

Optimal Budget Allocation for American Shad Conservation

A Case Study from the Structured Decision Making Workshop

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Decision Problem

The USFWS Northeast Region Fisheries Program needs to develop a tool to support allocating externally-determined budgets to best assist meeting shared USFWS and partner conservation objectives for American shad populations on a region-wide scale. The desired approach will support budget allocation over the next 5 years, during which budgets are expected to remain flat or decline. Also, more generally, the ability to project shad conservation success given a variety of possible budgets would be beneficial in garnering additional funding. Ultimate responsibility for fisheries budget allocation lies with the Assistant Regional Director (ARD) for Fisheries.

Use of the budget allocation tool will be initiated next fiscal year (FY 2009) and will be revisited every five years. Funding allocations will be made on an annual basis, and output from the tool will inform funding priorities. This report records the authors' efforts to develop an initial prototype decision-support tool during a July 21-25 2008 workshop at the National Conservation Training Center, in Shepherdstown, West Virginia. While the scope of the endeavor described herein technically includes only American shad conservation (defined as management, restoration, and protection of self-sustaining and imperiled species populations) within the Northeast Region, it will be linked to conservation decisions elsewhere in the shad's range, and actions should complement and build on conservation efforts undertaken by other Service programs and other agencies and organizations.

Background

Legal, regulatory, and political context

The American shad budget allocation strategy will become part of a multi-faceted strategic plan for the Northeast Region Fisheries program. The Fisheries Program, under the authority of federal laws, executive orders, legislation, rules, regulations, compacts, treaties, Memoranda of

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Understanding, and other authorities, works in partnership with the Northeast states, District of Columbia, and tribes to maintain, restore and recover aquatic habitats and species. The Program is a member of several interstate and international partnerships with commitments to produce fish for restoration and recovery programs, facilitate or implement habitat restoration, and provide technical assistance. State partners expect that the Program will continue to support projects that are important to them. In addition, public interest in American shad is high because of its commercial and recreational importance.

Ecological context

American shad are undergoing a coast-wide population decline, although status varies among the different river-specific populations. Conservation actions must address the causes of this decline, including overfishing, pollution (from aluminum and other metals), and habitat loss. Threats to habitat include dams and other physical obstructions, water withdrawals, thermal and toxic discharges, channelization and dredging, and land use (farming, logging and urbanization). Additionally, global climate change is an ecological reality that affects how the Program should allocate its resources.

Decision Structure

We developed a decision structure, including objectives (the values to be realized through conservation), alternative actions (the set of potential conservation actions that could be taken), and a predictive model, which predicts the outcome, for each action, with respect to each of the conservation objectives.

Objectives

Four conservation objectives were identified during the prototyping process:

1. Maintain or restore abundant shad populations over the long-term and throughout the Region)
2. Maintain public benefits of American shad (economic benefits, use and appreciation, educational opportunities)
3. Maintain or restore ecosystem function (biological, chemical, and physical integrity of the system)
4. Meet tribal trust responsibilities.

We then determined a measurable attribute for each of these four objectives:

1. Population objective: population size for each river range-wide
2. Public benefit: dollars per year (economic), number of anglers per year (use and appreciation), and number of visitor contacts per year (education)
3. Ecosystem function: percent of historical habitat opened multiplied by percent of population goal met.
4. Tribal trust responsibility: percent of technical assistance requests addressed.

We initially focused on objectives 1 and 3 (population and ecosystem function objectives) for reasons described below. We conducted an expert elicitation exercise with a subset of the team members (WN, BA, KF-A, JM, LM, MO, and PP) to determine how these two objectives should be weighted (i.e., their relative importance). To do this, we asked each expert to conduct a

thought experiment in which they imagined an action that held the greatest possible benefits for shad populations but no ecosystem function benefits, as well as an action that held no benefits for shad populations, but substantial ecosystem function benefits. We then asked each expert to weight the relative desirability of these actions, using the swing weighting technique described by Goodwin and Wright (2004). The result of the exercise was that the team members weighted the shad population and ecosystem function objectives equally.

Constraints

The group identified several constraints on the decision-making process. The most obvious constraint identified was the total budget available for shad conservation in the Northeast Region. In addition, the team decided that the geographic distribution of conservation activities is important: activities must be distributed among the six coastal subregions in the Northeast Region (Gulf of Maine, Connecticut River/Long Island Sound, Hudson River, Delaware River, Chesapeake Bay, and Roanoke-Tar-Nuese), with at least some money distributed to shad conservation in each of these subregions.

Alternative actions

For the initial rapid prototype, we chose to focus on 4 categories of on-the-ground actions that are commonly funded in the Northeast Region.

1. Fish stocking (involves maintenance of hatchery infrastructure and fish culture).
2. Fish trap and transport (involves capturing fish and moving via truck around impassable dams).
3. Fish passage (involves establishment of fish passage mechanisms to allow passage around dams).
4. Dam removal.

Specific conservation activities in each of these categories are identified every year by managers throughout the Region. As an illustrative example, we selected a set of 12 activities that had been identified as candidates for funding through a database called the Fisheries Operations Needs System (FONS); again, these activities were applications of the actions identified above in various locations throughout the Region (e.g., fish stocking on the Charles River in the Gulf of Maine subregion).

Alternative conservation actions are specified, in this prototype, by identifying all possible combinations of these specific conservation activities; we refer to these combinations of activities as portfolios. For example, a portfolio might include fish stocking on the Charles River in the Gulf of Maine subregion, trap and transport on the Connecticut River in the Connecticut River/Long Island subregion, and so on.

Predictive model

To determine where to focus modeling efforts for our first prototype, we developed an influence diagram; this diagram includes one additional action (habitat enhancement) that was not considered in this initial prototype, but will likely be of interest in the future (Figure 1). The influence diagram led us to the insight that the American shad population provides part of the necessary basis for achieving all of the other objectives. However, the team believed that it was

critical to recognize that the shad population objective and the ecosystem function objective were not perfectly correlated (i.e., some actions would benefit one of these objectives more than the other). Therefore, we focused our initial efforts on predicting the effects of alternative actions on the American shad population and ecosystem function. We did not attempt to model the remaining two objectives (tribal trust responsibility and public benefit) for this initial prototype, as we believed they were closely related to the population objective.

Our initial prototype model was based on qualitative professional judgments of the impacts of conservation, obtained through elicitation of expert knowledge represented by the team members. Experts rated the magnitude of effects of each of the specific activities (again, using a set of 12 example activities for illustration purposes) on each of the two objectives on a scale of zero to ten; the average rating across experts was taken as the benefit for a given activity.

The benefit score of a given portfolio (comprised of multiple activities) was calculated as:

$$\sum_i P_i * w_p + E_i * w_E$$

where P_i is the average rating for activity i relative to the population objective, E_i is the average rating for activity i relative to the ecosystem function objective, w_p is the weight placed on the population objective (equal to 0.5) and w_E is the weight placed on the ecosystem function objective (equal to 0.5).

The other necessary piece of information was the total cost of a given portfolio, necessary to ensure that this cost did not exceed the total available budget. This was the summed cost of each activity in the portfolio, where the cost was determined based on projections made by managers entering the project into the FONS database.

Decision Analysis

Optimization by inspection was used to identify the portfolio of activities that would yield the greatest benefit (as described above) while complying with the identified constraints (i.e., staying within budget, and funding at least one activity in each of the 6 subregions). In our illustrative example, the total identified budget was \$350,000. The necessary computations were performed in the R programming environment (versions 2.5.1 2007). Given 12 different projects in our provisional suite of activities, it was possible to construct 4095 different portfolios. However, only 169 of these portfolios met the constraints (under budget and with at least one activity in each subregion). Given these 169 portfolios, we propose that the optimal portfolio is the portfolio with the highest benefit score.

In Figure 2 we present a graphical depiction of the cost and benefits of each of the 169 portfolios that met the decision constraints. Three of the 169 portfolios had the greatest benefit score of 23.5 (2 of these portfolios had exactly the same cost, so only 2 points appear at the top of Figure 2. Given exactly the same benefit, presumably one would choose the cheaper portfolio. In our example, this portfolio, with a total cost of \$295,833, involved 9 of the 12 proposed activities. It

is possible to see also, from Figure 2, the efficiency frontier. This frontier is described by the set of projects that are maximally beneficial for a given cost, and those points that are cheapest for a given benefit). The leftmost points for a given benefit and the topmost points for a given cost constitute the efficiency frontier.

Uncertainty

The prototype decision framework, which relied on qualitative modeling to predict the impacts of conservation activities on populations, did not address uncertainty. However, a critical form of uncertainty that affects this prototype is the uncertainty underlying the expert judgments that were used in the qualitative modeling.

The team did not use a quantitative population model because the uncertainties were daunting. First, the team was not able to identify river-specific population targets over specified spatial distributions. Existing shad population targets vary in their reliability and units of expression, and many rivers do not have targets. This constitutes uncertainty in the objectives, rather than in the model predictions

Another uncertainty relevant to a quantitative population model is lack of information on demographic rates in shad populations. There is available information on survival rates for certain life stages of cultured American shad in some areas, but survival rates for natural populations, intermediate life stages and other geographic areas are not available. Finally, there is substantial uncertainty about the effects of identified actions on objectives.

Regardless of the form of uncertainty, the issue can be addressed through sensitivity analysis. To do this, one would vary values of parameters across likely ranges, rerun the optimization, and evaluate how changing the values affects the decision. In some cases, substantial uncertainty in a particular parameter may not greatly affect the decision, while in other cases, even relatively minor uncertainties can be critical to decision-making. This kind of analysis can provide insights into the types of research and monitoring activities that should be undertaken to reduce critical uncertainties.

One advantage of the structure of this decision problem is that budgeting decisions are made repeatedly. As a result, an adaptive process with appropriate monitoring can be used to reduce uncertainty and improve decision making over time.

Discussion

Prototyping process

The idea behind rapid prototyping is to include all elements of a structured decision, but keep them very simple. By going through the decision process at a simple level first, one can gain insights into the primary elements of the decision that will be helpful as more details are incorporated. One of the insights gained by our team was the need to develop a quantitative population model that is complex enough to analyze the consequences of actions.

Population Model

For our first prototype, our team developed and applied a simple quantitative population model to evaluate the consequences of our proposed activities against our objectives. As we were developing the model, team members became concerned about the lack of availability of quantitative information. A related concern was that other forums (e.g. Atlantic States Marine Fisheries Commission) use technical teams to develop and apply population models for American shad, and developing a model outside of that context may create problems with partners. Because of the concerns around the population model, for this prototype we relied on a qualitative model to evaluate consequences of activities. However, our team believes that we still need to pursue development of a quantitative population model because it could provide specific predictions of the success of our activities that could be tested. It could be revised as a result of these tests or in light of new information from other sources, and would provide greater transparency to partners. Our development and use of a population model would need to take place in the appropriate forum and be peer-reviewed. Our challenge is to find a level of resolution that will help us make predictions about the effects of our activities.

Recommendations

We believe that the Northeast Region Fisheries Program can use the structured decision making process for five-year planning and annual allocations. To do this, the program needs to revisit and expand upon the key steps of Structured Decision-Making, with full participation by the relevant program managers and technical staff. The program may wish to consider including key partners in the effort.

The following steps will be necessary:

- Confirm or redefine the existing problem statement. Identify externally-imposed constraints. Re-consider whether geographic distribution of program activities represents a constraint. Additional constraints that must be dealt with in subsequent developments are the various dedicated cost structures that must be followed within the budget, as well as the human capital objectives.
- Confirm, modify, add to or delete objectives. Consider objectives that were not included in the prototype, such as a partnership objective or workforce objective. Clarify which are means objectives and which are fundamental objectives, and define the relative importance of objectives. Define measurable attributes for each objective.
- Revisit development of alternatives. If alternatives are to be based on specific activities, as in the prototype, identify alternatives for all categories of actions in combination with appropriate ecosystems. Additional categories of actions that are commonly funded in the Northeast Region, but were not fully addressed in the prototyping process, included stream habitat restoration, technical assistance, cooperative agreements and grants, policy board (e.g. Atlantic States Marine Fisheries Commission), and monitoring and assessment (including applied research and development).
- Consider developing strategic portfolios of alternatives.
- Develop a quantitative American shad population model, incorporating existing data. Further develop qualitative approaches where quantitative information is not available. Aim for a requisite model, just complicated enough to make the decision at hand.
- Explore other approaches to decision analysis presented by other groups during the July 2008 workshop. Many insights gained by other groups could be applied to this problem. For instance,

the problem could be broken down into multiple levels: local (office/hatchery), ecosystem, and Northeast Region.

- Develop a monitoring program to inform the decision framework so that it can be improved over time.

Literature Cited

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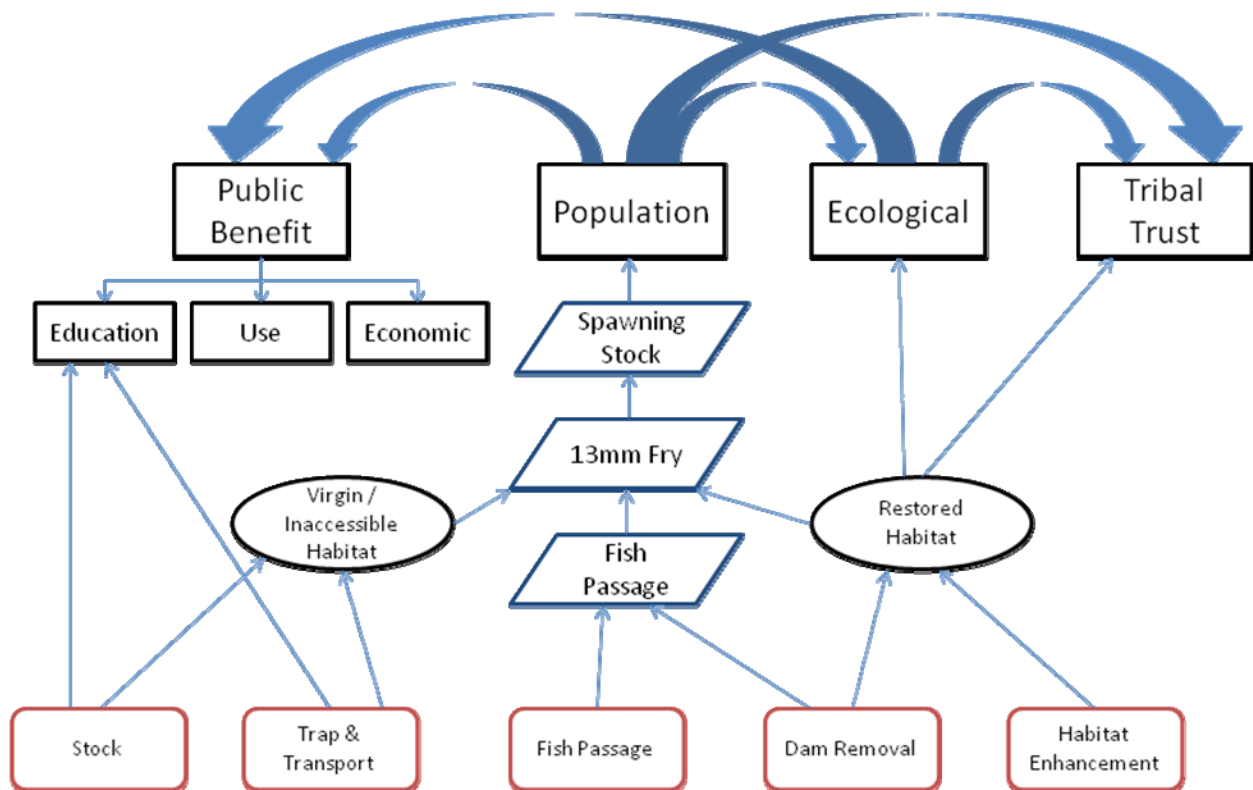


Figure 1. An influence diagram illustrating the links between potential conservation actions taken by the US Fish and Wildlife Service Region 5 Fisheries Program for American shad populations and habitat (bottom row) and Program conservation objectives (top row) related to American shad conservation.

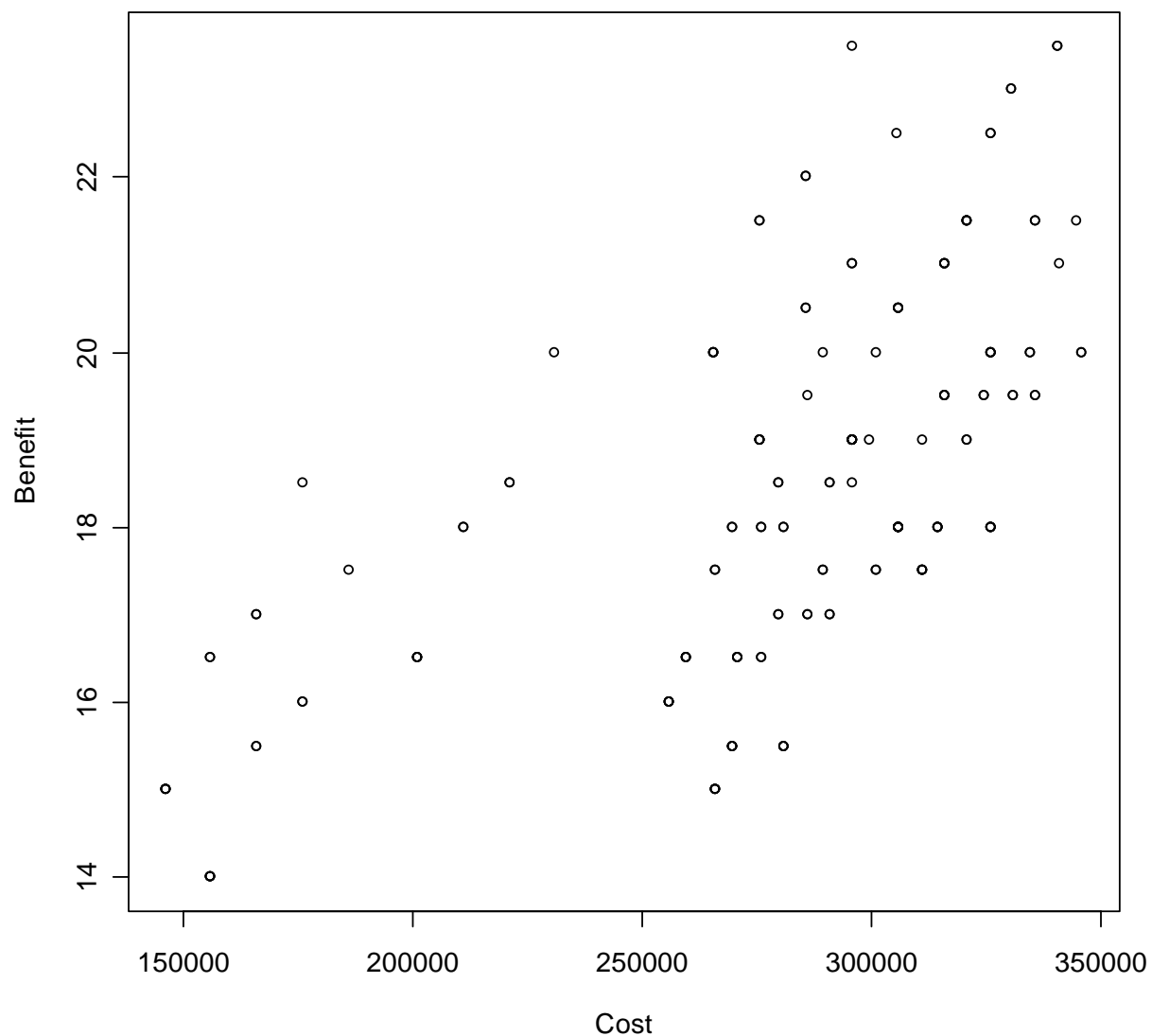


Figure 2. Graphical depiction of the cost (in dollars) and benefits (constructed scale, higher numbers indicate greater benefit) of each of 169 portfolios of actions identified in the prototype decision support framework for American shad conservation.