopardy to the endangered species. Judge Bunton ordered that spring flow must be maintained even during a drought like in the 1950s (drought of record). He directed the Texas Water Commission (now Texas Water Development Board) to prepare and submit a plan to ensure spring flows, and he directed the Service to determine spring flow levels that would result in "take" or "jeopardy" of the species (Table 1).

Table 1. U.S. Fish and Wildlife Service determination of minimum springflows needed to prevent take, jeopardy, or adverse modification of critical habitat. All flow rates are given in cubic feet per second (cfs).

Species	Take	Jeopardy	Adv. Mod.
Fountain darter in Comal	200	150	N/A
Fountain darter in San Marcos	100	100	100
San Marcos gambusia	100	100	100
San Marcos salamander	60	60	60
Texas blind salamander	50*	50*	N/A
Damage and Destruction			
Texas wild-rice	100	100	100

* Refers to San Marcos springflow

Recovery Implementation Program

The Edwards Aquifer Recovery Implementation Program (RIP) is a voluntary, multi-stakeholder initiative that seeks to balance water use and development with the recovery of federally-listed species. Due to the diversity of issues and level of conflict often associated with water issues, the RIP will take a long-term, interdisciplinary approach that incorporates policy formation, scientific research, habitat restoration, education, and other activities as defined by the participants.

Formation of a RIP requires that the stakeholders participating in the program develop a comprehensive document that outlines the program goals, activities, timelines, measurements of success, and roles of the participants. Development of the program document may take several years. However once the program document is finalized, all stakeholders who are interested in participating in program implementation sign a Cooperative Agreement to implement the activities outlined in the program document. The program document will include a Habitat Conservation Plan providing incidental take through Section 10(a)(1)(b) of the Act for water development and other management activities that result in take of listed species. The Edwards Aquifer RIP began in early 2007 and will include the southern segment of the Edwards Aquifer (Figure 1).

Texas State Legislation

Senate Bill 3 (SB 3), passed by the Texas Legislature on May 28, 2007, mandated certain milestones and schedules associated with the Edwards Aquifer RIP process. Several of these milestones were met such as hiring a program director, establishing an MOA between the participants and the Service, and establishing steering committee and a scientific subcommittee. SB 3 also increased the total permitted pumping limit from 450,000 acre feet (af) per year, to 572,000 af per year and mandated different drought management requirements, called the Critical Period Management Plan (CPMP). CPMP requirements apply reductions to aquifer withdrawals based on groundwater levels at "pool" index wells, and/or when spring flow declines to a specified level.

Edwards Aquifer Federally-Listed Species

There are seven species listed under the Act endemic to spring outflows discharging from the southern segment of the Edwards Aquifer. The following are these species and their known occupied range:

Texas blind salamander (*Typhlomolge rathbuni*) – subterranean caverns of San Marcos River
San Marcos salamander (*Eurycea nana*) – San Marcos River
Fountain darter (*Etheostoma fonticola*) – San Marcos and Comal River
Texas wild-rice (*Zizania texana*) – San Marcos River
Comal Springs riffle beetle (*Heterelmis comalensis*) – Comal and San Marcos River
Comal Springs dryopid beetle (*Stygoparnus comalensis*) – Comal River and Fern Bank Springs
Peck's Cave amphipod (*Stygobromus pecki*) – Comal River and Hueco Springs

An eighth species, the San Marcos gambusia (*Gambusia georgei*) was known to inhabit the San Marcos River, but is believed to be extinct. The reason for its extinction is unclear, but several factors, such as habitat modification, nonnative species, and recreation contribute to the decline of the Edwards Aquifer species (U.S. Fish and Wildlife Service, 1995).

Decision Structure

Our purpose is to develop a framework for (a) promoting recovery of listed species, (b) determining appreciable change in survival and recovery of given Edwards aquifer species, specifically Texas wild rice (TWR), Comal Springs dryopid beetle, and fountain darter and (c) provide information to Edwards Recovery Implementation Program. We determined the area of occupancy would serve as our surrogate for status of TWR and then identified the influential factors and diagramed their interactions as they relate to the status of the species.

Alternative actions

We focused on influence diagrams primarily of factors that fall within the alternative actions that may be considered in development of the RIP. We explored alternative values for influencing factors to test our assumptions of the influence diagram in a Bayesian Belief Network and thereby to predict area of occupancy of TWR in the river.

Objectives

Our objective was to develop a framework to compare baseline conditions with several alternatives. We wanted to understand how alternatives affect area occupied by Texas wild rice and hopefully decrease probability of extinction for a given period of time. We also developed similar objectives for Comal Springs dryopid beetle.

Predictive model

Below is an example (Figure 1) of our influence diagram for Texas wild-rice one of three model runs predicting Texas wild rice coverage based on influencing factors identified by group. Our belief diagram was than converted into a Bayesian Belief Network model in Netica. The model consisted of both continuous (e.g., springflow discharge in cubic feet per second) and categorical data (high, moderate, and low level of invasive species).

We also created influence diagrams for the Comal Springs dryopid beetle and fountain darter but we did not develop models to explain the effects of the influencing factors on the probabilities of extinction of the species.

Decision Analysis

Of the several species that will eventually be covered in the RIP, for our initial analysis we chose the Texas wild-rice because of the extensive data available for this species in comparison with others.

An influence diagram was developed to identify the factors and interactions most likely to affect the status of the species. Because of the difficulty in defining and identifying what constitutes and "individual" (because of vegetative reproduction), the overall status of the wild-rice was expressed in terms of extent of area covered by the plant.

A Bayesian network was developed from the influence diagram. Various values for states within nodes were used to explore the behavior of the model. Alternatives were identified that minimized the likelihood that wild-rice cover would drop to zero, which represents extinction.

A preliminary simulation model was developed to translate values for percent cover to probabilities of extinction.

In addition to the wild-rice modeling, influence diagrams were developed for impacts to two other aquifer-dependent species, the Comal Spring dryopid beetle and the fountain darter.

Uncertainty

A major source of uncertainty for determining whether actions are jeopardizing the species is the great variability in flows resulting from natural variation in precipitation and recharge. This variability generates variation in the baseline flows against which the effects of water withdrawals must be measured for section 7 analysis.

The simulation to estimate probabilities of extinction from changes in area covered requires further development.

The basic Bayesian network model can be used to evaluate a large number of alternative scenarios to identify combinations of actions that can be considered by the RIP to meet project objectives for use of water resources and protection of listed species.

Discussion

Value of decision structuring

In the past, the problem of maintaining and recovering the listed species dependant on the Edwards Aquifer was addressed primarily by setting flow limits for take and jeopardy. The structured decision-making process and the PrOACT approach allowed our group to broaden our focus regarding the essential biological factors that influence the status of the species and illustrated that there are multiple important factors beyond spring flow that must be considered when developing alternatives and making decisions. We feel that this structured decision making will improve the chances of success in the Edwards Aquifer RIP. The RIP is viewed by many as having an advantage over traditional approaches to the endangered species conflict associated with the Edwards Aquifer in that it brings in multiple stakeholders that have a wide variety of goals and objectives. We believe that structured decision is well adapted for addressing the complexity associated with Edwards Aquifer issues and that it will increase the capacity of the group to work through the problem and develop viable alternatives for meeting their objectives while promoting the recovery of the listed species.

Further Development Required

Our next step is to bring the structured decision making process to the Edwards Aquifer RIP and work with the stakeholders to further develop the influence diagrams that have been created. This will include the important aspects of refining the objectives, developing alternatives, and engage in thoughtful discussion regarding consequences and tradeoffs. This will require the development and refinement of several simulation models and may include one or more sensitivity analyses to better inform the RIP regarding their proposed actions within their HCP and provide sufficient information to the Service for our jeopardy analysis associated with issuance of the incidental take permit.

Prototyping process

The rapid prototyping process allowed the group to manage the complexity of the problem by breaking it down into what most members viewed as the most important factors influencing the status of the species. The paring down process allowed the members to not only focus on the relevant factors, but also understand how each factor interacts within the system and subsequently influences the probability of extinction for a given species.

In reflecting on our decision making process, we now recognize that the group initially spent too much time on developing the rapid prototype model and analyzing the associated consequences without investing sufficient time in the development of objectives by which we could judge and refine our model. As a result, the team was forced to take a step back to discuss and evaluate our objectives within and outside the RIP process and then refine our model to identify the discrete components that will involve input from the stakeholder group and clarify where our decision-making responsibility lies. By doing this, we were able to identify the interplay between the risk analysis that will be undertaken by the stakeholders in developing and evaluating alternatives and the risk management process we must undertake associated with our evaluation of the HCP and issuance of an incidental take permit.

Due to the complexity of our problem and the make-up of the team, it was easy to get caught up in the details and minutia of the system and species dynamics. The Coach and the Apprentice were essential for keeping us on task and challenging our assumptions.

Recommendations

We believe that the structured decision making process will improve the likelihood of success in meeting the broad array of stakeholder interests while contributing to the recovery of the listed species associated with the Edwards Aquifer.

As a participant in the Edwards Aquifer RIP, we recognize that the rapid prototype models must be refined to incorporate the objectives and concerns of the broader stakeholder group. In addition, this stakeholder group will be engaged in developing additional models for additional species, evaluate their alternatives, and analyze the trade-offs and consequences (risk) of each alternative. Although we expect to participate and assist in this process, we must communicate to the RIP that the Service has the ultimate responsibility for conducting the jeopardy analysis as outlined in the problem statement.

Literature Cited

Hammond JS, Keeney RL, Raiffa H. 1999. Smart Choices: A Practical Guide to Making Better Life Decisions. Broadway Books, New York.

U.S. Fish and Wildlife Service. 1995. San Marcos/Comal (Revised) Recovery Plan, Albuquerque, New Mexico.

Figures

Figure 1. Influence diagram for Texas wild-rice