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QUANTIFYING WHITEWATER RECREATION OPPORTUNITIES IN CATARACT CANYON OF THE COLORADO RIVER, UTAH: AGGREGATING ACCEPTABLE FLOWS AND HYDROLOGIC DATA TO IDENTIFY BOATABLE DAYS

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ABSTRACT

The structural norm approach was combined with the Potential for Conflict Index to define recreation streamflow needs for the Colorado River in Utah and Colorado. An online survey was completed by 128 commercial and non-commercial boaters, who evaluated a range of flows for whitewater boating. For the Cataract Canyon reach, respondents rated the quality of their recreation experience of specific flows, describing the quality of boating opportunities across the full range of historical streamflows. Ranges for both acceptable and optimum flows were defined, as well as thresholds for unacceptable flows. These ranges were then evaluated against historical hydrologic records to quantify the timing, frequency, and duration of days when defined whitewater flows exist across different year types (i.e. average boatable days). Results indicated that on average, a total of 257 boatable days existed in dry years, and 353 total boatable days occurred in dry-typical years. In wet and wet-typical years, 362 and 365 total boatable days respectively, occurred on average. Results of the boatable days' analysis indicated that over the 23-year period of record, whitewater boating opportunities occurred nearly every day of the year in all but the driest year types. Results from this study provide resource managers with information which can be used in the development of annual operating plans for the Colorado River Basin and help managers understand how changes in flow impact the quality of recreational opportunities. This application demonstrates the value of analysing boatable days on any river where recreation management is a priority. Copyright © 2016 John Wiley & Sons, Ltd.

KEY WORDS: boatable days; river recreation management; Colorado river; instream flows; Potential for Conflict Index$_2$

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INTRODUCTION

In Southeastern Utah, the Colorado River flows through Cataract Canyon — carving one of America's premier wild river canyons. For approximately 112 miles, from Moab to the river's abrupt end at the head of Lake Powell, the Colorado traverses some of the most remarkable landscapes in the deserts of the American southwest. The stream corridor provides rare fish and wildlife habitats, globally significant plant communities, and other flow-influenced natural resource values. The Colorado River also provides high-quality whitewater recreation, such as rafting, kayaking, and canoeing. In the early 1960s, Cataract Canyon was in the crosshairs of the Bureau of Reclamation's golden era of dam building when Secretary of the Interior Stewart Udall put into motion the creation of Canyonlands National Park, providing the landscape permanent protection as a national treasure.

The canyon's rapids are generally considered 'big water', with a character similar to those found downstream in the Grand Canyon. Unlike the Grand Canyon, where flows are highly regulated, streamflow through Cataract Canyon has multiple inputs and can reach extreme levels during the spring runoff in years following plentiful snow throughout the Upper Colorado River watershed. The Colorado and the Green River's confluence is located directly above Cataract Canyon. The combined flow of these two rivers creates the actual flow whitewater user experience through the canyon's rapids. Cataract Canyon peaks at approximately 52 000 cubic feet per second (cfs) (1500 m^3/s) during an average spring runoff, while a minimum average flow during the winter months drops to approximately 4000 cfs (113 m^3/s). A maximum recorded flow of 114 900 cu ft/s (3250 m^3/s) occurred on 27 May 1984 (NPS web page, 'historic flows in cataract canyon'). This article describes how changes in flows affect recreation quality and define recreational flow needs in Cataract Canyon, including the quantity, timing, and frequency of streamflows that support high-value whitewater boating values below the confluence of the Green and Colorado rivers (Figure 1).

Changes in flow can have direct effects on the quality of whitewater boating. Direct effects may change quickly and

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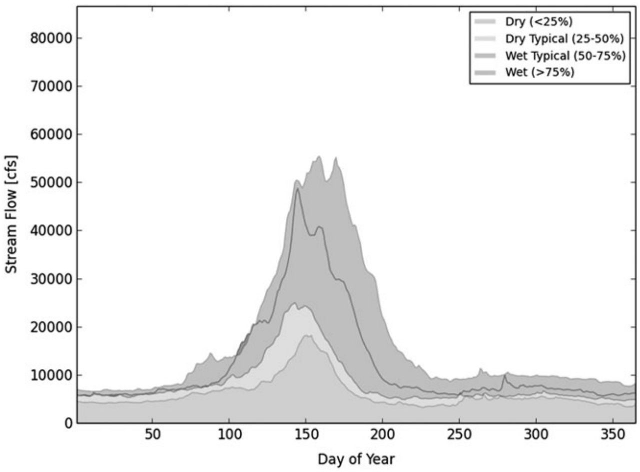

Figure 1. Cataract Canyon, Colorado River (1990–2013), year types (wet, wet typical, dry typical, and dry) ranked by yearly volume*. [11]

as flows change (e.g. safety in running rapids, number of boat groundings, travel times, quality of rapids, beach and camp access). Over the long term, flows indirectly affect wildlife viewing, scenery, fish habitat, and riparian vegetation (Shelby *et al.*, 1992b; Whittaker *et al.*, 1993). Clear definitions of recreational flow-needs, combined with their potential frequency and timing in the Colorado River, would aid in the development of annual operating plans and deliver predictable flows for recreational values, such as whitewater boating.

Whitewater boating is a flow-dependent recreation activity. Over the last several decades, considerable research has examined the flow–recreation relationship (Brown *et al.*, 1991; Shelby *et al.*, 1992a; Whittaker *et al.*, 1993). Flow–recreation studies tend to focus on whitewater boating, as flow influences opportunities to take a trip and the challenge or social value provided (Whittaker and Shelby, 2002b). Different flow levels offer varied boating opportunities. As flows increase, different paddling challenges exist along a spectrum: too low, minimal acceptable, optimal, and too high. These opportunities from different flow ranges are often described as 'niches' (Shelby *et al.*, 1997). Mean (average) responses to flow evaluations provide useful descriptions of group acceptability ratings (i.e. norms) and provide a useful metric managers can use to define instream flow targets with respect to year-to-year weather patterns and seasonal hydrologic models. This is especially true in the southwestern USA, where scarce water resources are affected greatly by subtle changes in climate (Ficklin *et al.*, 2013).

Structural norm approach

The structural norm model describes norms (evaluative standards) by means of a graphic device referred to as an impact acceptability curve (refer to Vaske *et al.*, 1986 and Shelby *et al.*, 1996 for a complete discussion). The curves describe social norms in terms of averages of individual evaluations. Impacts are displayed on a horizontal axis, with impact increasing from left to right (Figure 2). Evaluation is displayed on the vertical axis, with positive evaluations on the top, negative evaluations on the bottom, and a neutral category in between. The curve can be analysed for various normative characteristics, including optimum conditions, the range of acceptable conditions, the intensity or strength of the norm, and the crystallization or level of agreement about the norm (Vaske *et al.*, 1986; Shelby *et al.*, 1996).

The high point of the curve shows the *optimum* or best resource conditions (flow) or those receiving the most positive evaluation. The range of impacts where evaluations are above the neutral line defines the *range of acceptable resource conditions*. The relative distance of the curve above or below the neutral line describes norms of higher or lower *intensity*. Finally, the variation among evaluations at each impact level shows the amount of agreement or *crystallization*.

The approach has been applied extensively to natural resource issues, often with respect to instream flows for recreation

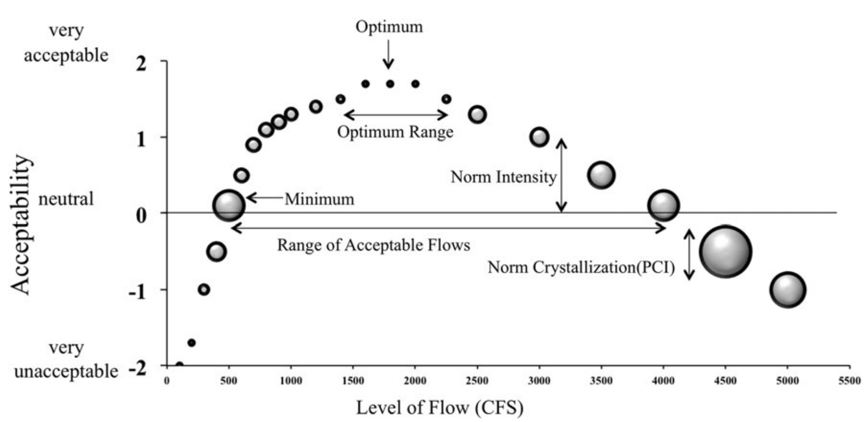

Figure 2. Example impact acceptability curve with Potential for Conflict Index

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(Shelby and Whittaker, 1995; Shelby *et al.*, 1992a; Vandas *et al.*, 1990; Whittaker and Shelby, 2002b). Other applications have extended this approach to different indicators and impacts such as encounter norms that describe how many people are considered to be too many in a given setting (refer to Donnelly *et al.*, 2000; Manning, 2011; Shelby *et al.*, 1996; Vaske & Donnelly, 2002; Vaske *et al.*, 1986, for reviews), campsite impacts or site sharing (Heberlein and Dunwiddie, 1979; Shelby, 1981), fishing site competition (Martinson and Shelby, 1992; Whittaker and Shelby, 1993), discourteous behaviour (Whittaker and Shelby, 1988, 1993; Whittaker *et al.*, 2000), and resource indicators such as litter and campsite impacts (Shelby *et al.*, 1988; Vaske *et al.*, 2002).

Norm crystallization and Potential for Conflict Index

Defining management standards is often more efficient if there is a high degree of norm crystallization or consensus regarding acceptable and unacceptable resource conditions, such as various levels of instream flow. Traditional measures of norm crystallization have included the standard deviation, coefficient of variation, and interquartile range (Krymkowski *et al.*, 2009; Manning, 2011; Shelby and Vaske, 1991). All of these measures, however, have limitations, and recent studies have established that each of these measures does not effectively differentiate between total consensus and no consensus distribution or between skewed and complete agreement distributions. They also lack an upper bound, which can challenge or leave ambiguous the interpretation of findings with total or no consensus (Vaske *et al*., 2013).

The Potential for Conflict Index$_2$ (PCI_2) was developed to help address these concerns and facilitate understanding and applicability of human dimension findings to managerial concerns. Although specifics of the PCI_2 are beyond the scope of this article, a detailed description of this statistic is reported in Vaske *et al.* (2010). In general, the PCI_2 ranges from 0 to 1. The least amount of consensus ($PCI_2 = 1$) occurs when responses are equally divided between two extreme values on a response scale (e.g. 50% extremely unacceptable, 50% extremely acceptable). A distribution with 100% at any one point on the response scale yields a PCI_2 of 0 and suggests complete consensus (row 1 in Table I).

The PCI_2 results can be displayed using graphs similar to impact acceptability curves (Figure 2). Degree of consensus is illustrated as bubbles where the size of bubble depicts the magnitude of PCI_2 and indicates the extent of crystallization/consensus regarding acceptance of a particular issue (i.e. degree of dispersion). A small bubble represents high crystallization, and a larger bubble represents low crystallization. The centre of the bubble represents the mean evaluative response as plotted on the vertical axis, and these points can be joined to form a curve similar to an impact acceptability curve (i.e. central tendency). The bubble's location relative to the neutral point illustrates whether or not the distribution of acceptance of an action is skewed (Vaske *et al.*, 2010). This article combines the structural norm approach with the PCI_2 to better describe flow-level evaluations.

Table I. Cataract canyon. Mean acceptability scores and Flow Acceptability Agreement Index

Specific flow CFS	Mean acceptability	PCI_2
100	−3.00	0.00
500	−3.00	0.00
1000	−2.76	0.00
1500	−2.40	0.08
2000	−1.91	0.19
2500	−1.38	0.25
3000	−0.71	0.31
3500	−0.40	0.34
4000	0.47	0.30
5000	1.33	0.26
7500	2.00	0.16
10 000	2.40	0.04
12 500	2.62	0.00
15 000	2.72	0.04
20 000	2.75	0.04
30 000	2.52	0.09
40 000	1.98	0.16
50 000	1.67	0.31
75 000	0.86	0.63
100 000	0.45	0.82

Flows represented are combined flow levels at USGS Colorado River at Cisco, Utah, and the Green River near Green River, Utah Gages.

METHODS

To develop standards that define flow needs for whitewater boating on the Colorado River, we collected and organized individual evaluations of resource conditions and recreation-relevant hydrology consistent with standard methodologies published by the National Park Service (Whittaker *et al*., 2005). The 2014 online survey involved 128 commercial and non-commercial boaters who evaluated flows and recreation quality for multiple segments of the Colorado River in Utah. For this article, we focused on the Cataract Canyon river segment. The sample frame was developed from (i) online paddling forums and social media; (ii) American Whitewater email newsletters; (iii) outfitter contacts in the Colorado River Basin; and (iv) other private boaters contacted through networking in the river community (e.g. staff at boating shops, instructional community, and regional paddlers).

Although the sample for this study comes from an online collection of self-selected respondents from several sources, only respondents who had paddled the stretch and could confidently identify flows in cubic feet per second were asked to complete the survey. There exists no master list

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of all Cataract Canyon river recreationists, yet by reaching as many experienced users as possible, through the frame detailed in the preceding texts, a sufficient sample of the population was surveyed. It may also be noted as a limitation that only experienced users were analysed, but previous research suggests that experienced boaters are more knowledgeable about how flows affect recreation attributes and are better able to evaluate specific flows (the objective of the flow study), while because of their lack of experience, inexperienced boaters are unable to specify ways that attributes are specifically affected by flows (Shelby *et al.*, 1992b). Although inexperienced users were not analysed, it is appropriate to apply the normative standards developed to the entire population, because inexperienced users would only be partaking in river recreation in Cataract Canyon under the guidance of more experienced river users.

Variables measured

Independent variables. The questionnaire asked the respondents to report their skill level as expert (41%), advanced (52%), intermediate (11%), or novice (0%) paddlers, and their boating frequency: 1 time (0%), 2–5 times (2%), 5–20 times (23%, 20+ times (43%), or 50+ times per season (32%). A wide range of craft types was surveyed with oar rafters (50%), catarafters (10%), kayakers (36%), and paddle rafters (4%) all represented.

Dependent variables. The respondents evaluated the acceptability of instream flows for Cataract Canyon ranging between 100 and 100 000 cfs. The respondents evaluated the *overall* recreation quality of these flows on seven-point scales ranging from totally unacceptable (−3) to totally acceptable (3), with neutral equal to zero.

Data analysis

Structural norm characteristics were used to graphically represent the relationship between flows and recreation quality for each increment of streamflow. Mean evaluations for each flow value are plotted graphically to create flow-acceptability curves. The PCI_2 was used for estimating consensus or crystallization regarding each of the specific streamflows considered. The PCI_2 scores in conjunction with norm intensity (evaluation's distance from the neutral line) were used to determine optimal flows. Optimal flows occur at the peak of the impact acceptability curve and where PCI_2 indicate complete or near complete consensus (lowest PCI_2 scores, represented graphically by tiny bubbles in Figure 2).

Boatable days' analysis

Whitewater boating opportunities (or 'boatable days') were defined by the number of days that flows meet recreational needs. Boatable days is the dominant metric most relevant to managing for flow-dependent recreation opportunities. Evaluations of defined whitewater recreation flows within hydrologic year types describe the number of 'boatable days' within acceptable and optimal flow ranges defined by overall flow evaluation curves. Boatable days within flow ranges have been used to protect, mitigate, or enhance paddling opportunities (Fey and Stafford, 2009; Menges *et al.*, 2013; Shelby and Whittaker, 1995; Whittaker *et al.*, 1993).

A 23-year study period from 1990 through 2013 was chosen for the boatable days' analysis, as it best represents the period for which continuous daily streamflow was available for Cataract Canyon. For this assessment, hydrologic year types (wet, wet-typical, dry-typical, and dry) were defined by ranking the total annual flow (in acre-ft) at each stream gage and then dividing the total annual flows into quartiles. Figure 2 shows a hydrograph based upon the ranking of the daily average streamflow at the Colorado River through Cataract Canyon for the study segment (combined flows at the USGS gauges Colorado River at Cisco, Utah, and the Green River near Green River, Utah).

After the hydrologic data were organized by year type, the daily average streamflow was compared with the preferred flow ranges from the user surveys described in the preceding texts. If the streamflow on a particular day fell within the preferred flow range for a particular experience class (e.g. the range of optimal flows), the flow was counted as a boatable day. The same analysis was completed for every day of the study period in all year types and for the range of preferred flows for every flow class (low acceptable, optimal, and high acceptable levels). The boatable days in each flow class were then summed by month for comparison with other months throughout the year. The mean (average) number of boatable days by month for each year type was determined in order to compare the various floatboating experiences that occur across different year types in general.

RESULTS

For the Cataract Canyon reach of the Colorado River, the lowest acceptable flow was 4000 cfs (refer to minimum in Figure 3 and Table I). Optimum flows for this segment ranged between 10 000 and 30 000 cfs, with high norm intensity values (2.4–2.75) and extremely high agreement levels (PCI_2 values ranged from 0.0 to 0.09). The mean acceptability for high flows never fell below the neutral line, even up to 100 000 cfs, suggesting that flows in the Colorado River at Cataract Canyon never reach levels that are too high to meet the needs of a majority of river runners. PCI_2 scores at 75 000 and 100 cfs did jump to 0.63 and 0.82 respectively, the two highest scores for any of the flows surveyed, as acceptability scores drop to 0.86 and 0.45 respectively, suggesting that the recreation quality for many respondents declines as flows exceed 50 000 cfs, but at these

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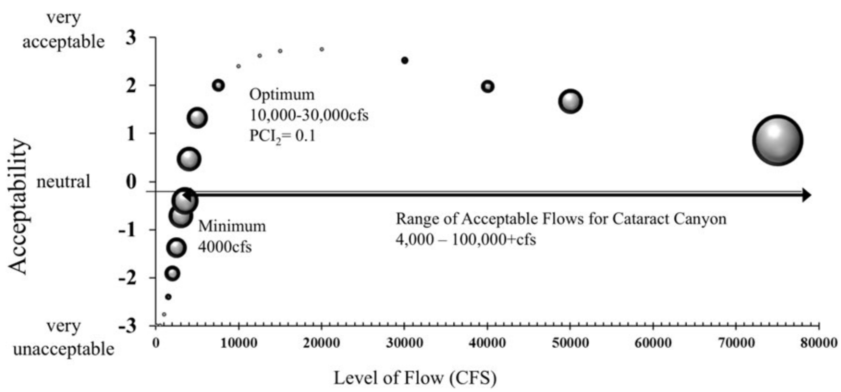

Figure 3. Impact acceptability curve with Potential for Conflict Index for Cataract Canyon of the Colorado River*. [11]

flows, quality still does not drop below acceptable levels for a majority of river users.

For the study segment, the results of hydrological comparisons were illustrated by overlaying the mean annual hydrograph for a given historical year type, with the optimal thresholds and the low and high bounds of the acceptable whitewater recreation categories (Figure 4). The story of boatable days is best described by plotting the mean monthly boatable days for each year type (wet, wet-typical, dry-typical, or dry). Figure 5 mentioned in the succeeding texts provides a representative sample of these comparisons for the study segment, with the number of boatable days by year type on the vertical axis and monthly values on the horizontal axis. This graphical comparison provides a complete picture of the historical timing of recreational flows in Cataract Canyon measured on a monthly average basis.

The boatable days' analysis indicated that on average, 257 boatable days existed in the driest years; however, all

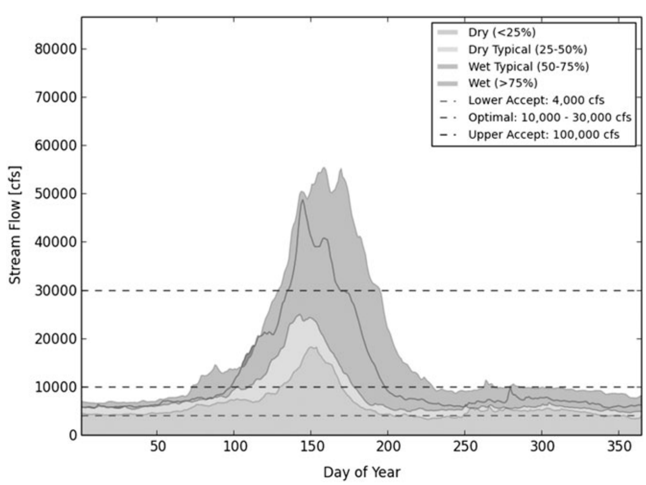

Figure 4. Cataract Canyon, Colorado River (1990–2013), year types ranked by yearly volume* with flow thresholds. [11]

except for 39 of those days fall within low-acceptable levels (Table II). In wet and wet-typical year types, 362 and 365 boatable days respectively, occurred on average. In addition, the full range of whitewater flows was available in wet and wet-typical year types, including days within low acceptable, optimal, and high acceptable levels. The results of the boatable days' analysis indicated that over the 23-year period of record, whitewater boating opportunities occurred in every year type. In the driest year types, however, only a short window for optimal flows (37 days) and a virtually non-existent window for high acceptable flows (2 days) existed, primarily in the months of April–June. For dry-typical year types, almost twice as many optimal days occurred on average (67 days) than in dry-year types; however, there are still only 2 days where high acceptable flows are found on average.

Table II details the results of the boatable days' analysis by year for Cataract Canyon and provides key pieces of information regarding the timing, quality, and quantity of flows for whitewater boating in the Colorado River. For example, in wet typical years, there were a total of 92 boatable days between June 1 and Aug 31 (summer high visitation season for the park, where three of the top six visitation months on average throughout the year exist) or days when flows were at or above the minimum acceptable flow of 4000 cfs. Of those 92 days, 48 were within the 4000–10 000 cfs range that defines low acceptable flows, and 26 days were in the optimal flow range, between 10 000 and 30 000 cfs. Nineteen days were above 30 000 cfs in the high acceptable flow range. In wet-typical years, all of the whitewater experiences defined in this flow study from low water technical descents to high water spring runoff descents are represented during the height of the seasonal visitation to Canyonlands National Park. The results from this analysis help describe when whitewater boating opportunities are typically available in Cataract Canyon, as well as what types of experience those opportunities provide.

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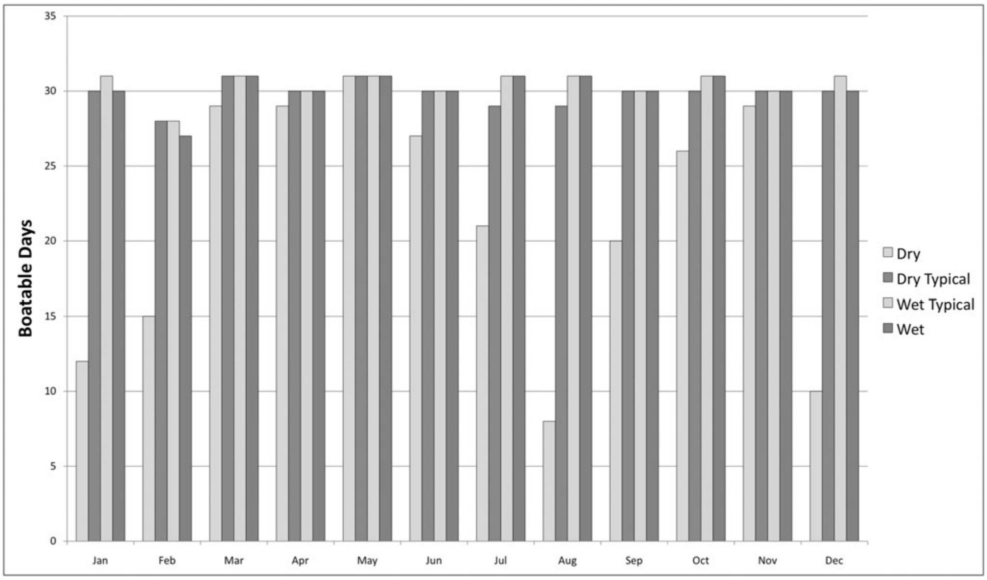

Figure 5. Cataract Canyon number of monthly boatable days by year type

Table II. Average boatable days (1990–2013) by month and year type*, cataract canyon, Colorado river

Month	Flow indicator	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year total
Dry year type boatable days	Low	12	15	27	24	15	11	21	8	20	26	29	10	218
	Optimum	0	0	2	5	15	15	0	0	0	0	0	0	37
	High	0	0	0	0	1	1	0	0	0	0	0	0	2
	Total	12	15	29	29	31	27	21	8	20	26	29	10	257
Dry typical year type boatable days	Low	30	28	28	17	2	7	28	29	30	30	30	30	289
	Optimum	0	0	3	13	28	22	1	0	0	0	0	0	67
	High	0	0	0	0	1	1	0	0	0	0	0	0	2
	Total	30	28	31	30	31	30	29	29	30	30	30	30	358
Wet typical year type boatable days	Low	31	27	28	7	0	1	16	31	30	29	30	31	261
	Optimum	0	1	3	23	15	10	15	0	0	2	0	0	69
	High	0	0	0	0	16	19	0	0	0	0	0	0	35
	Total	31	28	31	30	31	30	31	31	30	31	30	31	365
Wet year type boatable days	Low	29	27	20	6	0	0	1	14	17	22	19	29	184
	Optimum	1	0	11	24	10	3	21	17	13	9	11	1	121
	High	0	0	0	0	21	27	9	0	0	0	0	0	57
	Total	30	27	31	30	31	30	31	31	30	31	30	30	362

*Days per month that existing hydrology met whitewater boating flow preferences.

DISCUSSION

The mean number of boatable days for each year type described in Table II can aid in developing more predictable flow-management guides for Cataract Canyon in Canyonlands National Park that can improve public understanding, enjoyment and safety on the water. For example, as of April 1, if Natural Resource Conservation Service snowpack conditions indicate wet-typical conditions, a reasonable expectation for the upcoming summer visitation season would be that June would offer the most high challenge, high flow experience days (19), while providing few to no low flow experience days (1), and 10 optimal flow days. August, however, would provide low flow experience days for all of its 31 days. Knowing which types of experience are most likely to occur during high visitation periods could allow the park to adjust its management plans, marketing materials, and permitting operations to match expected flow-type experiences in the canyon.

An analysis of daily flow data from 1990 to 2013 indicates that Cataract Canyon provided an incredible amount of user days for river users. Even in extremely dry year types, the canyon on average boasts 258 boatable days.

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While many other rivers throughout the southwest may not have sufficient flows for paddling, Cataract Canyon will have 29 boatable days in November. Almost all of the boatable days in a dry year will fall into the low acceptable flow experience type (220 of 258), and there will only be two high acceptability experience days throughout the year. However, in the spring months of April, May, and June, there will still be 35 days of optimal flow levels (5, 15, and 15 respectively, Table II). Such knowledge of boatable days for a dry year gives park service management a more nuanced idea of the range and amount of paddling opportunities Cataract Canyon provides in dry years.

In comparison with Cataract Canyon, a boatable days' analysis for the Dolores River in southwestern Colorado (Fey *et al.*, 2014) indicated that on average, no boatable days exist in dry years, and 5 boatable days occur in dry-typical years, and only then at low-acceptable levels. In wet and wet-typical year types, 31 and 54 boatable days respectively, occurred on average. The full range of whitewater flows was available in wet and wet-typical year types on the Dolores, including days within low acceptable, optimal, and high acceptable levels. Even in these wettest two year types, however, only 2 days in wet-typical years and 27 days in wet year types existed at the high acceptable flow levels on average. The results of the boatable days' analysis for the Dolores River are important for recreation management, partially because there were so few boatable days found throughout the year and even between years. The different management scenarios these two studies address demonstrate the value of the boatable days' analysis for managing other rivers across the southwest and anywhere where river recreation management is a priority.

The Dolores River basin currently supplies the San Juan basin, with supplemental water supplies from the Dolores Project and McPhee Dam. The project impounds all of the water from the upper Dolores basin and only releases flows downstream when inflow exceeds storage capacity, an obvious factor in the limited number of recreational days available to paddlers in the lower Dolores River. To help mitigate recreation impacts, this previous analysis was able to set a baseline of river recreation opportunities that currently exist and have historically existed. The same baseline is now established for the Colorado River and Cataract Canyon where water projects and complex water management strategies will assuredly be a part of the region future (Ficklin *et al.*, 2013).

Streamflows affect whitewater recreation in a number of ways, determining whether a stretch has recreational opportunities for whitewater paddlers and others, such as anglers, tubers, or swimmers. This article provides information critical for understanding the relationship between instream flows and whitewater boating in Cataract Canyon and establishes qualitative and quantitative targets that can inform future flow allocation negotiations. Defined flow needs for recreation are crucial elements in any river management planning or decision-making process, particularly on the Colorado River, where storage projects and wild and scenic river suitability are under consideration, as flow management is a central issue (Fey and Stafford, 2009).

To define the streamflows needed to provide recreational opportunities in Cataract Canyon, this article collected and organized personal evaluations of recreational resource conditions and recreation-relevant hydrology, consistent with standard methodologies. In aggregate, the survey respondents rated flows of 4000 cfs as the minimum acceptable flow for all crafts, while flows between 10 000 and 30 000 cfs provide for optimal flows. Highest acceptable flows were greater than 30 000 cfs for all whitewater craft, and in aggregate, no flow measured was too high to be acceptable. Disagreement over flow acceptability suggests that a number of individual respondents found flow levels of at least 3000 cfs acceptable, and flows above 50 000 cfs unacceptable.

It is possible that for different whitewater boating crafts, different sets of challenges and flow preferences exist, and that other variables such as experience and skill level may play a role in determining the acceptability of flows. For example, the respondents who reported predominantly using a kayak in Cataract Canyon rated 3500 cfs as the minimum acceptable flow, expanding their flow range to include more boatable days than oar-frame rafts, who rated 4000 cfs as their minimum acceptable flow. The participants who self-classified themselves as expert and advanced paddlers did not find any flow level up to 100 000 cfs to be unacceptable, while self-classified intermediate paddlers felt neutral about 75 000 cfs and found 100 000 cfs too high to be an acceptable flow. Future papers with further analysis of these variables will help refine our understanding of flow recreation needs.

Integrating results from overall flow evaluations with PCI_2 statistics provides more information than simple impact acceptability curves and helps validate the optimum flows presented here. Flow levels where both acceptability and agreement ratings are high define optimum flows for the entire set of respondents, because there is essentially no disagreement (PCI = 0.0–0.09) about the top range of the aggregate acceptability norm ratings (2.4–2.75). Efficient use of a managed release would meet the needs of the greatest number of users by providing optimal flows for the highest number of days possible, given hydrologic conditions. For Cataract Canyon, we understand that this would take a high degree of upstream coordination as a result of the numerous water management scenarios on the Upper Colorado and Green Rivers; however, for other rivers where their flow is directly controlled by an upstream impoundment, such as the Dolores River, knowing the optimal flow for releases will ensure that recreation mitigations (United States, Department of the Interior, Bureau of Reclamation, 1979) are the most beneficial to the greatest number of paddlers.

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The boatable days' analysis described here indicates that existing whitewater boating opportunities typically occur throughout the entire year in Cataract Canyon. The results indicate that optimal flows were available in even the driest of the years between 1990 and 2013. The boatable days' metric provides a relative comparison value to evaluate potential effects of continued flow manipulation in the Upper Colorado and Green River drainages on whitewater boating opportunities while allowing for annual variability in hydrologic and snowpack conditions in their respective basin. To the extent that flow regimes can be managed to produce different resource conditions downstream, this study provides critical information for resource managers responsible for making the most efficient use of available flows through scheduling and prediction of releases for whitewater boating.

REFERENCES

Brown TC, Taylor JG, Shelby B. 1991. Assessing the direct effects of stream flow on recreation: a literature review. *Water Resources Bulletin* **27**(6): 979–989.

Donnelly MP, Vaske JJ, Whittaker D, Shelby B. 2000. Toward an understanding of norm prevalence: a comparative analysis of 20 years of research. *Environmental Management* **25**: 403–414.

Fey N, Stafford E, Wynne K. 2014. Defining recreational streamflow needs in the Lower Dolores River: integrating specific and overall evaluations of flow and recreation quality. Report prepared for Dolores River Dialogue & U.S. Bureau of Land Management.

Fey N, Stafford E. 2009. Flow-recreation evaluations for the Upper Colorado River basin. Report prepared for Upper Colorado River Wild and Scenic Stakeholders Group & U.S. Bureau of Land Management.

Ficklin DL, Stewart IT, Maurer EP. 2013. Climate change impacts on streamflow and subbasin-scale hydrology in the Upper Colorado River Basin. *PLoS ONE* **8**(8): e71297. DOI:10.1371/journal.pone.0071297.

Heberlein TA, Dunwiddie P. 1979. Systematic observations of use levels, campsites selection and visitor characteristics at High Mountain Lake. *Journal of Leisure Research* **11**: 307–316.

Krymkowski DH, Manning RE, Valliere WA. 2009. Norm crystallization: measurement and comparative analysis. *Leisure Science* **31**: 403–416.

Manning RE. 2011. Studies in Outdoor Recreation: Search and Research for Satisfaction, 3rd edn. Corvallis, OR: Oregon State University Press.

Martinson KS, Shelby B. 1992. Encounter and proximity norms for salmon anglers in California and New Zealand. *North American Journal of Fisheries Management* **12**: 559–567.

Menges C, Fey N, Stafford E, Wynne K. 2013: Assessing streamflow needs for whitewater recreation in the Gunnison River basin: applying overall flow-comparisons and single-flow judgments to define the range of flows that support whitewater recreation. Appendix C, A subset of projects at which whitewater boating has been analyzed.

Shelby B. 1981. Encounter norms in backcountry settings: studies of three rivers. *Journal of Leisure Research* **13**: 129–138.

Shelby B, Vaske JJ, Harris R. 1988. User standards for ecological impacts at wilderness campsites. *Journal of Leisure Research* **20**: 245–256.

Shelby B, Vaske JJ. 1991. Using normative data to develop evaluative standards for resource management: a comment on three recent papers. *Journal of Leisure Research* **23**: 173–187.

Shelby B, Brown TC, Baumgartner R. 1992a. Effects of streamflows on river trips on the Colorado River in Grand Canyon, Arizona. *Rivers* **3**(3): 191–201.

Shelby B, Brown TC, Taylor JG. 1992b. Streamflow and Recreation. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station: Ft. Collins, CO (General Technical Report RM-209).

Shelby B, Stankey G, Schindler B. 1992b. Introduction: the role of standards in wilderness management. In Defining Wilderness Quality: The Role of Standards in Wilderness Management, Shelby B, Stankey G, Shindler B (eds). U.S. Forest Service, Pacific Northwest Research Station: Portland, OR (General Technical Report PNW-GTR-305); 1–4.

Shelby B, Whittaker D. 1995. Flows and recreation quality on the Dolores River: integrating overall and specific evaluations. *Rivers* **5**(2): 121–132.

Shelby B, Vaske JJ, Donnely MP. 1996. Norms, standards and natural resources. *Leisure Sciences* **18**: 103–123.

Shelby B, Whittaker D, Hansen W. 1997. Streamflow effects on hiking in Zion National Park, Utah. *Rivers* **6**(2): 80–93.

United States, Department of the Interior, Bureau of Reclamation. 1979: Final environmental impact statement, authorized Dolores project, INT FES 77–12.

Vandas S, Whittaker D, Murphy D, Prichard D, MacDonnell L, Shelby B, Muller D, Fogg J, Van Havern B. 1990. Dolores River Instream Flow Assessment. U.S. Bureau of Land Management: Denver, Co (BLM/YA/PR-90-003).

Vaske JJ, Donnelly MP. 2002. Generalizing the encounter-norm-crowding relationship. *Leisure Sciences* **24**: 255–269.

Vaske JJ, Heesemann LM, Loomis DK, Cottrell SP. 2013. Normative tolerances for SCUBA divers and snorkelers: An application of the potential for conflict index$_2$. *Tourism in Marine Environments* **9**(1-2): 69–80.

Vaske JJ, Shelby B, Graefe AR, Heberlein TA. 1986. Backcountry encounter norms: theory, method, and empirical evidence. *Journal of Leisure Research* **18**: 137–187.

Vaske JJ, Whittaker D, Shelby B, Manfredo MJ. 2002. Indicators and standards: developing definitions of quality. In Wildlife Viewing in North America: A Management Planning Handbook, Manfredo MJ (ed). Oregon State University Press: Corvallis, OR; 143–171.

Vaske JJ, Beaman J, Barreto H, Shelby LB. 2010. An extension and further validation of the potential for conflict index. *Leisure Sciences* **32**: 240–254.

Whittaker D, Shelby B, Jackson W, Beschta R. 1993. Instream Flows for Recreation: A Handbook on Concepts and Research Methods. Us National Park Service, Rivers, Trails, and Conservation Program: Anchorage, AK.

Whittaker D, Shelby B, Gangemi J. 2005. Flows and recreation: a guide to studies for river professionals. Report for Hydropower Reform Coalition and National Park Service – Hydropower Recreation Assistance.

Whittaker D, Shelby B. 1988. Types of norms for recreation impacts: extending the social norm concept. *Journal of Leisure Research* **20**: 261–273.

Whittaker D, Shelby B. 1993. Kenai River Carrying Capacity Study: Findings and Implications for Management (FTCA Report, Alaska State Parks). Alaska Department of Natural Resources: Anchorage, AK.

Whittaker D, Vaske JJ, Williams TV. 2000. Gulkana River 1999 on River User Survey. (Project Rep. No. 45). Colorado State University, Human Dimensions of Natural Resources Unit: Fort Collins, CO.

Whittaker D, Shelby B. 2002b. Evaluating Instream Flows for Recreation: A Handbook on Concepts and Research Methods. U.S. Department of Interior: National Park Service, Anchorage, AK.

Whittaker D, Shelby B. 2002b. Evaluating instream flows for recreation: applying the structural norm approach to biophysical conditions. *Journal of Leisure Research* **24**: 363–374.

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