Comparing Alternative Management Approaches

We considered the conservation benefits and management costs of each approach on fundamental population objectives (Figure 6) for fishes at the 12-digit HUC level (Table 5, Figure 2) and on fundamental population objectives for mussels at the stream reach level (Table 6, Figure 3). A tradeoff analysis compared alternative approaches based on the simple multi-attribute rating technique (Goodwin and Wright 2004). Performance measures (i.e., measurable attributes) were projected over a 20-year period, standardized, and combined to result in a final score for each approach. Each performance measure is associated with a fundamental objective. Decision makers and stakeholders can give different levels of importance or value to each objective. To account for this relative importance, each performance measure was weighted when it was combined into a final score.

Table 5. Conservation benefits for imperiled fishes projected over a 20-year period to compare alternative management approaches. The management emphasis approaches were status quo, habitat, and population. Conservation benefits were measured by trend in abundance on a categorical scale (declining, stable, or increasing) and number of 12-digit HUCs occupied. The range for trend in abundance is –1 for high decline to +1 for high increase.

	Trend in Abundance within UTRB: declining = -1, stable = 0, and increasing = +1				Number of 12-digit HUCs Occupied			
Common Name	**Current**	**Status Quo**	**Habitat Emphasis**	**Population Emphasis**	**Current**	**Status Quo**	**Habitat Emphasis**	**Population Emphasis**
Chucky madtom	-1	-1	-1	-1	1	1	1	1
Citico darter	0	1	0	1	2	3	3	3
Duskytail darter	0	-0.5	0	1	2	1	2	3
Laurel dace	-1	-1	-0.5	0	4	2	3	4
Marbled darter	-1	-0.5	0	0.5	4	4	4	5
Pygmy madtom	0	0	0	0.5	1	1	1	3
Sicklefin redhorse	0	0.5	0.5	0.5	22	22	22	22
Slender chub	-1	-1	-1	-1	1	0	0	1
Smoky madtom	1	1	0	1	2	3	3	4
Snail darter	1	1	1	1	21	21	21	21
Spotfin chub	0	0	0.5	1	26	26	26	29
Yellowfin madtom	1	1	0.5	1	10	10	10	11
Average	-0.08	0.04	0.00	0.46	8.00	7.83	8.00	8.92

Table 6. Conservation benefits for imperiled mussels projected over a 20-year period to compare alternative management approaches. The management emphasis approaches were status quo, habitat, and population. Conservation benefits were measured by trend in abundance on a categorical scale (declining, stable, or increasing) and number of significant stream reaches occupied. The range for trend in abundance is –1 for high decline to +1 for high increase.

	Trend in Abundance within UTRB: declining = -1, stable = 0, and increasing = +1				**Number of Significant Stream Reaches Occupied**			
Common Name	**Current**	**Status Quo**	**Habitat Emphasis**	**Population Emphasis**	**Current**	**Status Quo**	**Habitat Emphasis**	**Population Emphasis**
Alabama lampmussel	0	-0.5	0	0.5	1	1	1	1
Appalachian elktoe	-1	-1	-1	-0.5	4	4	4	4
Appalachian monkeyface	-1	-1	-1	-0.5	4	2	2	4
Birdwing pearlymussel	0.5	0.5	0.5	1	7	7	6	10
Cracking pearlymussel	0	0	0	0.5	3	3	3	10
Cumberland bean	0	0	0.5	1	1	1	1	1
Cumberland monkeyface	-1	-1	-0.5	0.5	2	2	2	2
Cumberlandian combshell	0.5	0.5	0	1	6	6	6	10
Dromedary pearlymussel	0	0	0	1	5	5	5	10
Fanshell	0	0	0	1	3	3	3	9
Finerayed pigtoe	0.5	0.5	1	1	7	4	4	10
Fluted kidneyshell	0.5	0.5	1	1	11	10	11	10
Golden riffleshell	-1	-1	-1	0	1	0	0	1
Littlewing pearlymussel	-1	-1	-1	-0.5	2	0	0	6
Oyster mussel	0.5	.0.5	0	1	7	7	7	10
Pink mucket	-1	0	-1	1	1	2	2	10
Purple bean	0	0	0.5	1	8	8	8	12
Rough pigtoe	0.5	0.5	0.5	1	1	1	1	10
Rough rabbitsfoot	0	0	0.5	1	8	6	6	10
Sheepnose	0.5	0.5	0.5	1	7	7	7	10
Shiny pigtoe	0.5	0.5	1	1	8	5	5	10
Slabside pearlymussel	-1	-1	-0.5	0	11	5	5	10
Snuffbox	0	0	0	1	5	5	5	10
Spectaclecase	-1	-1	-1	-1	4	4	4	4
Average	-0.17	-0.13	-0.04	0.58	4.91	4.09	4.09	7.83

Projecting the consequences of each approach

Conservation benefits and management costs for each approach were projected over a 20-year period (Tables 5–8). To project conservation benefits and management costs, team members with knowledge and expertise for each particular subject were identified. We used common practices to elicit expert judgment for conservation benefits and management costs (Drescher et al. 2013). Species level consequences, or trends in abundance and occupancy of habitat units (12-digit HUCs for fishes and important stream reaches for mussels; Tables 5 and 6), and habitat quality (Table 7) that would result from approach implementation were projected by species experts[3]. Expected risks for decline in genetic diversity as a result of approach implementation were elicited from a population geneticist[4] (Table 9). Costs (staffing level and operational cost) for individual management actions were assessed under status quo management (Appendix 5), and then the relative effort among alternative approaches (Table 4) was used to estimate cost under each approach (Table 8). Cost estimates were generated for the three approaches:

- $4,856,000 for status quo management,
- $5,423,000 for habitat management, and
- $4,729,000 for population management.

[3] Species experts for fishes were Bob Butler, Brian Evans, and Peggy Shute. Species experts for mussels were Stephanie Chance, Catherine Gatenby, Shane Hanlon, and Jess Jones.
[4] Meredith Bartron, USFWS.

Table 7. Predicted habitat quality performance measure for current conditions and alternative management approaches. Characteristics of quality aquatic habitat for imperiled species include free-flowing streams and suitable substrate, temperature, water quality, and water quantity. One point was awarded for each characteristic present within a sub-basin, for a maximum of 5 points. This measure represents general habitat suitability and might not reflect species specific requirements. The average from this table is used in the consequence table (Table 9).

	Predicted Habitat Quality (maximum of 5 points)			
Sub-basin (8-digit HUC)	**Current Condition**	**Status Quo Management**	**Habitat Management Emphasis**	**Population Management Emphasis**
Sequatchie	3.0	3.0	4.0	3.0
Hiwassee	2.0	2.0	3.0	2.0
Middle Tennessee-Chickamauga	1.0	0.5	2.0	0.5
Emory	3.0	3.0	3.8	3.0
Lower Little Tennessee	4.0	4.0	4.5	4.0
Upper Clinch	4.0	4.0	4.5	4.0
North Fork Holston	3.5	3.5	4.0	3.5
Powell	3.5	3.5	4.0	3.5
Holston	2.5	2.5	3.0	2.5
Nolichucky	2.5	2.5	3.0	2.5
Upper Little Tennessee	4.0	4.0	4.0	4.0
Watts Bar Lake	1.0	0.5	1.0	0.0
Average	2.82	2.73	3.34	2.68

Table 8. Annual cost (in $1,000s) to implement actions under the status quo management approach (Appendix 5) and cost based on relative effort to implement alternative management approaches (Table 4).

		Alternative Approaches ($1,000)	
Type of Management Action	**Status Quo Management**	**Habitat Management Emphasis**	**Population Management Emphasis**
Population Management	1,973	1,722	2,578
Habitat Management	1,632	2,176	563
Monitoring/Research	1,125	1,312	1,424
Communication and Partnerships	71	157	108
Agency Operations	56	56	56
Total	4,856	5,423	4,729

Table 9. Consequence table with performance measures to compare alternative management approaches.

			Alternative Approaches		
Objective	**Sub-objective (footnoted performance measures)**	**Direction**	**Status Quo Management**	**Habitat Management Emphasis**	**Population Management Emphasis**
Species persistence and viability	Fish abundance trend[1]	Maximize	0.04	0.00	0.46
	Fish distribution[2]	Maximize	7.83	8.00	8.92
	Mussel abundance trend[3]	Maximize	-0.13	-0.04	0.58
	Mussel distribution[4]	Maximize	4.09	4.09	7.83
	Genetic diversity[5]	Maximize	-0.17	-0.17	0.52
	Habitat quality[6]	Maximize	2.73	3.34	2.68
Operating costs	Staff[7]	Minimize	9.5	11.5	11.5
	Management costs[8]	Minimize	4.8	5.4	4.7

[1]Average trend in abundance at UTRB level: declining, stable, improving (–1, 0, 1); averaged across species (Table 5).
[2]Average number of 12-digit HUCs occupied per species: averaged across species (Table 5).
[3]Average trend in abundance at UTRB level: declining, stable, improving (–1, 0, 1); averaged across species (Table 6).
[4]Average numbers of reaches occupied per species: averaged across species (Table 6).
[5]Risk to loss of genetic diversity: (–1 = no removal of threats and no add populations, 0 = addressing threats to existing populations, 1 = moving individuals using BMPs, 2 = both addressing threats and individuals using BMPs).
[6]Average habitat score (suitable habitat components: free-flowing and suitable substrate, temperature, water quality, and water quantity); averaged across 8-digit HUCs (Table 7).
[7]Staffing level (full-time equivalent) within UTRB.
[8]Millions of dollars per year (Table 8).

The performance measure for trend in abundance over a 20-year period was categorical (–1 = high decline, 0 = stability, +1 = high increase). The trend in abundance was projected for current conditions, and what would be expected as a consequence of implementing population management emphasis (primary focus is restoration and conservation/protection of populations), habitat management emphasis (primary focus is restoration and conservation/protection of habitat), and status quo management approaches (Tables 5 and 6). Trend in abundance was projected for each species, and the average across species was used in the consequence table (Table 9).

The performance measure for distribution was the number of habitat units occupied at the end of a 20-year period. Distribution was projected for current conditions, and what would be expected as a consequence of implementing population management emphasis, habitat management emphasis, or status quo management approaches (Tables 5 and 6). The number of occupied habitat units was projected for each species, and the average across species was used in the consequence table (Table 9).

The performance measure for habitat quality was based on the presence of suitable habitat components at the end of a 20-year period. The habitat components were free-flowing water, suitable substrate, suitable temperature, suitable water quality, and suitable water quantity. Habitat quality was projected at the 8-digit HUC level (Table 7), and the average across habitat units was used in the consequence table for each approach (Table 9).

The performance measure for risk for decline in genetic diversity over a 20-year period was related to removal of threats and expanding populations (–1 = no removal of threats and no additional populations, 0 = addressing threats to existing populations, 1 = moving individuals using BMPs, 2 = both addressing threats and individuals using BMPs). Risk for decline in genetic diversity for all species combined was projected for what would be expected as a consequence of implementing population management emphasis, habitat management emphasis, and status quo management approaches (Table 9).

Trade-off and sensitivity analyses

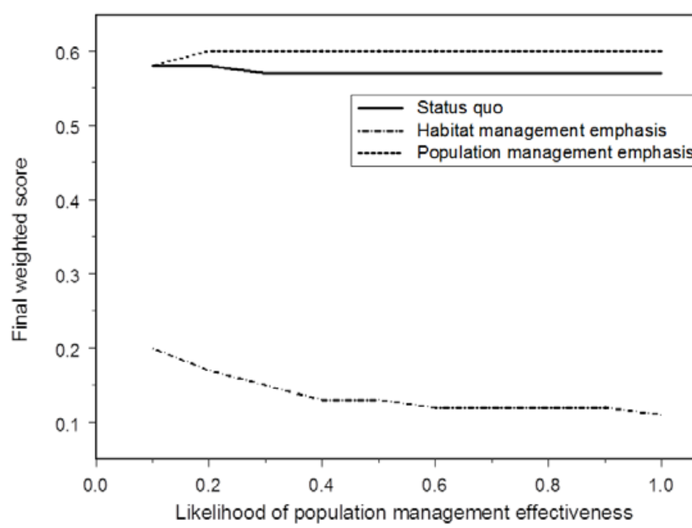
Conservation involves unavoidable trade-offs between achieving conservation benefits and minimizing management costs (Bottrill et al. 2008, Joseph et al. 2009). We evaluated those trade-offs in the comparison among management approaches (Table 9). To conduct the tradeoff analysis, the projected conservation benefits and management costs for each management approach were placed in a consequence table (Table 9) and followed the simple multi-attribute rating technique (Goodwin and Wright 2004). The first step is to normalize the raw projected performance measures (i.e., rows in Table 9), followed by taking a weighted average within each alternative management approach (i.e., columns in Table 9). The weights used in the weighted average are assigned to each fundamental objective (Figure 6). The weighted average of normalized measures becomes the final score and the basis for comparison. The optimal approach is the one with the highest final score (Appendix 7).

Weights assigned to the fundamental objectives reflect the relative importance of the various objectives, which can (and often does) vary among stakeholders. Specific weights for the objectives were not elicited from any specific stakeholders. Rather, a sensitivity analysis was conducted to determine the optimal approach for a wide range of weightings that assigned: (1) relative weight to species persistence/viability versus costs and (2) relative weight to abundance/distribution versus genetic diversity/habitat quality (Appendix 7). The purpose of the sensitivity analysis was to determine if the optimal approach was robust relative to how stakeholders might vary in how they place importance on the conservation objectives.

The population management emphasis approach was found to be optimal across a wide range of objective weightings and by extension, to variation in stakeholder values. Only when minimizing cost (labor and operations) was highly important (i.e., weight on species persistence and viability is <40% of total weight) did the status quo management approach become optimal (Appendix 7).

Uncertainty can obscure the identification of optimal management (Runge et al. 2011). One important source of uncertainty is management effectiveness. To examine the sensitivity of identifying the optimal approach to management effectiveness, the trade-off analysis (described above) was repeated for a range in the likelihood of management effectiveness. The likelihood of management effectiveness ranged from 0.1 to 1.0 (e.g., from a 10% chance to a 100% chance of management achieving the expected conservation benefit). As the likelihood declined from fully effective (i.e., 1.0) the population management emphasis approach remained optimal, and its final weighted score converged with that of status quo management only after management was deemed highly ineffective (i.e., likelihood <0.2) (Figure 7). Unless the likelihood of population management effectiveness drops below 0.1, the population management emphasis approach remained optimal.

Figure 7. Sensitivity analysis to examine how uncertainty about management effectiveness might alter selection of optimal approach. The final weighted score for each approach is shown across a range in likelihood of population management effectiveness. The optimal approach is indicated by the line with the highest final weighted score given management effectiveness. The particular scenario represents a boundary condition with 40% of total objective weight on maximizing persistence/viability and 60% on minimizing cost and with half of the weight on persistence allocated to abundance and distribution and half the weight on genetic diversity and habitat quality.



The approach that emphasized population management was found to be optimal for all other scenarios as long as the weight on maximizing persistence was at least 40% of total objective weighting relative to minimizing cost. The particular scenario shown in Figure 7 represents a boundary condition with 40% of total objective weight on maximizing persistence/viability and 60% on minimizing cost and with half of the weight on persistence allocated to abundance and distribution and half of the weight on genetic diversity and habitat quality. For all other scenarios where objective weight on maximizing persistence exceeded 0.4 and likelihood of management effectiveness exceeded 0.1, the final weighted score for population management emphasis exceeded that of the other two approaches. Therefore, the selection of population management emphasis as an optimal management approach was found to be robust to relative uncertainty in management effectiveness.

Species and Location Prioritization

Because conservation benefit is not likely to be achieved equally among all species and locations under the population management emphasis approach, species and locations were prioritized. Based on a trade-off between expected conservation benefit and management costs and while accounting for degree of imperilment, imperiled fishes and mussels were prioritized for management (Table 10 and 11). To prioritize locations for habitat management emphasis actions, richness of imperiled species and feasibility of management implementation were used as the driving variables (Table 12). These prioritizations are intended to allow for flexibility in decisions regarding specific conservation projects.

For species prioritization, the degree of imperilment was based on a qualitative assessment of rangewide extinction risk over the next 20 years (Appendices 2 and 3). Expected conservation benefit, the maximum gain in abundance trend and distribution over 20 years relative to the current condition, was calculated by the difference between current status and what would be expected to result from applying the population emphasis approach (Tables 5 and 6). For distribution, the numerical difference between current status and the population emphasis was divided by current status to account for species-specific distribution (Table 10 and 11). Management cost was on a categorical scale based on a summary of cost for management actions (Appendix 5).

Species prioritization was carried out in steps. The first priority score, which was based on imperilment and conservation benefit, was derived as follows:

- If gains in both abundance trend and distribution are expected, then assign priority 1
- If a gain in either abundance trend or distribution is expected,
    - and degree of imperilment is high, then assign priority 1
    - but degree of imperilment is not high, then assign priority 2
- If no gain in abundance trend and distribution is expected, then assign priority 3

The second priority score reflected the categorical scale for management cost. Lastly, a final priority was calculated by multiplying the first and second priority scores (Tables 10 and 11).