Devils Hole Pupfish Rapid Prototyping
November 8, 2007

1. Decision Problem

Over the past eighteen months the Fish and Wildlife Service, National Park Service and Nevada Department of Wildlife have been working cooperatively and in conjunction with other knowledgeable entities and individuals to reverse the precipitous decline in the numbers of Devils Hole pupfish. Causes of the decline are unclear and many unforeseen factors including genetic questions, hybridization, and fish health issues have complicated the process. Although all agencies have demonstrated a full commitment to reversing the decline of the species, the myriad of issues and constantly changing nature of the problem have resulted in a less coherent recovery strategy than we desired. The challenge was to develop a comprehensive, transparent and defendable decision-making process by which the agencies can focus their efforts on activities that are most likely to avoid short-term declines and increase the population sufficiently so that we have more flexibility in future recovery actions.

2. Background

a. Legal, regulatory, and political context

The Devils Hole pupfish (*Cyprinodon diabolis*) was listed as endangered in 1967. This iridescent blue inch-long fish's only natural habitat is in the 93 degree Fahrenheit waters of Devils Hole, which is a detached unit of Death Valley National Park. Although the cavern is over 500 feet deep, the pupfish are believed to spawn exclusively on a shallow rock shelf just under the waters surface. Narrow endemic species such as the Devils Hole pupfish are at great risk of extinction since they do not have the flexibility to change locations to adapt to changing environments.

This short-lived species (approximately one year) has a natural high and low cycle, with the population in the fall being larger than that in the spring due to natural die-off during the winter months. However, the population of Devils Hole pupfish has not exceeded 553 individuals since population surveys began in 1972.

From late 1970 through 1996, the population appeared to be relatively stable with an average population size of 324 individuals. In 1997, the fall population surveys started to indicate a downward trend for unknown reasons. The population from 1997 to 2004 declined from an average of 275 individuals to 171 fish. In August and September 2004, two separate rainfall events deposited 1.66 cubic meters of sediment on the main spawning shelf, resulting in the loss of approximately 54 percent of pupfish spawning habitat. Subsequent multi-agency initiated restoration efforts are believed to have restored much of this habitat on the shelf. The adult population count conducted in November 2005 indicated a population of 84 individuals, and an April 2006 population count indicated an adult population of 38 individuals, the lowest count on record. A dive survey in November 2006 resulted in 84 adult pupfish within Devils Hole indicating the pupfish were recruiting and reproducing in their natural environment. An April 2007 survey recorded 38 adult pupfish.

b. Ecological context

The specific cause of the population decline is unknown although a variety of hypotheses have been proposed. They include genetic bottlenecks, alterations in the physical structure of Devils Hole resulting from changes in the safety fencing enclosing the Hole, natural biological cycles in the algae composition, continuing decline in water level, observed increase in ambient air temperature, decreases in system productivity, and shifts in community state.. Complicating the issue was the loss the Point of Rocks refuge population due to the introduction of a closely related pupfish that hybridized with the pure fish, the need to remove all pupfish from the Hoover Dam refuge because a population of introduced snails were consuming pupfish eggs, the historical difficulty in propagating the Devils Hole pupfish in captivity in contrast to other species of pupfish, and fish health issues including nephrocalcinosis and lymphosarcoma in captive populations.

3. Decision Structure

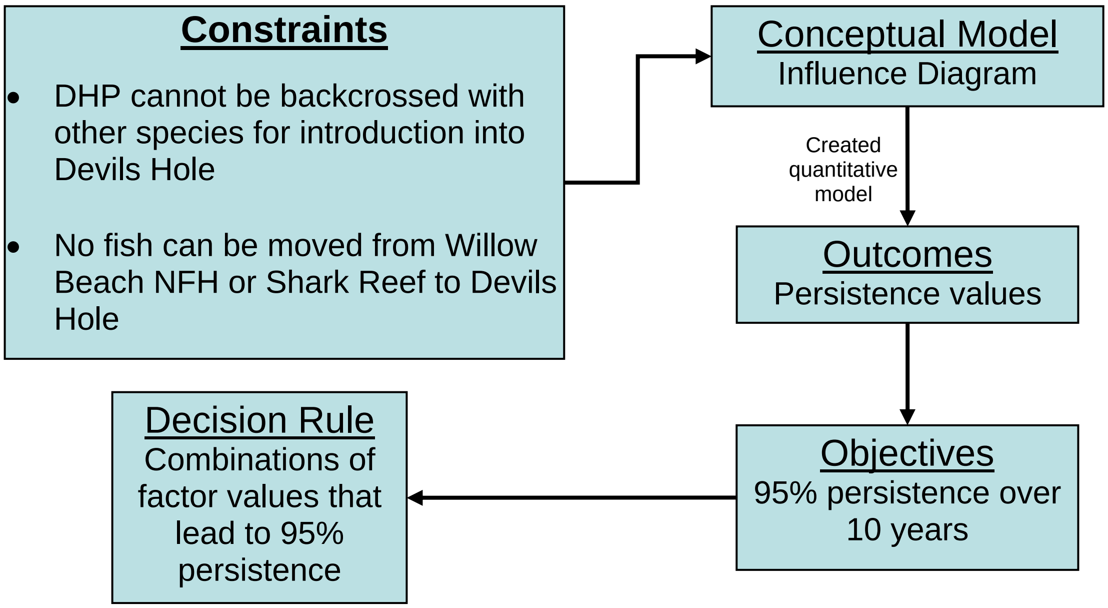
We stated our problem as: ***We need to increase the population to an acceptable range recognizing annual fluctuations, to ensure the species survival in the short-term and allow future management for long-term persistence.*** The solution needs to be transparent so that we will be able to logically defend our future actions to any out side critique. A secondary problem was whether to recommend if any pupfish should be removed from Devils Hole following the September 2007 survey. This was formulated as: ***At what number should the pupfish population be during the Fall 2007 survey to move fish from Devils Hole to any other facility without significantly decreasing the probability of persistence in Devils Hole?***

To proceed we formulated our objectives. Throughout the process we continually revisited and modified our problem statement and objective to better reflect our needs and thoughts. This decision aiding process is iterative in many ways and as new information is uncovered it will be critical to reassess the problem and objectives.

Our objective reflected both our goal and risk tolerance. It is important to recognize that risk tolerance differs from risk management. Risk tolerance reflects the decision makers acceptance of a possibility of failure. Risk management includes actions to reduce the possibility of failure. In this case the risk tolerance was reflected in the probability of persistence. Our objective eventually became to have ***95% probability that after 10 years 168 individuals will be estimated in the spring survey.*** The 168 figure is the mean of the spring survey population less one standard deviation between the years 1975 and 1997. These years exclude early and recent surveys when the population was at historically low levels and thus assumed to be subject to conditions that threatened the species survival.

After establishing our objective we followed the roadmap laid out by the structured decision-making process, as illustrated in Figure 1.

Figure 1. Structured decision-making process for developing recovery criteria for the Devils Hole pupfish.



a. Constraints

We identified constraints within which our model must work. Constraints may be financial, legal, biological or otherwise. Furthermore, they can be amended, discarded, or otherwise modified in the future if circumstances change or new information becomes available. For this situation we identified two state variables:

1. We cannot backcross pure Devils Hole pupfish with the intention of introducing the progeny to Devils Hole.

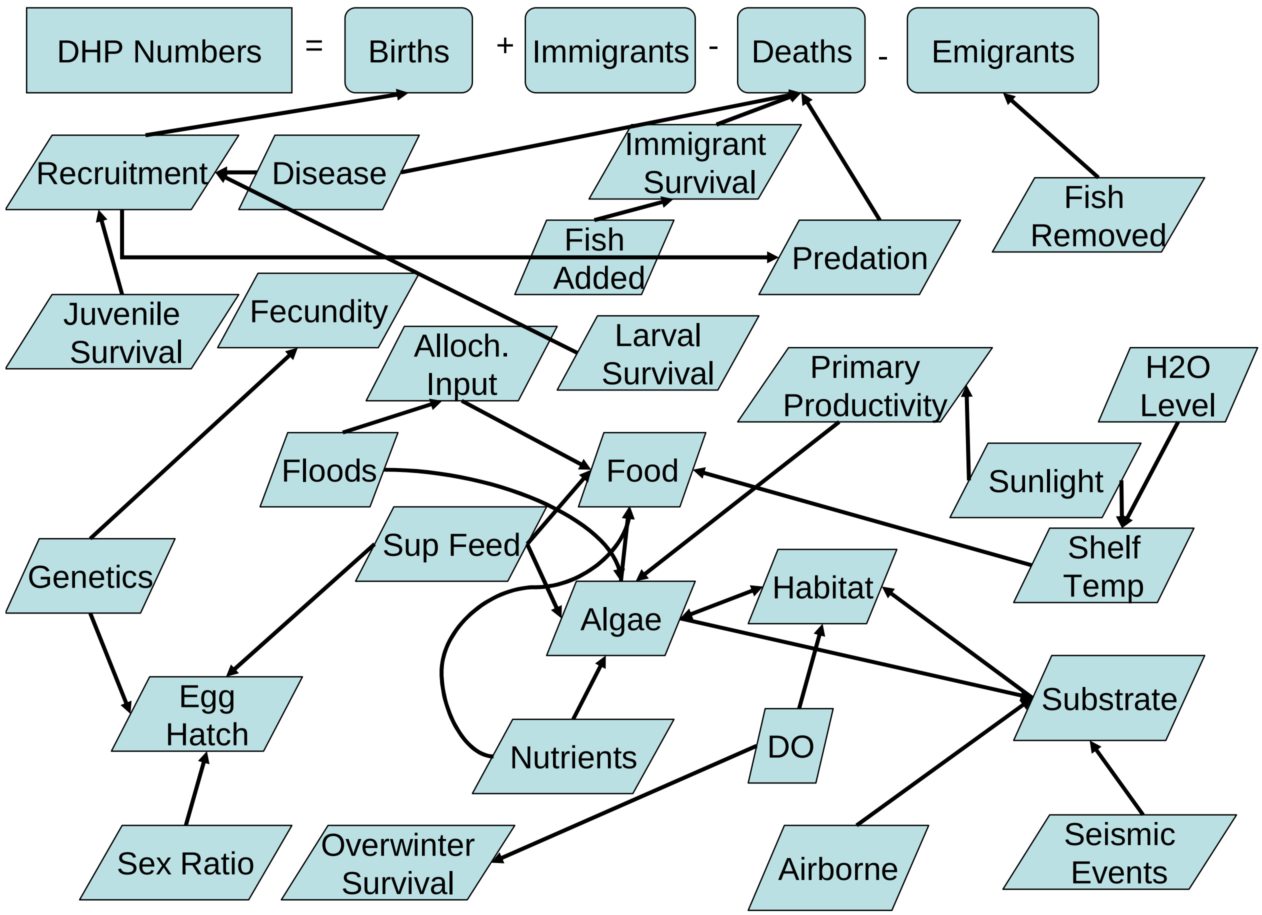
2. We cannot move pupfish from Willow Beach NFH or Shark Reef to Devils Hole.

b. Conceptual Model (Influence Diagram)

We identified specific factors that are thought to be influencing population size (i.e., factors affecting birth, death, immigration and emigration). Factors were added based on our experience with Devils Hole and the species, literature, and existing models and assessments. Interestingly because Devils Hole is physically and biologically isolated and the sole source of Devils Hole pupfish, unlike most systems, immigration and emigration are fully within our control.

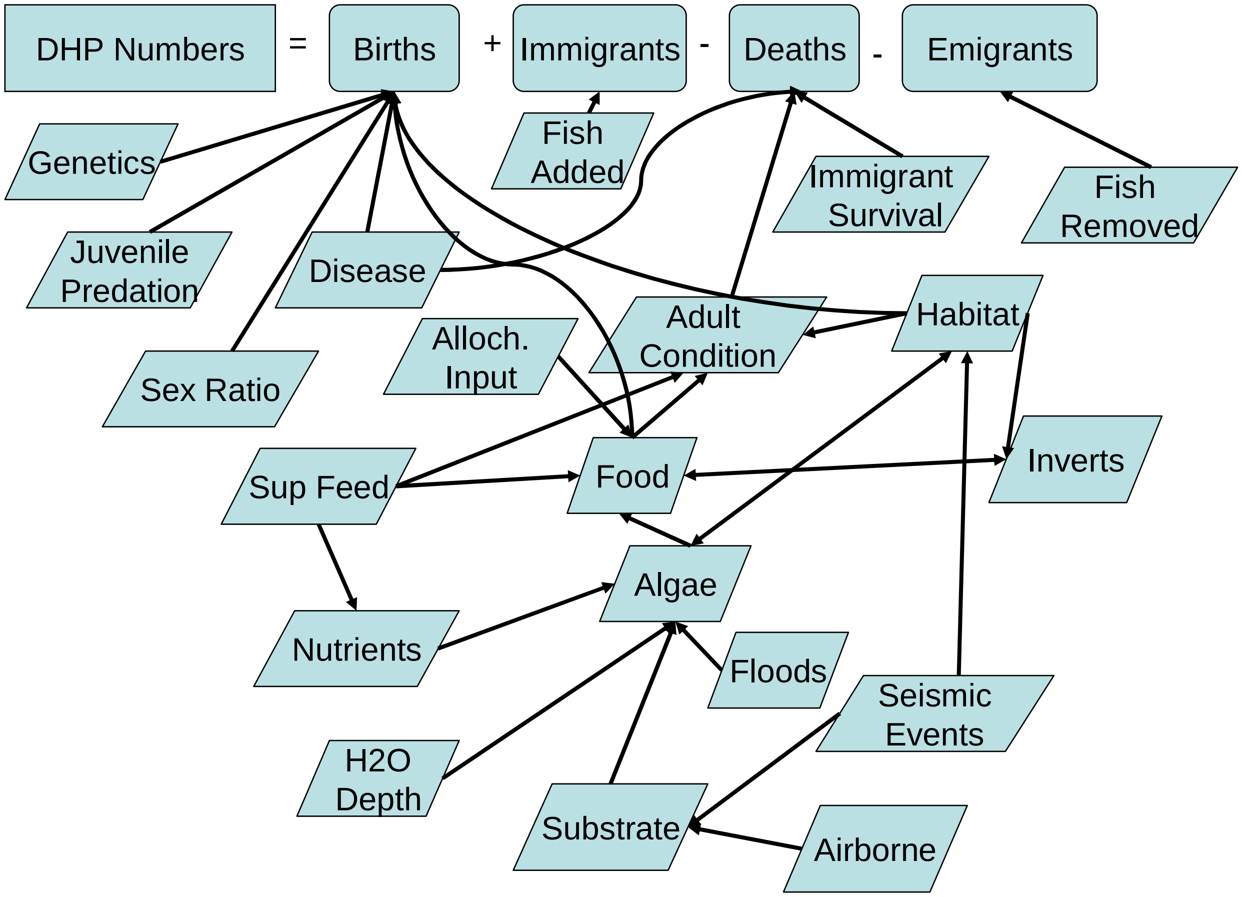
We developed an influence diagram to illustrate the relationships between these factors (e.g., supplemental feeding and food resources). Our influence diagram is illustrated in Figure 2.

Figure 2. Influence Diagram for the Devils Hole pupfish.



We then assessed which factors are reasonable to assume have either a minor influence or are incorporated in others. For example, recruitment for our purposes is incorporated in births. After reducing the number of factors and reevaluating their influence our first simplification is illustrated in Figure 3.

Figure 3. First simplified conceptual model for the first prototype predictive model for Devils Hole pupfish.

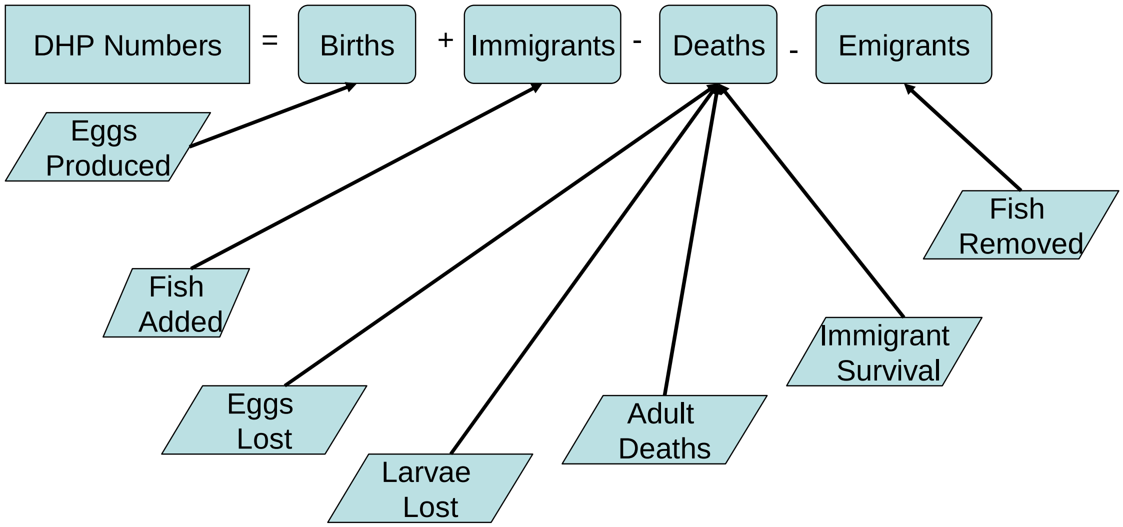


c. Predictive Model

In order to predict the consequences of our influence diagram in relation to our objective, we constructed a basic population dynamics model in Excel. The model allows us to input specific parameters or in some cases ranges of parameters. In the latter instance the model selects a random number from a given distribution from within the range run a simulation. For each set of inputs, the model runs 250 simulations and tallies the final population after ten years.

However after several attempts to construct the model based on our first simplification we concluded it best to further reduce the model to some basic population parameters as illustrated in Figure 4.

Figure 4. Second simplified conceptual model for the first prototype predictive model for Devils Hole pupfish.



4. Decision Analysis

The initial model uses lifestage ratios combined with stochastic simulation to predict total population after 10 years. Initial population size, immigration, emigration, lifestage survival rates and variances can be altered. This model can tell us which lifestages are most sensitive or critical to the overall population survival. When we identify the critical stages we can then build in additional components that are likely to influence them such as predation, genetic constraints, or food limitations. Unfortunately, existing information on many basic life history parameters is sorely lacking.

Our first step will be to acquire better assessments of the life history ratio. This will initially be done by querying species experts using a Delphi procedure (Dalkey and Helmer 1963). Eventually it will be better to conduct rigorous experiments to quantify these numbers and variation within the population. When particularly critical life stages are identified we will then add complexity to the model by estimating the effect of various management actions of the long-term population. We may learn that there are some lifestages that we have no capacity to manage. On the other hand there are likely specific management actions we can do to increase survivorship. For example if overwinter survival is critical, we can continue or increase supplemental feeding. If predation on larvae constitute a major mortality factor, the use of in-situ live cars to protect them may be a priority.

5. Uncertainty

In this exercise uncertainty involved the influence of one factor on another and the doubt surrounding basic lifestage survival ratios. To address these we examined existing literature and studies and when necessary introduced stochasticity into the model, and ran hundreds of iterations of each scenario. This stochasticity used a range of possible values, coupled with a distribution to select numbers for each iteration. Thus no two runs need be exactly alike. As complexity is added to the model we will introduce additional uncertainty, particularly as we judge how specific inputs influence each other.

6. Discussion

This decision structure provides some advantages over how the problem had been approached in the past. The advantages include a transparent process through which the Incident Command Team, Mid-Managers, Managers, and others can evaluate the factors influencing the births and deaths of Devils Hole pupfish. Furthermore, these analyses can be manipulated and various management strategies simulated before they are attempted in the field. This should offer us the opportunity to guide our efforts and determine if a given action should be pursued when an opportunity arises.

7. Recommendations

In the short term, additional life history information is needed. Initially this will be gathered via expert solicitation. Eventually both laboratory experiments and field observations will be used to refine these estimates. When our estimation of the life history parameters are sufficiently robust we can then begin experiments to determine which management actions are likely to improve them.

We were also charged by the Managers with recommending a level, if any, at which we should consider moving Devils Hole pupfish to a refuge or into captivity after the September 29 Devils Hole pupfish survey. Until we further refine this model using better estimate of population dynamics ratios, it is premature to apply it to that question. However, in lieu of using the model we have received a recommendation from the genetic subcommittee that it is most important to increase the numbers of fish in Devils Hole before initiating any refuge populations.

Literature Cited

Dalkey, N., and O. Helmer. 1963. An experimental application of the Delphi method to the use of experts. Management Science 458-467.