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# Evaluating a science-based decision support tool used to prioritize brook charr conservation project proposals in the eastern United States

**Abigail J. Lynch · William W. Taylor**

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**Abstract** Declines in brook charr (*Salvelinus fontinalis*) throughout its historic eastern United States of America (U.S.) range prompted the formation of the Eastern Brook Trout [Charr] Joint Venture (Joint Venture) whose mandate is to restore these charr by working cooperatively at a range-wide, regional-scale. Joint Venture habitat projects in the U.S. are initiated by local community-based organizations, assisted by fisheries management institutions, and funded through the U.S. Fish and Wildlife Service. In order to assist with ranking these community-based proposals for available funding, the Joint Venture designed a quantitative scoring method as a decision support tool that addressed range-wide threats that were documented to limit brook charr production. These threats include habitat modification (e.g., dams, urbanization, and agricultural landuse) and interactions with antagonistic non-native species [i.e., brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*)]. This article evaluated the prioritization method used by comparing the quantitative rankings of the proposals with the final reports for 12 completed projects using paired $t$ tests for unequal sample sizes and variance. Two of the 12 comparisons revealed statistically significant differences ($P < 0.05$) between project proposals and final reports; namely, the scoring criteria for the proposals did not accurately reflect the outcome of these projects in relation to brook charr management. Large inter-quartile ranges between reviewer scores were common, indicating that the quantitative scoring method includes qualitative elements. In addition to the science-based criteria, subjective value judgments by individual reviewers have factored into the Joint Venture's decision making process. By evaluating the decision support tool, this analysis aims to assist the Joint Venture in structuring its approach to conservation and rehabilitation of brook charr populations in the eastern U.S. To better improve the Joint Venture's ability to address brook charr management on a regional level, we recommend that future proposal prioritization scoring criteria provide more explicit guidance for accurate scoring, separate scoring methods for policy and assessment work, and a weighting factor for larger than sub-watershed projects and for scoring criteria for which information is unknown.

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A. J. Lynch (✉) · W. W. Taylor
Center for Systems Integration and Sustainability, Department of Fisheries and Wildlife, Michigan State University, 1405 S. Harrison Rd, Suite 115 Manly Miles Bldg, East Lansing, MI 48823-5243, USA
e-mail: Lynchabi@msu.edu

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## Introduction

Brook charr (*Salvelinus fontinalis* Mitchill 1814) are an ecologically, economically, and culturally important species native to eastern North America. Over the past 200 years, these charr have been exposed to many anthropogenic perturbations which have impacted their physical, chemical, and biological environments and led to severe declines in their abundance and their productivity, including localized extirpations of some populations (Marschall & Crowder, 1996; see Fig. 1). Changes in land use practices resulting in deterioration of water quality and impaired temperature regimes, increases in sedimentation, introductions of non-native salmonids [principally brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*)], and alteration of in-stream habitats by dams and stream channelization have all contributed to the widespread decline of brook charr in the eastern U.S. (see Hudy et al., 2008).

Historically, rehabilitation efforts have typically focused on stocking of hatchery-reared brook charr and site-specific habitat (i.e., stream segment) restoration (Bonney, 2007). However, these efforts were largely unsuccessful in halting the loss of brook charr throughout their eastern U.S. range (Guffey et al., 1998). Fortunately, while many of these brook charr watersheds have been significantly impaired (Fig. 1), these systems have not been destroyed beyond repair; they need more effective, holistic restoration strategies which address regional threats to brook charr, such as those posed by agricultural practices, climate change, and urbanization. The Eastern Brook Trout [Charr] Joint Venture (Joint Venture) was recently created as one such approach. This Joint Venture is a regional management strategy facilitated by the U.S. National Fish Habitat Action Plan, which was formed to improve upon site-based historical management practices (EBTJV, 2008). The Joint Venture goals are to address the causes of brook charr decline across their eastern U.S. range with a regional Conservation Strategy to direct personnel and financial resources

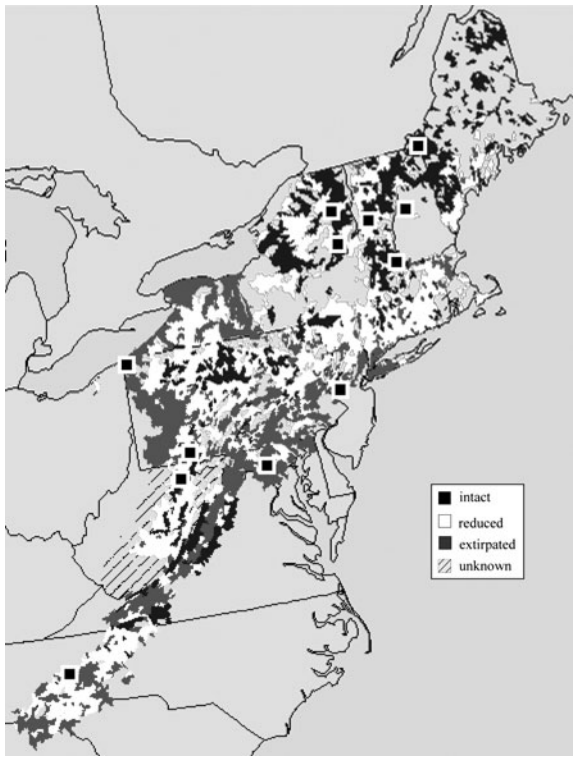


**Fig. 1** Distribution of brook charr (*Salvelinus fontinalis*) status classification of sub-watersheds throughout the species's eastern U.S. range from Hudy et al. (2008) and approximate locations of analysis projects. *Intact*: over 90% of habitat supporting reproducing brook charr populations; *Reduced*: between 50 and 90% of habitat supporting reproducing brook charr populations; *Extirpated*: less than 50% of habitat supporting reproducing brook charr populations. Distribution reproducible at: http://www.farmapper.psu.edu/easternbrooktrout/

across federal, state, and local jurisdictions (EBTJV, 2008). At its core, it is a collaborative, multi-organization partnership of state and federal agencies, nongovernmental organizations, and academic institutions. The Joint Venture seeks to produce strategies and tactics for rehabilitation and conservation of brook charr that are effective on a range-wide scale. These strategies are used to select community-based projects, funded through the U.S. Fish and Wildlife Service, and implemented by local jurisdictions.

In order to help rank project proposals for funding using the goals of the Joint Venture Conservation Strategy, a quantitative scoring method was developed by the Joint Venture steering committee as a decision support tool. Decision support systems can be powerful tools to assist decision-makers, including

fisheries and aquatic managers, with complex decision making and problem solving (Shim et al., 2002). These tools incorporate scientific and technical knowledge into a form that can have practical use to a diverse, often non-scientific, audience who is tasked with allocating scarce resources for projects by prioritization (Lannan, 1993). These tools are particularly useful when dealing with ecosystem management problems. These decisions are generally best dealt with at larger spatial scales, over longer time frames, and must be socially and politically acceptable to a wide range of constituents, economically feasible, and ecologically sustainable (Rauscher, 1999).

In order to implement science-based decision support for brook charr in the eastern U.S., the Joint Venture used an assessment of brook charr population and habitat status conducted by Hudy et al. (2008) which evaluated the current distribution and status of self-sustaining populations of brook charr in the eastern U.S. at the sub-watershed level (i.e., sixth level hydrologic unit). An understanding of the geographic distribution, population status, and habitat status for a given species is vital because knowing the distribution and production dynamics of fish as related to regional and site-specific habitat relationships is necessary to plan a course of action for their rehabilitation and conservation (Williams et al., 1993).

Hudy et al.'s (2008) evaluation of 63 candidate factors that potentially impact brook charr production determined that five core metrics could be used to define the classifications for predicted extirpated, reduced, or intact brook charr habitat in the eastern U.S. These core metrics were: (1) the sum of mean sulfate ($SO_4$) and nitrate ($NO_3$) deposition; (2) the percentage mixed forested land in the sub-watershed; (3) the sum of sub-watershed lands supporting agricultural uses; (4) the road density in the sub-watershed; and (5) the sum of sub-watershed forested lands. Extirpated sub-watersheds were defined as having less than 50% of habitat supporting reproducing brook charr populations; reduced sub-watersheds were defined as having between 50 and 90% of habitat supporting reproducing brook charr populations; and intact sub-watersheds were defined as having over 90% of habitat supporting reproducing brook charr (Hudy et al., 2008). For each sub-watershed type (i.e., extirpated, reduced, and intact), the Joint Venture developed priority scores for identifying sub-watersheds that were best suited for restoration, enhancement, and protection projects (extirpated, reduced, and intact watersheds, respectively). These priority scores were incorporated into the Joint Venture's quantitative scoring method used to assist with community-based project selection on the basis that they consider each project in the context of its regional contribution to restoration of the brook charr rather than just a site-specific impact for one small population segment. The goal of this study was to evaluate the project prioritization method by comparing the quantitative rankings of proposals with final reports for 12 completed projects to test implementation effectiveness (i.e., proposed vs. realized restoration) for brook charr in the eastern U.S.

## Materials and methods

### Scoring criteria

The Joint Venture scoring criteria for prioritization of community-based proposals are divided into four categories: (I) conservation of sustainable populations, (II) project planning and success, (III) management assets, and (IV) partnerships and project leveraging of other fiscal and personnel resources. In each category, there is a series of questions; the questions are weighted by allotted points compared with the maximum point value, which is determined by the Joint Venture steering committee (see Appendix 1—Supplementary material for scoring sheet).

The Joint Venture has incorporated the resulting sub-watershed assignments from the Hudy et al. (2008) analysis into its ranking methodology for the first category: conservation of sustainable populations. This process enables project leaders to design habitat projects in high priority sub-watersheds and helps reviewers decide which proposals are likely to provide the best outcomes for brook charr in the eastern U.S. given the limited funding and personnel resources available. The other three scoring categories: project planning and success, management assets, and partnerships and project leveraging are also given quantitative metrics, but they are more qualitative in nature (for example, what is the recreational quality of the potential fishery?). Project planning and success addresses watershed-scale planning, considering the primary cause(s) of watershed degradation, the probability of long-term

success of brook charr rehabilitation to self-sustaining, fishable populations, and the inclusion of appropriate ongoing project evaluation. Management assets consider stakeholder interests and support in the Joint Venture, principally the ability of Joint Venture projects to provide public fishing access and education for the local community; thereby building stewardship for brook charr in local communities throughout its eastern U.S. range. Partnerships and project leveraging encourages funding contribution by other funding sources, the involvement of partner groups, and projects led by community-based organizations.

## Reviewers

The Joint Venture steering committee assembles a project review team each year to score project proposals in competition for funding. The review team is composed of members from all partner perspectives: federal government, state governments, non-governmental organizations, and academia. For each of the four scoring categories, the reviewers provide numerical responses to a series of questions and the values are totaled; higher values equate to better scores and thus greater likelihood of funding (see Appendix 1 for scoring sheet). All reviewers are familiar with the Joint Venture and are asked to provide responses based on their prior knowledge and experience, use of the Joint Venture Conservation Strategy, the sub-watershed priority scores, and State Fish and Wildlife Action Plans, which assess the condition of each state's fish and wildlife populations and their habitats, identify problems, and outline actions needed for long-term conservation.

## Analysis of ranking scheme

A modified version of the scoring criteria was applied to project proposals and final reports for 12 completed projects related to brook charr restoration across their eastern U.S. range (Fig. 1). All categories except for partnership and project leveraging were included in the scoring sheet. This category was removed because it was related to funding requirements internal to the U.S. National Fish Habitat Action Plan and did not specifically pertain to the primary focus of our study, the ecological impact of the selected projects on the rehabilitation of brook charr.

The project proposals and final reports were solicited from federal and state governments, non-governmental organizations, and academia. As this was a back-casting analysis, projects were required to relate to brook charr management, but were not specifically designed to address Joint Venture priorities. Additionally, the proposals and reports were not necessarily completed by the same individuals. This methodology ensured that analysis of each project was an independent assessment of the ranking scheme.

Fifty Joint Venture partners were selected to review the project proposals or final reports (for project locations, see Fig. 1). The reviewers were selected to represent the same partners present on Joint Venture project review teams. Of the 50 potential reviewers contacted, 30 completed reviews (60% response rate). Each reviewer was provided with three proposals or three final reports to review, the scoring sheet (Appendix 1), and directions on how to complete the scoring sheet. The reviewers were directed to the Joint Venture Conservation Strategy and the Joint Venture priority scores for guidance on the Joint Venture priorities and then asked to complete the scoring sheet for each project using their knowledge and understanding of the Joint Venture.

The reviewer scores were compared between each proposal and final report using a paired $t$ test for unequal sample sizes and variance (Sokal & Rohlf, 1987). This test compares the difference between two group means, in this case, between proposals and final reports, to zero. If the difference between the two means was statistically significant from zero, the proposals and final reports are scored differently; if the difference was insignificant, the proposals and final reports are scored similarly and the proposal objectives were met with the completion of the project.

The statistical analyses were performed using SAS 9.1.3 (SAS, 2004) with significance set at $P < 0.05$. Additionally, the median, upper, and lower quartiles, and minimum and maximum data values were plotted with boxplots for each project (Fig. 2). This visual analysis provided the spread of project scores which allowed for an evaluation of the variance within the method.

## Results

Scores varied between project proposals and reports with reviews ranging from 5 to 142 (maximum potential score on scoring sheet = 185). Of the 12 comparisons, two were identified as statistically different from one another ($P < 0.05$; Table 1): a population survey in Maryland and a pond reclamation project in New York. In both cases, the project proposals were given significantly higher scores than their final projects (i.e., the proposals more closely aligned with Joint Venture goals than the outcome of the projects). In the case of the survey in Maryland, a large emphasis in the final report was placed on the production of trophy brown trout (*Salmo trutta*) as opposed to rehabilitation of brook charr, their initial focus. With the New York pond reclamation study, the implementation and completion of the project was hindered by staffing reductions, which delayed the development and approval of expected brook charr management plans.

The 10 other comparisons revealed no statistical difference between the proposals as written and the final product as delivered in regards to management of brook charr. As an evaluation of this decision support tool, this result showed the scoring criteria to be an effective indicator of project potential, i.e., only projects likely to be successful at improving brook charr production should be funded by the Joint Venture. It is interesting to note the general trend in project reviews with proposal scores generally rated higher than final report scores. In terms of implications for restoration goals, this highlighted that management expectations exceeded realized outcomes.

One additional observation was the large variance between proposal or report scores for many of the projects. Boxplots reveal the large interquartile ranges, skewness, and outliers with many of the proposal and report score comparisons (Fig. 2). While the scoring is quantitatively based, this indicated that there was still an element of qualitative judgment to the process.

## Discussion

### Regional-based fisheries management

Modeled after North American migratory waterfowl management strategies (EBTJV, 2008), the Joint Venture is one of the first applications of regional-based habitat conservation and management to fisheries and aquatic systems. Migratory waterfowl management was motivated by recognition of decline in waterfowl populations, due in large part, to habitat degradation and the need for large-scale, multi-jurisdictional restoration efforts, particularly "migration corridors" that connected all life stages of these migratory birds (Williams et al., 1999). These interconnections between suitable patches of habitat for each life stage of the various species of waterfowl are particularly important for migratory birds because they are traveling extensive distances and need places to rest, feed, and breed (Noss, 1983). But, for this to be effective, this could only be achieved through the regional cooperation and coordination of management policies and actions among different agencies, jurisdictions, and stakeholders (Petit et al., 1995).

For brook charr, the issues necessitating a regional approach to management are somewhat different. Although brook charr will migrate for a better foraging arena or suitable spawning habitat, and in some cases miles to avoid poor thermal habitats, they are generally not considered migratory in any large-scale sense (Treml-Drake & Taylor, 1996). There are specific large scale threats, however, such as climate change, acidification, agriculture, and urbanization, that cannot be effectively addressed solely by site-specific management. They require management activities at a higher level of governance which prioritize landscape-level actions for rehabilitation efforts (see Liu & Taylor, 2002 for examples). By working at a regional-scale, all sites are not viewed as equally valuable at producing results that will make a difference over the entire eastern U.S. range of brook charr. Prioritization allows the Joint Venture to effectively allocate scarce available resources for the greatest gain across this species range.

### Science-based decision support

Implementation of a science-based decision support tool is particularly important for regional management programs like the Joint Venture because it helps prioritize project proposals to achieve defined conservation goals at a broad scale (Rauscher, 1999). The Joint Venture's evaluation system as currently designed is not perfect; but it can still be helpful if decisions made using it take into account limitations

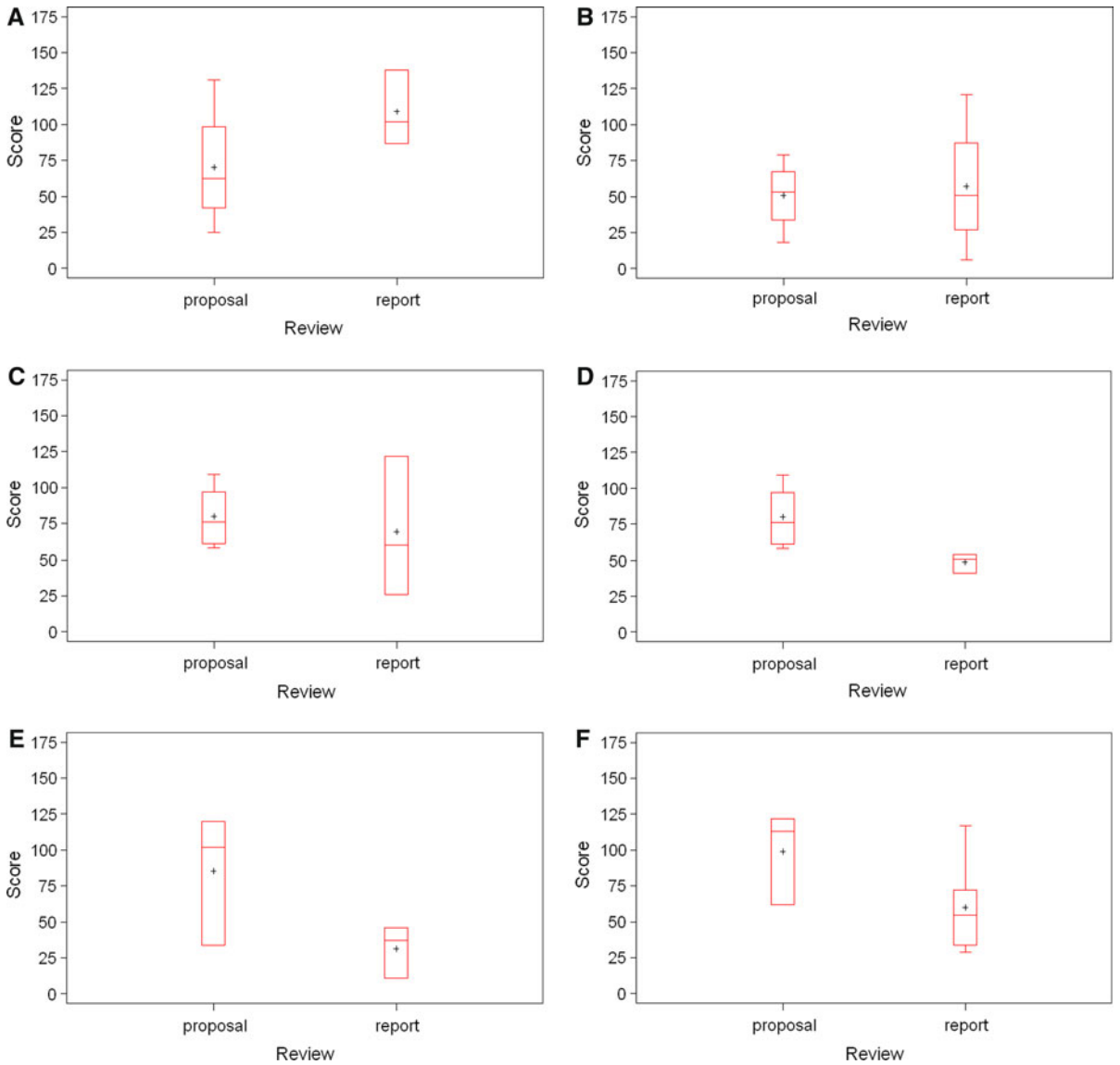


**Fig. 2** Box plots of the median, upper and lower quartiles, and minimum and maximum data values for 12 brook charr (*Salvelinus fontinalis*) conservation projects in the eastern United States, comparing proposal and final report scoring for each project (**A**–**L**)

of a standardized scoring approach (Shim et al., 2002).

While the scoring criteria are, indeed, a quantitative metric, they are subject to qualitative value judgments by both the reviewers, using the scoring sheets, and the Joint Venture steering committee, designing the scoring methodology. Many reviewers indicated that the weighting factors on some criteria did not accurately reflect the full value of the projects because they did not consider policy components or monitoring. Similarly, some questions asked reviewers to score projects on a gradient from low to high. This style of question, in particular, invites a value judgment upon the part of the reviewer and thus provides for a relatively subjective measure. Inherently, reviewers will interpret the question or value differently without explicit guidance. A project can, for example, score a seven out of 10 from a more lenient reviewer and a three out of 10 from a more critical reviewer for the same question, leading to confusion as to how to rank the project overall in relation to the other worthy proposals.

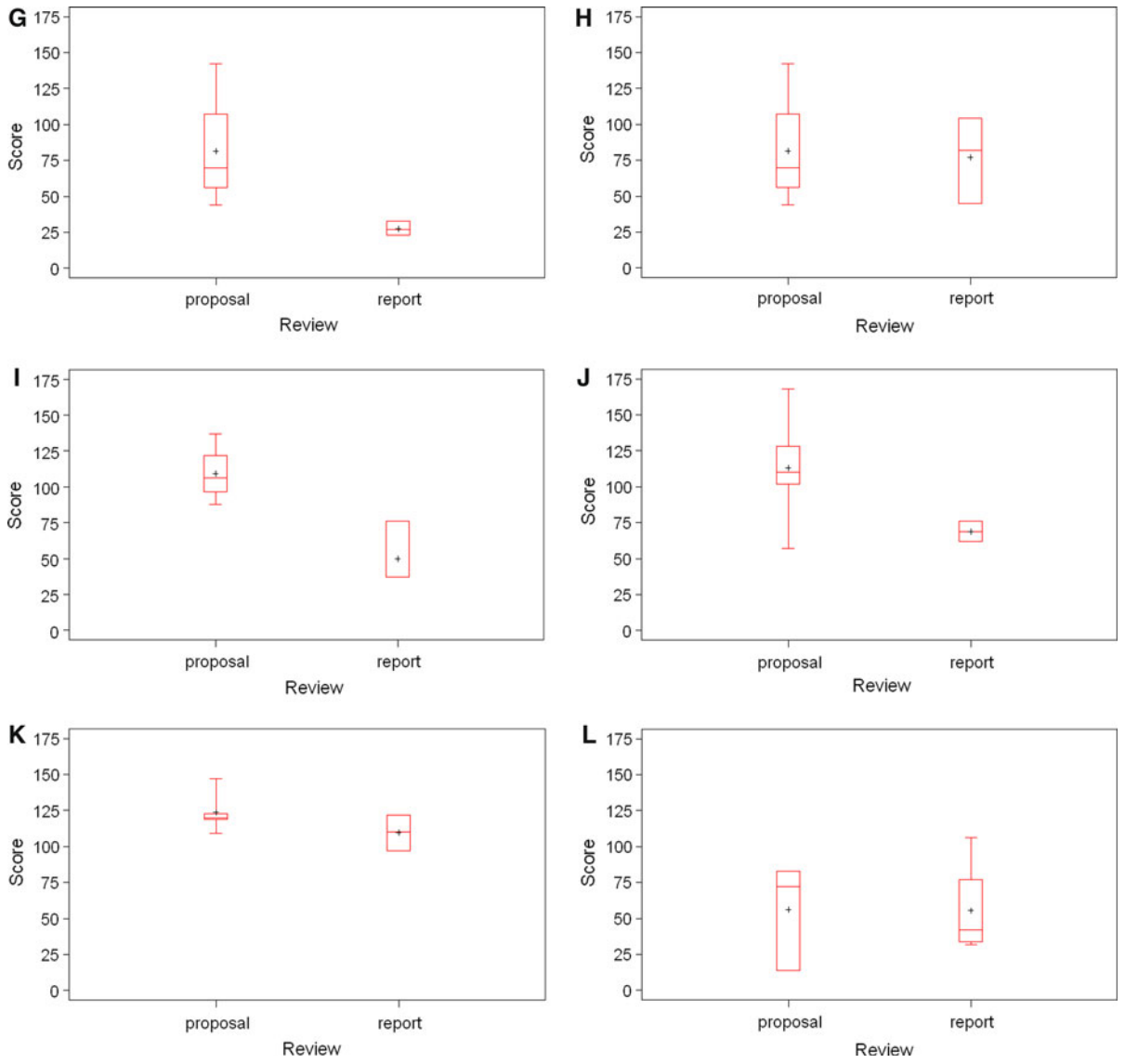


**Fig. 2** continued

To some extent, value judgments like this can never be eliminated from this or any decision support system using a reviewer-based decision model (Jelassi & Foroughi, 1989; Pomeroy et al., 1997). This reality necessitates that the regional governance structure for the Joint Venture provide overarching guidance with specific definitions of terms for more effective decision-making and be inclusive of the entire management system, assessment, and policy trade-offs. We attempted to reduce overall subjectivity in our evaluation of the scoring system by employing multiple reviewers to mitigate disparate opinions. But variation, as evident by the box plots (Fig. 2) in this analysis, should be considered by the Joint Venture steering committee when making the final project decisions. If, for example, one project has wide variance, the Joint Venture Project Review Team should discuss the cause of the discrepancies before accepting its given score.

Uncertainty of reviewer ranking is surely a weakness of this and any other decision support tool. While this technique seeks to orchestrate an objective forum for management decisions, substantial uncertainty impacts its effectiveness. In order to form more

**Table 1** Paired *t* tests of two independent means with unequal variance for 12 brook charr (*Salvelinus fontinalis*) conservation projects in the eastern United States, comparing proposal and final report scoring for each project

| Project | Sample size (proposal; report) | Degrees of freedom | *t* value | *P* value |
|---|---|---|---|---|
| 1 | 4; 4 | 4.56 | −0.24 | 0.820 |
| 2 | 4; 3 | 4.87 | −1.44 | 0.210 |
| 3 | 5; 3 | 2.52 | 0.36 | 0.744 |
| 4 | 5; 3 | 5.09 | 2.94 | **0.032** |
| 5 | 3; 3 | 2.63 | 1.91 | 0.165 |
| 6 | 3; 6 | 4.20 | 1.68 | 0.165 |
| 7 | 4; 3 | 3.11 | 2.53 | 0.083 |
| 8 | 4; 3 | 5.00 | 0.16 | 0.880 |
| 9 | 4; 3 | 4.16 | 3.59 | **0.022** |
| 10 | 5; 3 | 4.39 | 2.38 | 0.070 |
| 11 | 5; 3 | 4.81 | 1.45 | 0.208 |
| 12 | 3; 4 | 4.23 | 0.03 | 0.977 |

*Bolded P* values indicate significance ($P < 0.05$)

accurate and precise representations of project outcomes from their proposals, uncertainty must be minimized more directly within the scoring criteria and between the reviewers. Systematic and timely monitoring of project successes and continued follow-up assessment protocols must be weighted higher in the point structure to minimize the disconnection between the rankings and the effectiveness of brook charr management in this regional landscape. Additionally, criteria must be clearly defined and prioritized for reviewers to form realistic expectations of project outcomes from their proposals.

### Future directions for the Joint Venture scoring criteria

For this Joint Venture, our analysis evaluated the implementation effectiveness of its associated science-based decision support tool. Clearly, our results show that there is still a need for further evaluation and refinement of the scoring criteria. Using a more comprehensive review scheme, a power analysis and a principle component analysis could be performed to reveal which questions on the scoring sheet are contributing most to the final scores and which questions are covariate (Zar, 1999). This information would be particularly helpful for the Joint Venture to decide if these questions are, in fact, the scoring criteria that they would like to drive their project prioritization and funding allocation processes.

Regardless of intent and because the scoring criteria are weighted differently, this decision support tool does make an implicit judgment on Joint Venture priorities and must be acknowledged as such. The perplexity that many reviewers in this analysis faced was that the scoring criteria did not necessarily align with their own expectations of brook charr needs or Joint Venture priorities. Many reviewers reported that they felt that the scoring system was, for example, inappropriate for policy and assessment work, as currently designed. Projects with policy or assessment work were consistently scored lower than habitat restoration projects though both subjects are critical to the success of regional multijurisdictional management approaches such as this Joint Venture (see Schechter et al., 2008).

Though the Joint Venture is an advocate for regionalization of management efforts, the current scoring criteria are also not set up to maximize the opportunity for projects covering more than one sub-watershed. Because each sub-watershed is given an individual priority score, a project covering a high priority sub-watershed and a lower priority sub-watershed were scored lower than a smaller project solely located in a high priority sub-watershed. Additionally, some elements of the scoring criteria were unknown for some sub-watersheds (for example, if a population is a genetically distinct unit) so the criteria were either scored inappropriately or not at all; in both cases, to the detriment of the overall project score and its usefulness to the Joint Venture project review team in making decisions.

We recommend that future proposal prioritization scoring criteria consider separate scoring sheets for policy and assessment work; apply a weighting criterion for larger than sub-watershed projects; include more explicit guidance and definitions for accurate scoring; and incorporate a scoring scheme which does not penalize projects when information for listed criteria is not available.

## Conclusions

Designing an effective and responsive decision support tool is not easy. It is a constantly evolving

process with the addition of new scientific data, governance, outreach, and education on an interjurisdictional, regional basis. By applying this science-based decision support tool to its range-wide conservation strategy, the Joint Venture seeks to reverse declines in brook charr populations and genetic diversity in the eastern U.S., improve technology transfer, and prioritize funds and projects to restore brook charr habitat, increase their productivity, and encourage brook charr fishing opportunities throughout their historic eastern U.S. range. The use of an adaptive decision support system methodology will help the Joint Venture structure its approach to conservation and improve its utility to addressing regional issues, such as large landscape-level changes in the streams where these fish live, and the impact of global environmental changes, such as climate change, on brook charr populations, and their production.

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