Missouri River Emergent Sandbar Habitat Creation: Structured Decision Making Rapid Prototype

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Decision Problem

The U.S. Army Corps of Engineers (Corps) is implementing an emergent sandbar habitat creation program as part of the Reasonable and Prudent Alternative (RPA) in the Missouri River Biological Opinion (BO) (USFWS 2003). The BO included habitat creation as the primary management action to offset the effects of Missouri River operations on interior least terns, piping plovers and their habitat. The performance metrics for this effort are sandbar habitat acres and tern and plover fledge ratios (chicks fledged per adult pair). Those metrics are intended to ensure that the quantity and quality of nesting and brood-rearing habitat is sufficient to avoid jeopardy for the two bird species. Our challenge is to develop a long-term, sustainable program of sandbar habitat creation to support these species, given great logistical uncertainty and environmental stochasticity.

In addition to specific habitat goals, the RPA also mandates an adaptive management framework to implement the multiple elements necessary to offset jeopardy. Over the last 10-15 years, the Corps has conducted an intensive tern and plover monitoring program along the Missouri River. While that effort provides a solid information base on the birds and their habitat, there is a critical need for a structured decision-making process to incorporate that data, and other relevant information, into system operations and the habitat creation program. This rapid prototype is our first attempt to develop such a process, focusing on mechanical creation of sandbar habitat in the Gavins Point reach of the Missouri River.

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Background

The Corps operates six dams along the Missouri River to provide flood control, navigation, hydropower, recreation, water supply, and fish and wildlife. Construction and operation of this system has been the focus of multiple consultations between the Corps and the Service pursuant to the Endangered Species Act. The most recent consultation resulted in a jeopardy opinion for the piping plover and interior least tern because river management has caused significant loss of habitat for these species The dams have created huge reservoirs and blocked passage of sediments that are the foundation of sandbars, and water management has eliminated the habitat-forming flows except in the extremely wet years The area just below Gavins Point, the lowermost dam, is the most important nesting, brood rearing and fledging habitat for piping plovers and interior least terns along the river.

Legal, regulatory, and political context

The Corps has consulted with the Service on Missouri River operations several times over the past 20 years. These consultations have been contentious, with a number of lawsuits following each consultation. In addition to measures to create or restore habitat for piping plovers and interior least terns, all the Biological Opinions have included flow components both to improve bird nesting and brood rearing habitat and to benefit the endangered pallid sturgeon, another federally listed species endemic to the Missouri River. Flow changes are especially controversial in the downstream states, as any change to the status quo is seen by some as having implications on other congressionally authorized purposes of the system.

Under the current water management system, lack of sediment and high flows limit island creation. Islands that are created still become vegetated and erode, leading to a perpetual shortage of bare sandbar islands suitable for nesting. Efforts to implement this RPA element by mechanically creating islands have met with some success, but the logistical and environmental uncertainties present daunting challenges for long-term planning. In addition to the Corps and the Service, the National Park Service has responsibility for this river reach as part of the Missouri National Recreational River under the Wild and Scenic Rivers Act. For decision makers to reconcile diverse agency missions, stakeholder expectations, and system water demands while providing habitat for these two species requires a flexible, clearly articulated decision-making process.

Ecological context

Sandbars are transient in the riverine system. In a natural system, they emerge through sediment deposition during high flows. Over the next few years, they start to erode and become covered with vegetation before being washed away or reshaped by another high flow event. Construction of multiple dams altered the sediment budget for the river, while channelization and water management have led to an altered and asynchronous hydrograph. These changes have changed the river from a dynamic, braided river system to a largely impounded, entrenched, and highly controlled river. These actions have limited the suitable habitat for the birds in both the short and long-term. However, in 1996 and 1997, unprecedented high flows in the Gavins reach created more ESH than had been available since the Missouri River System was operational. The bird populations appeared to respond to the increased habitat by achieving (in some cases for the first time) fledge ratios sufficient to sustain the populations. Elevated nesting success continued for several years, presumably as a result of abundant suitable habitat, increased forage, and decreased predation. As ESH has eroded and became vegetated fledge ratios have declined.

Decision Structure:

Our initial conceptual decision structure (Figure 1) was a simplistic attempt to visualize the major decision points described in the Biological Opinion. Although it served as a starting point for our consideration, ultimately, our decision structure will need to accommodate site specific, multi-year, multi-agency project implementation. A long-term, reach-level monitoring and evaluation program will be included as a critical part of those efforts. That information will be used to track progress towards our habitat goals, or possibly redirect actions based on unanticipated results, habitat conditions, or operational constraints.

Objectives

The objectives are designed to most efficiently provide the quantity and quality of habitat needed for interior least terns and piping plovers, while minimizing impacts to other species and the stakeholders. These objectives reflect the interests of each agency involved in the prototype development. While we started with a larger list, we were able to refine our objectives using a consequences table which also reflected how we would measure achievement towards that particular item.

We identified our objectives for the rapid prototypes as follows:

- Minimize cost/acre
- Meet fledge ratios
- Minimize construction-related disturbance (F&W, aesthetics, cultural, human)
- Meet acreage target for 2015
- Minimize socio-economic impact to stakeholders

Alternative actions

Selection of the alternatives started slowly. We had to revisit and change our decision statement before we could effectively delve into the discussion of objectives. Our objectives discussion was detailed and somewhat heated but once we agreed up on objectives, the alternatives were very easy to select.

- Build new emergent sandbar habitat through mechanical means (dredging or bulldozing)
- Devegetation of existing sandbar habitat
- Flow (low summer flow, conditioning flow, habitat creating flows)

Alternative actions described below include several options beyond our immediate charge, i.e., mechanical creation activities only. The primary alternatives are mechanical creation (dredge or bulldozing), vegetation removal, and vegetation removal and overtopping with sand. Vegetation removal uses a combination of spraying, mowing and overtopping with sand to return sandbars to bare conditions. We have not yet determined the best tools to create ESH under various habitat conditions and water levels, so part of this strategy is to try these methods under a range of conditions and compare performance.

While flow manipulations are included in our alternatives, specific scenarios are currently not well developed. “Conditioning” flows are a pulse of water to overtop created or old ESH to improve the habitat quality (i.e., reduced vegetation, increased invertebrate colonization). Low summer flows and habitat creating flows are beyond the sideboards of our current efforts.

Predictive Model

We started out with a simple model to describe changes in ESH during any one year. We used that model to explore different treatments of the sandbars and better understand the construction needs based on numbers in the BO and additional ESH evaluations. We also were able to estimate costs of each method and look at tradeoffs and budgets. As we looked at different scenarios, it was obvious that we needed to consider linked-decision effects of the previous year’s efforts (habitat creation) and their accumulation over time. A multi-year model allowed us to estimate yearly creation needed to achieve longer-terms goals and identify any shortfalls.

We then introduced stochasticity into several environmental variables. It was helpful to see how variability between years and uncertainty in parameter estimates affected predicted outcomes. This was especially true in a dynamic river system, where water years and river levels can vary greatly. Our improved model (Figure 2) assumes stable river level and no flows to naturally create habitat.

We also developed a life history model to attempt to predict numbers of birds on the river and also reflect the quality of the various habitats through fledge ratios. We agreed that this model has a great deal of uncertainty because of highly variable population numbers and fledge ratios which reflect multiple factors (predation, weather, survival) beyond habitat quality. However, this model highlighted the importance of the direct but poorly understood connections between habitat availability, population size, and fledge ratios.

Decision Analysis

Our primary approach to decision analysis was the use of consequences tables to examine how different actions or scenarios affected the objectives. For example, we used our initial model to predict the number of acres of habitat we could create within a defined budget, as well as estimate the effects of creation methods on fledge ratios (reproductive success) and bird numbers along the river. Although our habitat model is simplistic, it was clear to the group that river level drove the overall results of model**,** essentially overwhelming other variables. This identified a critical need to better characterize effects of river stage on available habitat.

Several scenarios did not meet habitat goals, and essentially reflected degrading habitat that is available only in low flow years. Almost all modeled scenarios met bird target numbers, but almost none achieved desired productivity goals. (This indicates problems within the model and the need to more accurately reflect the relationship of habitat suitability and bird numbers.) It took several years before management scenarios showed differences in available habitat that weren’t masked by natural habitat. Interestingly, the model indicated the most cost effective habitat creation method (vegetation control) was limited by the habitat available to be treated since habitat is continually lost through erosion.

Uncertainty

The major uncertainties influencing our ESH creation efforts are both logistical and environmental. We have limited ability to predict the long-term resources that will be needed or budgeted for these efforts. It is likely not something we can model. There is also great interannual variability in river flows that, to a great extent, drive the amount and suitability of available sandbar habitat. This may well be a greater source of variance in reproductive success than the differential nesting success (fledge ratios) among different habitats.

Discussion

Value of decision structuring

Although our group had several conference calls before the course, participants brought a wide range of expectations to the workshop and our desired outcome. A key area of disagreement arose when discussing the "product" of the week – some team members expected finished models and predictions. However, the most important product of the week was the initiation of a *process* of collaborative model building and analysis. By the end of the week, we built a process/decision making framework; gained training in building and using that framework; documented deconstruction of the ESH issues on the Gavins reach; developed prototypes of life history and ESH predictive models, consequences tables; and identified additional questions/information needs. The structure of the workshop provided the framework necessary to brainstorm and analyze our problem to a productive endpoint, rather than get caught up in unanswerable "what-if" scenarios. When the group collectively questioned "Why?" it focused us on the critical elements of our task. This process will be extremely useful as we further refine some of our predictive models, and look at how to best evaluate long-term creation methods. In addition, this process will need to be repeated throughout the development and likely even the implementation phase to ensure that we have clearly identified our expected outcomes and are choosing actions that will move us towards it.

Further development required

There are a number of opportunities to improve the predictive capabilities of habitat and reproductive success. Of primary importance is a better understanding of the relationship between river levels and the various habitat types. Although there is room for improvement on the life history models, the efforts to increase accuracy in those parameters may be overwhelmed by the difference in acres among management scenarios. Using actual field data to rerun some aspects of our modeling efforts could be informative, particularly those areas where we did not have the data available at the workshop.

Prototyping process

The rapid prototyping helped the group focus on a defined aspect of the problem. Working through the models helped us develop greater comfort in estimating inputs, manipulating elements in a model to better understand relationships among the variables; examining consequences for specific actions, and thinking about additional factors in future iterations including multiyear issues. As the process progressed, the group began to open the discussion from the model to the much more complicated real world more frequently and with increased recognition of how the two related. Explicit discussions throughout the process helped to clarify assumptions, thus simplifying decision-making.

Use of consequences tables helped to clarify for the first time the results and trade offs for the decisions we face in the ESH program. Once we did this, team members recognized that we made it through the whole process once. Our other spreadsheets gave us the ability to look at acreage numbers in the context of acres needed and work required to get this done. The models are not perfect, but the effort to "go around the track" a second time produced a more complex model that was nevertheless perceived as less helpful, primarily because we did not have sufficient time to properly develop it or understand the implications of some of the early results. It is important to continue the process of refining the tools we recently developed and identifying other tools we need to support decisions in this arena.

Recommendations

One of the greatest needs identified in our workshop was the continuing involvement of outside experts skilled in both the SDM and modeling fields. The group endorsed efforts to retain such expertise in future development and refinement of our ESH creation program. In addition, given the significant role river stage plays as a driver in ESH, it is essential to add expertise in hydrology/fluvial geomorphology to the team that develops the adaptive management framework. Although beyond the scope of our workshop, the development of the larger adaptive management plan for the entire ecosystem recovery process will benefit from expertise in economics and human dimensions, as it necessary to consider the economic and societal consequences of management actions. Above all else, it is essential to continue the collaborative process begun in Shepardstown through regular meetings, focused analysis of existing data and exchange of information.

Literature Cited

USFWS. 2003. U.S Fish and Wildlife Service 2003 Amendment to the 2000 Biological Opinion of the Operation of the Missouri River Main Stem Reservoir System, Operation and Maintenance of the Missouri River Bank Stabilization and Navigation Project, and Operation of the Kansas River Reservoir System. 308 Pages.

Figures

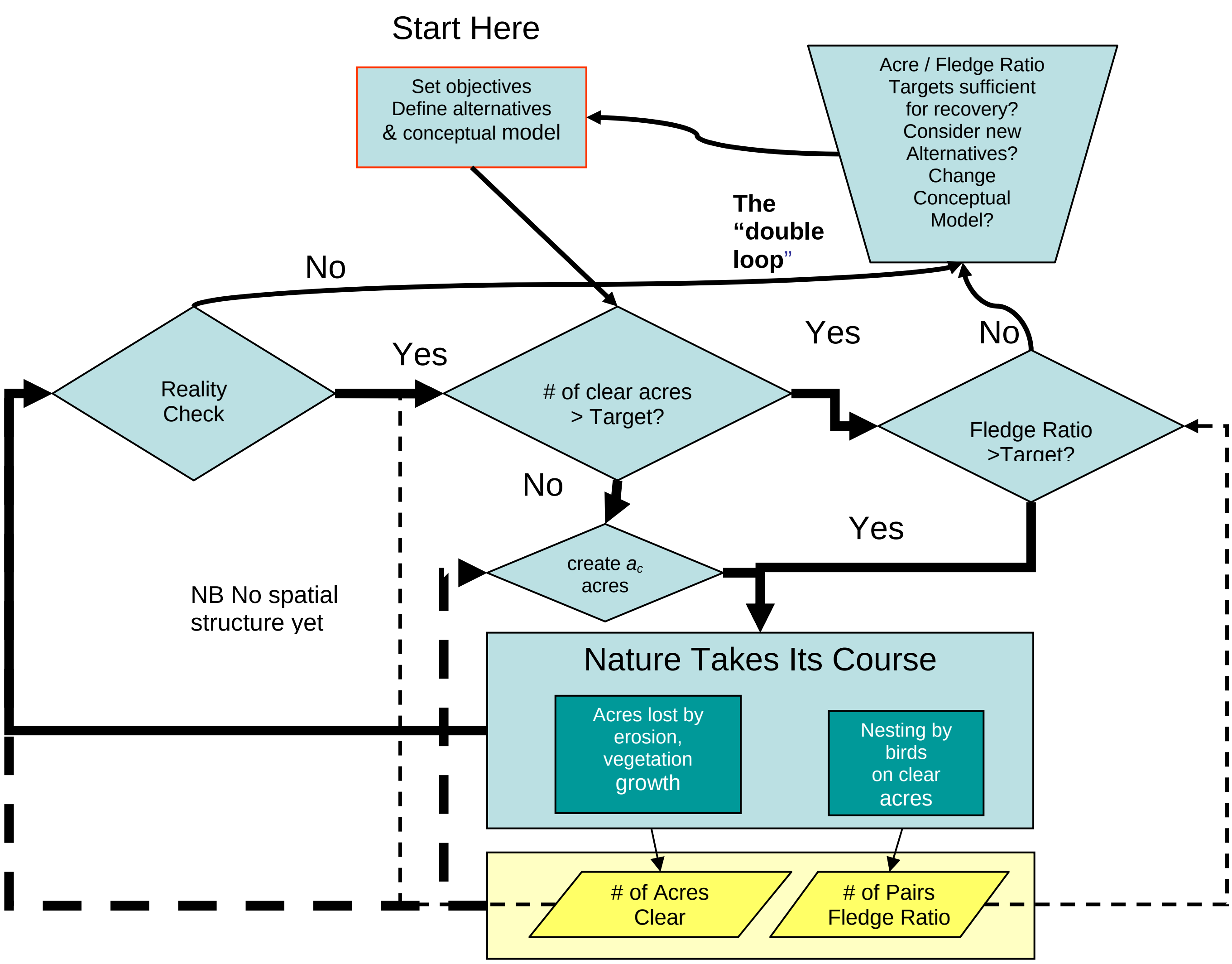

Figure1. Example of a Conceptual Model of ESH Decision-Making Process

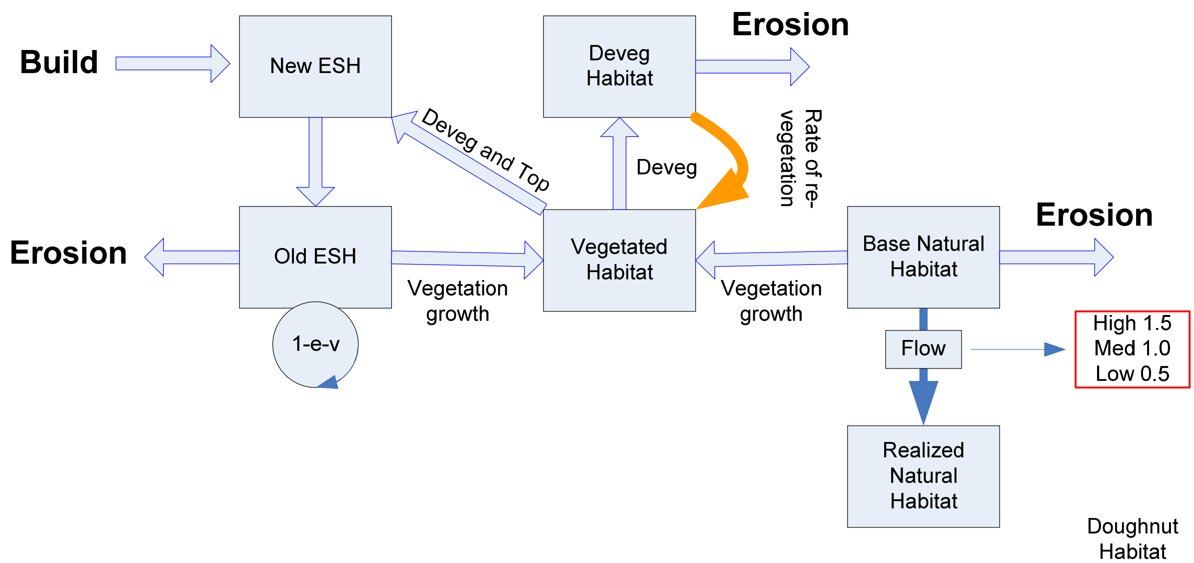

Figure 2. Improved habitat creation model

Figure 3. Predicted Fledge ratios

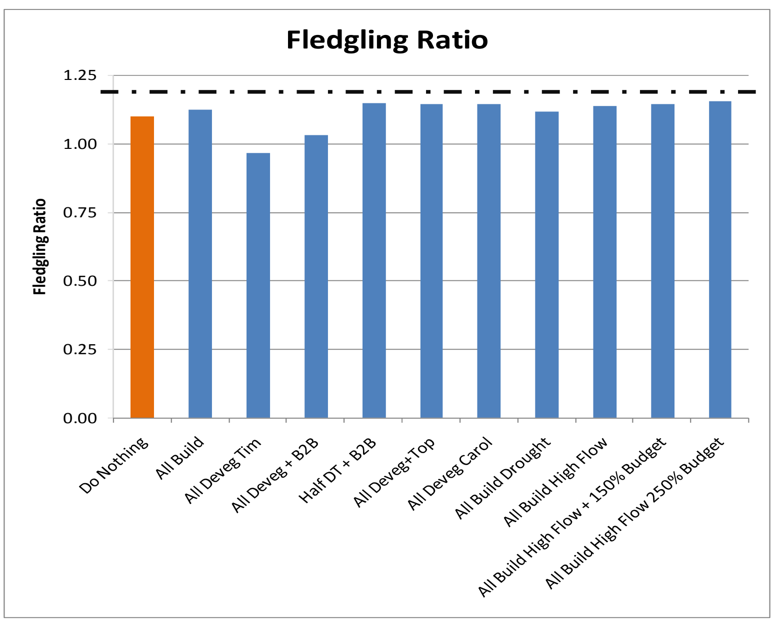

Figure 4. Predicted Minimum Populations