ASSESSMENT OF STREAMFLOW NEEDS FOR SUPPORTING RECREATIONAL WATER USES ON THE ROARING FORK.

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Summary

The recreational use assessment presented in this report provides baseline information relating streamflows and recreational use. This body of work supplements ongoing strategic water planning efforts in the upper Roaring Fork watershed. The current planning effort does not consider impacts of water management and/or climate change on recreational use opportunities on the river. This report discusses study locations and methods used to collect and analyze streamflow preference information from recreational users. User survey responses provided by 67 respondents delineated acceptable and optimal streamflow thresholds for supporting recreational use activities on 9 segments on the Roaring Fork (Table ES.1). Threshold identification supported quantification of the Boatable Days metric for each assessment reach across wet and dry hydrological year types. The assessment followed recommendations from the State of Colorado's Basin Implementation Plan guidance documents for quantifying non-consumptive recreational needs.

Respondent numbers for the flow preference study conducted in 2020-2021 are robust for a remote or sparsely populated region of western Colorado. The large number of responses to flow-related questions for most reaches made delineation of flow acceptability thresholds fairly straightforward. There was a relatively lower response rate among survey participants for Reach 1 on the Roaring Fork, which is only accessible by expert/elite boaters. This may introduce some uncertainty into flow preference threshold delineated on that sections of river. Lower response rates may indicate there is less use on this section during most times of the year. Alternatively, it may indicate that the survey distribution did not reach the typical users of this reach. Future recreational use assessment activities may benefit from targeted outreach to those users known to recreate on the reach.

Table ES.1. User-defined flow preferences for reaches included in the Boatable Days assessment.

Reach	River	Reach Description	Min. Navigable	Min. Acceptable	Min. Optimal	Max. Optimal	Max. Acceptable
1	Roaring Fork	Weller Lake to Difficult Campground	100	200	300	400	600
2	Roaring Fork	North Star	100	100	200	1200	1600
3	Roaring Fork	Downtown Aspen	100	450	800	1600	1600
4	Roaring Fork	Slaughterhouse	100	450	800	1700	3000
5	Roaring Fork	Jaffee Park to Lower Woody Creek Bridge	100	500	1000	2000	3000
6	Roaring Fork	Toothache	100	450	800	1800	10000
7	Roaring Fork	Basalt to Carbondale	100	450	800	3000	5000
8	Roaring Fork	Pink to Black	100	550	800	6000	8000
9	Roaring Fork	Cemetery	100	550	1200	4000	20000

Variable streamflow conditions were found to impact use opportunities on all reaches. The total number of Boatable Days and the number of Optimal Boatable Days generally increase throughout the assessment area as hydrological conditions transition from dry to wet. The number of Optimal Boatable Days are highest on river segments either during Wet Typical years (Reaches 5, 6 & 9) or during the Wet Year type (Reaches 1-4, 7 & 8). Peak streamflows drop below lower acceptable thresholds only on Reaches 1 & 3 during drier years resulting in no Boatable Days. Other segments maintain some period of flows sufficient for boating even during dry hydrologic conditions. River segments lower on the Roaring Fork generally offered much longer boating seasons, particularly in

Wet Typical and Wet years. Additional work may be required to understand how alternative water management or climate change impacts diminish or increase the number of Boatable Days available to recreational users on each reach, and whether those changes occur in times of the year when recreation is most likely to occur.

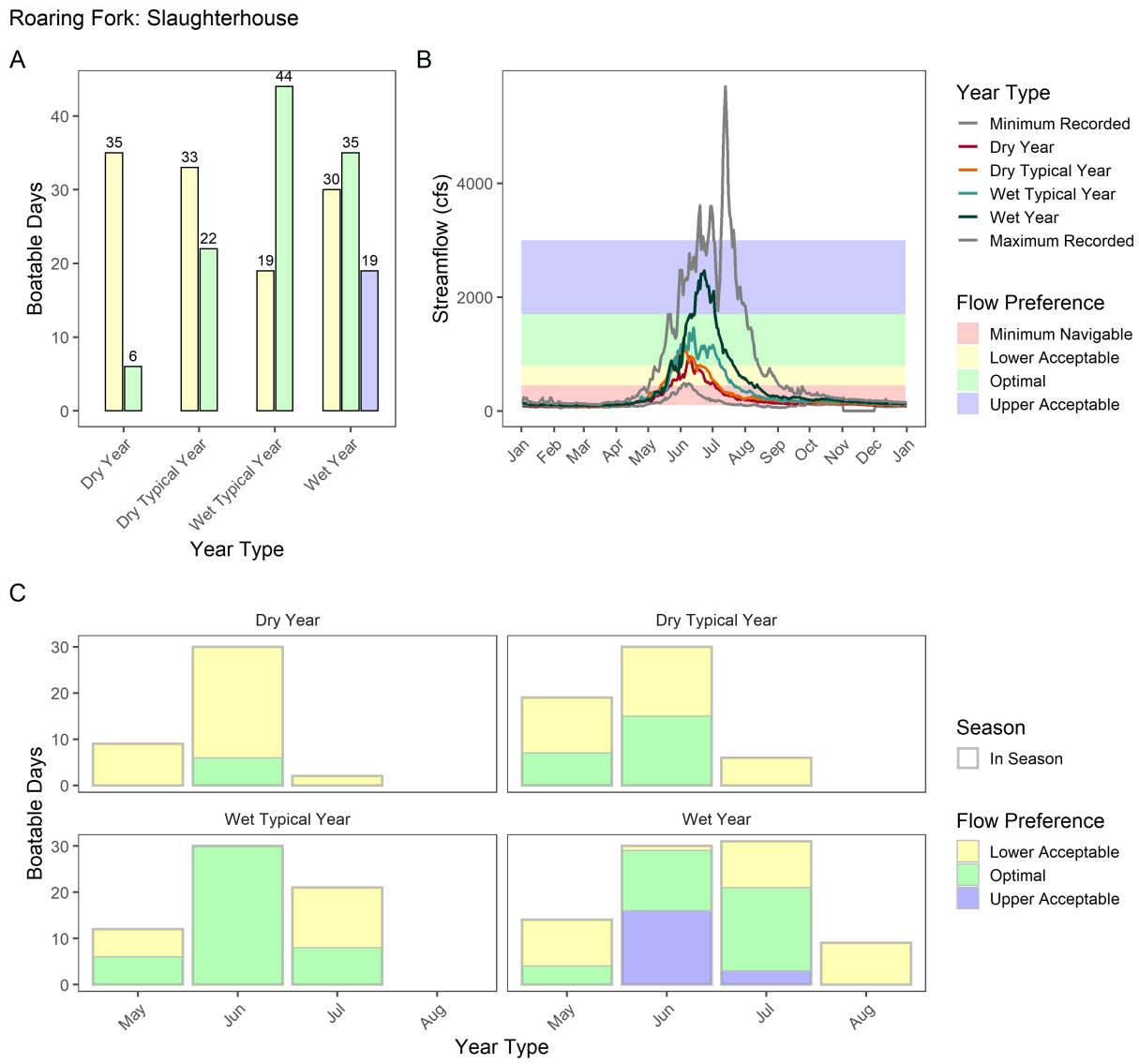

Figure ES.1. Boatable Days totals for the Roaring Fork: Slaughterhouse. (A) Annual Boatable Days totals summarized by hydrological year type. (B) Flow preference ranges mapped to representative streamflow time series for wet, wet typical, dry typical, and dry years. Minimum and maximum recorded daily streamflows also included for reference (C) Monthly Boatable Days totals summarized by hydrological year type.

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1. Introduction

Considerable work evaluating relationships between streamflow and recreational use opportunities occurred over the last several decades (Brown et al., 1991; Shelby, Brown, & Taylor, 1992; Whittaker and Shelby, 2002). Many flow-recreation studies focus on whitewater boating, such as rafting, kayaking, and canoeing, as flow often determines whether people have opportunity to successfully complete a trip. On many river segments, flow level contributes to the risk, challenge, and/or aesthetic attributes of on-water activities (Whittaker & Shelby, 2000). Natural and man-made changes in streamflow can have direct and indirect impacts on recreational boating experiences. Direct effects include navigation, safety/difficulty, travel times, quality of whitewater stretches, and beach and camp access (Brown, Taylor, & Shelby, 1991; Whittaker et al., 1993; Whittaker & Shelby, 2002). Indirectly, variability in streamflow affects wildlife viewing, scenery, fish habitat, and riparian vegetation over the long term as a result of changes in flow regime (Bovey, 1996; Richter et al., 1997; Jackson & Beschta, 1992; Hill et al., 1991).

Streamflow is often manipulated through releases from dams and reservoirs, pipelines, and diversions. Additional scenarios, such as climate change, drought, and new water rights development can all impact flows and recreation quality. Decision-makers within land and resource management and regulatory agencies, and state and local governments are increasingly interested in the extent that flow regimes can be managed to provide desirable recreational resource conditions. The various recreational use opportunities provided by different flow ranges can be delineated into "niches" (Shelby et al., 1997). These flow niches may include: unacceptably low flow; minimum navigable flows, technical, but enjoyable flows; optimal flows; challenging high flows; and unacceptably high flows. Methodologies developed by American Whitewater are regularly used to delineate user-defined streamflow niches and subsequently quantify recreational user opportunities under different hydrological conditions. Implementation of these assessment methodologies aims to support water management decision-making. Specific evaluative information on how flow affects recreation quality is often critical, particularly where social values are central to decision-making (Kennedy and Thomas 1995). American Whitewater's Boatable Days assessment methodology is recognized as a best practice for defining recreation flow needs and opportunities (Stafford et al., 2016).

American Whitewater is currently undertaking a river recreation assessment to supplement ongoing strategic water planning efforts in the upper Roaring Fork watershed. The characterization of Boatable Days provides an objective, science-based measure of existing whitewater recreation opportunities related to variability in streamflow on reaches throughout the assessment area (Figure 1). This information aims to support conversations about how hydrologic conditions currently impact whitewater recreation opportunities and how these opportunities might change under future hydrological conditions and water management scenarios. Boatable Days modelling can further be used to identify opportunities and constraints for implementation of future water projects in the Roaring Fork watershed.

In addition to meeting objectives of local watershed planning efforts, the results of this assessment advance implementation of the Colorado Water Plan[1]. The State's draft Basin Implementation Plan Guidance document[2] recommends quantification of recreational values (e.g., boating and fishing). Section 2.1 of the Guidance calls for the evaluation of non-consumptive needs in terms of 'measurable outcomes', data, and assessment using methods described in CWCB's Non-consumptive Toolbox (CWCB, 2013). Appendices C and D of the toolbox identify the flow-evaluation methodology developed and used by American Whitewater as an example of a recreation tool that can produce measurable outcomes. This assessment aims to 1) address gaps in data and understanding regarding flow conditions necessary to sustain recreational values on the Roaring Fork river and 2) improve stakeholders' collective understanding of existing recreational use opportunities and how these opportunities may be impacted by climate change and consumptive water projects.

1. Study Area

River reaches considered in this assessment were identified collaboratively between American Whitewater and Lotic Hydrological staff. Nine segments on Roaring Fork were determined to have significant recreational values and were, therefore, included in the assessment (Table 1). The Basalt Whitewater Park on the Roaring Fork was not included in this analysis due to an ongoing effort to improve safety by modifying the park's whitewater structures; consistent flow preferences may be identified in the future once this work is completed. Each segment was mapped to an existing United State Geological Society (USGS) streamflow gauging station. Mapping streamflow gauge locations to each assessment reach considered: 1) the historical period of record (POR) for streamflow observations, 2) the distance between the gauge and river segment, and 3) the gauge most commonly used by recreationalists to inform their use of the segment. For some cases, a single stream gauge represents flows for adjoining river segments in multiple locations. . Influences such as large tributary inputs or major water diversion locations may impact a gauge's 'representativeness' for a given reach. Flow thresholds used in the Boatable Days analysis correspond to streamflow at the gauges and may not always reflect accurate streamflow levels at the reach.

Table 1. River segments and corresponding streamflow measurement gauges considered in this study.

Reach	River	Reach Description	USGS Gage ID	USGS Gage Description
1	Roaring Fork	Weller Lake to Difficult Campground	09073300	Roaring Fork River AB Difficult Creek, Nr Aspen
2	Roaring Fork	North Star	09073400	Roaring Fork River Near Aspen
3	Roaring Fork	Downtown Aspen	09073400	Roaring Fork River Near Aspen
4	Roaring Fork	Slaughterhouse	09076300	Roaring Fork River Blw Maroon Creek, Nr Aspen
5	Roaring Fork	Jaffee Park to Lower Woody Creek Bridge	09076300	Roaring Fork River Blw Maroon Creek, Nr Aspen
6	Roaring Fork	Toothache	09076300	Roaring Fork River Blow Maroon Creek, Nr Aspen
7	Roaring Fork	Basalt to Carbondale	09081000	Roaring Fork River Near Emma
8	Roaring Fork	Pink to Black	09085000	Roaring Fork River At Glenwood Springs
9	Roaring Fork	Cemetery	09085000	Roaring Fork River At Glenwood Springs

[1] https://www.colorado.gov/pacific/cowaterplan/plan

[2] http://cwcbweblink.state.co.us/WebLink/0/doc/172522/Electronic.aspx?searchid=da8f2c6c-3efa-48d6-a43e-892b5c2bd750

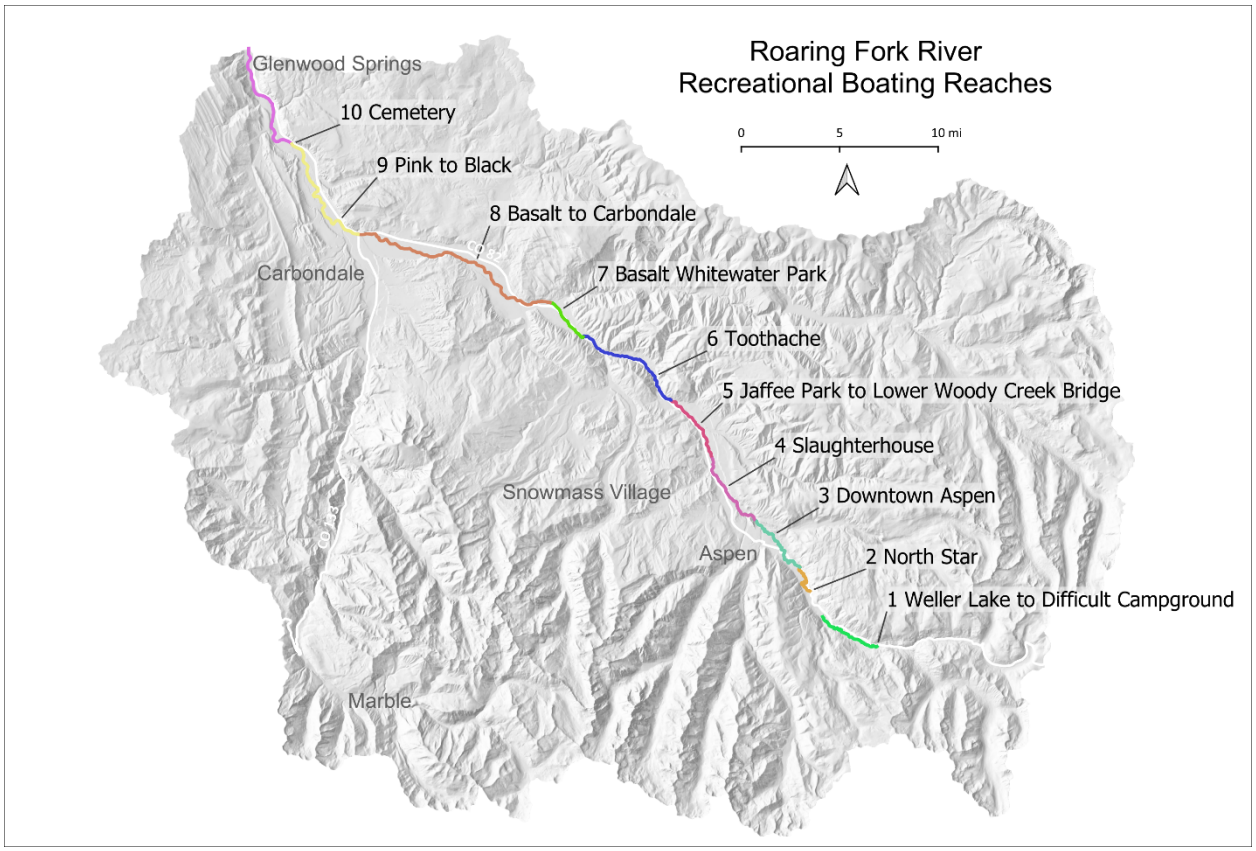

Figure 1: Roaring Fork River Recreational Assessment Map.

2. Methods

American Whitewater collected recreational user feedback through a web-based survey (Appendix B). Three types of questions were included in the survey. The first type of question captured demographic information about each participant's skill level, frequency of participation in river-related recreation, etc. The second type of question allowed users to assign use-acceptability rankings to various streamflows. The third question type asked users to identify flows associated with different trip types (technical low-water, standard, challenging high-flow, etc.). These questions were organized around each assessment reach and were supported with general mapping and narrative information about that reach from American Whitewater's website. The survey also clearly defined which streamflow measurement gauge to reference when assigning acceptability rankings for conditions on the reach. An announcement of the survey was emailed to American Whitewater's members, posted on the website and distributed via American Whitewater's online newsletter.

The flow acceptability questions included in the user-survey are the principal focus of this assessment. These questions asked respondents to evaluate recreational use acceptability for a range of measured flows on each study segment using a five-point scale that included the following rankings: Unacceptable, Moderately Unacceptable, Marginal, Moderately Acceptable, and Acceptable. Each ranking in the scale was mapped to an integer value between -2 and 2 where an

'Unacceptable' ranking mapped to a value of -2, a 'Marginal' ranking mapped to a value of 0, and an 'Acceptable' ranking mapped to a value of 2. To further explore and characterize the relationship between flows and recreational use opportunities, the survey posed a series of open-ended questions about streamflows associated with distinct niche experiences. These niche experiences included: lowest navigable flow (minFlow), minimum acceptable flow (lowAcceptable), technical but navigable flows (technicalTrip), flows experienced during a standard trip (standardTrip), challenging high-water (highChallenge), and highest safe flow (highSafe).

The flow options provided in the flow acceptability questions were directly informed by historical hydrology data from each individual stream gauge. Both the minimum flow option and the maximum flow option were informed by historical minimums and maximums.

Flow-acceptability rankings provided through the survey were used to describe preferences among recreational users for various ranges of streamflow. Researchers collecting and organizing survey-based evaluative information often employ a normative approach for analyzing results. The normative approach considers each individual's evaluation (personal norms) of a range of potential conditions. Aggregation of many individuals' personal norms describe a group's collective evaluation (social norms) of resource condition. This approach has been applied extensively in natural resource management settings, often with respect to instream flows for recreation (Shelby and Whittaker, 1995; Shelby et al., 1992a; Vandas et al., 1990; Whittaker and Shelby, 2002b) and is particularly useful for developing thresholds that define low, acceptable, and/or optimal resource conditions (Shelby et al. 1992). Other applications have extended this approach to different indicators and impacts, including: evaluation of how many people are considered 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 behavior (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). Notably, the normative approach was employed to understand user preferences for various streamflows on the Grand Canyon (Shelby et al. 1992) and on several other rivers in Colorado (Vandas et al. 1990, Shelby & Whittaker 1995, Fey & Stafford 2009, Fey & Stafford 2010).

Defining management standards is often more efficient if there is a high degree of consensus (or "norm crystallization") among users regarding acceptable and unacceptable resource conditions. Traditional measures of norm crystallization have included the standard deviation, coefficient of variation, and interquartile range of survey responses (Krymkowski et al., 2009; Manning, 2011; Shelby and Vaske, 1991). The Potential for Conflict Index-2 (PCI2) was developed to help address some of the shortcomings associated with traditional measures of norm crystallization when applied to ordinal data. A detailed description of the PCI2 metric is provided by Vaske et al. (2010). Briefly, computed PCI2 values range from 0 to 1.0 where the least amount of consensus (PCI2 = 1.0) occurs when responses are equally divided between two extreme values on a Likert response scale (e.g. 50% Highly Unacceptable and 50% Highly Acceptable). A set of responses with unanimous consensus among respondents yields a PCI2 value of zero.

The normative approach was the basis for describing flow preference ranges for streamflows on different reaches within the assessment area. The numerical representations of flow acceptability preference rankings were used to compute PCI2 scores for each flow included in the survey. The central tendency of survey responses was computed as the mean value of the flow acceptability preference ranking for each streamflow on each reach. Computed PCI2 values were plotted against the central tendency of survey responses to create use acceptability curves for each of the study reaches.

Use acceptability curves, tabular data summaries, and responses to open-ended questions about niche conditions were used to delineate various normative streamflow characteristics. These characteristics included a minimum acceptable streamflow, a range of acceptable streamflow conditions, and a range of optimum streamflow conditions. The upper and lower thresholds delineated for acceptable, optimal and minimum navigable streamflow conditions were then compared under Wet, Wet Typical, Dry Typical, and Dry hydrological conditions in order to complete a Boatable Days analysis.

The computation of Boatable Days is the dominant quantitative approach used by American Whitewater to characterize recreational use opportunities on rivers (Fey and Stafford, 2009; Shelby and Whittaker, 1995; Whittaker et al., 1993). The metric itself reflects the number of days in a given year that fall within certain defined flow ranges (i.e., lower acceptable flows, optimal flows, upper acceptable flows). The Boatable Days analysis performed on reaches within the assessment area responded to the inter-annual natural and management-induced variability in streamflows by computing the number of Boatable Days that occur in each of four hydrological year types: wet-year, Wet, Wet Typical, Dry Typical, and Dry.

Representative streamflow time series for the four year types on each reach required synthesis of historical USGS streamflow data. Daily streamflow data was collected from stream gauges throughout the assessment area for a 34-year period (1986 – 2020). Two USGS gauges were not operational for the full period and have shorter streamflow records, including USGS station #09081000 (1999 – 2020) and USGS station #9076300 (1989-2017). Streamflow time series data from each gauge were then ordered by annual peak flow. Average daily streamflows across all years in the lower 25th percentile of the ordered list were computed to produce a representative dry year streamflow time series. The same approach was used to create representative streamflow series for dry typical years, wet typical years and wet years where dry typical years fell between the 25th and 50th percentiles of annual peak flows, wet typical years fell between the 50th and 75th percentiles of annual peak flows, and wet year types were those years that fell above the 75th percentile of the ordered list.

3. Results

The web-survey captured complete responses from 67 recreational users. Survey respondents were generally very experienced boaters. 91% of respondents indicated they were somewhat comfortable or very comfortable reporting flows, 89% of respondents identified themselves as advanced or expert paddlers, 100% identified as Class III or greater paddlers, and 63% recreate on the Roaring Fork at least 20 days per season (Figure 2). The majority of respondents indicated their preferred craft types were kayaks (51%) or rafts (21%) while a minority indicated other crafts, including stand-up paddle boards (16%), inflatable kayaks/rafts (6%) and canoes (2%). Craft preferences did vary by reach. On most upper reaches of the Roaring Fork (Reaches 1, 3-4), kayaking was strongly preferred by users. On lower reaches, user preferences were mostly split between kayaking and rafting (Reaches 5-8). The one exception was on North Star (Reach 2) where stand up paddle boarding was the preferred activity.

Survey responses were aggregated by reach, reviewed for quality, and displayed graphically to aid in interpretation (Appendix A). An example summary graphic is included for survey responses for the Slaughterhouse section of the Roaring Fork (Figure 3).

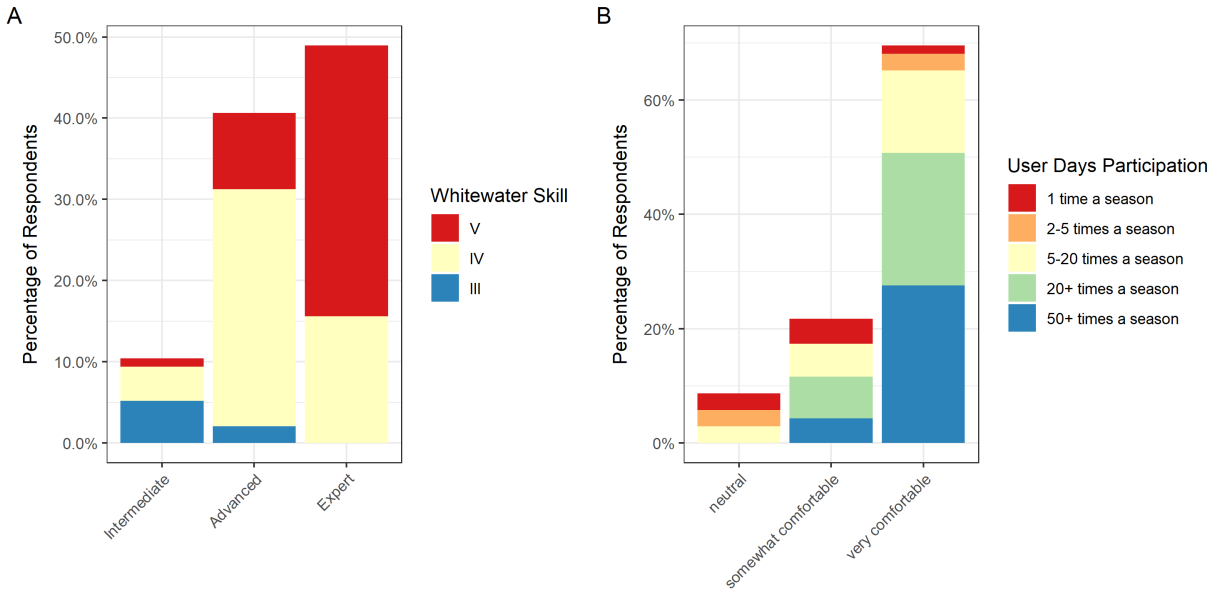

Figure 2: Survey responses from 67 users indicating (A) experience level and maximum comfortable whitewater class; (B) participant confidence in providing flow acceptability rankings for one or more reaches in the assessment area.

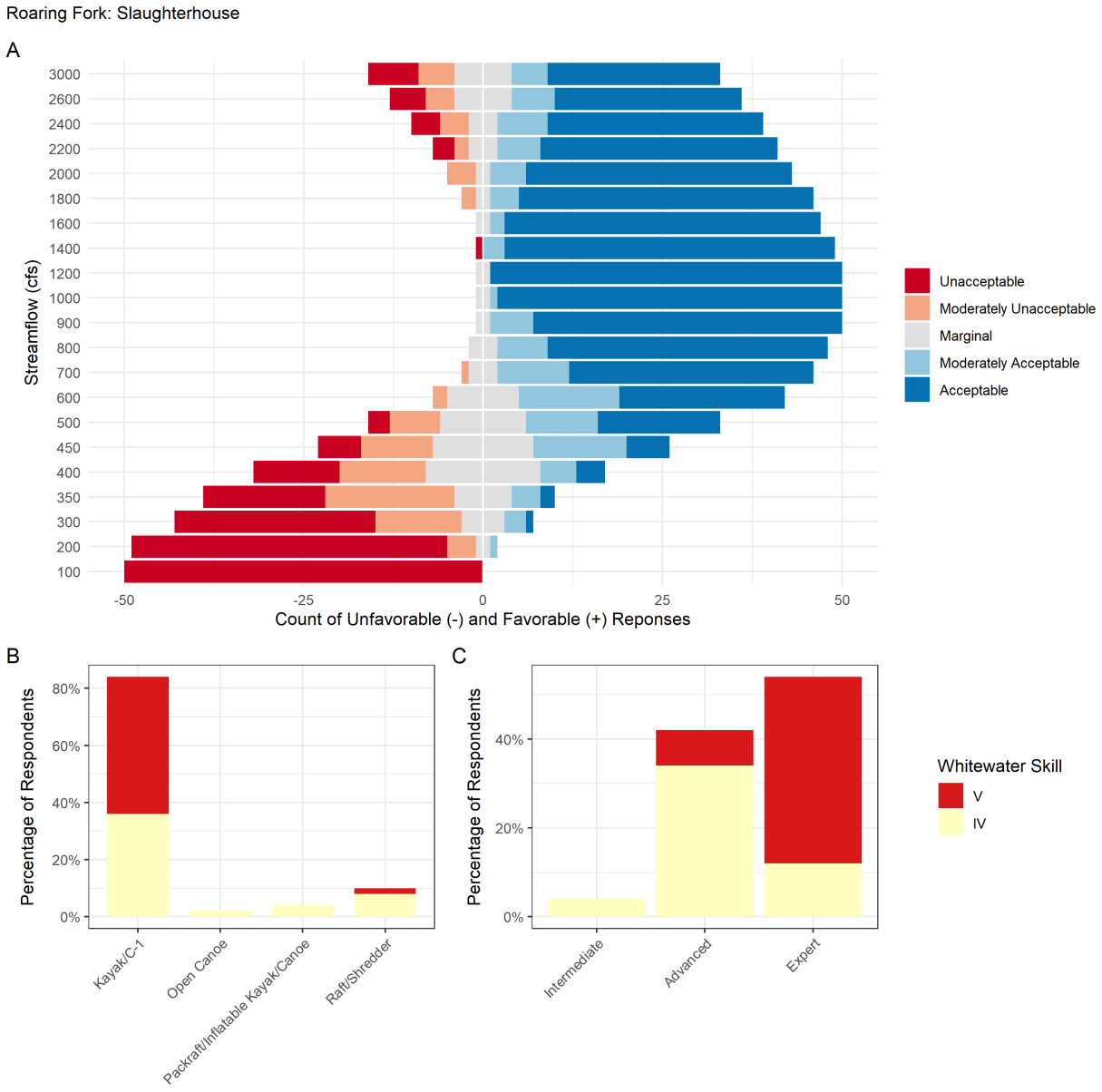

Figure 3: Survey responses for the Slaughterhouse section of the Roaring Fork. (A) Counts of the various flow acceptability rankings provided by respondents where survey responses reflect streamflow variability as measured at the Roaring Fork River Below Maroon Creek, Near Aspen (USGS Station ID: 09076300). (B) User identified craft types and whitewater skill level for the reach. (C) The self-identified experience and whitewater skill levels provided by survey respondents.

Use acceptability curves, tabular data summaries, and responses to open-ended questions about niche conditions were used to delineate various normative streamflow characteristics, including the 'Minimum Acceptable', 'Minimum Optimal', 'Maximum Optimal', and 'Maximum Acceptable' streamflow on each reach (Table 2). An example graphic of use acceptability curves and delineated flow preferences from is included the Slaughterhouse section of the Roaring Fork (Figure 4).

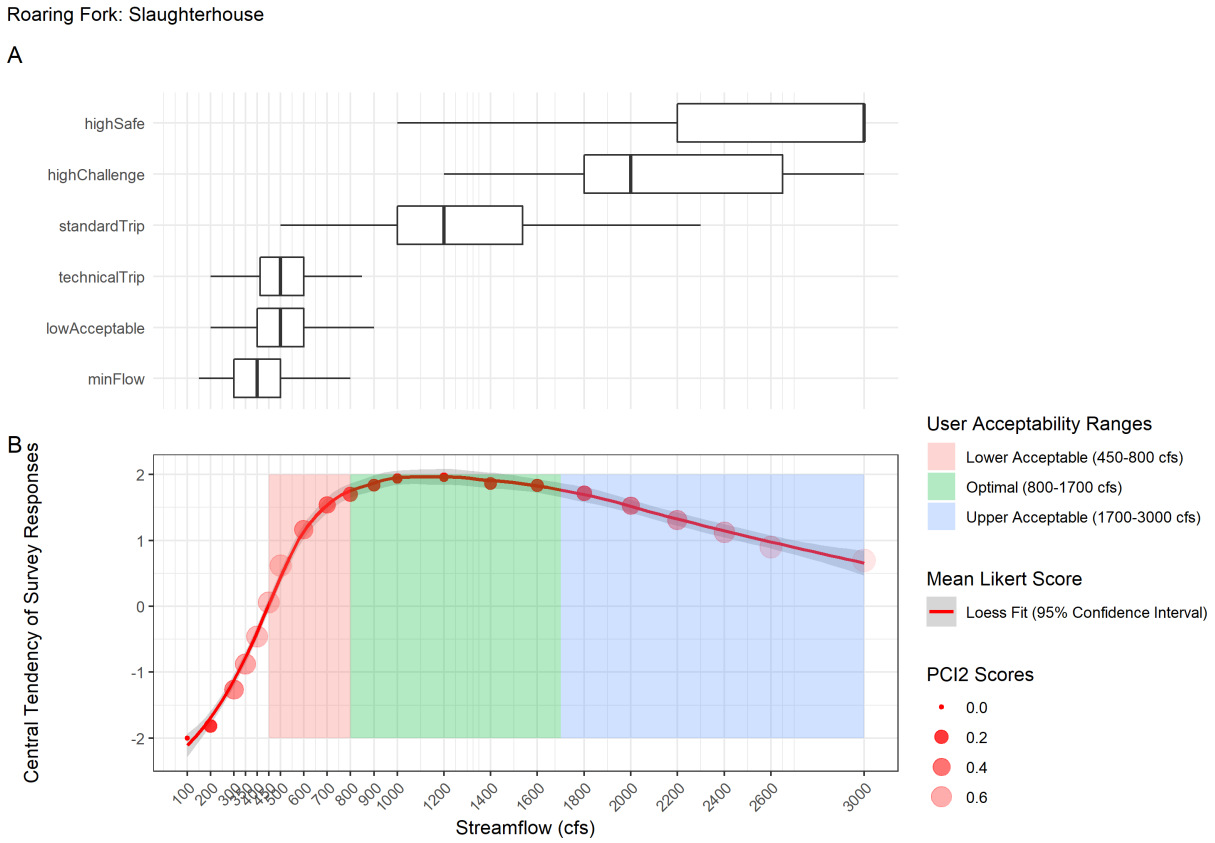

Figure 4: Flow preferences reported by users for the Roaring Fork: Slaughterhouse. A) Boxplot of responses to open-ended questions about different categories of flow. B) PCI2 analysis results plotted against the central tendency of flow acceptability preference rankings at each flow category. A Loess curve was fit to support visualization of flow acceptability ranges.

Use acceptability curves for some reaches did not indicate an upper bound for the maximum acceptable flow. The upper bound was therefore estimated at some reaches as being above the streamflow categories on the survey. Responses to open ended questions suggest that navigation hazards due to bridges can increase at high flow at some segments but the risk may depend also the type of craft used. Further work may be needed to assess these navigation hazards to better constrain the upper bound of acceptable flows for differing crafts.

The advanced and expert skill levels reported among the majority of survey participants may be the primary reason that use acceptability curves fail to indicate an upper bound for desirable recreational flows. It is, therefore, most appropriate to view survey responses within the context of the user groups that participated in the survey. The upper flow acceptability thresholds delineated for reaches in the assessment area are, probably, most relevant to advanced and expert users and are not likely appropriate for novice or intermediate users. Additionally, novices or intermediate users often have not yet developed sufficient river and boating knowledge to understand what flows may constitute an upper safe level for themselves or other users at their level, further making the quantification of consensus upper limits difficult to completely resolve.

Table 2. Flow preference thresholds delineated for each reach in the assessment area. All values are reported in cubic feet per second (cfs).

Reach	River	Reach Description	Min. Navigable	Min. Acceptable	Min. Optimal	Max. Optimal	Max. Acceptable
1	Roaring Fork	Weller Lake to Difficult Campground	100	200	300	400	600
2	Roaring Fork	North Star	100	100	200	1200	1600
3	Roaring Fork	Downtown Aspen	100	450	800	1600	1600
4	Roaring Fork	Slaughterhouse	100	450	800	1700	3000
5	Roaring Fork	Jaffee Park to Lower Woody Creek Bridge	100	500	1000	2000	3000
6	Roaring Fork	Toothache	100	450	800	1800	10000
7	Roaring Fork	Basalt to Carbondale	100	450	800	3000	5000
8	Roaring Fork	Pink to Black	100	550	800	6000	8000
9	Roaring Fork	Cemetery	100	550	1200	4000	20000

Streamflows preferred by users generally were lower on headwater segments and increased on downstream segments of the Roaring Fork. Variability in flow thresholds between reaches also can be attributed to different user groups recreating in different locations, the unique geomorphic or hydraulic characteristics of each reach, and/or variability in the sample size of respondents providing flow rankings on each reach and for each listed streamflow. As noted above, maximum acceptable flows were estimated above those provided on the survey for Reaches 6 & 9.

Flow preference thresholds were used to compute the number of Boatable Days associated with different hydrological conditions on each reach in the assessment area (Table 3). Results were summarized graphically and in tabular form (Appendix A; Figure 5, representative example). The total number of Boatable Days and the number of Optimal Boatable Days generally increase throughout the assessment area as hydrological conditions transition from dry to wet. The number of Optimal Boatable Days are highest on river segments either during Wet Typical years (Reaches 5, 6 & 9) or during Wet years (Reaches 1-4, 7 & 8). Several upper river segments including Reaches 1 & 3 appeared to be more marginal for boating. These reaches had low numbers or zero total Boatable Days in the Dry and Dry Typical years and had around one month of boating opportunity in Wet years. River segments lower on the Roaring Fork generally offered much longer seasons for boating, particularly in Wet Typical and Wet years.

Flows on several reaches of the Roaring Fork did not tally any boatable days in the 'Upper Acceptable range'. This is due, in some locations, to the lack of a discernible upper bound on the range of "Optimal" flows identified by recreational users. In other locations, the streamflow time series never exceeded the upper bound of user-defined "Optimal" flows. A different representation of hydrological year types (i.e., different thresholds for what constitutes a dry, typical, or wet year) will result in different Boatable Days totals.

Table 3. Boatable Days falling within each acceptability category calculated for reaches within the assessment area for typical Dry, Dry Typical, Wet Typical and Wet hydrological year types.

Reach	Reach Description	Flow Preference Category	Dry Year	Dry Typical Year	Wet Typical Year	Wet Year
1	Weller Lake to Difficult Campground	Lower Acceptable	0	7	23	12
		Optimal	0	0	3	9
		Upper Acceptable	0	0	0	11
		Total Days	0	7	26	32
2	North Star	Lower Acceptable	22	22	28	39
		Optimal	25	34	46	62
		Total Days	47	56	74	101
3	Downtown Aspen	Lower Acceptable	0	0	7	18
		Optimal	0	0	0	10
		Total Days	0	0	7	28
4	Slaughterhouse	Lower Acceptable	35	33	19	30
		Optimal	6	22	44	35
		Upper Acceptable	0	0	0	19
		Total Days	41	55	63	84
5	Jaffee Park to Lower Woody Creek Bridge	Lower Acceptable	37	43	28	35
		Optimal	0	6	32	26
		Upper Acceptable	0	0	0	16
		Total Days	37	49	60	77
6	Toothache	Lower Acceptable	35	33	19	30
		Optimal	6	22	44	36
		Upper Acceptable	0	0	0	18
		Total Days	41	55	63	84
8	Basalt to Carbondale	Lower Acceptable	31	88	116	93
		Optimal	27	49	60	85
		Upper Acceptable	0	0	0	10
		Total Days	58	137	176	188
9	Pink to Black	Lower Acceptable	21	40	51	56
		Optimal	27	49	60	95
		Total Days	48	89	111	151
10	Cemetery	Lower Acceptable	102	168	170	165
		Optimal	48	59	77	75
		Upper Acceptable	0	0	19	41
		Total Days	150	227	266	281

Table 4. Boatable Days analysis results broken out by month for the Roaring Fork: Slaughterhouse. Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Flow Preference Category	Dry Year	Dry Typical Year	Wet Typical Year	Wet Year
May	Lower Acceptable	9	12	6	10
	Optimal	0	7	6	4
	Total Days	9	19	12	14
Jun	Lower Acceptable	24	15	0	1
	Optimal	6	15	30	13
	Upper Acceptable	0	0	0	16
	Total Days	30	30	30	30
Jul	Lower Acceptable	2	6	13	10
	Optimal	0	0	8	18
	Upper Acceptable	0	0	0	3
	Total Days	2	6	21	31
Aug	Lower Acceptable	0	0	0	9
	Total Days	0	0	0	9

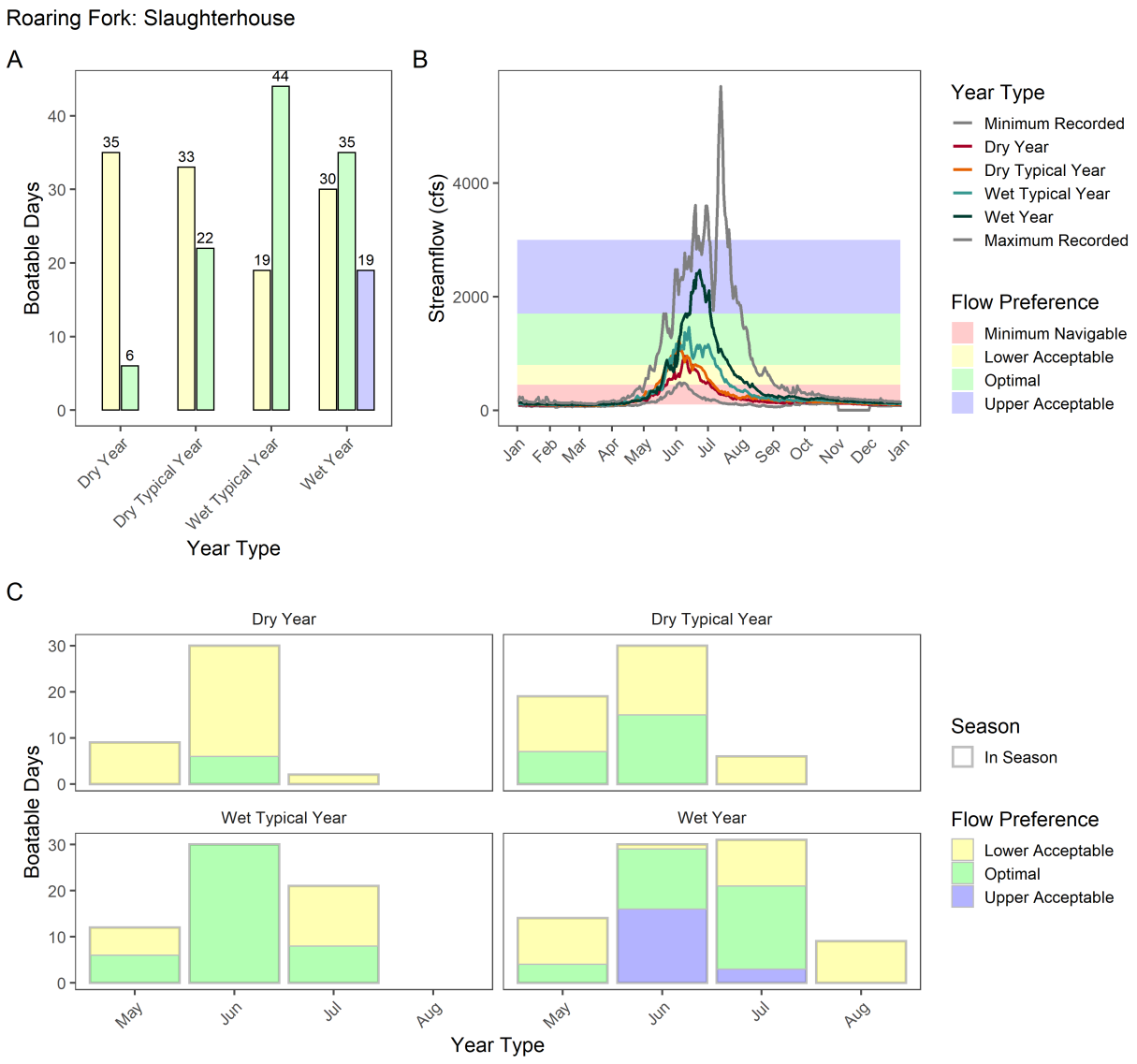

Figure 5: Boatable Days totals for the Roaring Fork: Slaughterhouse. (A) Annual Boatable Days totals summarized by hydrological year type. (B) Flow preference ranges mapped to representative streamflow time series for wet, wet typical, dry typical, and dry years. Minimum and maximum recorded daily streamflows also included for reference (C) Monthly Boatable Days totals summarized by hydrological year type.

It is important to note the difference between a Boatable Day and a user-day. A Boatable Day describes when acceptable flows are met to provide an *opportunity* for recreation. User-days indicate the actual numbers of known recreational users present on a reach over a period of time. User-days are affected by numerous factors including weather, hazards, river access, etc. while Boatable Days are solely affected by flow conditions. The number of total Boatable Days for the Cemetery reach include days in March, November and December when recreational use is likely to be light. There is limited known use on these segments during the fall and winter months due to weather conditions, ice hazards on the river, and poor river access due to snow and road closures. When using the Boatable Days analysis results to inform management decisions it will be particularly useful to consider the monthly Boatable Days totals during the typical user-season

rather than the annual totals. While ice coverage varies depending on the year and the location, ice has potential to impact user days on most reaches between November 1 and March 31.

4. Discussion and Conclusions

This report discusses study locations and methods used to collect and analyze streamflow preference information from recreational river users. User survey responses provided by 67 respondents were used to delineate acceptable and optimal streamflow thresholds for supporting recreational use activities on 9 segments on the Roaring Fork. Threshold identification supported quantification of the Boatable Days metric for each assessment reach under wet, typical, and dry hydrological year types. The assessment followed recommendations in the State of Colorado's Basin Implementation Plan guidance documents for quantifying non-consumptive recreational needs.

Respondent numbers for the flow preference study conducted in 2020-2021 are robust for a remote or sparsely populated mountain region of Colorado. The large number of responses to flow related questions for most reaches made delineation of flow acceptability thresholds fairly straightforward. However, low response rates (<10 respondents) among survey participants for Reach 1, an expert/elite headwaters reach, may introduce some uncertainty into the flow preference threshold delineated for that section. Low response rates may indicate there is little to no use on these sections during most times of the year. Alternatively, it may indicate that the survey distribution did not reach the typical users of this reach. Future recreational use assessment activities may benefit from targeted outreach to those users known to recreate on this reach and inquiries into whether or not they have companions or are aware of additional users/groups that recreate at those locations (i.e., 'snowball' or 'referral' sampling methods). It may also be useful to ascertain why this reach may be receiving so little use and whether or not there is opportunity or interest to increase recreational activity through awareness campaigns, development of river access points, or through some other means.

Variable streamflow conditions impact use opportunities on all reaches. The total number of Boatable Days generally increase throughout the assessment area as hydrological conditions transition from dry to wet. Boatable Days on the majority of upper segments on the Roaring Fork (Reaches 1-6) are only during high flow months (May – July) while lower segments (Reaches 7-9) generally have boating seasons that start earlier into the spring and extend further into the summer and fall. During wetter years, the boating season is generally longer on all Roaring Fork segments.

The results presented in this report represent baseline information characterizing the relationships between flows and recreational use. As such, this body of work supplements ongoing strategic water planning efforts in the Roaring Fork watershed. Future efforts may choose to build upon this assessment by calculating the number of Boatable Days available in a greater diversity of hydrological year types, by different user groups (such as boat-based anglers), or in anticipation of altered future hydrology due changes in water management and climate change.

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APPENDIX A: Analysis Results by Reach

Roaring Fork: Weller Lake to Difficult Campground (Reach 1)

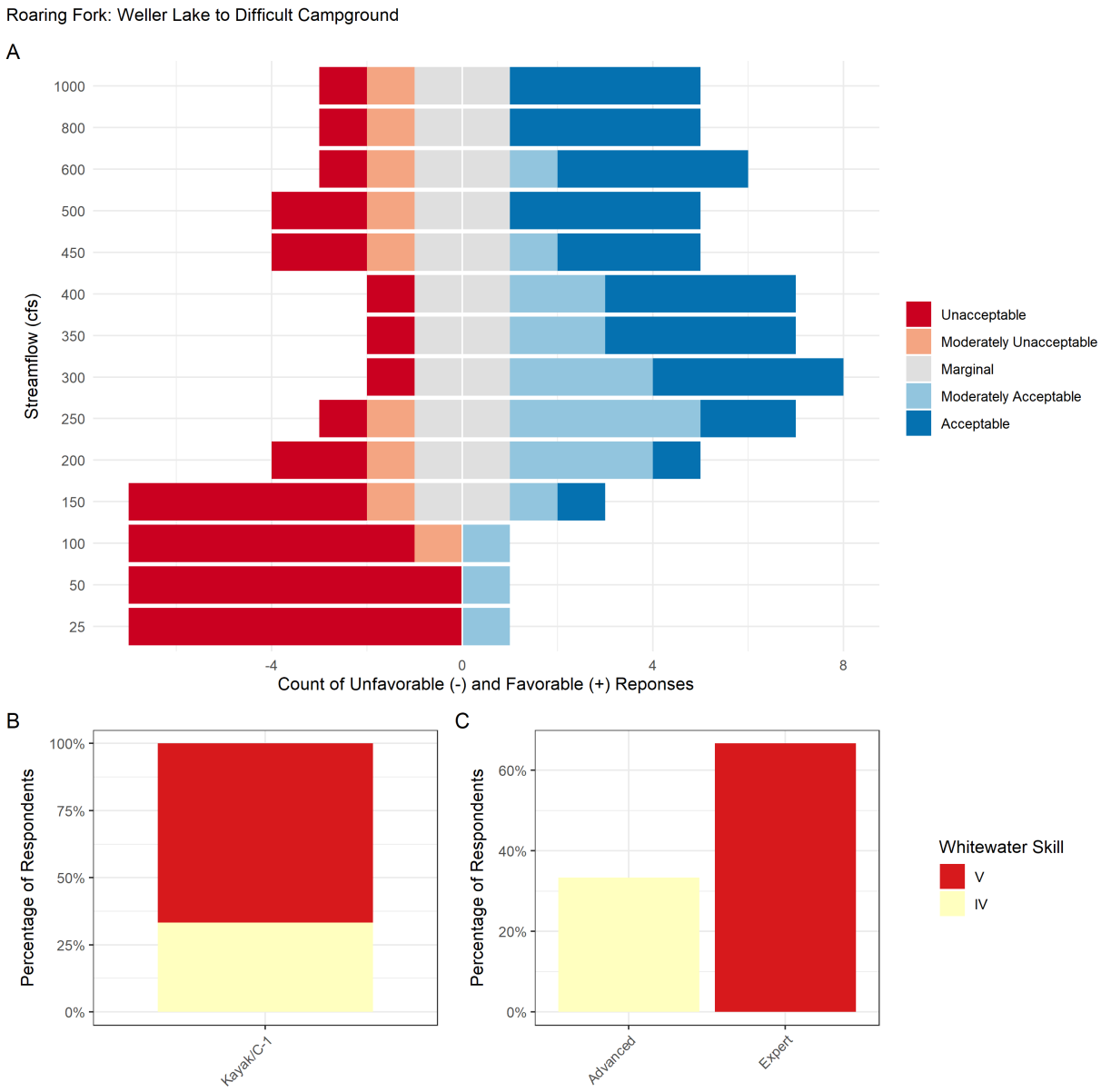
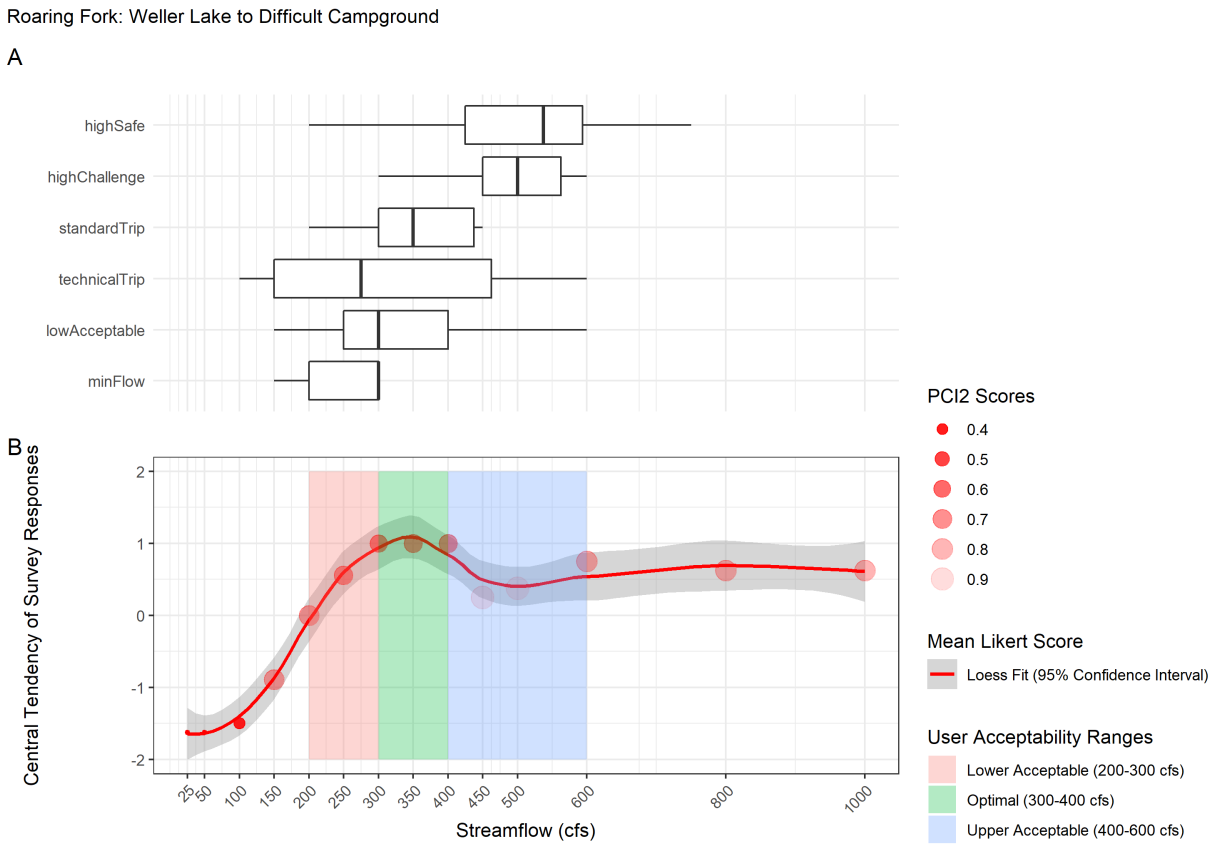


Figure 1: Survey responses for Roaring Fork: Weller Lake to Difficult Campground. (A) Flow acceptability rankings. (B) User identified preferred craft types and whitewater skill level. (C) User identified expertise and whitewater skill level.



C

Survey Question	25th Percentile	Median Response	75th Percentile	Response Count
Minimum Flow (cfs)	200	300	300	9
Low Acceptable Flow (cfs)	250	300	400	9
Technical Flow (cfs)	150	275	462	7
Standard Trip Flow (cfs)	300	388	538	8
Challenging High Flow (cfs)	450	512	650	8
Highest Safe Flow (cfs)	475	588	962	8

Figure 2: Flow preferences reported by users for Roaring Fork: Weller Lake to Difficult Campground. A) Boxplot of responses to open-ended questions about different categories of flow. B) PCI2 analysis results plotted against the central tendency of flow acceptability preference rankings at each flow category. Loess curve was fit to support visualization of flow acceptability ranges. C) Summarized open-format flow-preference question responses.

Table 1: PCI2 analysis results for Roaring Fork: Weller Lake to Difficult Campground.

Flow (cfs)	Median Likert Response	n	Max. Distance	Total Distance
25	-1.63	8	128	42
50	-1.63	8	128	42
100	-1.50	8	128	52
150	-0.89	9	160	120
200	0.00	9	160	120
250	0.56	9	160	108
300	1.00	9	160	100
350	1.00	8	128	84
400	1.00	8	128	84
450	0.25	8	128	116
500	0.38	8	128	118
600	0.75	8	128	100
800	0.63	8	128	102
1000	0.63	8	128	102

Table 2: Boatable Days analysis results broken out by month for the Roaring Fork: Weller Lake to Difficult Campground. Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Flow Preference Category	Dry Year	Dry Typical Year	Wet Typical Year	Wet Year
May	Lower Acceptable	0	2	1	2
	Total Days	0	2	1	2
Jun	Lower Acceptable	0	5	22	4
	Optimal	0	0	3	3
	Upper Acceptable	0	0	0	19
	Total Days	0	5	25	26
Jul	Lower Acceptable	0	0	0	6
	Optimal	0	0	0	6
	Upper Acceptable	0	0	0	2
	Total Days	0	0	0	14

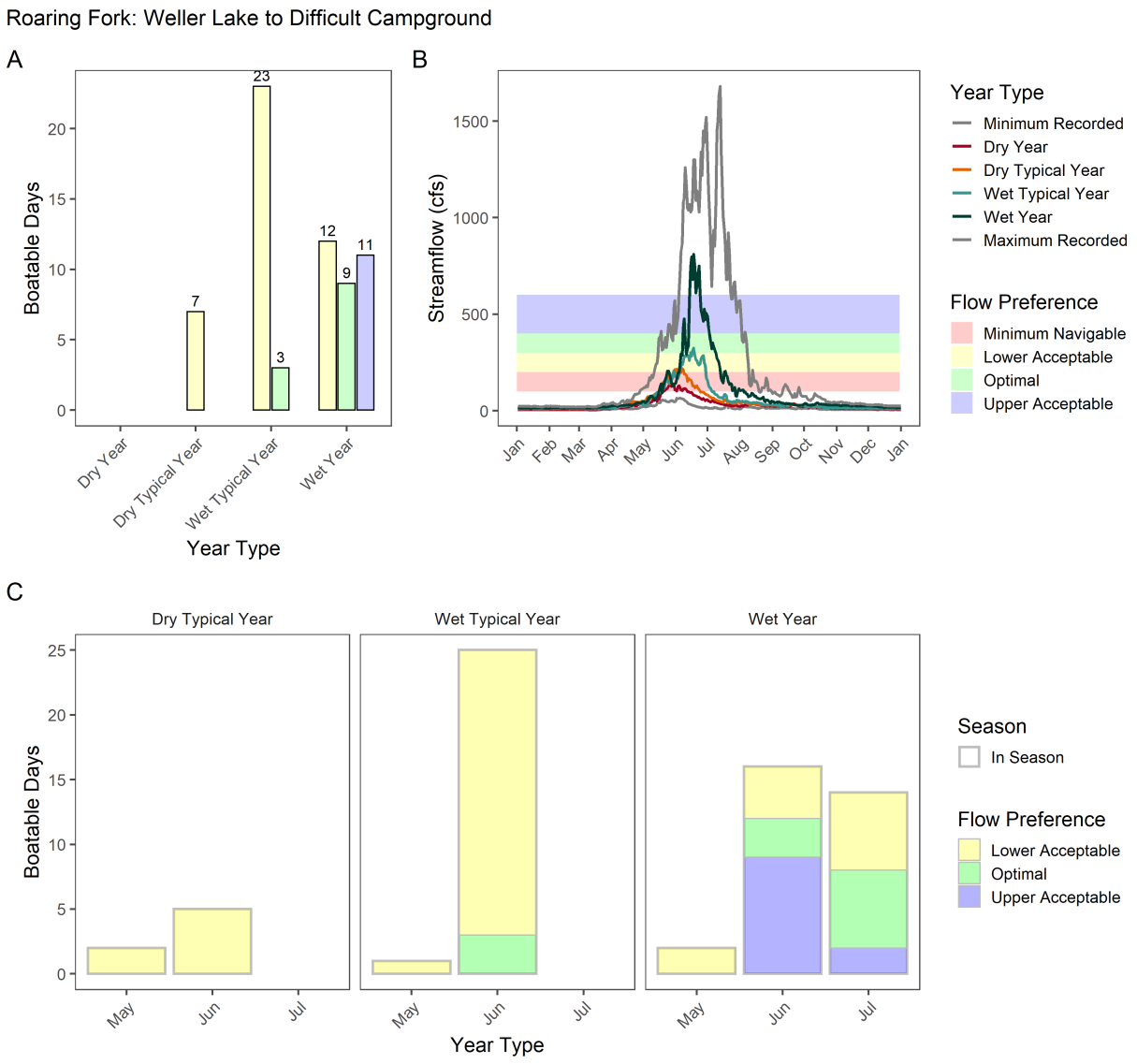


Figure 3: Boatable Days analysis results for the Roaring Fork: Weller Lake to Difficult Campground. (A) Annual Boatable Days totals summarized by hydrological year type. (B) Flow preference ranges mapped to representative streamflow time series for wet, wet typical, dry typical, and dry years. Minimum and maximum recorded daily streamflows also included for reference (C) Monthly Boatable Days totals summarized by hydrological year type.

Roaring Fork: North Star (Reach 2)

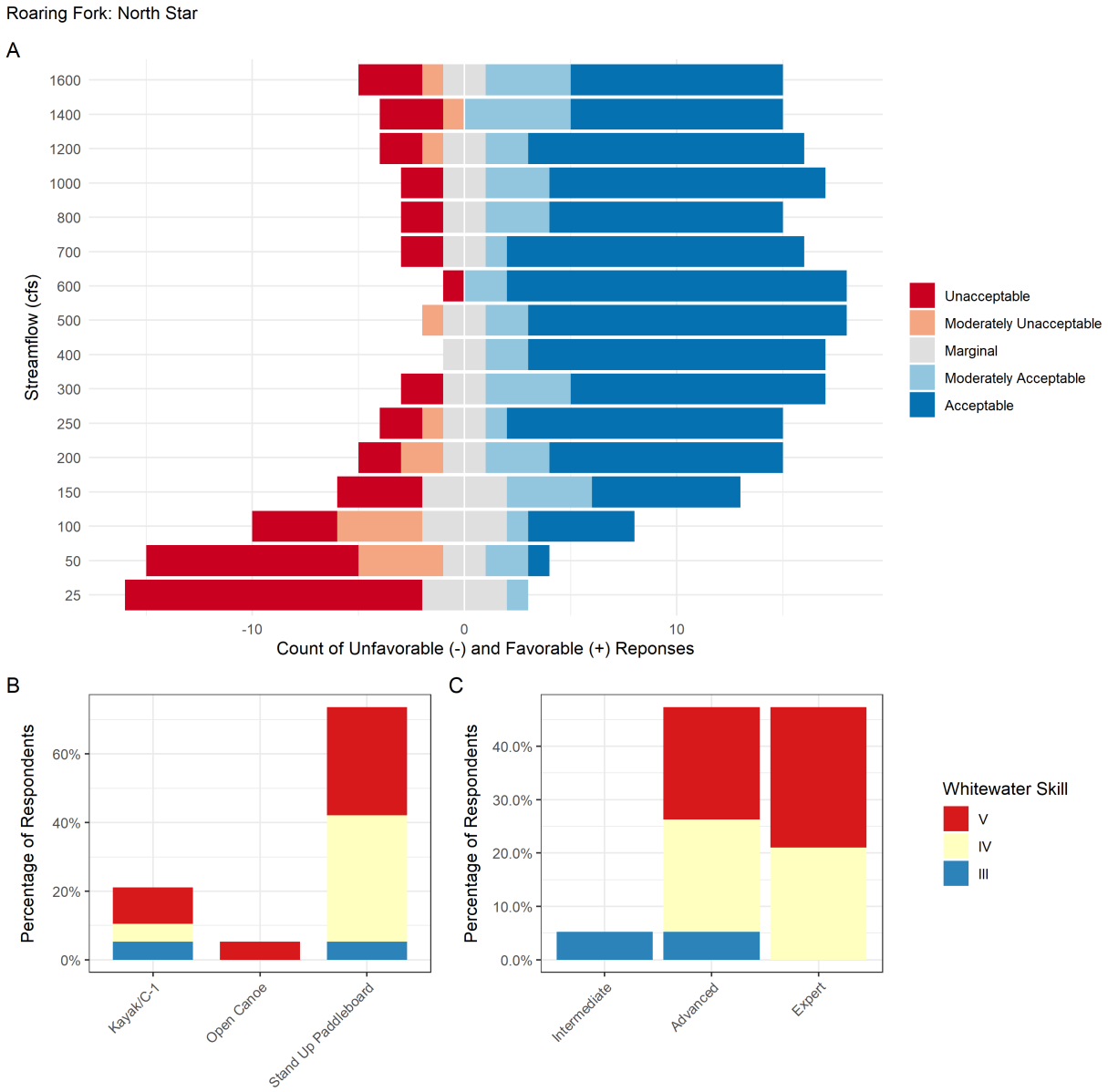
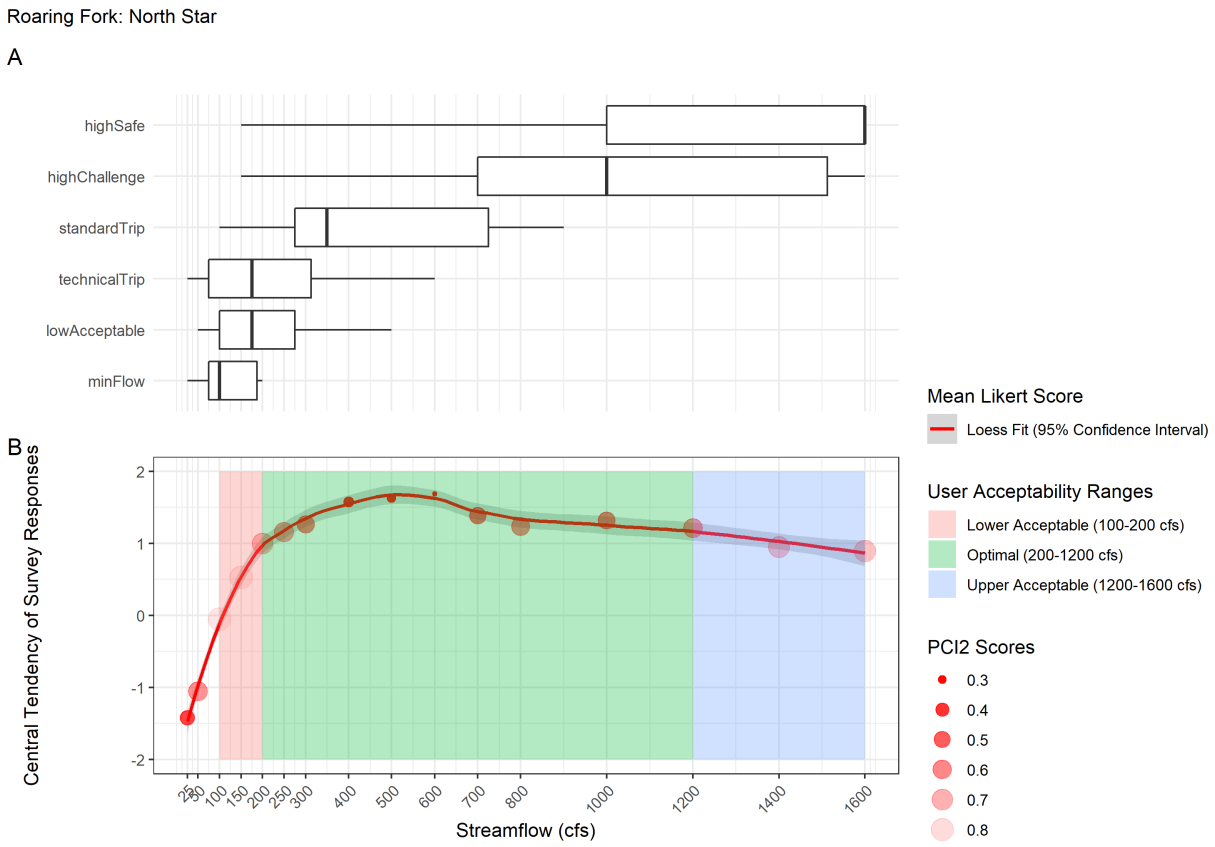


Figure 4: Survey responses for Roaring Fork: North Star. (A) Flow acceptability rankings. (B) User identified preferred craft types and whitewater skill level. (C) User identified expertise and whitewater skill level.



C

Survey Question	25th Percentile	Median Response	75th Percentile	Response Count
Minimum Flow (cfs)	75	100	188	19
Low Acceptable Flow (cfs)	100	175	275	19
Technical Flow (cfs)	75	175	312	19
Standard Trip Flow (cfs)	275	350	725	19
Challenging High Flow (cfs)	700	1000	1512	18
Highest Safe Flow (cfs)	1000	1600	1600	19

Figure 5: Flow preferences reported by users for Roaring Fork: North Star. A) Boxplot of responses to open-ended questions about different categories of flow. B) PCI2 analysis results plotted against the central tendency of flow acceptability preference rankings at each flow category. Loess curve was fit to support visualization of flow acceptability ranges. C) Summarized open-format flow-preference question responses.

Table 3: PCI2 analysis results for Roaring Fork: North Star.

Flow (cfs)	Median Likert Response	n	Max. Distance	Total Distance
25	-1.42	19	720	316
50	-1.05	19	720	452
100	-0.05	19	720	592
150	0.53	19	720	584
200	1.00	19	720	504
250	1.16	19	720	460
300	1.26	19	720	400
400	1.58	19	720	236
500	1.63	19	720	224
600	1.68	19	720	204
700	1.39	18	648	330
800	1.24	17	576	336
1000	1.32	19	720	388
1200	1.21	19	720	440
1400	0.95	19	720	516
1600	0.89	19	720	536

Table 4: Boatable Days analysis results broken out by month for the Roaring Fork: North Star. Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Flow Preference Category	Dry Year	Dry Typical Year	Wet Typical Year	Wet Year
May	Lower Acceptable	11	9	13	12
	Optimal	12	12	12	14
	Total Days	23	21	25	26
Jun	Lower Acceptable	11	8	0	0
	Optimal	13	22	30	30
	Total Days	24	30	30	30
Jul	Lower Acceptable	0	5	15	13
	Optimal	0	0	4	18
	Total Days	0	5	19	31
Aug	Lower Acceptable	0	0	0	14
Aug	Total Days	0	0	0	14

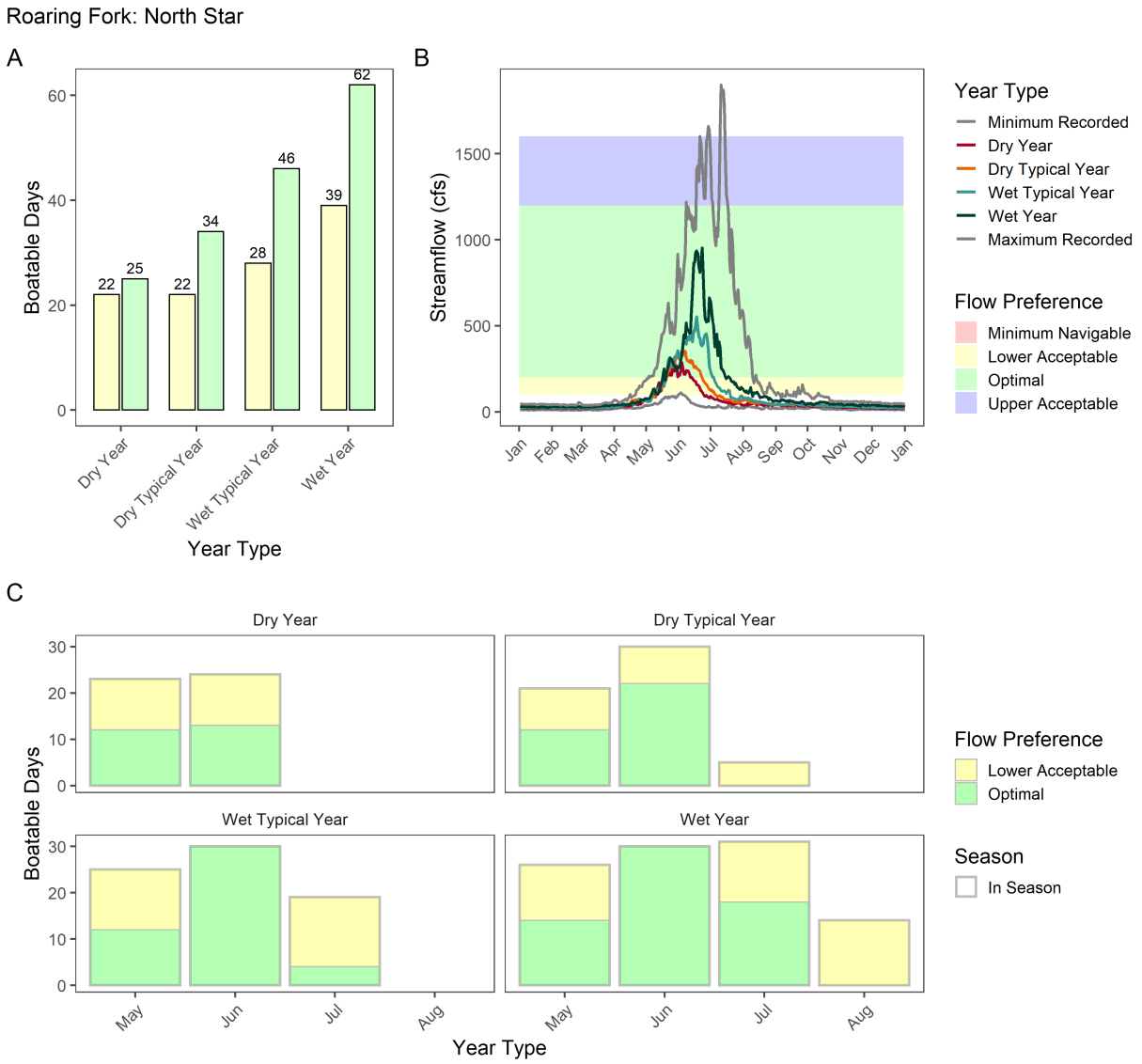


Figure 6: Boatable Days analysis results for the Roaring Fork: North Star. (A) Annual Boatable Days totals summarized by hydrological year type. (B) Flow preference ranges mapped to representative streamflow time series for wet, wet typical, dry typical, and dry years. Minimum and maximum recorded daily streamflows also included for reference (C) Monthly Boatable Days totals summarized by hydrological year type.

Roaring Fork: Downtown Aspen (Reach 3)

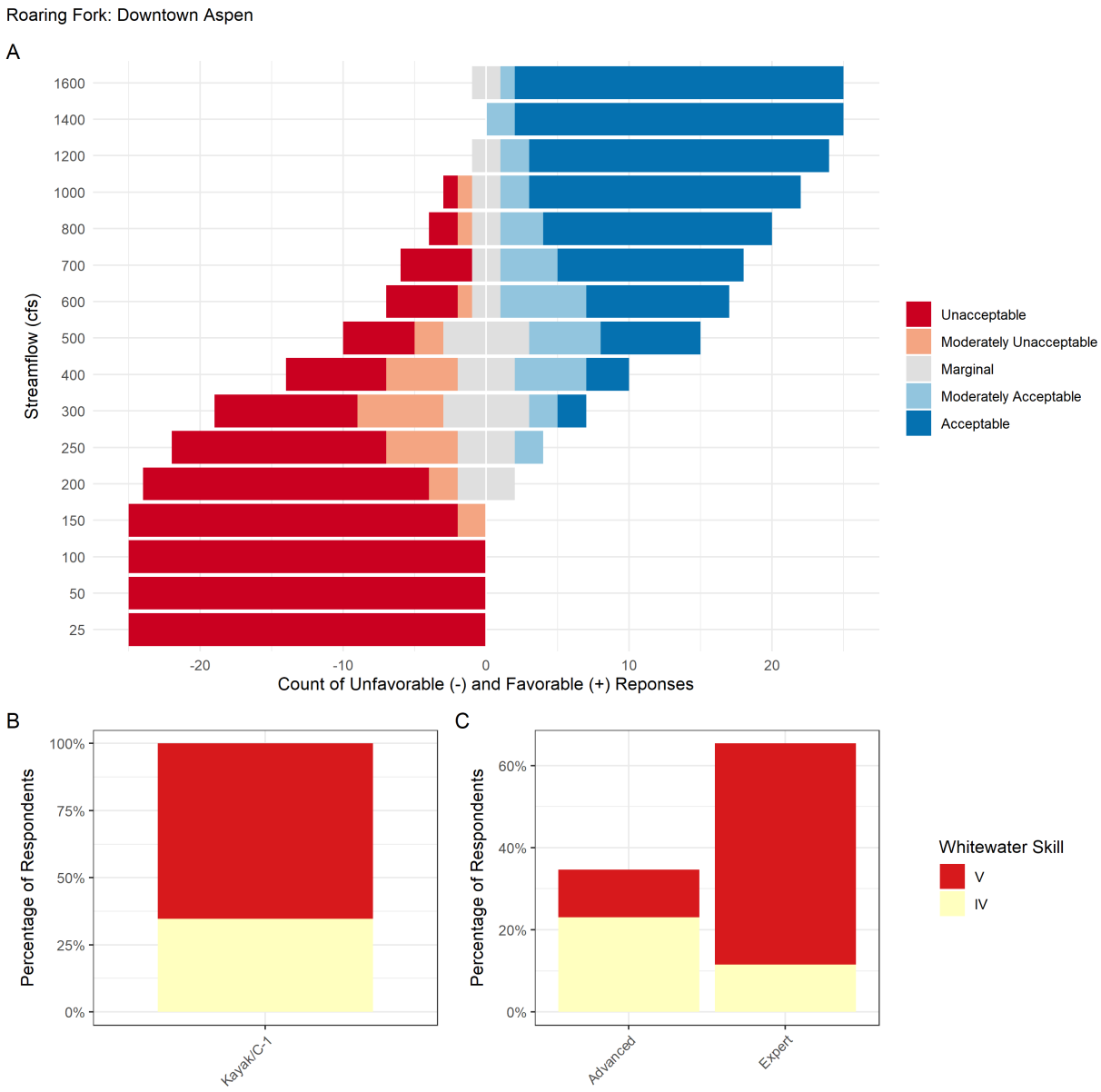
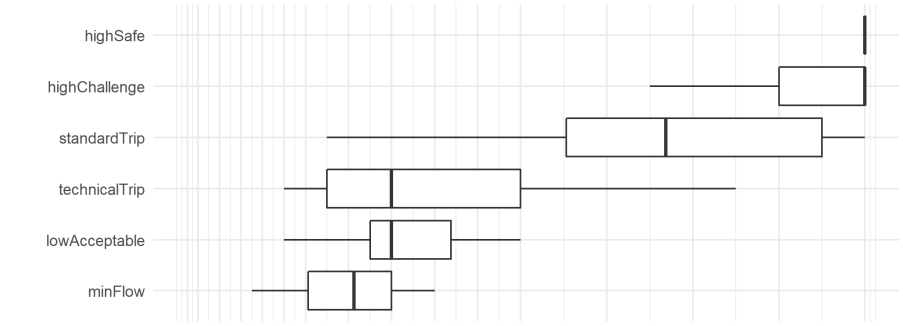


Figure 7: Survey responses for Roaring Fork: Downtown Aspen. (A) Flow acceptability rankings. (B) User identified preferred craft types and whitewater skill level. (C) User identified expertise and whitewater skill level.

Roaring Fork: Downtown Aspen

A



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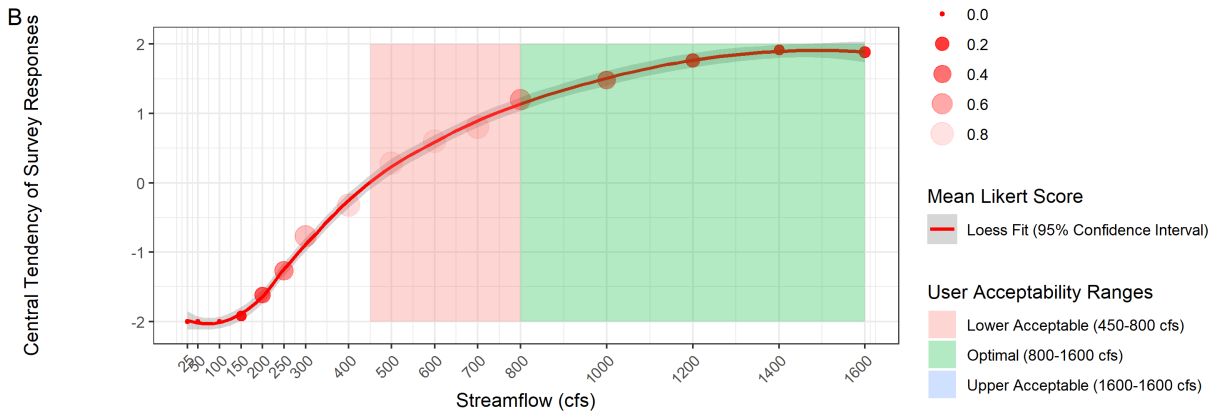


C

Survey Question	25th Percentile	Median Response	75th Percentile	Response Count
Minimum Flow (cfs)	306	412	500	26
Low Acceptable Flow (cfs)	450	500	638	26
Technical Flow (cfs)	350	500	800	26
Standard Trip Flow (cfs)	906	1138	1500	26
Challenging High Flow (cfs)	1400	1600	1600	26
Highest Safe Flow (cfs)	1600	1600	1600	26

Figure 8: Flow preferences reported by users for Roaring Fork: Downtown Aspen. A) Boxplot of responses to open-ended questions about different categories of flow. B) PCI2 analysis results plotted against the central tendency of flow acceptability preference rankings at each flow category. Loess curve was fit to support visualization of flow acceptability ranges. C) Summarized open-format flow-preference question responses.

Table 5: PCI2 analysis results for Roaring Fork: Downtown Aspen.

Flow (cfs)	Median Likert Response	n	Max. Distance	Total Distance
25	-2.00	25	1248	0
50	-2.00	25	1248	0
100	-2.00	25	1248	0
150	-1.92	25	1248	92
200	-1.62	26	1352	416
250	-1.27	26	1352	666
300	-0.77	26	1352	912
400	-0.32	25	1248	968
500	0.28	25	1248	1016
600	0.60	25	1248	1016
700	0.80	25	1248	984
800	1.20	25	1248	740
1000	1.48	25	1248	536
1200	1.76	25	1248	260
1400	1.92	25	1248	92
1600	1.88	25	1248	140

Table 6: Boatable Days analysis results broken out by month for the Roaring Fork: Downtown Aspen. Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Flow Preference Category	Dry Year	Dry Typical Year	Wet Typical Year	Wet Year
Jun	Lower Acceptable	0	0	7	13
	Optimal	0	0	0	10
	Total Days	0	0	7	23
Jul	Lower Acceptable	0	0	0	5
	Total Days	0	0	0	5

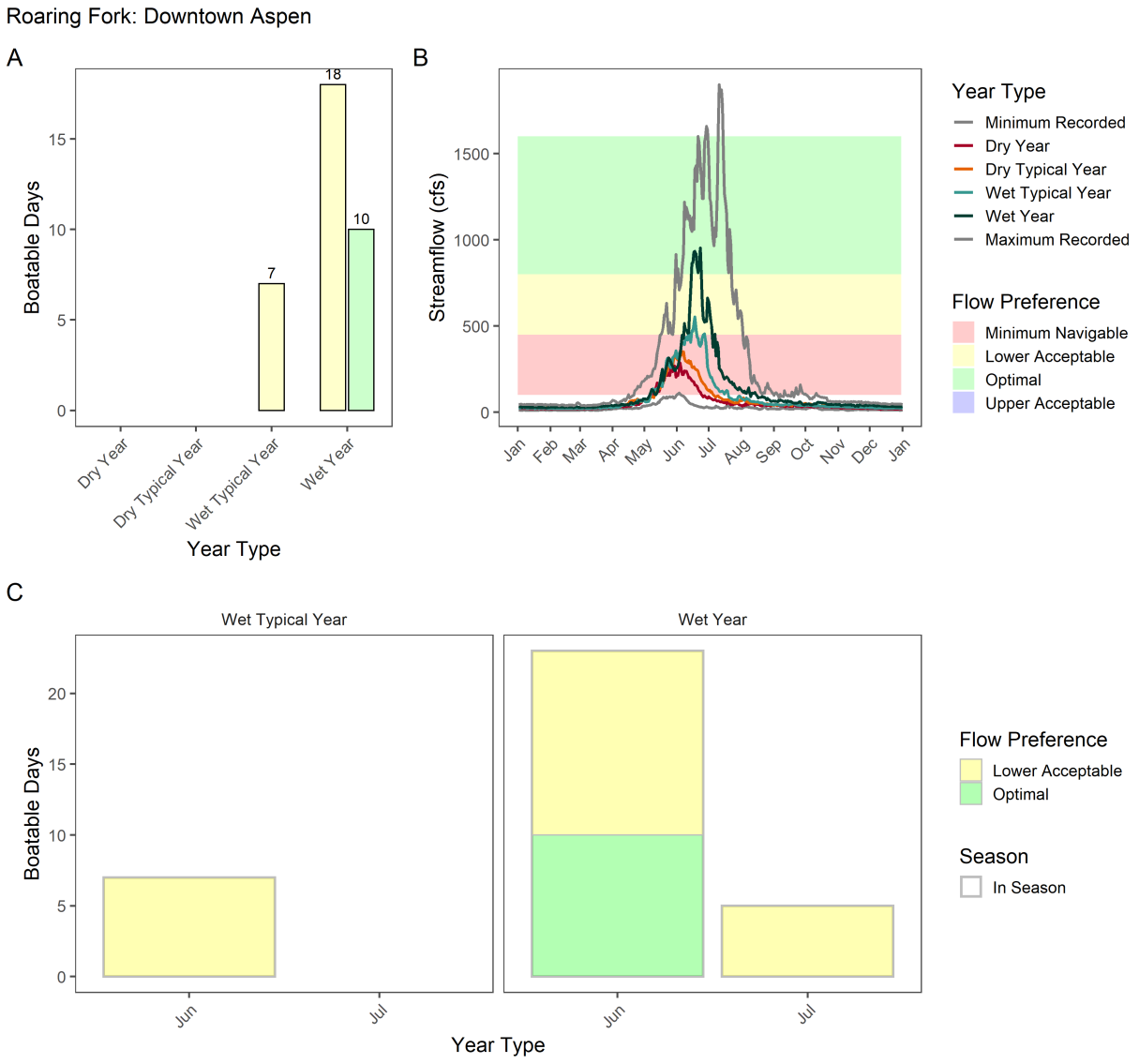


Figure 9: Boatable Days analysis results for the Roaring Fork: Downtown Aspen. (A) Annual Boatable Days totals summarized by hydrological year type. (B) Flow preference ranges mapped to representative streamflow time series for wet, wet typical, dry typical, and dry years. Minimum and maximum recorded daily streamflows also included for reference (C) Monthly Boatable Days totals summarized by hydrological year type.

Roaring Fork: Slaughterhouse (Reach 4)

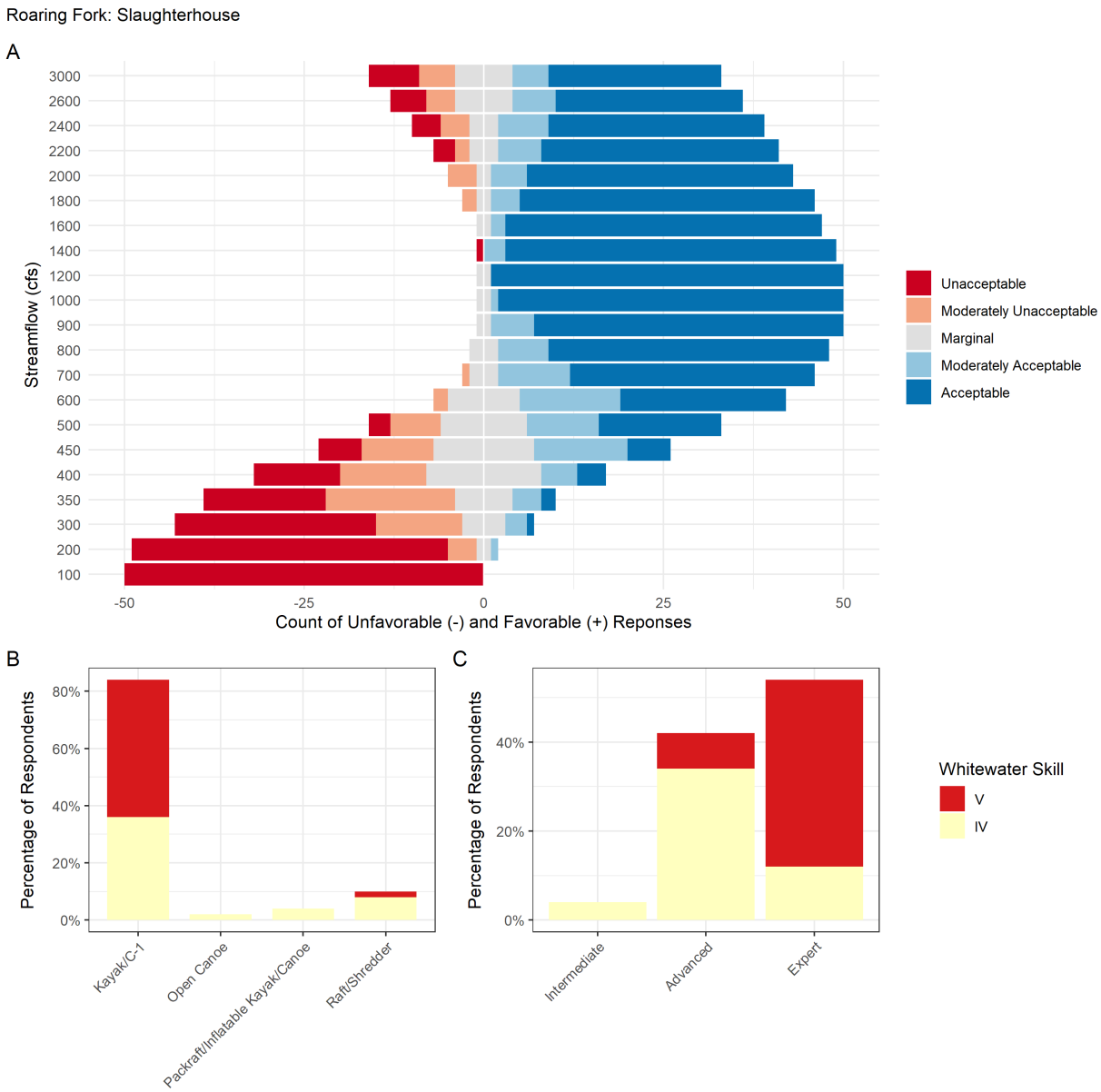
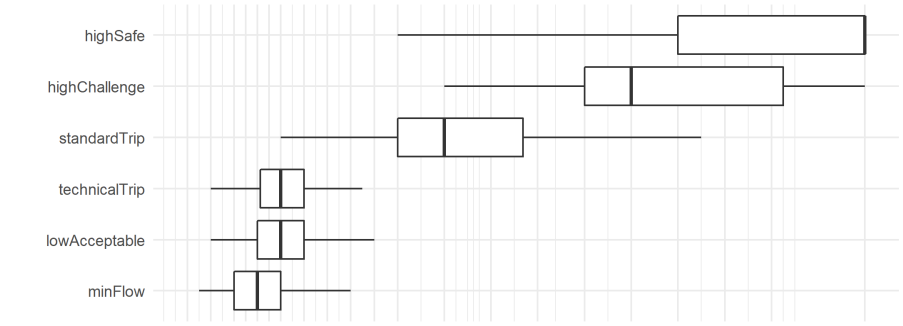


Figure 10: Survey responses for Roaring Fork: Slaughterhouse. (A) Flow acceptability rankings. (B) User identified preferred craft types and whitewater skill level. (C) User identified expertise and whitewater skill level.

Roaring Fork: Slaughterhouse

A



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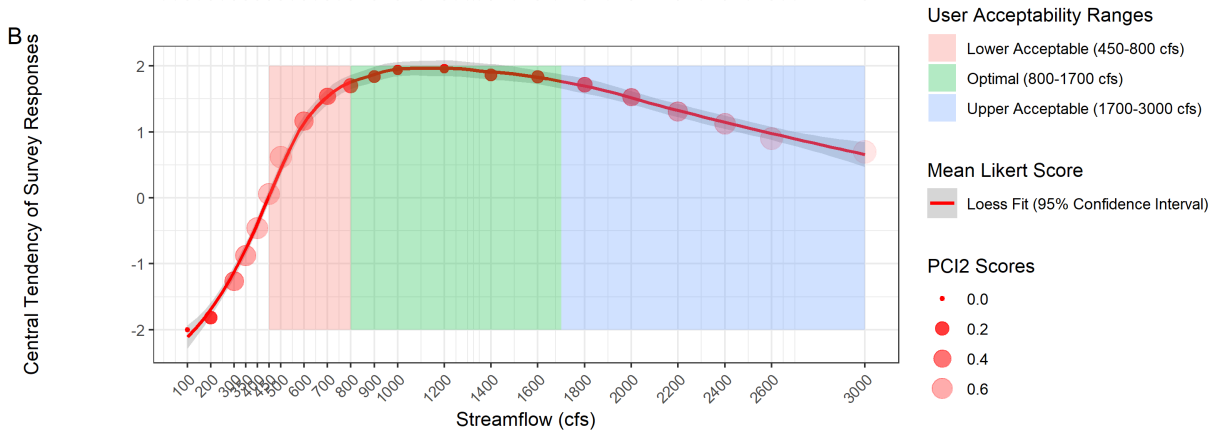


C

Survey Question	25th Percentile	Median Response	75th Percentile	Response Count
Minimum Flow (cfs)	300	400	500	50
Low Acceptable Flow (cfs)	400	500	600	50
Technical Flow (cfs)	412	500	600	50
Standard Trip Flow (cfs)	1000	1200	1538	50
Challenging High Flow (cfs)	1800	2000	2650	50
Highest Safe Flow (cfs)	2200	3000	3000	49

Figure 11: Flow preferences reported by users for Roaring Fork: Slaughterhouse. A) Boxplot of responses to open-ended questions about different categories of flow. B) PCI2 analysis results plotted against the central tendency of flow acceptability preference rankings at each flow category. Loess curve was fit to support visualization of flow acceptability ranges. C) Summarized open-format flow-preference question responses.

Table 7: PCI2 analysis results for Roaring Fork: Slaughterhouse.

Flow (cfs)	Median Likert Response	n	Max. Distance	Total Distance
100	-2.00	50	5000	0
200	-1.82	50	5000	818
300	-1.26	50	5000	2498
350	-0.88	50	5000	2892
400	-0.46	50	5000	3266
450	0.06	50	5000	3322
500	0.62	50	5000	3446
600	1.16	50	5000	2396
700	1.54	50	5000	1714
800	1.70	50	5000	1226
900	1.84	50	5000	700
1000	1.94	50	5000	290
1200	1.96	50	5000	196
1400	1.86	50	5000	662
1600	1.84	49	4800	716
1800	1.71	49	4800	1204
2000	1.53	49	4800	1836
2200	1.31	49	4800	2552
2400	1.12	49	4800	3044
2600	0.90	49	4800	3444
3000	0.69	49	4800	3836

Table 8: Boatable Days analysis results broken out by month for the Roaring Fork Slaughterhouse. Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Flow Preference Category	Dry Year	Dry Typical Year	Wet Typical Year	Wet Year
May	Lower Acceptable	9	12	6	10
	Optimal	0	7	6	4
	Total Days	9	19	12	14
Jun	Lower Acceptable	24	15	0	1
	Optimal	6	15	30	13
	Upper Acceptable	0	0	0	16
	Total Days	30	30	30	30
Jul	Lower Acceptable	2	6	13	10
	Optimal	0	0	8	18
	Upper Acceptable	0	0	0	3
	Total Days	2	6	21	31
Aug	Lower Acceptable	0	0	0	9
	Total Days	0	0	0	9

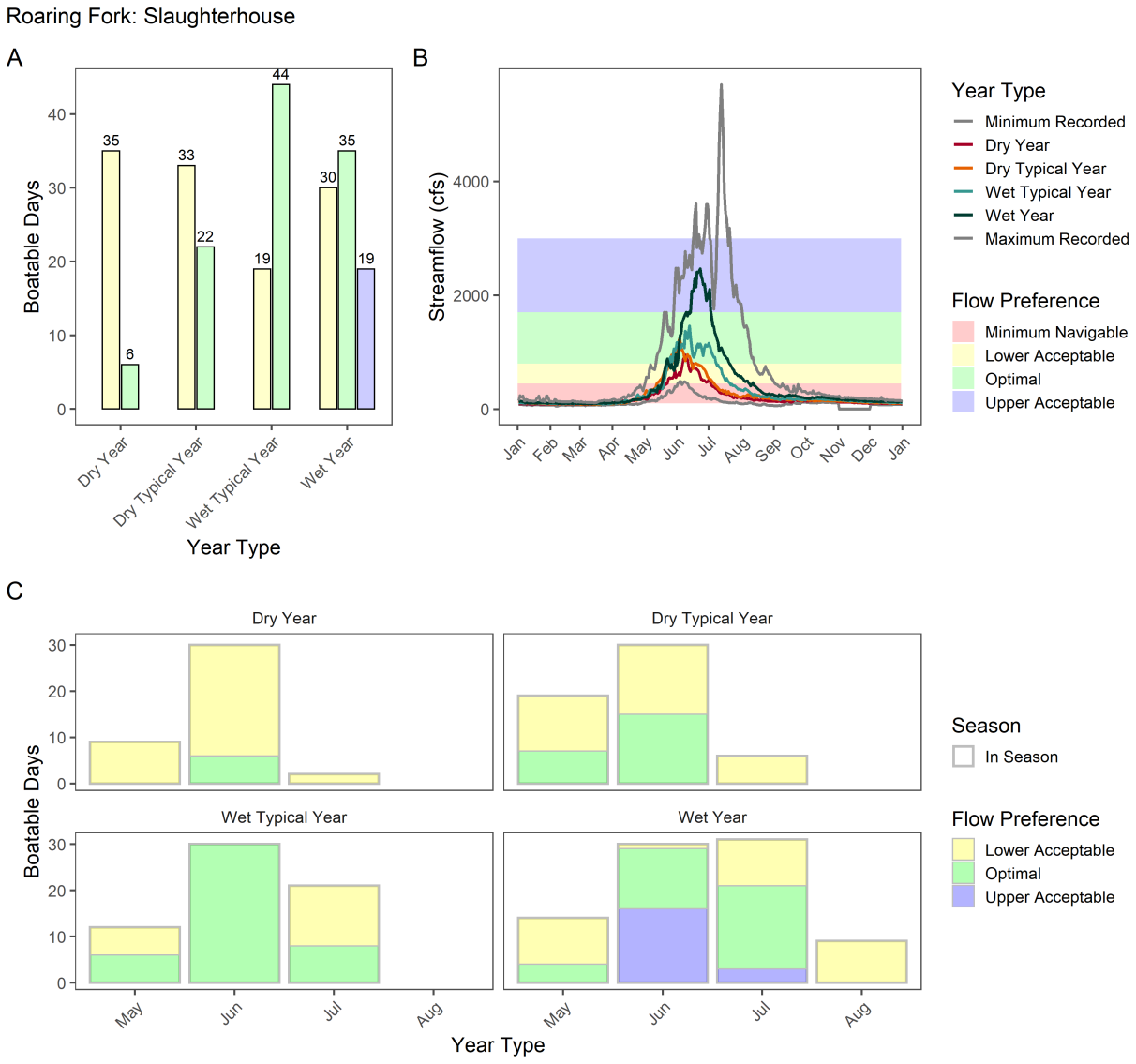


Figure 12: Boatable Days analysis results for the Roaring Fork: Slaughterhouse. (A) Annual Boatable Days totals summarized by hydrological year type. (B) Flow preference ranges mapped to representative streamflow time series for wet, wet typical, dry typical, and dry years. Minimum and maximum recorded daily streamflows also included for reference (C) Monthly Boatable Days totals summarized by hydrological year type.

Roaring Fork: Jaffee Park to Lower Woody Creek Bridge (Reach 5)

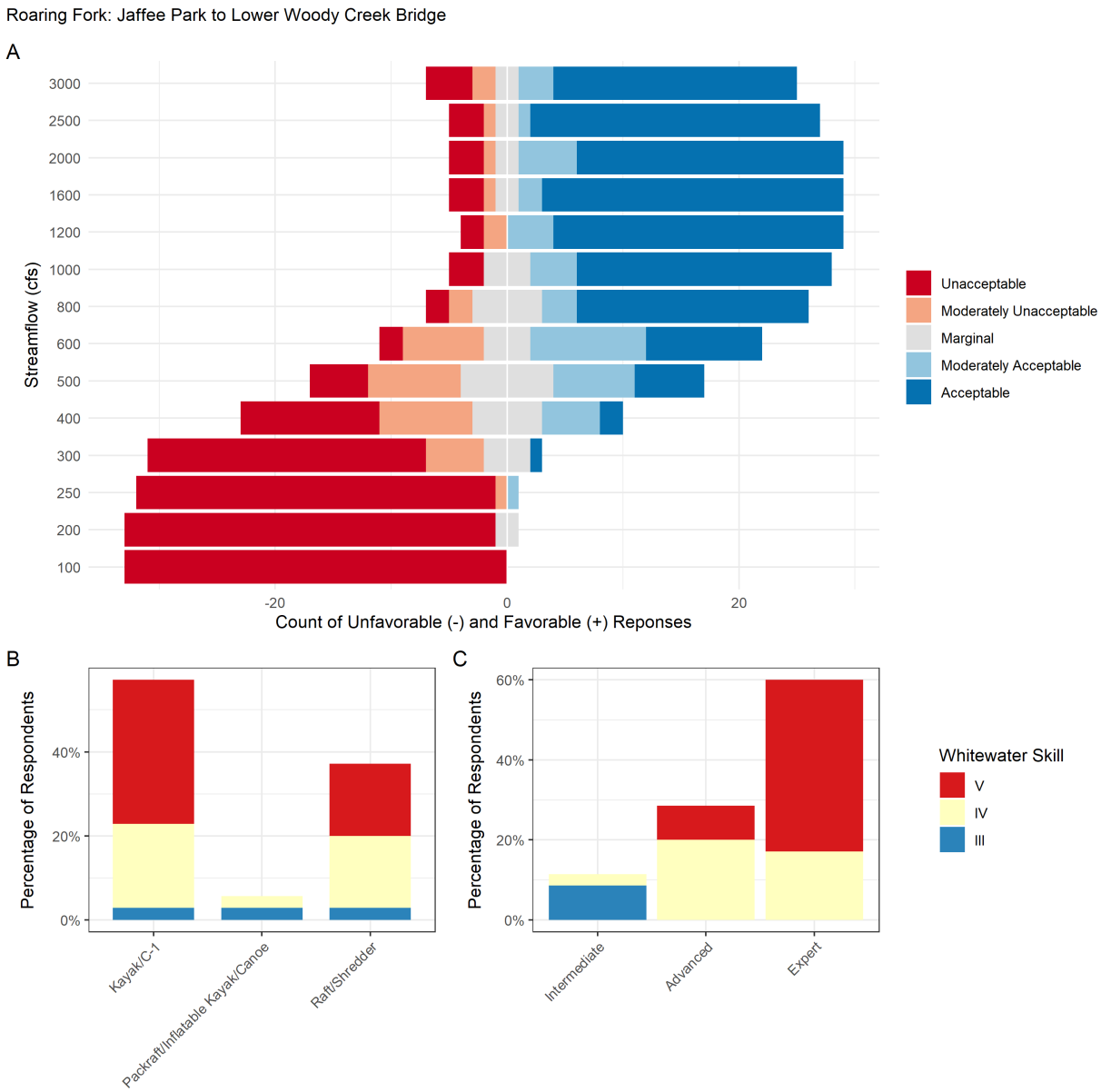
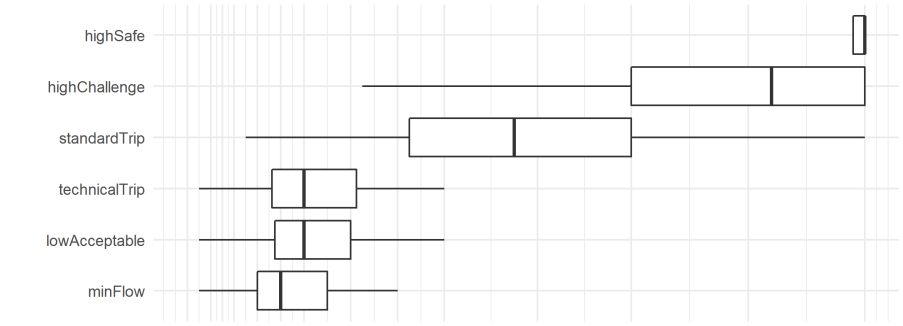


Figure 13: Survey responses for Roaring Fork: Jaffee Park to Lower Woody Creek Bridge. (A) Flow acceptability rankings. (B) User identified preferred craft types and whitewater skill level. (C) User identified expertise and whitewater skill level.

Roaring Fork: Jaffee Park to Lower Woody Creek Bridge

A



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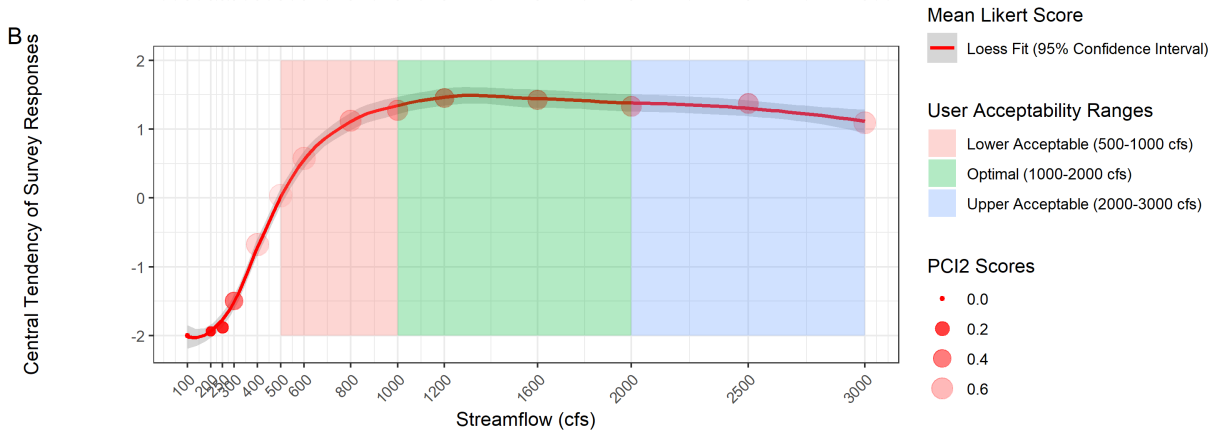


C

Survey Question	25th Percentile	Median Response	75th Percentile	Response Count
Minimum Flow (cfs)	400	500	700	35
Low Acceptable Flow (cfs)	475	600	800	35
Technical Flow (cfs)	462	600	825	34
Standard Trip Flow (cfs)	1050	1500	2000	33
Challenging High Flow (cfs)	2000	2600	3000	32
Highest Safe Flow (cfs)	2950	3000	3000	33

Figure 14: Flow preferences reported by users for Roaring Fork: Jaffee Park to Lower Woody Creek Bridge. A) Boxplot of responses to open-ended questions about different categories of flow. B) PCI2 analysis results plotted against the central tendency of flow acceptability preference rankings at each flow category. Loess curve was fit to support visualization of flow acceptability ranges. C) Summarized open-format flow-preference question responses.

Table 9: PCI2 analysis results for Roaring Fork: Jaffee Park to Lower Woody Creek Bridge.

Flow (cfs)	Median Likert Response	n	Max. Distance	Total Distance
100	-2.00	33	2176	0
200	-1.94	33	2176	128
250	-1.88	33	2176	252
300	-1.50	34	2312	902
400	-0.68	34	2312	1594
500	0.03	34	2312	1718
600	0.58	33	2176	1536
800	1.12	33	2176	1336
1000	1.27	33	2176	1208
1200	1.45	33	2176	988
1600	1.42	33	2176	1056
2000	1.33	33	2176	1152
2500	1.38	32	2048	1060
3000	1.09	32	2048	1382

Table 10: Boatable Days analysis results broken out by month for the Roaring Fork Jaffee Park to Lower Woody Creek Bridge. Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Flow Preference Category	Dry Year	Dry Typical Year	Wet Typical Year	Wet Year
May	Lower Acceptable	8	16	8	13
	Optimal	0	0	3	0
	Total Days	8	16	11	13
Jun	Lower Acceptable	27	24	4	2
	Optimal	0	6	26	14
	Upper Acceptable	0	0	0	14
	Total Days	27	30	30	30
Jul	Lower Acceptable	2	3	16	17
	Optimal	0	0	3	12
	Upper Acceptable	0	0	0	2
	Total Days	2	3	19	31
Aug	Lower Acceptable	0	0	0	3
	Total Days	0	0	0	3

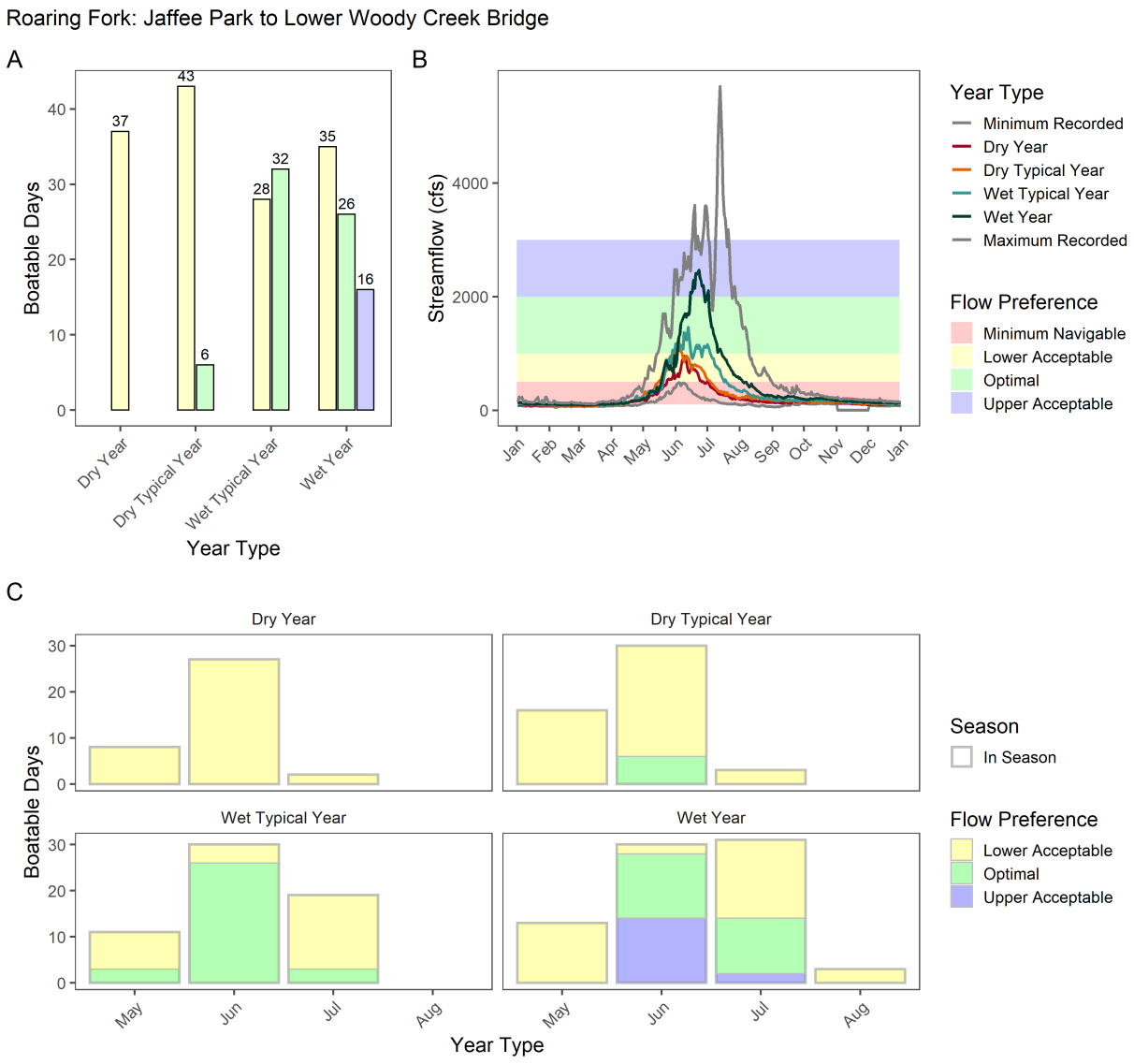


Figure 15: Boatable Days analysis results for the Roaring Fork: Jaffee Park to Lower Woody Creek Bridge. (A) Annual Boatable Days totals summarized by hydrological year type. (B) Flow preference ranges mapped to representative streamflow time series for wet, wet typical, dry typical, and dry years. Minimum and maximum recorded daily streamflows also included for reference (C) Monthly Boatable Days totals summarized by hydrological year type.

Roaring Fork: Toothache (Reach 6)

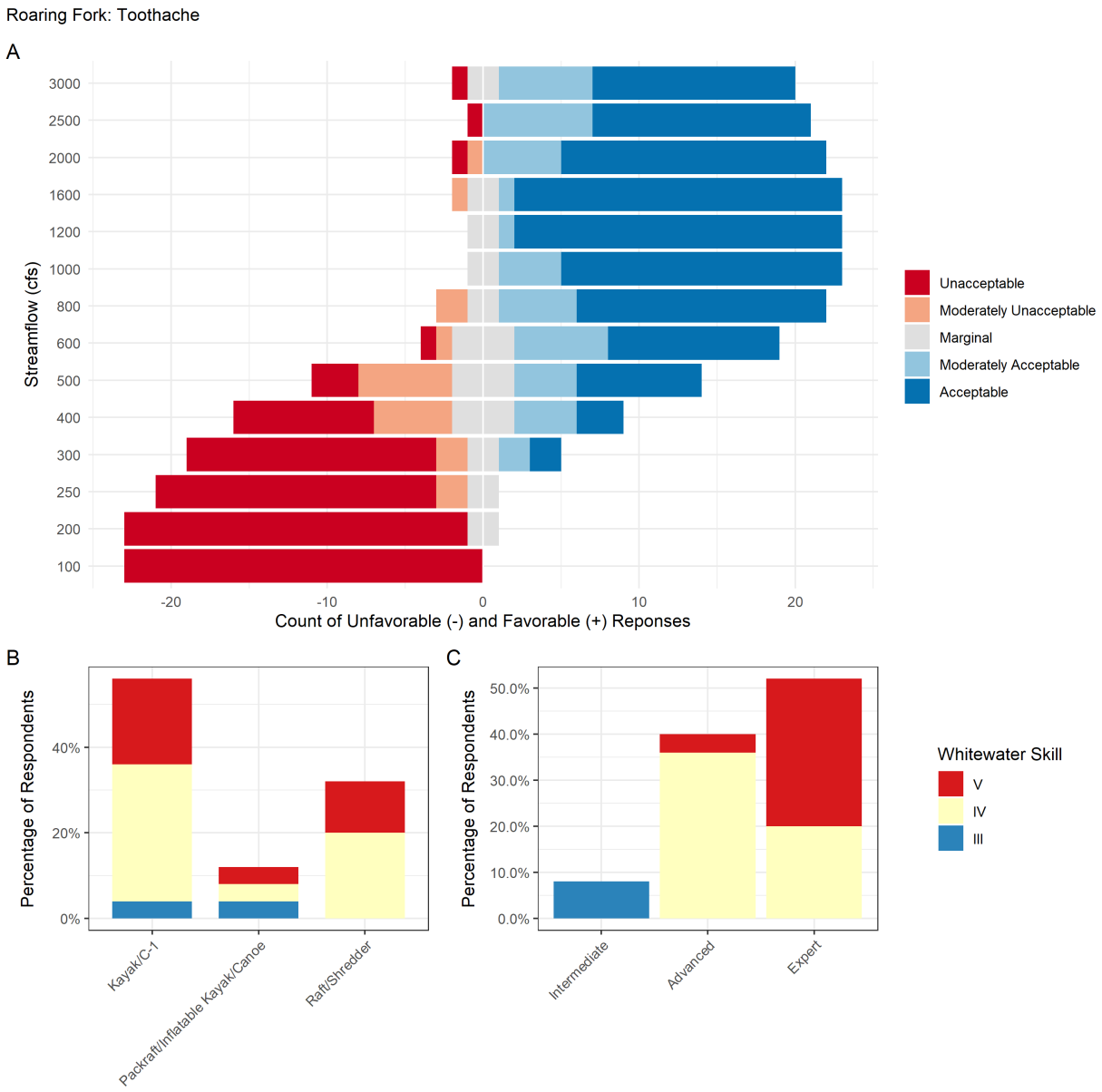
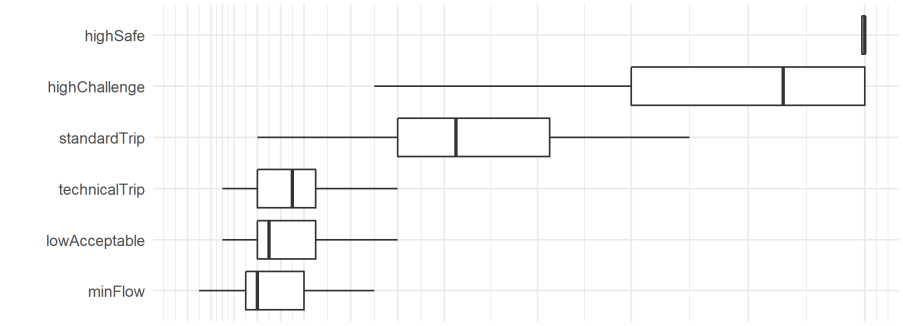


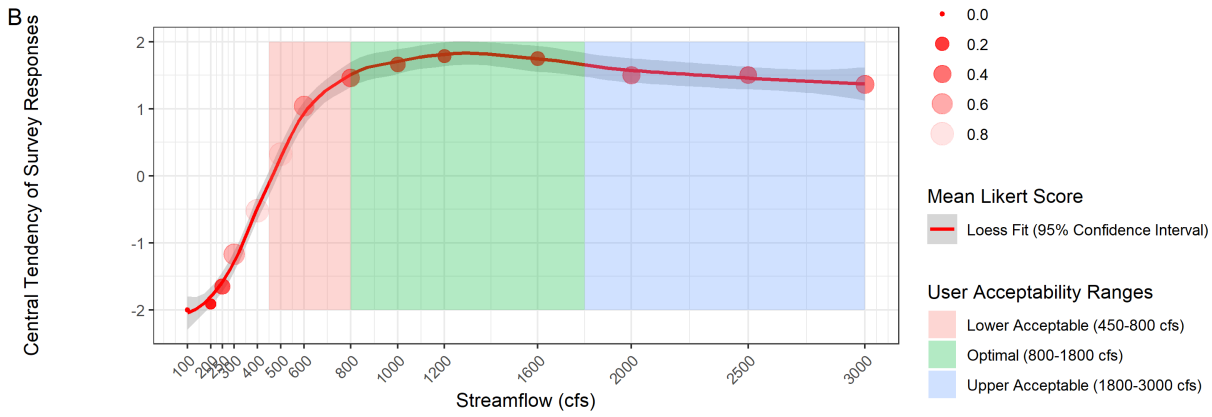
Figure 16: Survey responses for Roaring Fork: Toothache. (A) Flow acceptability rankings. (B) User identified preferred craft types and whitewater skill level. (C) User identified expertise and whitewater skill level.

Roaring Fork: Toothache

A



B



C

Survey Question	25th Percentile	Median Response	75th Percentile	Response Count
Minimum Flow (cfs)	350	400	600	25
Low Acceptable Flow (cfs)	400	450	650	25
Technical Flow (cfs)	400	550	650	25
Standard Trip Flow (cfs)	1000	1250	1650	24
Challenging High Flow (cfs)	2000	2650	3000	24
Highest Safe Flow (cfs)	2988	3000	3000	24

Figure 17: Flow preferences reported by users for Roaring Fork: Toothache. A) Boxplot of responses to open-ended questions about different categories of flow. B) PCI2 analysis results plotted against the central tendency of flow acceptability preference rankings at each flow category. Loess curve was fit to support visualization of flow acceptability ranges. C) Summarized open-format flow-preference question responses.

Table 11: PCI2 analysis results for Roaring Fork: Toothache.

Flow (cfs)	Median Likert Response	n	Max. Distance	Total Distance
100	-2.00	23	1056	0
200	-1.91	23	1056	88
250	-1.65	23	1056	300
300	-1.17	24	1152	720
400	-0.52	25	1248	980
500	0.32	25	1248	1004
600	1.04	24	1152	658
800	1.46	24	1152	470
1000	1.67	24	1152	304
1200	1.79	24	1152	214
1600	1.75	24	1152	260
2000	1.50	24	1152	460
2500	1.50	22	968	350
3000	1.36	22	968	432

Table 12: Boatable Days analysis results broken out by month for the Roaring Fork: Toothache. Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Flow Preference Category	Dry Year	Dry Typical Year	Wet Typical Year	Wet Year
May	Lower Acceptable	9	12	6	10
	Optimal	0	7	6	4
	Total Days	9	19	12	14
Jun	Lower Acceptable	24	15	0	1
	Optimal	6	15	30	13
	Upper Acceptable	0	0	0	16
	Total Days	30	30	30	30
Jul	Lower Acceptable	2	6	13	10
	Optimal	0	0	8	19
	Upper Acceptable	0	0	0	2
	Total Days	2	6	21	31
Aug	Lower Acceptable	0	0	0	9
	Total Days	0	0	0	9

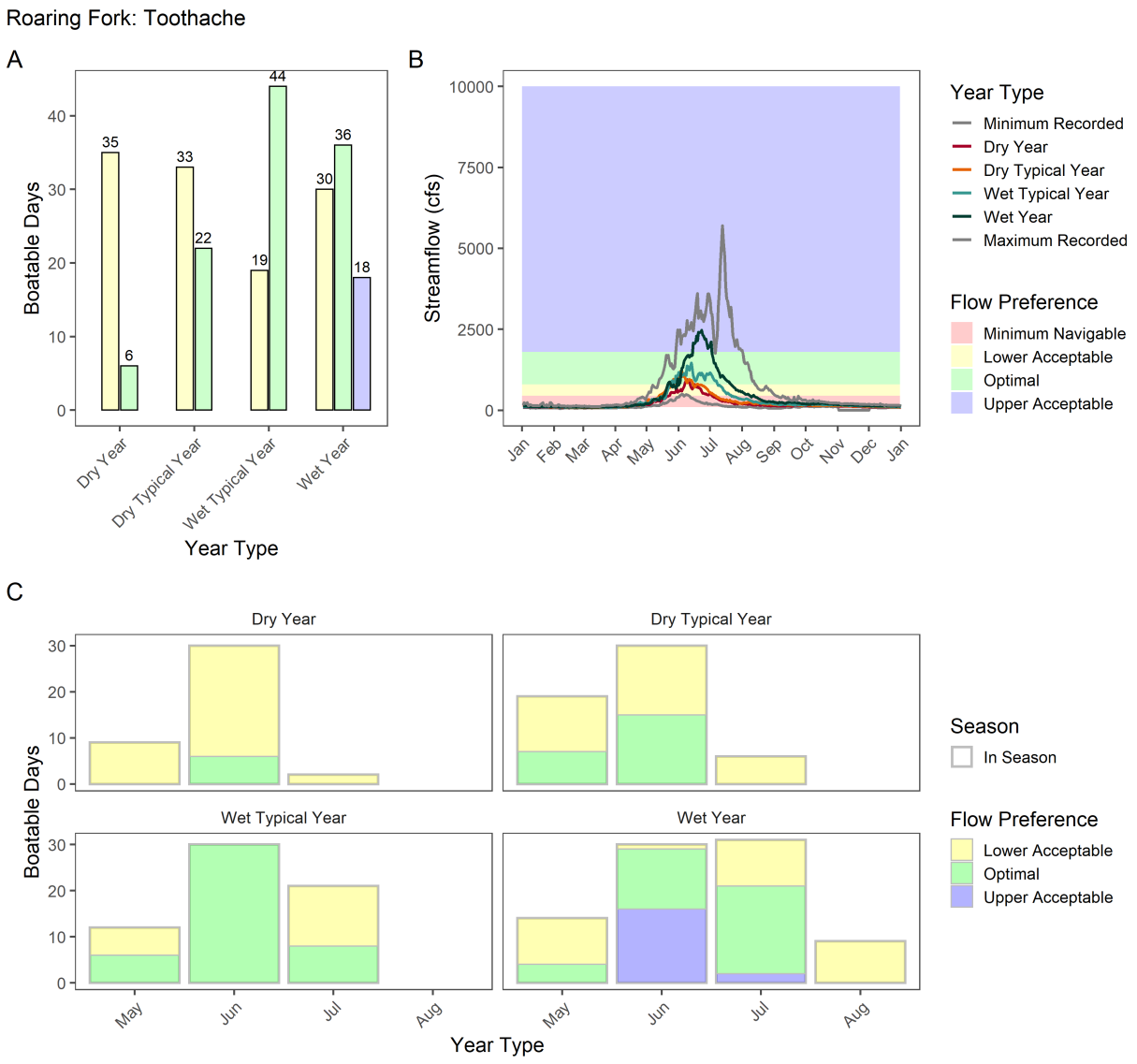


Figure 18: Boatable Days analysis results for the Roaring Fork: Toothache. (A) Annual Boatable Days totals summarized by hydrological year type. (B) Flow preference ranges mapped to representative streamflow time series for wet, wet typical, dry typical, and dry years. Minimum and maximum recorded daily streamflows also included for reference (C) Monthly Boatable Days totals summarized by hydrological year type.

Roaring Fork: Basalt to Carbondale (Reach 7)

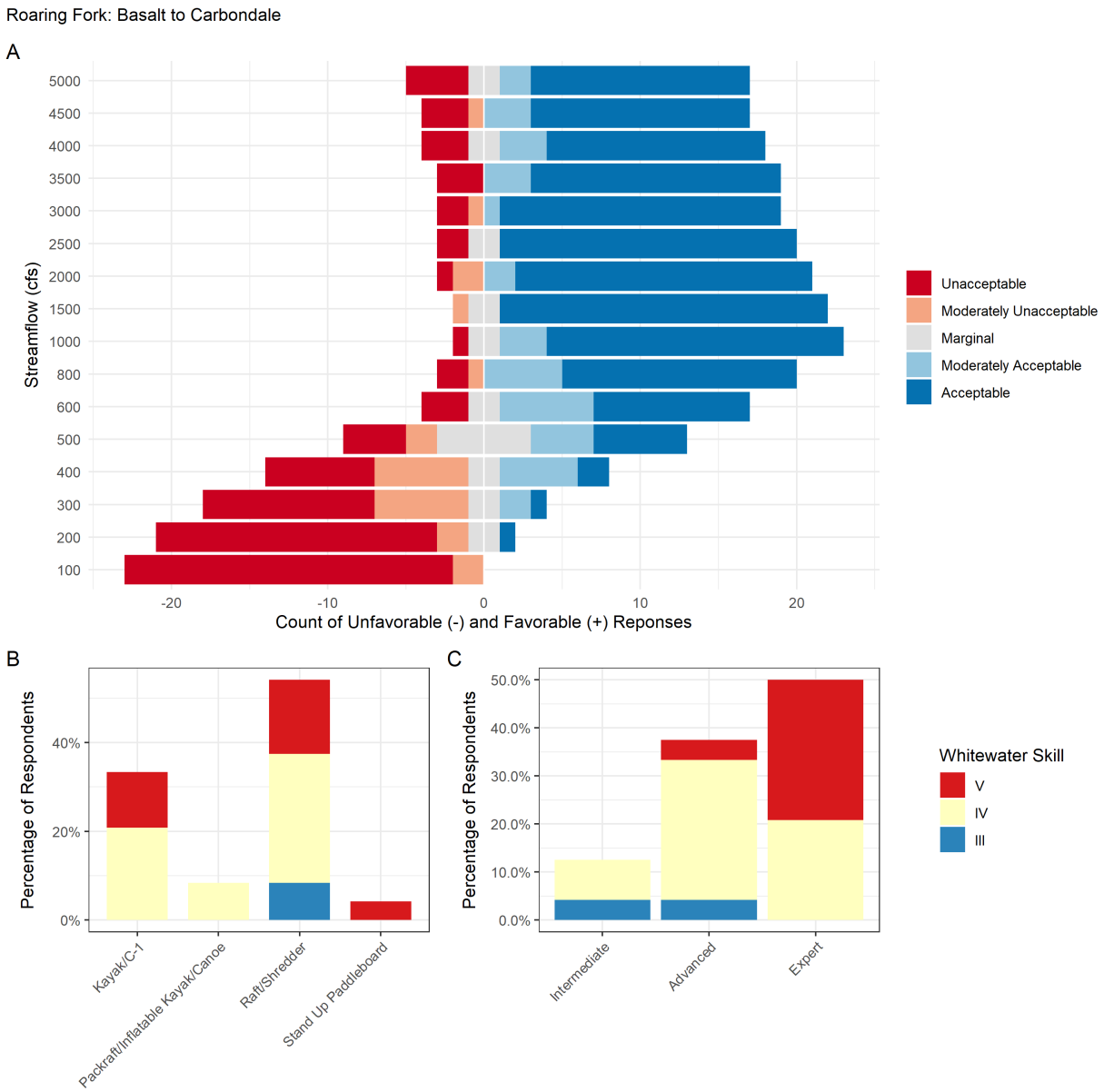
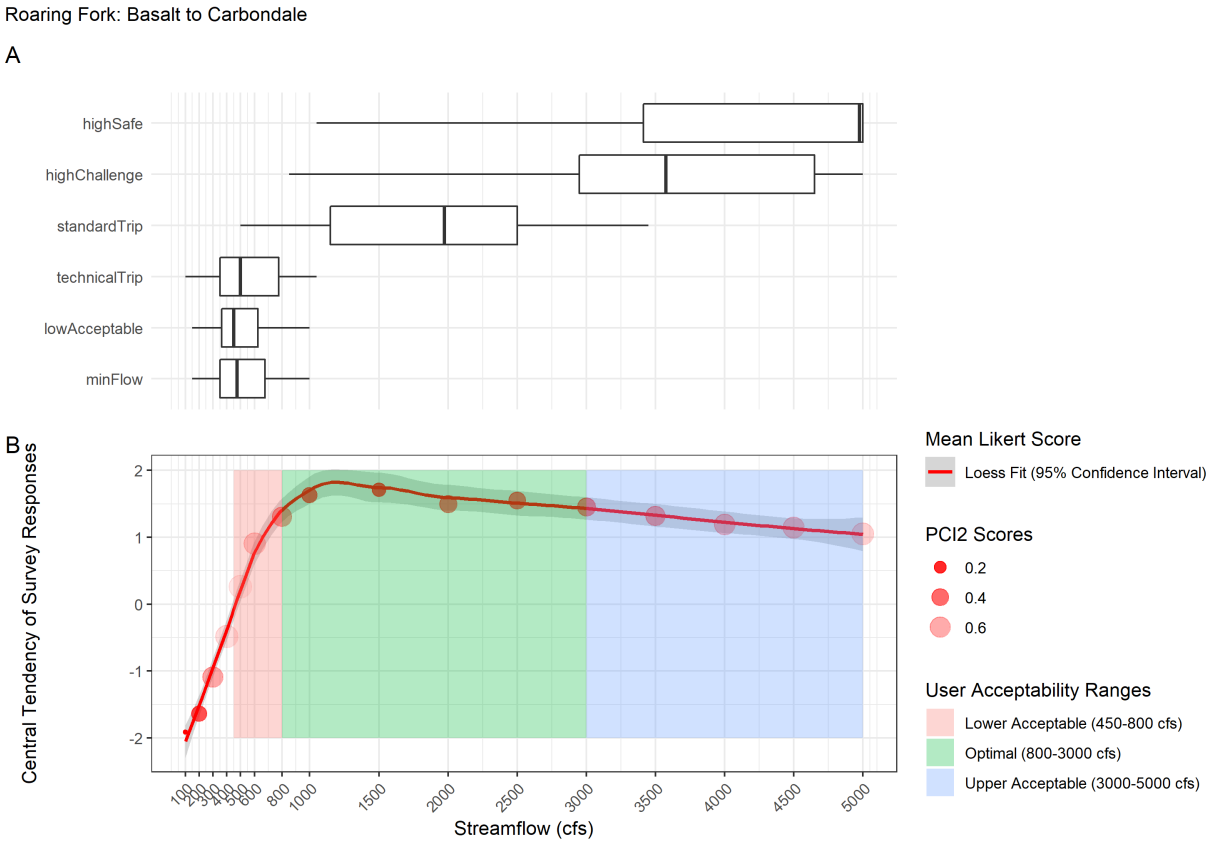


Figure 19: Survey responses for Roaring Fork: Basalt to Carbondale. (A) Flow acceptability rankings. (B) User identified preferred craft types and whitewater skill level. (C) User identified expertise and whitewater skill level.



C

Survey Question	25th Percentile	Median Response	75th Percentile	Response Count
Minimum Flow (cfs)	350	475	675	24
Low Acceptable Flow (cfs)	362	450	625	23
Technical Flow (cfs)	350	500	775	23
Standard Trip Flow (cfs)	1150	1975	2500	24
Challenging High Flow (cfs)	2950	3575	4650	24
Highest Safe Flow (cfs)	3412	4975	5000	24

Figure 20: Flow preferences reported by users for Roaring Fork: Basalt to Carbondale. A) Boxplot of responses to open-ended questions about different categories of flow. B) PCI2 analysis results plotted against the central tendency of flow acceptability preference rankings at each flow category. Loess curve was fit to support visualization of flow acceptability ranges. C) Summarized open-format flow-preference question responses.

Table 13: PCI2 analysis results for Roaring Fork: Basalt to Carbondale.

Flow (cfs)	Median Likert Response	n	Max. Distance	Total Distance
100	-1.91	23	1056	84
200	-1.64	22	968	308
300	-1.09	22	968	568
400	-0.48	23	1056	792
500	0.26	23	1056	820
600	0.91	22	968	660
800	1.30	23	1056	564
1000	1.63	24	1152	370
1500	1.71	24	1152	298
2000	1.50	24	1152	488
2500	1.55	22	968	388
3000	1.45	22	968	452
3500	1.32	22	968	534
4000	1.19	21	880	548
4500	1.14	21	880	576
5000	1.05	21	880	628

Table 14: Boatable Days analysis results broken out by month for the Roaring Fork: Basalt to Carbondale. Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Flow Preference Category	Dry Year	Dry Typical Year	Wet Typical Year	Wet Year
Apr	Lower Acceptable	0	0	13	19
	Optimal	0	0	0	1
	Total Days	0	0	13	20
May	Lower Acceptable	10	16	14	4
	Optimal	6	15	16	27
	Total Days	16	31	30	31
Jun	Lower Acceptable	9	0	0	0
	Optimal	21	30	30	21
	Upper Acceptable	0	0	0	9
	Total Days	30	30	30	30
Jul	Lower Acceptable	12	27	17	0
	Optimal	0	4	14	30
	Upper Acceptable	0	0	0	1
	Total Days	12	31	31	31
Aug	Lower Acceptable	0	31	31	25
	Optimal	0	0	0	6
	Total Days	0	31	31	31
Sep	Lower Acceptable	0	14	29	30
	Total Days	0	14	29	30
Oct	Lower Acceptable	0	0	12	15
	Total Days	0	0	12	15

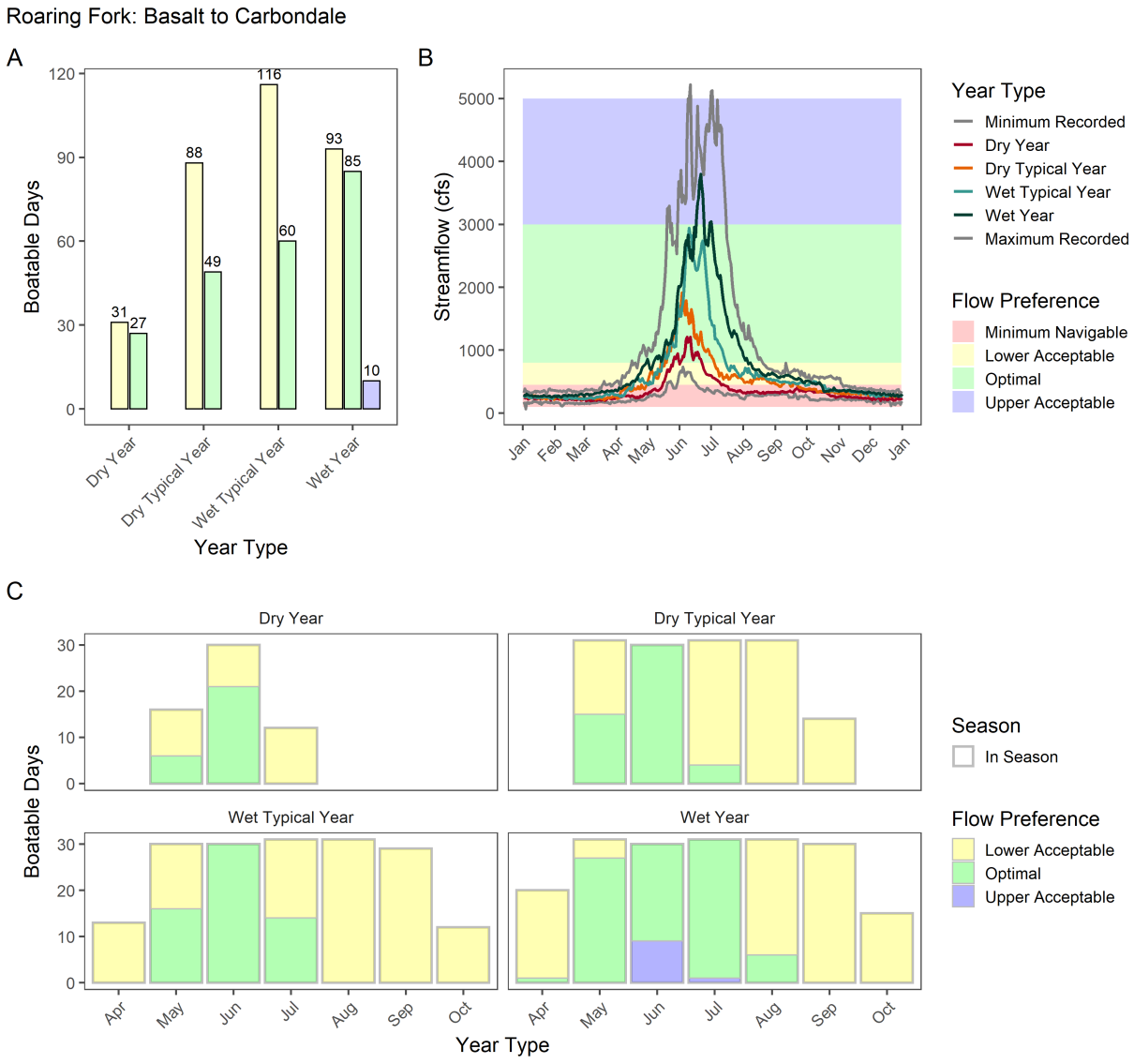


Figure 21: Boatable Days analysis results for the Roaring Fork: Basalt to Carbondale. (A) Annual Boatable Days totals summarized by hydrological year type. (B) Flow preference ranges mapped to representative streamflow time series for wet, wet typical, dry typical, and dry years. Minimum and maximum recorded daily streamflows also included for reference (C) Monthly Boatable Days totals summarized by hydrological year type.

Roaring Fork: Pink to Black (Reach 8)

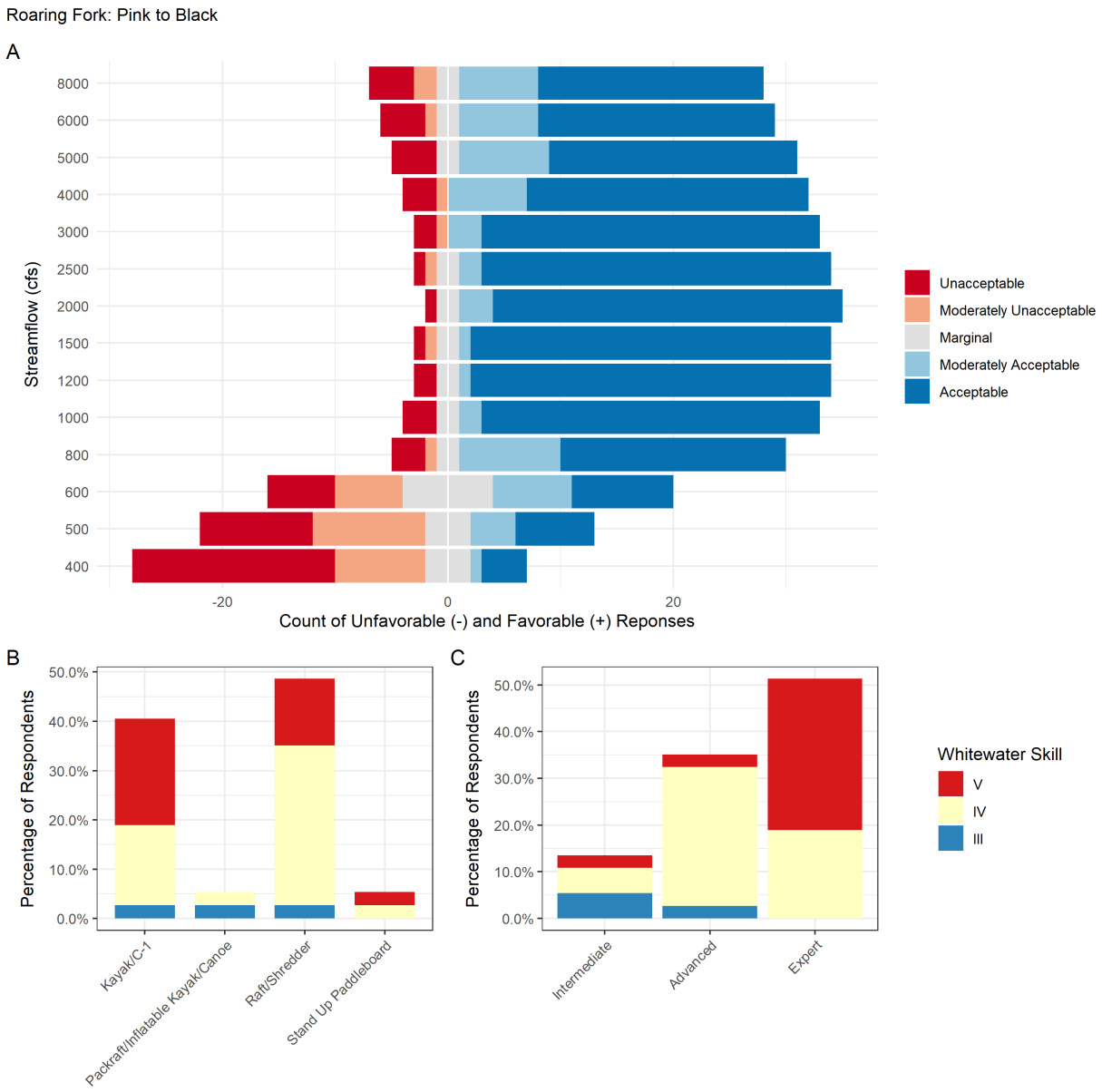
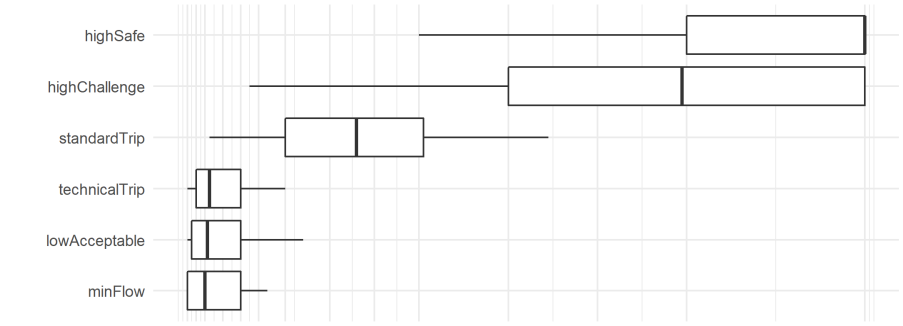


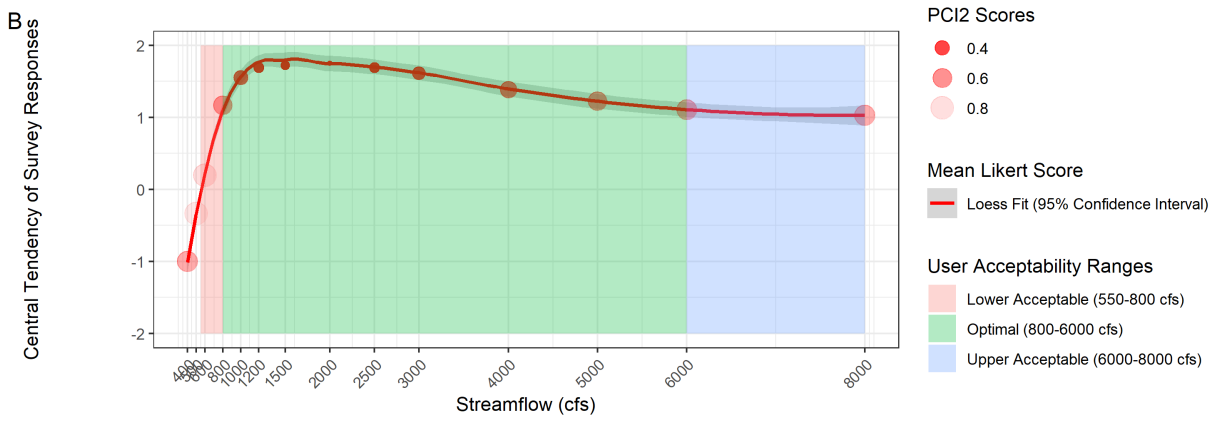
Figure 22: Survey responses for Roaring Fork: Pink to Black. (A) Flow acceptability rankings. (B) User identified preferred craft types and whitewater skill level. (C) User identified expertise and whitewater skill level.

Roaring Fork: Pink to Black

A



B



C

Survey Question	25th Percentile	Median Response	75th Percentile	Response Count
Minimum Flow (cfs)	400	600	1000	37
Low Acceptable Flow (cfs)	450	625	1000	36
Technical Flow (cfs)	500	650	1000	35
Standard Trip Flow (cfs)	1500	2300	3050	36
Challenging High Flow (cfs)	4000	5950	8000	37
Highest Safe Flow (cfs)	6000	8000	8000	37

Figure 23: Flow preferences reported by users for Roaring Fork: Pink to Black. A) Boxplot of responses to open-ended questions about different categories of flow. B) PCI2 analysis results plotted against the central tendency of flow acceptability preference rankings at each flow category. Loess curve was fit to support visualization of flow acceptability ranges. C) Summarized open-format flow-preference question responses.

Table 15: PCI2 analysis results for Roaring Fork: Pink to Black.

Flow (cfs)	Median Likert Response	n	Max. Distance	Total Distance
400	-1.00	35	2448	1628
500	-0.33	36	2592	2116
600	0.19	36	2592	2062
800	1.17	36	2592	1500
1000	1.56	36	2592	1012
1200	1.69	36	2592	726
1500	1.72	36	2592	660
2000	1.75	36	2592	586
2500	1.69	36	2592	714
3000	1.61	36	2592	892
4000	1.39	36	2592	1260
5000	1.22	36	2592	1488
6000	1.11	36	2592	1644
8000	1.03	36	2592	1742

Table 16: Boatable Days analysis results broken out by month for the Roaring Fork: Pink to Black. Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Flow Preference Category	Dry Year	Dry Typical Year	Wet Typical Year	Wet Year
Apr	Lower Acceptable	0	0	3	8
	Optimal	0	0	0	1
	Total Days	0	0	3	9
May	Lower Acceptable	8	14	9	4
	Optimal	6	15	16	27
	Total Days	14	29	25	31
Jun	Lower Acceptable	9	0	0	0
	Optimal	21	30	30	30
	Total Days	30	30	30	30
Jul	Lower Acceptable	4	23	17	0
	Optimal	0	4	14	31
	Total Days	4	27	31	31
Aug	Lower Acceptable	0	3	22	25
	Optimal	0	0	0	6
	Total Days	0	3	22	31
Sep	Lower Acceptable	0	0	0	19
	Total Days	0	0	0	19

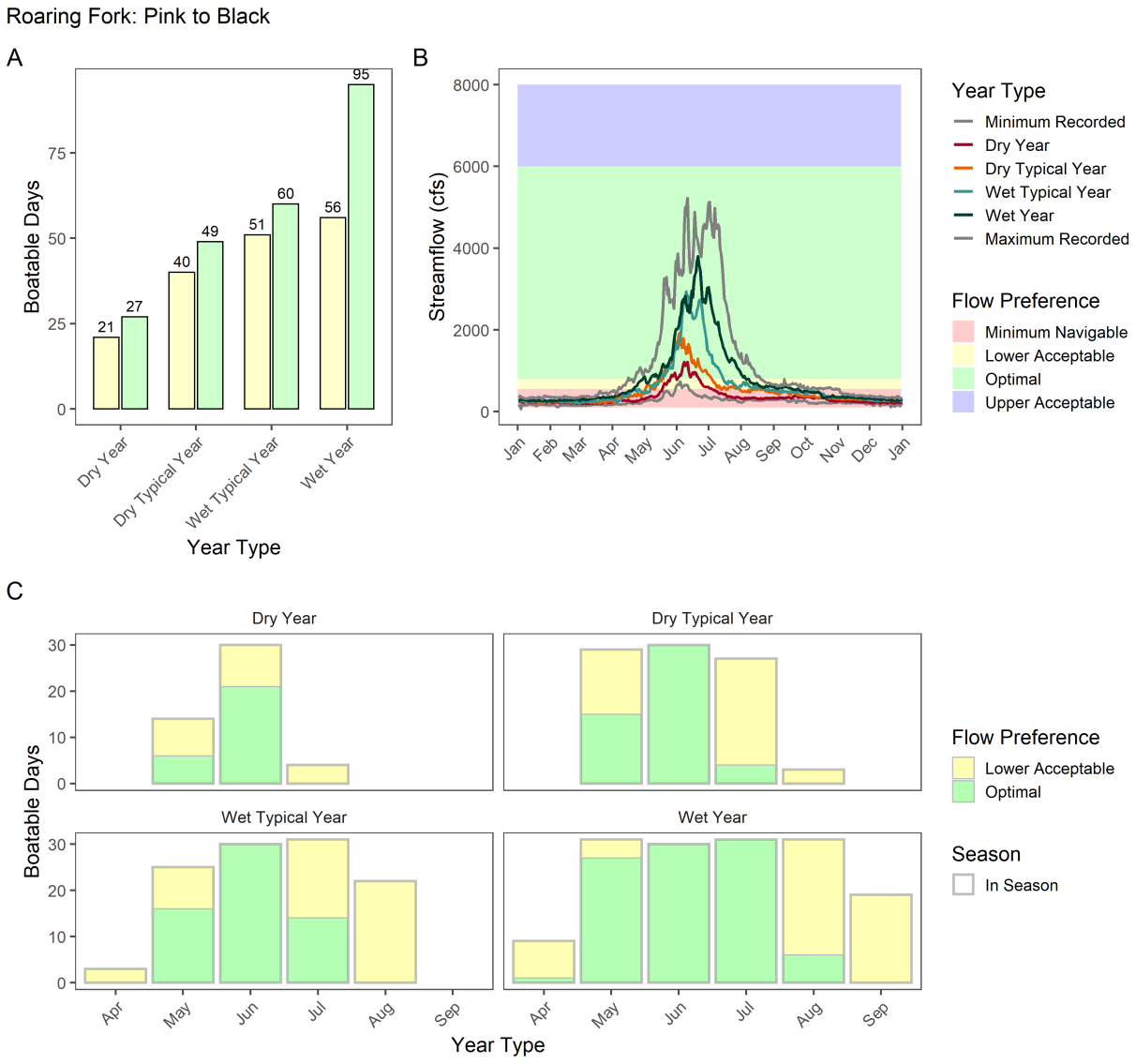


Figure 24: Boatable Days analysis results for the Roaring Fork: Pink to Black. (A) Annual Boatable Days totals summarized by hydrological year type. (B) Flow preference ranges mapped to representative streamflow time series for wet, wet typical, dry typical, and dry years. Minimum and maximum recorded daily streamflows also included for reference (C) Monthly Boatable Days totals summarized by hydrological year type.

Roaring Fork: Cemetery (Reach 9)

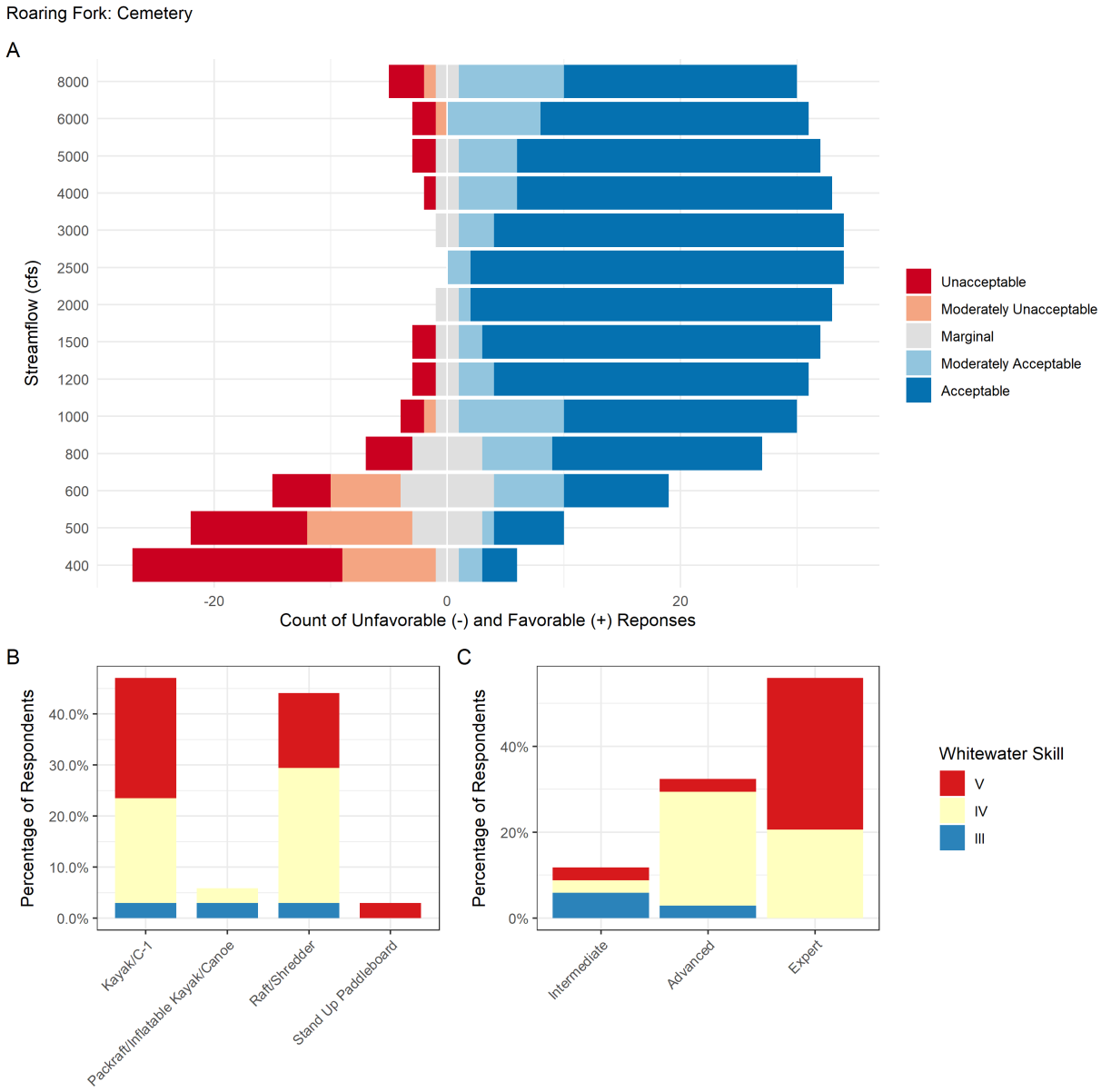
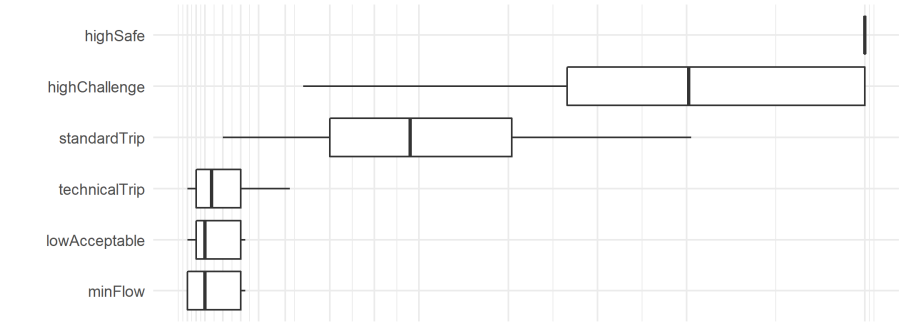


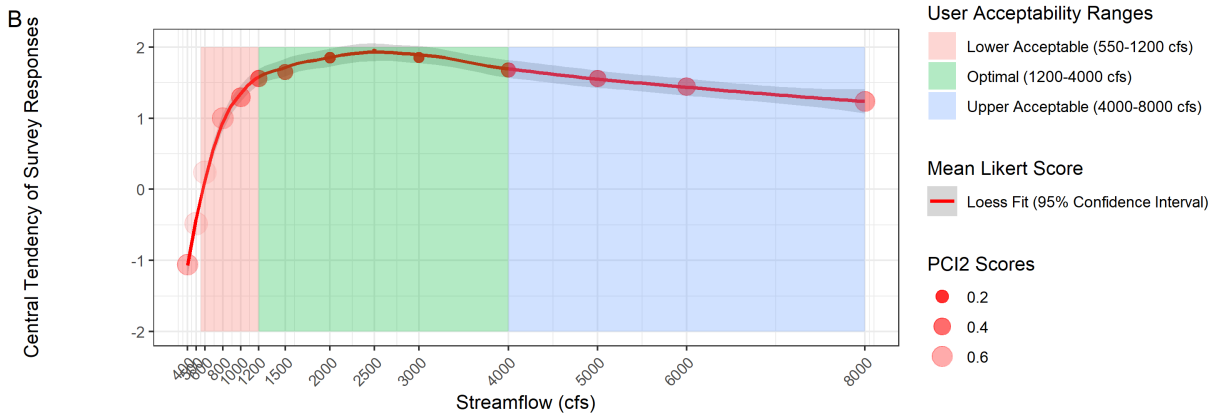
Figure 25: Survey responses for Roaring Fork: Cemetery. (A) Flow acceptability rankings. (B) User identified preferred craft types and whitewater skill level. (C) User identified expertise and whitewater skill level.

Roaring Fork: Cemetery

A



B



C

Survey Question	25th Percentile	Median Response	75th Percentile	Response Count
Minimum Flow (cfs)	400	600	1000	34
Low Acceptable Flow (cfs)	500	600	1000	34
Technical Flow (cfs)	500	675	1000	34
Standard Trip Flow (cfs)	2000	2900	4038	34
Challenging High Flow (cfs)	4662	6025	8000	34
Highest Safe Flow (cfs)	8000	8000	8000	34

Figure 26: Flow preferences reported by users for Roaring Fork: Cemetery. A) Boxplot of responses to open-ended questions about different categories of flow. B) PCI2 analysis results plotted against the central tendency of flow acceptability preference rankings at each flow category. Loess curve was fit to support visualization of flow acceptability ranges. C) Summarized open-format flow-preference question responses.

Table 17: PCI2 analysis results for Roaring Fork: Cemetery.

Flow (cfs)	Median Likert Response	n	Max. Distance	Total Distance
400	-1.06	34	2312	1468
500	-0.48	33	2176	1680
600	0.24	34	2312	1816
800	1.00	34	2312	1536
1000	1.29	34	2312	1164
1200	1.56	34	2312	874
1500	1.65	34	2312	732
2000	1.85	34	2312	314
2500	1.94	34	2312	128
3000	1.85	34	2312	306
4000	1.68	34	2312	638
5000	1.56	34	2312	858
6000	1.44	34	2312	1006
8000	1.24	34	2312	1276

Table 18: Boatable Days analysis results broken out by month for the Roaring Fork: Cemetery. Where an Acceptability Category (e.g. 'Optimal') is missing for a given month, zero days were observed to fall within that category and the row was left out of the table for brevity.

Month	Flow Preference Category	Dry Year	Dry Typical Year	Wet Typical Year	Wet Year
Mar	Lower Acceptable	0	0	14	14
	Total Days	0	0	14	14
Apr	Lower Acceptable	22	23	25	23
	Optimal	0	0	5	7
	Total Days	22	23	30	30
May	Lower Acceptable	15	11	5	0
	Optimal	16	20	26	28
	Upper Acceptable	0	0	0	3
	Total Days	31	31	31	31
Jun	Optimal	30	30	11	1
	Upper Acceptable	0	0	19	29
	Total Days	30	30	30	30
Jul	Lower Acceptable	29	22	0	0
	Optimal	2	9	31	22
	Upper Acceptable	0	0	0	9
	Total Days	31	31	31	31
Aug	Lower Acceptable	8	31	27	14
	Optimal	0	0	4	17
	Total Days	8	31	31	31
Sep	Lower Acceptable	7	30	30	30
	Total Days	7	30	30	30
Oct	Lower Acceptable	18	31	31	31
	Total Days	18	31	31	31
Nov	Lower Acceptable	3	20	30	30
	Total Days	3	20	30	30
Dec	Lower Acceptable	0	0	8	23
	Total Days	0	0	8	23

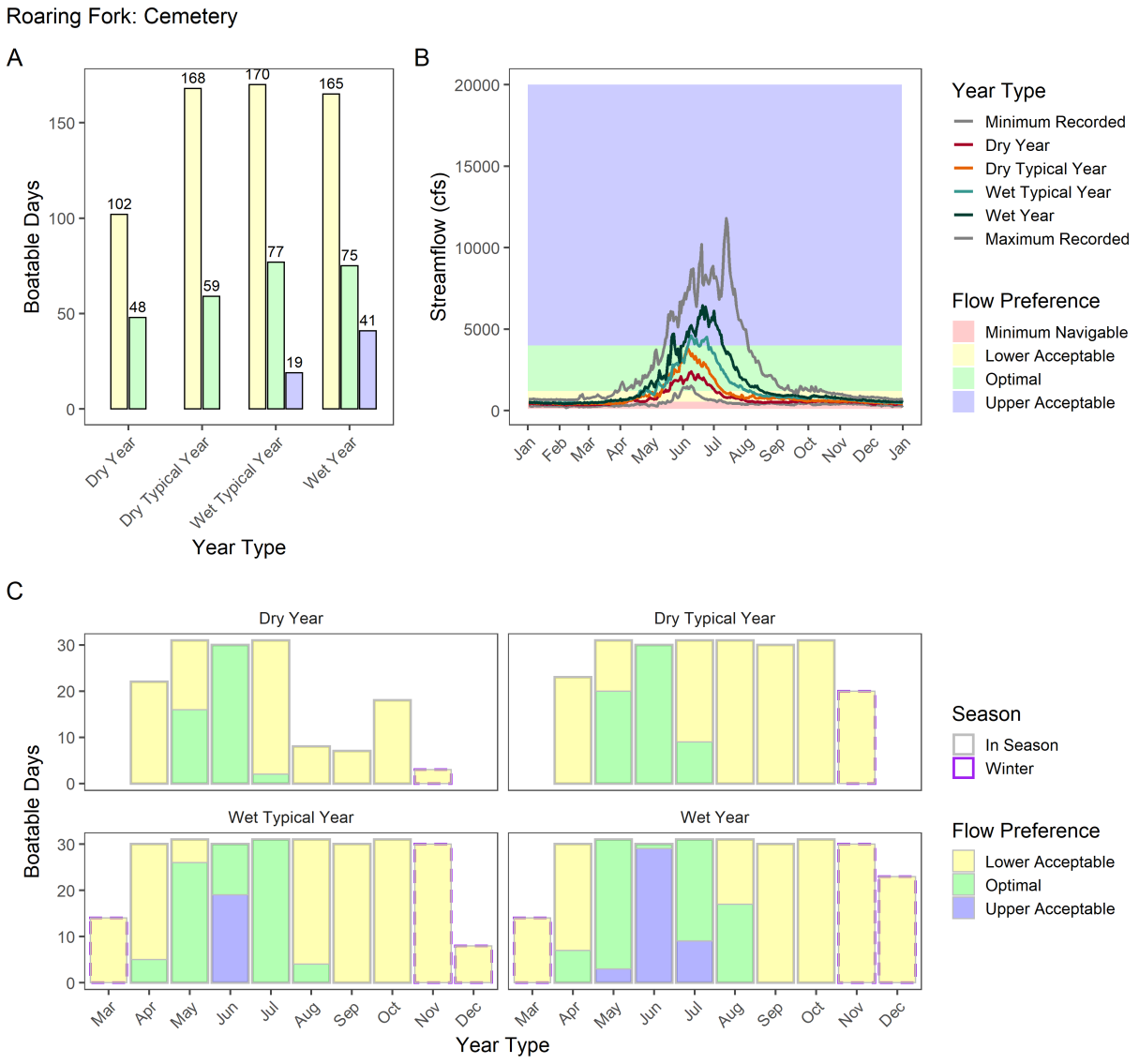


Figure 27: Boatable Days analysis results for the Roaring Fork: Cemetery. (A) Annual Boatable Days totals summarized by hydrological year type. (B) Flow preference ranges mapped to representative streamflow time series for wet, wet typical, dry typical, and dry years. Minimum and maximum recorded daily streamflows also included for reference (C) Monthly Boatable Days totals summarized by hydrological year type.