Flows and Recreation Quality on the Dolores River: Integrating Overall and Specific Evaluations

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ABSTRACT: Effects of instream flows on river recreation, such as whitewater boating, have received increasing attention in recent years. Many studies have documented relations between flows and specific trip attributes such as boatability and whitewater challenge, as well as between flows and overall recreation quality. A mailed survey was completed by 128 commercial and noncommercial boaters on the Dolores River in Colorado, who evaluated a range of flows. They also identified flows that provided minimum boatability, minimum whitewater, optimum whitewater, and safety. Overall evaluations show inverse "U-shaped" curves and highlight differences for boaters using different craft. More specific evaluations, along with data about level of agreement, allow interpretation of points along the overall curves.

KEY WORDS: Instream flow, recreation norms, streamflow standards, whitewater boating.

INTRODUCTION

Stream corridors provide a myriad of natural and recreation resource values, many of which depend directly or indirectly on streamflow (Jackson et al. 1989). Although competition for out-of-stream agricultural, municipal, industrial, and hydroelectric water use continues to increase, recent attention has also focused on the effects of those uses on resources requiring instream flows. Approaching this issue, however, requires information about the relation between instream flows and the associated resource values. Although there has been considerable work on relations between flows and fish or aquatic habitat, systematic work on flows and recreation experiences has only recently emerged (Brown et al. 1991; Shelby et al. 1992b). The purpose of this paper is to develop overall flow evaluation curves for whitewater boating and to use specific flow evaluation data to calibrate the curves.

Studies have shown that a variety of recreation resource opportunities depend on instream flows. Many studies have focused on whitewater boating opportunities, partly because the effects of flow changes on this type of recreation are so pronounced, but also because whitewater boating ad-

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vocates have brought increasing attention to the issue. Recently available legal or administrative avenues for negotiating improved recreation flows have helped turn this attention into formal studies. This has been most notable in the Federal Energy Regulatory Commission's relicensing process, but modified missions at the Army Corps of Engineers and Bureau of Reclamation, in concert with increasing concern expressed by downstream land managing agencies, have also led to reviews of dam operations.

Although overall whitewater recreation quality depends to some degree on all these attributes, direct effects associated with boatability and whitewater challenge appear to be important determinants of overall quality and have thus received the greatest research attention (Shelby et al. 1992b). Studies of the effects of flow on whitewater boating opportunities have identified direct and indirect effects (Shelby et al. 1992b; Whittaker et al. 1993). Direct effects include the quality of rapids, safety in running them, number of portages and boat groundings, travel times, and presence of beaches and camps, all of which may change quickly and directly as flow levels change. Indirect effects include opportunities for scenery and wildlife viewing, fish habitat, and the quantity and/or quality of "angling habitat," all of which change subtly over the long term as a result of a flow regime (particularly the flood flow regime).

As with other human-resource issues, exploring streamflow and recreation quality requires a distinction between descriptive and evaluative components (Shelby and Heberlein 1986). The descriptive component examines how management alternatives affect resource conditions; the evaluative component shows how humans respond to those conditions, providing information about which set of conditions is more desirable. Applied to flows and recreation, the descriptive component explores how various measurable conditions (e.g., the size of rapids or channel depths through a riffle) change at different flow levels. The evaluative component, in contrast, involves choices about what the resource "should" provide (e.g., whitewater vs. fish production). It is at the heart of most difficult management decisions, and water allocation decisions are no exception.

Researchers exploring evaluative data often employ a normative approach using survey-based techniques. This approach suggests that humans internally evaluate conditions in a setting and, if asked in the proper format, can express those evaluations to allow systemic analysis and discussion of group norms (Vaske et al. 1986; Shelby and Vaske 1991). Collecting and organizing evaluative information in this way is particularly useful for developing standards that define minimally acceptable or optimal conditions; standards, in turn, are crucial elements in any effective management planning or decision-making process (Shelby et al. 1992c; Whittaker and Shelby 1992).

Using this approach, norms are defined as standards that individuals use to evaluate activities, behavior, or environmental conditions in a particular setting. The approach examines individuals' evaluations of a range of conditions ("personal norms"). Aggregated personal norms define "social norms," which describe a group's collective evaluation of those same conditions. This approach has been used to understand tolerances for a variety of social or environmental impacts in recreation settings (see Shelby and Vaske 1991 for an overview). It has also been applied to streamflows for the recreation, most prominently for whitewater boating on the Colorado River in the Grand Canyon (Shelby et al. 1992a), but also on several other whitewater or wilderness rivers in Alaska (Shelby et al. 1990; Whittaker 1993), Oregon (B. Shelby and D. Whittaker, unpublished report), Utah/Arizona (Shelby et al. unpublished report), and Colorado (Vandas et al. 1990).

Overall Evaluations of a Range of Flows

In many of these flow-recreation examples, experienced boaters were asked to evaluate overall recreation quality for a range of flows that they have seen, usually on a five-point "acceptability" or "satisfaction" scale. The mean evaluation for each flow can then be marked on a graph. When connected, the points describe the group or social norm, also known as a "flow evaluation" or "flow preference" curve. The

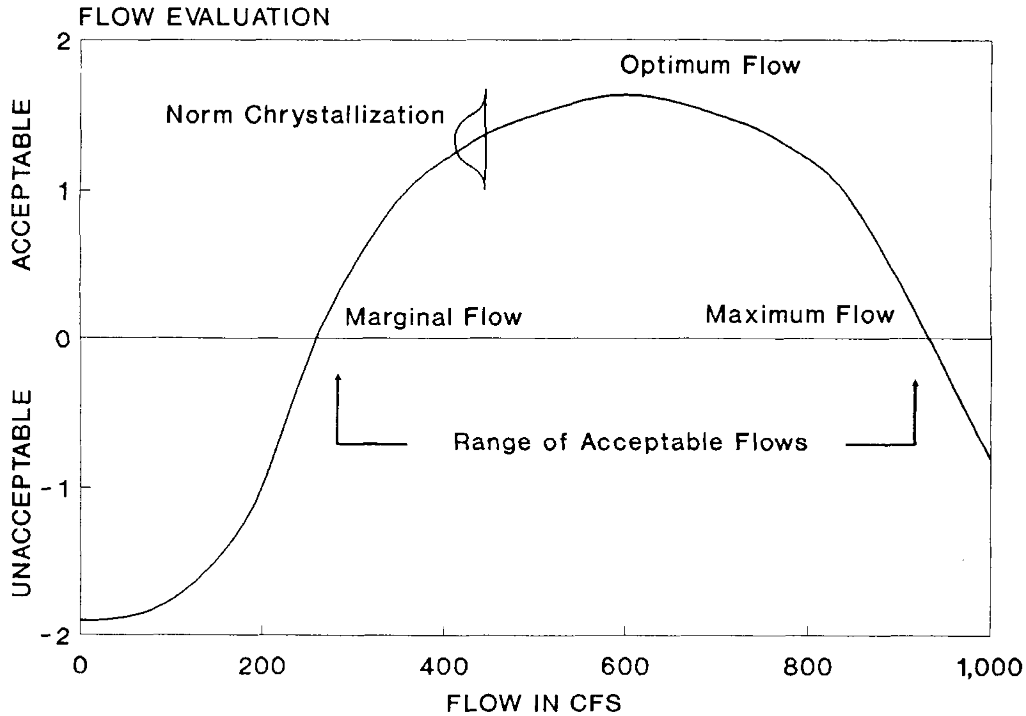

FIGURE 1. ***Hypothetical overall flow evaluation curve with identifying characteristics.***

curve (Figure 1) can then be analyzed in terms of certain characteristics, including: (1) optimum flow, at the peak of the curve; (2) range of acceptable flows, the part of the curve above the neutral or marginal line; and (3) norm crystallization, measured as the standard deviation for each mean evaluation or for the curve as a whole, which indicates the level of agreement about the evaluations.

The "overall flow evaluation" curves developed from this approach provide a meaningful way to understand how flows affect particular recreation opportunities. Usually taking the form of an inverted U-shape (very low and very high flows are evaluated lower), such curves provide a summary of the relation between flow and recreation quality. But curves based on mean responses may mask different evaluations of important subgroups. In addition, more information is needed about the points on the curve and what they mean in terms of specific trip attributes (Shelby et al. 1992a). For example, what are the important characteristics of the flow where the curve crosses the neutral line? Or at the point of inflection? Or when the curve flattens out or reaches a peak?

Specific Evaluations Identifying Single Flows

Other normative-based techniques ask boaters to identify flows that provide the best whitewater, minimally acceptable whitewater, or the minimum flow that enables them to get down the river. These "specific flow evaluation" data can also be represented effectively through graphs. One representation shows flow ranges along the x-axis and the percentage of respondents identifying that flow on the y-axis. The shape of the resulting curve can suggest different types of norms (Whittaker and Shelby 1988), which help describe group agreement. For example, unimodal distributions indicate strong agreement or a "single tolerance norm;" in contrast, multi-modal or nonmodal distributions suggest diversity of opinion, or a "multiple tolerance norm." Measures of central tendency (such as means or medians) can also provide useful descriptors of consensus in the single tolerance case, and measures of dispersion (such as standard deviations or confidence bands) may provide a useful measure of the level of agreement.

Because specific flow evaluation questions are focused on particular characteristics, resulting data provide information that overall evaluations do not. However, respondents only provide information about one flow at a time, even though, in some cases, a range of flows may be more applicable. In addition, respondents may know about a number of different flows, but are asked only to provide information about a few. Finally, these data do not easily allow development of an overall flow evaluation curve, a useful tool for the water allocation process where competing water users have organized their information in this manner.

Integrating Overall and Specific Flow Evaluations

Advantages and disadvantages of "overall" or "specific" flow evaluation approaches can be better understood through comprehensive efforts that utilize both. By integrating the results, researchers can explore the issue from both sides and gain a better understanding of evaluations.

The present paper integrates both types of information, using data from a study on Colorado's Dolores River. One set of questions was used to develop overall flow evaluation curves, and another set helped to identify and explain various points on the curves. Both sets helped explore the consensus issue. The objectives for our analysis are to: (1) develop "overall flow evaluation" curves for whitewater boating using different types of craft, (2) examine "specific flow evaluation" data to identify single or multiple tolerance norms, (3) integrate overall and specific flow evaluation information in order to "calibrate" points on the curves, and (4) examine levels of agreement for both kinds of evaluations to determine if agreement changes with the range of flows.

STUDY SITE AND METHODS

Data come from a survey of boaters on the Dolores River, a southwestern Colorado resource known for its desert canyon scenery, whitewater boating, and developing trout fishery (see Vandas et al. 1990 for the full details of the project). Float trips on the Dolores range from 12 to 60 mi long and take between 1 and 5 days, depending on the segment run. Most users run either the Upper Canyon, which features more challenging whitewater, or the Lower Canyon, which is surrounded by a Wilderness Study Area and features steeper walls and more slickrock terrain. A few users run the entire stretch through both canyons. Only data for the Upper Canyon are presented in this paper. Most trips on this segment are focused on moderately challenging pool/drop whitewater rapids, scenic floating between the rapids, picnicking and camping on undeveloped beaches, and hiking in the side canyons. The Upper Canyon features many Class II and III rapids, with a couple of Class III and IV stretches. Boaters travel in rafts, kayaks, and occasionally open canoes. Private use is slightly higher than commercial use.

The flow evaluation survey was conducted as part of a larger instream flow needs assessment undertaken by the Bureau of Land Management, which manages the river. The instream flow study was prompted by increasing concern over the effects from McPhee Dam (operational since 1985) on fishery, geomorphic, and recreation values, and the potential to secure additional water rights that could help protect those values.

The recreation survey was based on the normative approach discussed earlier. The development of specific questions was based on a series of Bureau of Land Management instream flow assessments on Alaska's Beaver Creek and Gulkana River and Arizona's San Pedro River, as well as an instream flow study conducted on the Colorado River in the Grand Canyon. Earlier drafts of the questions for our survey were modified after interviews with experienced Dolores river runners.

Because many Dolores boaters have taken multiple trips on the river, and are knowledgeable about flows and their effects, a mailed "flow comparison survey" was used. With this type of survey, boaters are asked to evaluate a variety of flows and to identify flows that provide specific optimal or tolerable conditions. This type of survey contrasts with surveys that have boaters evaluate a single flow following a trip (a "single flow survey") or surveys conducted among a select sample of boaters where flows are manipulated over a short period of time (a "controlled flow assessment"). Whittaker et al. (1993) review these and other related techniques in greater detail.

The survey focused on boaters with considerable experience on the Dolores River. Results from previous studies suggest that inexperienced users can identify important trip attributes, but, due to lack of experience, are unable to specify the ways those attributes are affected by flows (Shelby et al. 1992a). The survey sample included outfitters currently permitted on the Dolores, guides who work for the five outfitters who take the most trips on the Dolores each year, and noncommercial boaters. Because there were few differences between these groups, they were combined in the analysis.

The questionnaire and up to three reminder letters (the third was sent by certified mail) were sent to 170 users. In all, 128 users completed and returned the questionnaire, 13 wrote back to say that they felt unqualified to answer the survey, and 5 questionnaires were undeliverable. The final response rate was 84%.

The survey asked questions about user characteristics, evaluations of various flow levels, and opinions about various trade-offs implied by different flow scenarios. This paper focuses on users' flow evaluations in both the "overall" and "specific" flow evaluation formats.

Overall flow evaluation questions asked users to rate 15 different flows (from 150 to 5,000 cfs) on a 5-point Likert-type scale ranging from "unsatisfactory" (1) to "neutral" (3) to "satisfactory" (5). Five specific flow evaluation questions asked users to identify: (1) the "minimum flow you need to float the river" (minimum boatability), (2) the "optimum flow for floating the river" (optimum boatability), (3) the "lowest flow you consider acceptable for a good ride through the rapids" (minimum whitewater), (4) the "flow that provides the best ride through the rapids" (optimum whitewater), and (5) the "flow that provides the safest ride through the rapids" (optimum safety). Each respondent answered questions with respect to their preferred craft (i.e., open canoe, small raft [less than 14 feet], large raft [over 14 feet], or kayak) and results were analyzed separately.

RESULTS

Overall Flow Evaluations

For the overall flow evaluation questions, mean responses for each flow level were plotted and then connected to create a curve. The curves in Figure 2 show how flows affect the quality of boating for different craft. Results show some agreement among the three whitewater craft (large rafts, small rafts, and kayaks), whereas the open canoe results are considerably different. For the whitewater craft, flows lower than about 500 cfs are rated as unsatisfactory, neutral ratings are given to flows in the 800 to 1,000 cfs range, and flows above about 1,200 to 1,500 cfs are consistently rated as satisfactory. There is also a small downturn among evaluations for rafts at the highest flows. For open canoes, the lowest flows (less than 200 cfs) and the highest flows (over 3,000 cfs) are rated as unsatisfactory. Neutral ratings for this craft are found between 200 and 300 cfs; more optimal levels are between about 600 and 1,000 cfs. The lower flow needs for canoes fit with anecdotal evidence and resource reconnaissance work on the river; canoes can negotiate lower flow levels better than rafts, portaging canoes past short and rocky stretches is easier, and the bigger hydraulics associated with high flows tend to swamp open boats.

Level of agreement is shown by standard deviations of the evaluations for each flow (Table 1). Results suggest two interesting findings. First, there appears to be some agreement for most points on the curve, with standard deviations rarely larger than 1.5 on the 5-point scale; in many cases the deviation is less than 1.0. Second, there is less agreement when ratings shift from unsatisfactory to satisfactory (the steep part of the curve), and when flow levels are highest.

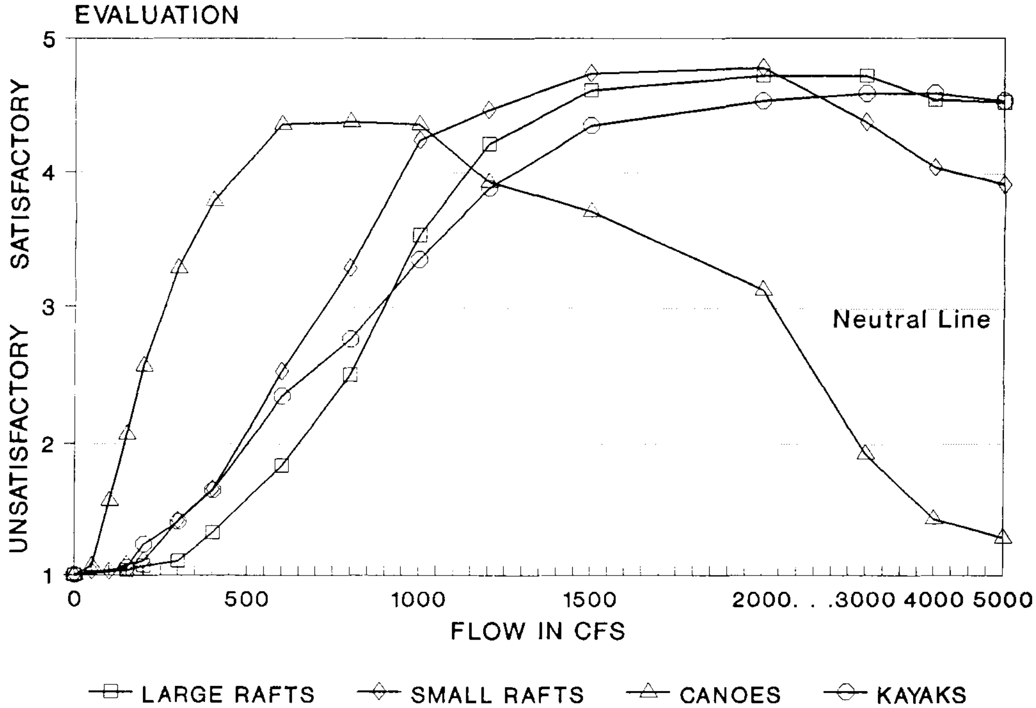

FIGURE 2. ***Overall flow evaluations for different craft types.***

Specific Evaluations Identifying Single Flows

For specific evaluations identifying single flows, examples of graphic results are given in Figures 3 and 4. Figure 3 shows responses to the question about minimum boatable flow for large rafts. This is an example of a "single tolerance norm," where there is considerable agreement. Over three-quarters of the respondents identified flows between 800 and 1,200 cfs in this example, and over one-third identified a single flow at 1,000 cfs. The resultant distribution is clearly unimodal, and there are few outliers. Although it is possible to debate about differences within the 800 to 1,200 cfs range, it would be hard to make the case that the minimum flow is outside this range. With single preference norms, measures of central tendency, such as the mean and median, are useful representations of the flow in question, and standard deviations around the mean are relatively small.

Figure 4, in contrast, shows responses to the question about optimum whitewater flow for large rafts. This is an example of a "multiple tolerance norm," where there is greater diversity of opinion. Although this graph shows a "peak" at 3,000 cfs, that peak represents just over 20% of the sample. About 12% identified 1,500 cfs, 15% identified 2,000 cfs, and 25% identified 5,000 cfs or more. Here, there is much less

TABLE 1
Level of agreement (standard deviations) for overall flow evaluations.

CFS	Large rafts	Small rafts	Kayaks	Open canoes
50	0.00	0.16	0.00	0.27
80	0.00	0.16	0.00	0.94
150	0.30	0.27	0.24	0.56
200	0.45	0.38	0.56	1.51
300	0.61	0.82	0.71	1.64
400	0.88	0.93	1.17	1.42
600	1.11	1.32	1.46	1.39
800	1.16	1.40	1.48	1.14
1,000	1.18	0.99	1.46	1.45
1,200	1.03	0.79	1.05	1.54
1,500	0.80	0.50	0.86	1.64
2,000	0.78	0.58	0.94	1.61
3,000	1.00	1.10	1.06	1.15
4,000	1.11	1.39	1.06	1.15
5,000	1.11	1.39	1.06	0.60

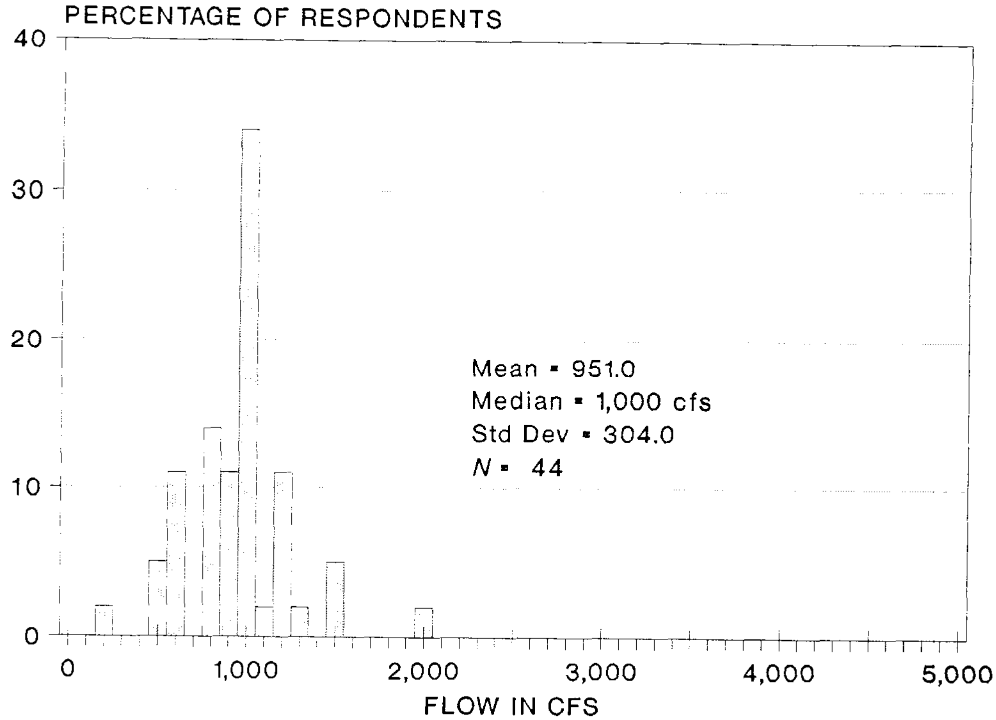

FIGURE 3. ***Example of a single tolerance norm: minimum boatable flow for large rafts.***

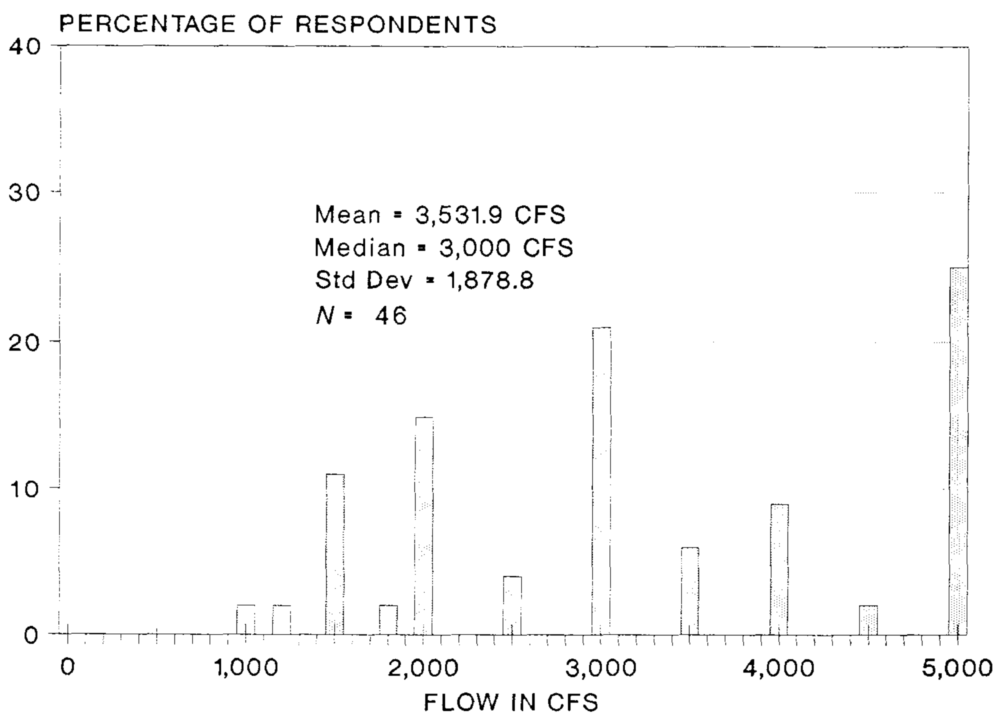

FIGURE 4. ***Example of a multiple tolerance norm: optimum whitewater flow for large rafts.***

TABLE 2
Specific evaluations of flows for different craft.

	Large rafts $n = 45$	Small rafts $n = 38$	Kayaks $n = 17$	Canoes $n = 15$
Minimum boatability median	1,000	800	1,000	300
Mean	950	793	902	408
Standard deviation	304	282	424	326
Type of norm	single	single	multiple	single
Optimum boatability median	2,500	1,500	2,500	800
Mean	2,853	1,844	2,982	869
Standard deviation	1,764	1,010	1,999	377
Type of norm	multiple	multiple	multiple	single
Minimum whitewater median	1,200	1,000	1,225	800
Mean	1,436	1,172	1,366	720
Standard deviation	770	526	541	409
Type of norm	single	single	multiple	single
Optimum whitewater median	3,000	2,500	3,000	1,350
Mean	3,531	2,605	3,681	1,366
Standard deviation	1,879	1,225	2,158	783
Type of norm	multiple	multiple	multiple	multiple
Safest median	2,000	1,500	2,000	600
Mean	2,231	1,763	2,123	820
Standard deviation	998	770	628	514
Type of norm	multiple	single	single	single

agreement about which flow is best. With multiple tolerance norms, measures of central tendency are less useful representations of the situation, and standard deviations are relatively large.

Table 2 gives the median, mean, standard deviation, and type of norm for all five specific evaluation questions for different types of craft. The type of norm is characterized as single tolerance if there is a clear peak (usually accounting for between one-third and one-half of the sample), and there are no other clusters of responses outside the peak range. These generally have standard deviations of less than 800 cfs (and often less than 500 cfs). Multiple tolerance norms, in contrast, lack a dominant peak, and often show significant numbers of responses clustered around several different flows. Standard deviations in these cases are usually more than 1,000 cfs.

Results suggest several interesting findings. First, they highlight the dramatic differences between open canoes and the whitewater craft, as well as some more subtle differences among the whitewater boats. All five identified flows are considerably lower for canoes than other craft, mirroring the overall evaluation results given in Figure 2. In addition, small rafts appear to require lower flows for minimum boatability and minimum whitewater than larger rafts or kayaks.

Second, there is a clear and consistent pattern to the specific identified flows: minimum boatability is less than minimum whitewater, which is similar to but slightly less than optimum boatability, which is considerably less than optimum whitewater. Safest flows are between minimum and optimum whitewater. These consistent patterns support the idea that data from specific evaluations identifying single flows can help explain flow preference curves (discussed below).

Finally, there is more agreement about minimum flows and safest flows than optimum flows. For minimum flows, 6 out of 8 cases (75%) were single tolerance norms, and for safest flows, 3 out of 4 cases (75%) were single tolerance norms. For optimum flows, only 1 out of 8 cases (13%) were single tolerance norms.

Integrating Overall and Specific Flow Evaluation Results

Overlaying the overall and specific flow evaluation results is another way to ana-

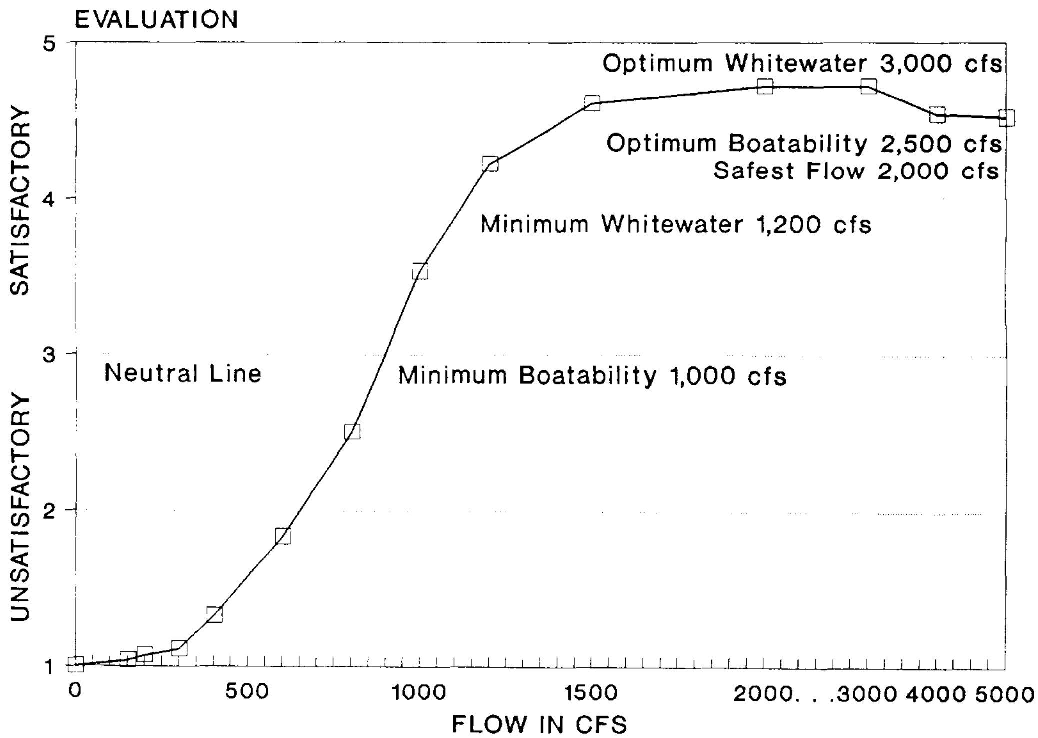

FIGURE 5. ***Overall evaluation curve and medians for specific evaluations for large rafts.***

lyze these data. An example of this for large rafts is given in Figure 5 (results for other craft were similar). Using Figure 5 as an example, the reader can overlay medians from Table 2 with overall curves in Figure 2.

Following along the curve for large rafts in Figure 5, the median flow identified for minimum boatability is 1,000 cfs. This is close to the point on the overall flow evaluation where the curve crosses the neutral line and mean ratings change from unsatisfactory to satisfactory.

Good whitewater conditions require higher flows than for minimum boatability alone. The median response for minimum whitewater is 1,200 cfs, which corresponds to the point where the overall evaluation curve begins to flatten out with consistently higher ratings.

The median response for optimal whitewater, however, is higher still, at 3,000 cfs. This corresponds to the peak in Figure 5, the point where ratings are the highest. That optimum whitewater is a multiple tolerance norm helps explain why the overall flow evaluation curve is relatively flat on the top: All the flows from about 1,500 to 5,000 cfs receive similarly high ratings because users disagree about which flow in that range is best. These results suggest that there is a relatively wide range of optimal flows. The optimum boatability flows are also in the flat part of the overall curves.

The high end of the optimal flow range is rarely available given current dam management, and all the whitewater curves show that the evaluations decline little even at historically rare flows (those above 3,000 cfs). One might expect some decline (generally for safety reasons) at higher flows, but the nature of Dolores rapids may allow safe runs throughout this upper range. Results from the question about the safest flow suggest that the middle of the optimum range is generally considered the safest, although this was a multiple preference norm for the large raft sample. In response to another question on the Dolores survey, only 20% of all users indicated that "high water" was an important cause of accidents on the river.

DISCUSSION

Results suggest several conclusions about relations between instream flows and whitewater boating quality as well as ways of collecting, analyzing, and presenting such data.

First, the normative approach is useful for examining the flow-recreation quality relation, and the two question formats are complementary. Experienced users were able to provide overall evaluations for a range of flows, as well as to identify flows that correspond to specific attributes. The analysis provides useful ways to display the results and develop conclusions about distinct flow needs for different types of opportunities.

Second, the overall flow preference curves generated through this method show the inverted U shape found in studies from other rivers (Shelby et al. 1992b). There are distinct ranges of flows that provide higher quality recreation experiences, and flows outside those ranges provide more marginal or unsatisfactory experiences. Identifying optimal and acceptable ranges is a key type of information needed to represent recreation interests in flow allocation negotiations.

Third, the results show differences for different craft, indicating that different kinds of recreation opportunities have different flow needs, even within the same general category of whitewater boating. There are substantial differences between whitewater craft and open canoes, and more subtle differences among whitewater craft. A specific implication of this finding is that, on a dammed river with a finite amount of water available (like the Dolores), management of flow regimes could provide for longer canoe seasons or shorter rafting and kayaking seasons. More generally, this result emphasizes the need to define different recreation opportunities in the beginning of a study so that data can be collected and analyzed separately.

Biologists examining relations between flows and fish habitat have developed distinct curves for different fish species or life stages (Milhous et al. 1984). Data presented in this paper suggest that recreation researchers must use a similar strategy (Hyra 1978; Whittaker et al. 1993). In addition to differences in craft type, researchers should also explore differences for users with different skill levels or users interested in different types of experiences (e.g., challenge oriented vs. scenic boating trips). Some of the variation in the Dolores results (the multiple preference norms) may be due to differences in skill levels or the type of experience sought by users.

Fourth, different flow levels provide different types of recreation experiences. Scenic trips (where the river is used as a waterway for transportation) are different experiences, and have different flow needs, than whitewater trips. This emphasizes the need to make judgments about the types of opportunities to be provided before developing instream flow regimes and protection strategies. If several different types of craft use a river, balancing competing needs may be difficult but important. In addition, in the case of a dam-controlled river and a finite water supply, providing higher flow or more optimum opportunities can mean very short seasons. This could result in crowding and other changes in the type of experience being provided. Identifying and carefully considering such trade-offs is a crucial component of planning.

Fifth, integrating results from both overall and specific flow evaluation questions provides more information than either format by itself. Overall curves are crucial for understanding changes in outputs through an entire range of flows, and they are necessary at the flow negotiation table (Shelby et al. 1992a; Whittaker et al. 1993). But overall curves sometimes lack important information that can be discovered by looking at specific flow evaluation results; the two types of information complement and inform each other.

These data also suggest that there may be fairly predictable patterns between overall and specific flow evaluation results. In the Dolores case, responses to the specific flow evaluation questions consistently helped identify the marginal flows or the point where curves cross the neutral line (minimum boatability); the lower end of the optimum range (minimum whitewater); and the peak or midpoint of the optimum range (optimum whitewater). If this kind of relation were to hold true on other whitewater rivers (as future studies might explore), it may be possible to develop overall flow evaluation curves from specific flow evaluation data alone or to infer the specific points from the curve alone. It seems premature to make those judgments before exploring these issues in a few more data sets.

Finally, level of agreement data are interesting and useful. Characterizing specific evaluations as single or multiple preference norms provides useful ways to discuss levels of group agreement and consider the ways in which evaluations might be used to determine flow needs. Critics of survey research sometimes complain that there is unlikely to be much agreement among users, and as a result they prefer methods that rely on professional judgments. However, because users often have considerable experience on the river in question and are often well-informed about the flows they have seen, considering user evaluations may be important from a public policy viewpoint. The approach we described provides an empirical way to find out about levels of agreement, and avoids the problem of having an expert's judgment represent the views of a potentially diverse user population.

In the Dolores case, there was considerable agreement for some points along the curve (generally minimums) and less agreement for others (the optimum flows). This led to more specific statements about the minimum flows necessary to provide opportunities, and more general ranges for the optimum flows. Because the Dolores has a very limited water supply (two-thirds of the natural flow is diverted or withdrawn from the basin), the most important allocation decisions concerned flows that would provide minimum boatability and minimum whitewater for different craft. These data helped clarify which opportunities would be provided under different dam operating scenarios. Less than 2 years after the study was completed, a commercial rafting organization used study results to convince the Bureau of Reclamation to develop new dam operation guidelines to provide longer rafting seasons in the future.

Level of agreement data also suggest additional ways to ask questions about flow needs in future studies. For example, optimum boatability and whitewater evaluations show multiple preference norms. We speculate that this may be due to differences between groups with different skill levels or those desiring different levels of challenge. To pursue this, we think that additional questions would be useful, perhaps asking about optimum flow for intermediate and advanced boaters, or about boaters seeking high and low challenge trips. Questions about safe flows might ask respondents to identify both the lowest and highest safe flows so that a safe range can be developed, and a similar strategy might be applied to optimum flows.

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