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HOW GREEN IS TOO GREEN? PUBLIC OPINION OF WHAT CONSTITUTES UNDESIRABLE ALGAE LEVELS IN STREAMS[1]

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ABSTRACT: A public opinion survey was carried out in Montana to ascertain if the public identifies a level of benthic (bottom-attached) river and stream algae that is undesirable for recreation. The survey had two parts; an On-River survey and a By-Mail survey. The On-River survey was conducted via 44 trips randomly scheduled throughout the state during which recreators were interviewed in-person at the stream. Selection of stream segments and survey dates/times was based on known, statewide recreational use patterns. By-Mail survey forms were sent to 2,000 individuals randomly selected from Montana's Centralized Voter File (CVF) available from the Montana Secretary of State. The CVF was current through 2004 and represented over 85% of the state's eligible voting population. In both surveys, eight randomly ordered photographs depicting varying levels of stream benthic algae were presented, and participants were asked if the algae level shown was desirable or undesirable for recreation. Survey form design, selection of photographs, and pretesting followed acceptable protocols that limited unintentional bias through survey execution. There were 433 returned forms (389 complete) for the By-Mail survey, while the On-River survey documented 563 interviews. In both surveys, as benthic algal chlorophyll *a* (Chl *a*) levels increased, desirability for recreation decreased. (Other measures of benthic algae biomass are presented as well.) For the public majority, mean benthic Chl *a* levels ≥200 mg/m^2 were determined to be undesirable for recreation, whereas mean levels ≤150 mg Chl *a*/m^2 were found to be desirable. Error rates were within the survey's statistical design criteria (≤5%). The largest potential error source was nonresponse in the By-Mail survey; however, the population represented by nonrespondents would have to exhibit profoundly different perceptions of river and stream algae to meaningfully alter the results. Results support earlier work in the literature suggesting 150 mg Chl *a*/m^2 represents a benthic algae nuisance threshold.

(KEY TERMS: rivers/stream; algae; environmental regulations; environmental impacts; public participation.)

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INTRODUCTION

One of the most basic components of water quality protection in the United States (U.S.) and abroad is the establishment of water body beneficial uses, which are also referred to as instream values. For example, the U.S. Clean Water Act (1972) requires that water bodies be classified for the type of beneficial water uses they are to support (e.g., fisheries, aquatic life, recreation and aesthetics, and drinking). Language of a similar nature is provided in New Zealand's 1991 Resource

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Management Act. Within the more detail-oriented text of the administrative rules, regulations, and guidance documents that support these laws are found water-quality criteria. Water-quality criteria are numeric or narrative expressions that, if met, assure protection of the beneficial water uses. The 1972 Clean Water Act is overseen by the U.S. Environmental Protection Agency (USEPA), and many water-quality criteria are provided in USEPA's so-called blue, red, and gold books (USEPA, 1973, 1976, 1986). These three documents indicate that the protection of recreation and aesthetics in U.S. waters requires the prohibition of undesirable or nuisance aquatic life (e.g., algae blooms). Similarly, New Zealand's guidance on interpreting the 1991 Resource Management Act (Biggs, 2000) addresses nuisance proliferations of periphtyon (i.e., stream bottom-attached algae) and recommends appropriate criteria to protect stream aesthetic, recreational, and landscape values. In Australia, guidelines for fresh and marine water quality indicate that nuisance organisms (including filamentous algal mats) should not be present in excessive amounts (Australian Department of the Environment, Water, Heritage and the Arts, available at http://www.mincos.gov.au/__data/assets/pdf_file/0003/316128/wqg-ch5.pdf, *accessed* September 30, 2008). In Montana, where the work to be presented took place, regulations that support the Montana Water Quality Act prohibit human caused conditions that result in undesirable aquatic life (Administrative Rules of Montana 17.30.637[1][e], available at http://www.deq.state.mt.us/dir/Legal/Chapters/CH30-06.pdf, *accessed* October 29, 2007).

What exactly constitutes an undesirable or nuisance level of aquatic life in a water body can be a subjective matter, especially when it comes to protecting beneficial water uses such as recreation and aesthetics. Nevertheless, work has been published in the scientific literature describing levels of benthic (i.e., bottom attached) algae in rivers and streams that may constitute a nuisance (Horner *et al.*, 1983; Welch *et al.*, 1988). These two papers suggest that benthic algae levels in excess of 100-150 mg chlorophyll *a* (Chl *a*)/m^2 are a nuisance. Horner *et al.* (1983) reviews 26 citations describing benthic algae growth in natural and artificial streams and finds that benthic algae levels greater than 150 mg Chl *a*/m^2 are only reported in cases where nutrient enrichment was above "ordinary natural levels" (page 131). Following up on this work, Welch *et al.* (1988) indicate that biomass greater than 100-150 mg Chl *a*/m^2 corresponds to streambed algae coverage >20%, which they suggest may present an aesthetic nuisance. Although algae of 100-150 mg Chl *a*/m^2 may impact recreation and aesthetics, impacts by such algae levels on aquatic life is unclear (Nordin, 1985; Welch *et al.*, 1988; Quinn and Hickey, 1990).

Horner *et al.* (1983) and Welch *et al.* (1988) – and the 100-150 mg Chl *a*/m^2 level they suggest to prevent nuisance growth – have been widely cited in the scientific literature and in government documents (e.g., Welch *et al.*, 1989; New Zealand Ministry for the Environment, 1992; Watson and Gestring, 1996; Dodds *et al.*, 1997; Biggs, 2000; Dodds and Welch, 2000; USEPA, 2000; Sosiak, 2002; Dodds, 2006; Carey *et al.*, 2007; Suplee *et al.*, 2007; Wang *et al.*, 2007). But Horner *et al.* (1983) recognized that establishing a nuisance algae level required further field verification, and government documents suggesting the use of the 100-150 mg Chl *a*/m^2 range qualify the recommendations by noting that what constitutes too much algae to the general public has not been firmly established, or stating that these levels will probably protect an aesthetic beneficial use (Biggs, 2000; USEPA, 2000). Thus, some type of assessment of the public's opinion on the matter is clearly warranted.

In our study, photographs of benthic stream algae at different levels were used to assess public opinion of what might constitute a nuisance. Independent studies show a high degree of consistency between perceptual judgment of photographs of environmental scenes and perceptual judgment of the same scenes experienced directly (Zube, 1974; Shuttleworth, 1980; Kellomäki and Savolainen, 1984; Stewart *et al.*, 1984; Stamps, 1990). Photographs preclude the need to transport large numbers of study participants to the environmental sites in question (Shuttleworth, 1980; Daniel and Meitner, 2001), and can be used to show conditions that may not currently exist (Manning and Freimund, 2004). The latter point was particularly relevant to our study, as some benthic algae (e.g., the filamentous algae *Cladophora* sp.) can demonstrate peak levels that develop rapidly in early summer and then again in early fall (Whitton, 1970), the timing of which is highly variable. It would have been very difficult to coordinate the study with such time-variable events.

The use of photographs to represent environmental scenes has the advantages outlined above, but is not without shortcomings. Photographs cannot invoke dynamic elements like sound, motion, or other factors which can be significant components especially in environments involving streams and rivers (Hetherington *et al.*, 1993; House, 1996). In general, the validity of using a particular presentation medium (like photographs) depends on how well that medium can convey the key components of an environmental scene to the participants who are judging specific aspects of the scene (Hetherington *et al.*, 1993; Manning and Freimund, 2004). We concluded that photographs would convey the "key components" needed for study participants to judge what were (or were not) undesirable algae levels, as previous work consistently discuss/present nuisance algae in contexts

that can readily be assessed by eye. For example, large benthic algal growths interfere with swimmers and boats (physical entanglement of both), are unpopular with fisherman because of the danger of slipping and the snagging of lines, and are very conspicuous (unaesthetic) from the bank (e.g., Whitton, 1970; Horner *et al.*, 1983; Biggs and Price, 1987; Welch *et al.*, 1988; Biggs, 2000). All these factors can be assessed visually in a quality photograph. Furthermore, the New Zealand Ministry for the Environment uses photographs of varying benthic algae levels to convey to the public the appearance of different algae quantifications (Chl a/m^2, % bottom cover, etc.) (New Zealand Ministry for the Environment, 1992; Biggs, 2000).

Herein, we present results from a survey that assessed the public's opinion concerning river and stream benthic algae levels. The objective was to determine if the general public identifies a particular level of benthic algae that is not desirable for recreation. In summer 2006, the Montana Department of Environmental Quality (MT DEQ) and the University of Montana surveyed the public on their perceptions of benthic algae in rivers and streams as it affected water recreational activities, whatever those activities might be. To our knowledge, this is the only large-scale research that has explored the relationship between public perceptions of benthic algae levels in rivers and streams and recreation water uses. Study surveys were carried out on two groups that were not mutually exclusive: river and stream users throughout Montana, and registered Montana voters. We found that the public majority showed a clear preference for benthic algae levels at or below 150 mg Chl a/m^2. These findings provide strong support for the more qualitatively derived recommendations of Horner *et al.* (1983) and Welch *et al.* (1988).

METHODS

Overview of Survey Goals and Design

The survey was carried out in Montana (Figure 1) on two public groups that were not mutually exclusive. An On-River survey was carried out on wadeable rivers and streams throughout the state, and a By-Mail survey was sent to randomly selected registered Montana voters. The first was undertaken because the opinion of active river and stream users was considered particularly relevant. This group included Montana residents and visitors. The second group (registered Montana voters) was chosen because the outcome of the survey had the potential to impact Montana water quality regulations, and therefore the opinion of a representative sample of Montanans was important. We also tracked in the On-River survey the opinions of residents *vs.* nonresidents to elucidate if actively recreating Montanans had opinions different from visitors. In both surveys we tracked opinions by region and by watershed, as the location where a public opinion survey is carried out can significantly influence the results (Ross and Taylor, 1998; Brunson and Shindler, 2004), and we wanted to be able to test for this.

Both surveys consisted of the same randomly ordered photographs of Montana rivers and streams, each photograph depicting a different algae level. In the On-River survey, the survey's purpose and instructions were verbally provided to participants in-person by an interviewer; for the By-Mail survey, these were provided on the survey form. In each survey, participants were asked to indicate if the algae level in each photograph was desirable or undesirable in relation to their main form of river and stream recreation. We did not specify which recreation, thus allowing survey participants to respond relative to whatever form of river and stream recreation they enjoyed. The terms desirable and undesirable (as opposed to alternatives like acceptable/unacceptable) were chosen because they have long been used in U.S. national water quality criteria (e.g., "surface waters should be free of substances attributable to discharges or wastes [which] ... produce undesirable aquatic life") (Federal Water Pollution Control Administration, 1968; USEPA, 1973, 1976, 1986), and

FIGURE 1. Map of North America Showing the State of Montana, Where the Study Took Place.

we believed they would be easily understood for making a choice. Error rates for responses to each photograph were targeted to be ≤5%. Further details about each survey are provided later in Methods.

Selection of Photographs for the Survey

Photographs representing a range of algae levels found in Montana rivers and streams were selected from the collection of one of the authors. At each photographed site, 10-20 benthic algae samples had been collected and analyzed so that the benthic algal Chl *a* (extracted with EtOH and corrected for phaeophytins) (Sartory and Grobbelaar, 1984) and ash-free dry weight (AFDW) (Clesceri *et al.*, 1998) of the stream cross-section seen in each photograph was known. Many different sites had been sampled over a number of years, providing a large collection of photographs. The mean of the repeat measures of algae at each site during any given sampling event provided a benthic Chl *a* density (mg/m^2) and AFDW (g/m^2) for each photograph. Photographs of river and stream sites were available that showed a range of mean benthic Chl *a* from <50 mg/m^2 to 1,276 mg/m^2. This generally covers the maximum range of benthic algae measured in MT rivers and streams. Photographs included streams in which bottom algae was filamentous, diatomaceous or, often, a combination of both.

Photographs were sorted by visual clarity and consistent perspective, and then grouped into benthic Chl *a* "bins" (ca. 50 mg Chl *a*/m^2 bin, ca. 100 mg Chl *a*/m^2 bin, ca. 150 mg Chl *a*/m^2 bin, etc.). Algae were staggered by about 50 mg Chl *a*/m^2 as it is the authors' experience that a visual distinction can best be made between algae levels staggered at this degree of resolution. A "zero" level was not provided because levels below 50 mg Chl *a*/m^2 are, in our experience, difficult to visually discern from 50 mg Chl *a*/m^2. Each algae bin was initially represented by between 5 and 20 photographs. The photographs were then provided to a review committee (MT DEQ Water Quality Standards Section; six individuals, one an author on the present study). Each member was asked to identify a photograph for each bin that best represented the central tendency of the series of photographs in the bin – that is, it was not too "green," and not too "clean." (The author who is a member of the Standards Section did not reveal his choices to the team prior to their selections.)

The survey was developed using eight of the committee-selected photographs. Each was assigned a letter, and are ordered here by reach mean Chl *a* values (lowest to highest): (A) 44 mg/m^2, (G) 112 mg/m^2, (F) 152 mg/m^2, (E) 202 mg/m^2, (B) 235 mg/m^2, (H) 299 mg/m^2, (C) 404 mg/m^2, and (D) 1,276 mg/m^2 (Appendix A). Other algae characterizations (g AFDW/m^2, dominant algae type, % filamentous cover) are shown in Table 1. In general, stream bottom coverage by filamentous algae is higher at higher Chl *a* levels (Welch *et al.*, 1988), and this is reflected in our photograph set. The photographs with the second-highest and highest Chl *a* values (C and D) do not follow the approximate 50 mg Chl *a*/m^2-increment pattern. This was carried out because (1) practical matters of design and simplicity kept the survey to eight photographs, (2) we wanted to have the most resolution among photographs in the mid-range algae levels, as that was where a nuisance threshold (per Welch *et al.*, 1988) was most likely to be identified, and (3) we wanted to show the public the full range of algae levels common in Montana. Variation around the reach-mean Chl *a* value for each of the eight photographs (SEM as a percent of the mean) ranged from 5 to 27% (mean 14%). Given this variation and for simplicity, for the remainder of this paper, each photograph's reach mean Chl *a* level is presented rounded to the nearest 10 mg/m^2.

Pretest of the Survey Form and Testing of Photograph Sequence

Survey form design and refinement followed generally accepted public opinion survey techniques (Dillman, 2000). A pretest of a draft By-Mail survey form was undertaken on 44 individuals in Helena, Montana. The pretest survey form closely resembled the final form in that it had an introduction and instructions, a dichotomous choice for each photograph, and presented the eight photographs in the same randomly derived order. The 44 individuals asked to take the survey were not randomly selected, but most were not directly involved with this water quality issue and so provided information on the survey form's clarity and logic. Two changes to the final survey form resulted from the pretest results. One photograph (D; 1,280 mg Chl *a*/m^2) was replaced with a photograph from the same site but looking downstream (rather than upstream) which also depicted 1,280 mg Chl *a*/m^2. This was performed because color hues of the original photograph were thought to be too bright relative to the other seven photographs and confused decision making. The other change was the addition of, in the survey form's introduction, a statement that if a stream's algae level was naturally high MT DEQ would take no action (Appendix A). This stemmed from individuals' comments that they were concerned that their answers would lead MT DEQ to chemically treat and kill algae in streams that have naturally elevated algae levels, an action they did not want to occur.

TABLE 1. Quantification of Algae Levels, Dominant Algae Type, and Reach Description From Field Notes on the Day of Sampling.

Photograph Letter	Mean Benthic Algae Level (mg Chl a/m^2)	Mean Benthic Algae Level (g AFDW/m^2)	Dominant Algae Type	Reach Description (field notes)
A	44	10	Diatoms	Almost bare to naked eye, no filaments
G	112	30	Diatoms	5-10% of rocks had *Cladophora*; the remaining rocks were bare or lightly coated with diatoms
F	152	36	Diatoms	50-80% *Cladophora* cover, but filaments only 1 cm long; the filaments were very diatom encrusted as were the rocks
E	202	95	Filamentous	20-60% *Cladophora* cover; 3-30 cm long filaments
B	235	117	Filamentous	50% *Cladophora* cover; very diatom-encrusted
H	299	209	Filamentous	30-100% *Cladophora* cover; 50-100 cm long filaments
C	404	136	Filamentous	70% *Cladophora* cover; 10-30 cm long filaments
D	1,276	221	Filamentous	90% *Cladophora* cover; 30-50 cm long filaments

Notes: AFDW, ash-free dry weight; Chl a, chlorophyll a.

To evaluate potential bias resulting from the presentation order of the survey photographs, in summer 2006, 32 recreators along the Clark Fork River in Missoula, Montana were asked for their opinion (desirable or undesirable) concerning the algae level shown in each of the eight photographs as it would affect their recreation. The eight photographs were shown on laminated 20.3 × 25.4 cm sheets and were presented in a particular random order. Later in the summer, a second randomly selected presentation order of the same eight photographs was prepared and 31 recreators along the same Clark Fork River reach were similarly interviewed. These data were not included in the By-Mail or On-River survey analyses.

By-Mail Survey

By-Mail surveys were sent to individuals randomly selected from Montana's Centralized Voter File (CVF) available from the Secretary of State. This file was current through 2004, contained about 624,000 records, and represented over 85% of the eligible voting population of Montana. The CVF list provided unbiased selection of sampling units because people on the CVF list are certified and there is minimal over representation or under representation of individuals, making it a good sample frame. Simple random sampling procedures were used to select individuals from the CVF. Sample size was determined using very conservative levels (99% confidence level, ±3% sampling error, 50/50 split, very large population >500,000) (Dillman, 2000). This calculates to 1,837 surveys; we mailed out 2,000 surveys as it was within our budget and helped assure we would ultimately achieve our goal of a 5% sampling error rate.

The cover of the By-Mail Survey (Appendix A) explained the purpose of the survey and provided instructions on how to fill it out. Inside the pamphlet, the eight photographs were presented in a random order. Next to each photograph, the respondent was asked to mark the box indicating if the algae level was desirable or undesirable relative to his or her major form of river and stream recreation. Respondents were also provided a few lines with each photograph to explain their answer, if they chose to. A return envelope with a postage stamp was included with each survey.

Survey implementation was intended to maximize response. We used as a guide generally accepted techniques from Dillman's (2000) Tailored Design Method (TDM), but departed from the TDM in some ways. Dillman (2000) calls for a five-contact approach, the last three of which are follow-ups after the survey is mailed ([3] a reminder/thank you postcard, [4] a replacement survey for nonrespondents, and [5] telephone/certified mail contact for nonrespondents). In our study, complete anonymity of respondents was deemed critical given the potential regulatory implications of the work and, in addition, anonymity may increase response rate (Kindra *et al.*, 1985) and accuracy (Kerin and Peterson, 1977). This decision precluded strict adherence to the last two TDM steps. In our study, each potential respondent was first sent a single-page letter introducing the project and notifying them that they would be receiving a survey. A week after the introductory letter, the survey forms were sent out. A week after the survey was sent, follow-up postcards were sent to everyone, encouraging recipients to complete and return their survey and thanking them if they already had. This three-contact process occurred between July 21 and August 4, 2006.

In September 2006, about 60 days after the By-Mail survey forms were mailed out, it was clear that nonresponse was high (ca. 78%). Preliminary analysis showed that response splits were far different from 50/50 for each photograph and, as a result, the

response rate was already adequate to meet the study's design criteria. But we wanted to try and characterize nonrespondent opinions due to concerns about potential bias, so results from respondents were then used to estimate the number of follow-ups needed. These were calculated by specifying particular confidence levels around the response to a photograph under different scenarios (e.g., number follow-ups required to maintain 95% confidence level in the response to a photograph when non-respondents respond X% differently than the original respondents). The calculations provided a range of follow-ups from 50 to 400. In September 2006, 150 randomly selected individuals from the CVF list were contacted by phone and asked if they would fill out and return the survey. Because the study was anonymous, this process included individuals that had already responded.

Selection of River and Stream Segments for the On-River Survey

On-River surveys were conducted via 44 survey trips randomly scheduled throughout the state. Angling is a dominant activity at fishing access sites throughout Montana (Montana Fish, Wildlife and Parks, http://www.fwp.mt.gov/content/getItem.aspx?id=11065, *accessed* April 2005), and therefore provided a good indication of relative river and stream recreation use. Selection of stream segments and survey dates for the survey was based on angling-use patterns summarized by the Montana Department of Fish, Wildlife, and Parks (FWP) (McFarland and Tarum, 2005; an updated, web-available version of the report is at http://www.fwp.mt.gov/content/getItem.aspx?id=29639). Prior to using FWP's list a few large, non-wadable river segments (as judged by the authors) were removed, as our main interest was the opinion of recreators using stream reaches similar to those in the photographs. FWP's list provided the On-River survey's sampling frame and directly informed unbiased selection of sample units (recreational use by time and location) through a two-stage random sampling scheme. Primary sample units were represented by FWP river drainages; probability of selection was proportional to angler use on wadeable streams. Within each primary sampling unit, secondary sample units were represented by streams that had been shown to have fishing pressure according to the FWP survey; probability of selection was proportional to angler use within the drainage. The randomly scheduled order in which stream reaches were to be surveyed was further scheduled (randomly) for interviews to occur either in the morning from 06:00 to 11:00, or in the afternoon and evening, 13:00 to 18:00 (Table 2).

Surveys were undertaken from June 17 to August 27, 2006. At the beginning of the survey (June 17 to June 20), a field interviewer noted that encounters with recreators would likely be more effective if the evening interview period was moved later in the day. The authors concurred and, from June 25 until the end of the survey, PM interviews were carried out from 14:00 to 19:00. Interview site and time scheduling was strictly adhered to, with only a small number of minor changes (e.g., two stream reaches within a primary sampling unit [drainage] to be sampled sequentially were performed in the reverse order from originally planned). Interviewer scheduling conflicts required that the ultimate surveys (August 28/29) be completed a week earlier (August 24/25).

On-River Survey Interview Process

River and stream segments on which survey interviews were carried out varied widely, but were often about 80 km long. Most river and stream segments had roads along them, with designated and undesignated public access points. Some segments, however, were only accessible by foot trails or by intermittent Forest Service roads crossing the water. The survey protocol reflects the diversity of accessibility to the segments.

The interviewer approached each survey segment from the headwaters and moved downstream. On a few occasions where travel time was underestimated, interviewing was begun before reaching the headwaters. The interviewer stopped at each designated or undesignated public fishing access point and interviewed any recreators present at that location. After finishing any available interviews, the interviewer proceeded to the next public access downstream. If the interviewer completed surveying along the length of the survey segment before the five-hour survey allocation, she turned around and repeated the process heading upstream.

In the case of a foot trail on a closed loop (no access from other trails/roads), the interviewer positioned herself at the trailhead to interview stream users both coming and going. If the river or stream was located along an open loop foot trail (access to other trails/roads), and there were vehicles present at the trailhead, the interviewer walked as much of the length of the stream as possible, given time and personal safety considerations.

Upon approaching a potential respondent, the interviewer identified herself as from the University of Montana, working on a project with MT DEQ. She explained to the respondent that the goal of the project was to determine if and when algae in rivers and streams was ever a nuisance to recreators.

TABLE 2. Prearranged, Randomly Derived Visitation Schedule for Stream Reaches in the On-River Survey.

Month	Drainage Trip	Drainage Name	Stream Trip	AM/PM	Stream Reach
June	17/18	Big Hole Drainage	Sat	PM	Big Hole River Sec 02
			Sun	AM	Big Hole River Sec 02
	19/20	Upper Clark Fork Drainage	Mon	PM	Rock Creek Sec 01
			Tues	AM	Little Blackfoot R Sec 02
	24/25	Bitterroot Drainage	Sat	PM	Bitterroot River Sec 02
			Sun	AM	Boulder Creek
	26/27	Madison Drainage	Mon	PM	Madison River Sec 02
			Tues	AM	Madison River Sec 02
July	1/2	Upper Yellowstone Drainage	Sat	PM	Sage Creek
			Sun	AM	Stillwater River Sec 02
	1/2	Upper Clark Fork Drainage	Sat	PM	Warm Springs Creek
			Sun	PM	Clark Fork River Sec 03
	3/4	Beaverhead Drainage	Mon	PM	Bloody Dick Creek
			Tues	AM	Poindexter Slough
	8/9	Upper Clark Fork Drainage	Sat	PM	Flint Creek Sec 01
			Sun	AM	Storm Lake Creek
	10/11	Big Hole Drainage	Mon	AM	Big Hole River Sec 03
			Tue	AM	Big Hole River Sec 02
	15/16	Bitterroot Drainage	Sat	PM	Lolo Creek
			Sun	AM	Bitterroot River Sec 02
	17/18	Beaverhead Drainage	Mon	PM	Beaverhead River
			Tue	PM	Beaverhead River
	24/25	Blackfoot Drainage	Mon	AM	Blackfoot River Sec 02
			Tue	AM	Blackfoot River Sec 02
	29/30	Upper Clark Fork Drainage	Sat	AM	Storm Lake Creek
			Sun	AM	Clark Fork River Sec 03
	31/Aug 1	Mussellshell Drainage	Mon	PM	Checkerboard Creek
			Tue	PM	Spring Creek
August	5/6	Upper Flathead Drainage	Sat	AM	M Fk Flathead River
			Sun	PM	M Fk Flathead River
	12/13	Bitterroot Drainage	Sat	PM	Lost Horse Creek
			Sun	PM	Bitterroot River Sec 02
	14/15	Upper Yellowstone Drainage	Mon	PM	Rock Creek Sec 01
			Tue	PM	Rock Creek Sec 01
	19/20	Upper Missouri Drainage	Sat	PM	Missouri River Sec 09
			Sun	AM	Missouri River Sec 09
	21/22	Upper Missouri Drainage	Mon	AM	Missouri River Sec 09
			Tue	PM	Missouri River Sec 09
	21/22	Upper Clark Fork Drainage	Mon	AM	Rock Creek Sec 02
			Tue	PM	Warm Springs Creek
	26/27	Upper Yellowstone Drainage	Sat	PM	Rock Creek Sec 01
			Sun	PM	Rock Creek Sec 01
	28/29	Upper Yellowstone Drainage	Mon	PM	Bighorn River Sec 01
			Tue	AM	Stillwater River Sec 01

Respondents were asked to examine the eight photographs provided (same photographs and order used in the By-Mail survey), and express whether they found the level of algae shown in each to be desirable or undesirable for their primary river or stream recreational activity, and why. At the end of the interview, the interviewer recorded for each respondent whether they were a Montana resident. She also gave each respondent the opportunity to ask any questions about the project. Most interviews lasted from two to three minutes, but up to 20 minutes in rare cases. Longer interviews resulted when respondents had extensive questions about the project or wanted to share their particular algae experiences. Any river user encountered who was capable of comprehending what the survey asked was encouraged to take the survey. This included some youths and several visitors from foreign countries.

Inferential Statistics

After the On-River surveys were complete and the By-Mail returns had stopped, six comparisons were evaluated using statistical test methods appropriate to binomially distributed data. These were (1) comparison of responses to a standard level of 50%, (2) comparisons of responses among photographs within

each survey, (3) comparisons of responses within each survey to Chl *a* levels, (4) comparisons of responses among survey locations, (5) comparisons of responses by residency, and (6) comparisons of responses between surveys (i.e., By-Mail *vs*. On-River). Where applicable, reach-mean Chl *a* values were used in tests. Specifics are provided below.

(1) The proportion of desirable responses for each photograph was compared with a standard value of 50%. Fifty percent was selected because it represents a simple majority, which is a logical and clearly understood threshold. For binomial data, it also represents a level the difference from which represents a meaningful response; i.e., different from a coin flip. For each comparison, a two-sided null hypothesis was stated that the proportion observed was equal to 50%; the alternative hypothesis was that the proportion observed was not equal to 50%. The binomial sign test for a single sample was employed (Sheskin, 1997) using a calculated *z*-statistic, appropriate for large samples, to approximate the test-statistic. All tests used an *a priori* 5% significance level.

(2) Within each survey, the McNemar test (Sheskin, 1997) was used to evaluate the likelihood that preferences differed among photographs presented. This test was conducted for all pairs of photographs, testing the null hypothesis that there was no difference in respondents' preferences between two photograph pairs. All tests were two-sided (*a priori* 5% significance level).

(3) Within each survey, the test of significance for Kendall's tau (Sheskin, 1997) was used to evaluate the relationship (correlation) between percent desirable response by photograph and the Chl *a* levels depicted. This was evaluated for each survey testing the null hypothesis that no correlation existed.

(4) Within each survey, comparisons were conducted to evaluate whether preferences varied significantly by survey location. The *z*-test for two independent proportions was employed (Sheskin, 1997) testing the null hypothesis that there was no difference in percent desirable responses between survey results from two locations. In the case of the By-Mail survey, respondent identities were unknown; however, the main post office of origin of each returned survey had been recorded. Therefore, for By-Mail surveys, comparisons were conducted among locations defined by the post office of origin. For the On-River surveys, comparisons were conducted among responses by the drainage where the survey was conducted. All tests were two-sided (*a priori* 5% significance level).

(5) In the On-River survey, comparisons were conducted to evaluate whether preferences varied significantly by residency. The *z*-test for two independent proportions was employed (Sheskin, 1997) testing the null hypothesis that there was no difference in percent desirable responses due to residency (MT resident *vs*. nonresident). All tests were two-sided (*a priori* 5% significance level).

(6) Comparisons were conducted to evaluate whether preference for a particular photograph varied significantly (*a priori* 5% significance level) between surveys. The *z*-test for two independent proportions was employed (Sheskin, 1997), testing the null hypothesis that there was no difference in percent desirable responses to a given photograph between surveys.

RESULTS

For each photograph, the percent of desirable responses was not significantly different between the two different randomly ordered photograph presentations. Both photograph orders yielded the same relative rank of photographs based on percent desirable responses (Table 3). Therefore, the effect of photograph order was not considered significant or meaningful and was not further considered in interpreting the results.

For the By-Mail survey there were 433 returned surveys, 389 of which were complete (all answers filled out) and could be used in statistical analyses. The 150 telephone follow-ups were unsuccessful, in that only 14 individuals indicated they would fill out a provided survey and, at most, seven of these were returned. For the On-River survey, there were 563 documented interviews. Recreators of all kinds were encountered during these interviews, including wading fisherman, rafters, canoeists, kayakers, swimmers, tubers, and sightseers. Results from each survey are summarized in Tables 4 and 5, indicating for each photograph the number of respondents who considered the Chl *a* level depicted to be desirable or undesirable, the percentage of respondents who considered the level to be desirable, and the 95% confidence level of this proportion expressed as percent error. All error rates are within the statistical design criteria for the survey (i.e., less than 5%). Results from the On-River and By-Mail surveys depict similar patterns of response to the Chl *a* levels represented. For both groups of survey respondents, as algal chlorophyll levels increased the desirability for recreation

TABLE 3. Summary of Random Photograph Order Surveys.

		Random Order #1 (n = 32)		Random Order #2 (n = 31)	
Photograph	**Chlorophyll *a* (mg/m^2)**	**Presentation Order**	**Percent Desirable**	**Presentation Order**	**Percent Desirable**
A	40	1	100	1	97
G	110	7	97	3	94
F	150	6	78	8	77
E	200	5	63	7	48
B	240	2	41	5	35
H	300	8	22	2	16
C	400	3	9	4	10
D	1,280	4	19	6	13

TABLE 4. Summary of the By-Mail Survey, Montana Residents (n = 389).

Photograph	**Chlorophyll *a* (mg/m^2)**	**Number Desirable**	**Number Undesirable**	**Percent Desirable**	**Percent Error**
A	40	372	17	95.6	2.0
G	110	369	20	94.9	2.2
F	150	271	118	69.7	4.6
E	200	64	325	16.5	3.7
B	240	112	277	28.8	4.5
H	300	49	340	12.6	3.3
C	400	65	324	16.7	3.7
D	1,280	44	345	11.3	3.1

TABLE 5. Summary of the On-River Survey, Recreational River and Stream Users (n = 563).

Photograph	**Chlorophyll *a* (mg/m^2)**	**Number Desirable**	**Number Undesirable**	**Percent Desirable**	**Percent Error**
A	40	553	10	98.2	1.1
G	110	527	36	93.6	2.0
F	150	427	136	75.8	3.5
E	200	179	384	31.8	3.8
B	240	164	399	29.1	3.8
H	300	114	449	20.2	3.3
C	400	65	498	11.5	2.6
D	1,280	51	512	9.1	2.4

decreased. Specifically, levels of Chl *a* ≥200 mg/m^2, represented by photographs E, B, H, C, and D (Appendix A) were determined to be undesirable for recreation by both groups of survey respondents. Levels ≤150 mg Chl *a*/m^2, represented by photographs A, G, and F, were determined to be desirable. Results for each of the six statistical analyses described in Methods are given below.

Comparisons to a Standard Level

In all instances – all photograph results in both surveys – the proportion of desirable responses was significantly different than 50% ($p < 0.05$). Therefore, all responses can be considered meaningful in that they show significant preferences (desirable or undesirable) for each photograph.

Comparisons Among Photographs Within a Survey

Within each survey, significant differences were found between most pairs of photographs within both surveys. Exceptions occurred at the lower extreme of Chl *a* levels – A (40 mg/m^2) *vs.* G (110 mg/m^2) from the By-Mail survey – and among selected photographs considered undesirable by the public majority – E (200 mg/m^2) *vs.* C (400 mg/m^2) and H (300 mg/m^2) *vs.* D (1,280 mg/m^2) from the By-Mail survey and E (200 mg/m^2) *vs.* B (240 mg/m^2) from the On-River survey. Therefore, responses can be

considered meaningful in that they show preferences that differ significantly among the photographs presented.

Comparisons of Responses to Algae Chl a Levels

In both surveys, the null hypothesis was rejected in favor of the one-sided alternative hypothesis that a negative correlation existed ($p < 0.05$). That is, as the Chl *a* levels depicted increased, the percent of desirable responses was shown to significantly decrease. Therefore, responses can be considered meaningful in that preferences show concordance with algae levels depicted in the photographs.

Comparisons Among Survey Locations

Table 6 summarizes By-Mail survey results showing percent desirable responses by post office of origin; 21 responses had an unidentifiable post mark and are not included in this summary. Table 7 summarizes On-River survey results showing percent desirable responses by drainage basin. Values in each table are shaded if the preference is significantly different than 50% (i.e., meaningful). In several instances – Billings, Butte, Missoula, and Kalispell postmarks and Big Hole, Bitterroot, and Upper Flathead drainages – results for all photographs were significantly different than 50% ($p < 0.05$). Otherwise, among the remaining locations, one or more results for photographs F through H – the midrange of algae levels depicted – exhibited preferences that were not significant. Small sample size is a factor in many of these negative results; however, several locations – Great Falls postmark and Beaverhead, Upper Clark Fork, and Upper Missouri drainages – had larger sample sizes and still exhibited no significant preference for one or more of these photographs.

Where photograph preferences were meaningful (i.e., significantly different from 50%) in Tables 6 and 7, the difference in percent desirable response between locations was evaluated. For the By-Mail survey, the null hypothesis was accepted in most cases; i.e., photograph preference did not vary

TABLE 6. Summary of the By-Mail Survey of Montana Residents by Post Office.

	Post Office of Response Origination								
Photograph	Billings (%) (n = 99)	Wolf Point (%) (n = 7)	Miles City (%) (n = 13)	Great Falls (%) (n = 48)	Havre (%) (n = 14)	Helena (%) (n = 23)	Butte (%) (n = 42)	Missoula (%) (n = 78)	Kalispell (%) (n = 44)
A	94.9	100	100	91.7	85.7	95.7	95.2	98.7	95.5
G	93.9	100	100	95.8	92.9	100	97.6	93.6	90.9
F	70.7	100	69.2	72.9	64.3	65.2	69.0	61.5	72.7
E	20.2	14.3	15.4	18.8	7.1	13.0	23.8	12.8	9.1
B	34.3	71.4	46.2	37.5	28.6	21.7	23.8	17.9	25.0
H	10.1	14.3	23.1	16.7	14.3	4.3	21.4	11.5	11.4
C	12.1	14.3	15.4	20.8	21.4	21.7	19.0	14.1	15.9
D	7.1	28.6	7.7	14.6	7.1	0.0	23.8	11.5	11.4

Note: Values are shaded if preference is significantly different from 50%.

TABLE 7. Summary of the On-River Survey of Recreational River Users by Drainage.

	FWP Drainage									
Photograph	Beaver-Head (%) (n = 63)	Big-Hole (%) (n = 70)	Bitter-Root (%) (n = 129)	Black-Foot (%) (n = 19)	Madison (%) (n = 21)	Mussel-Shell (%) (n = 15)	Upper Clark Fork (%) (n = 83)	Upper Flathead (%) (n = 67)	Upper Missouri (%) (n = 83)	Upper Yellowstone (%) (n = 13)
A	100	97.1	100	100	100	93.3	95.2	98.5	98.8	92.3
G	98.4	94.3	87.6	100	100	86.7	91.6	92.5	98.8	100
F	87.3	82.9	66.7	73.7	57.1	86.7	74.7	79.1	77.1	76.9
E	52.4	30.0	17.1	15.8	23.8	33.3	39.8	19.4	48.2	30.8
B	39.7	31.4	8.5	57.9	19.0	33.3	15.7	29.9	55.4	53.8
H	25.4	12.9	8.5	0.0	19.0	46.7	18.1	22.4	42.2	15.4
C	25.4	5.7	2.3	0.0	23.8	6.7	9.6	3.0	30.1	7.7
D	22.2	5.7	2.3	0.0	19.0	0.0	6.0	6.0	18.1	15.4

Notes: FWP, Montana Department of Fish, Wildlife, and Parks.
Values are shaded if preference is significantly different from 50%.

significantly between respondents with different postmarks. Two notable exceptions were respondents' preference for photograph B (240 mg Chl a/m^2) in Billings *vs.* Missoula, and preference for photograph F (150 mg Chl a/m^2) in Wolf Point *vs.* Missoula. Conversely, for the On-River survey, many significant differences were evident between drainages. Such differences occurred for each photograph and results from every drainage differed with one or more other drainages.

In no instance, in either survey, is there a significant difference where a photograph preference from one location was desirable (>50%) and the preference from another location indicated the same photograph was undesirable (<50%) – or vice versa. Rather, significant differences indicated differences in the degree of acceptability – or unacceptability – between locations. For instance, 34.3% of Billings respondents considered photograph B (240 mg Chl a/m^2) to be desirable compared with 17.9% of Missoula respondents; this difference is significant, but the majority of both Missoula and Billings respondents consider the algae level depicted to be undesirable. Therefore, whereas comparisons indicate some variation in photograph preferences among locations – more so in the On-River survey than the By-Mail survey – results were consistent at the level of 50% (simple majority).

Comparisons by Residency

Table 8 summarizes photograph preference for 382 Montana residents surveyed and 181 nonresidents encountered. All preferences are meaningful in that they are significantly different from 50% ($p < 0.05$). Within each group, most preferences were significantly different between photograph pairs; exceptions exist at the extremes, i.e., photograph A (40 mg Chl a/m^2) *vs.* G (110 mg Chl a/m^2) and C (400 mg Chl a/m^2) *vs.* D (1,280 mg Chl a/m^2), and also for photographs E (200 mg Chl a/m^2) *vs.* B (240 mg Chl a/m^2). Results from each group are concordant with associated Chl *a* levels. Finally, in no instance is there a significant difference in photograph preference between Montana residents and nonresidents. Therefore, results for each group are meaningful and, between each other, show comparable preferences for the photographs presented.

Comparisons Between Surveys

Figure 2 shows the percent desirable responses for each photograph as observed in each survey. Photographs are ordered in progression of Chl *a* levels depicted. Both surveys exhibit a similar pattern of response; however, there are notable differences. For most individual photographs – A, F, E, H, and C – percent desirable response differed significantly between the two surveys. Surveys only agree on the level of preference for photographs G, B, and D. Also, there appears to be confusion in the By-Mail survey between photograph E (200 mg Chl a/m^2) *vs.* B (240 mg Chl a/m^2) and photograph H (300 mg Chl a/m^2) *vs.* C (400 mg Chl a/m^2). Whereas both surveys are concordant with Chl *a* levels depicted, the By-Mail survey does not depict a perfect relationship. Nevertheless, there is clear threshold in both surveys between those photographs considered desirable (>50%) and those considered undesirable (<50%) – a level of interpretation relevant to a simple majority. Significant differences among preference levels noted above are only indications of differences in degree of acceptability – or unacceptability. Therefore, from the perspective of a simple majority, results between surveys can be considered comparable and supportive of one another.

DISCUSSION

Sample frames provided for coverage of most Montanans and most recreational users of wadeable rivers and streams in the state. Sampling design yielded results that met statistical design criteria for precision of results. Furthermore, sample size tended to provide sufficient power for detecting differences between photographs, between groups, and between surveys. Survey form design, selection of photographs, and pretesting followed acceptable protocols that limit unintentional bias through survey execution (Dillman, 2000). Independent evaluation of photograph order indicated that unintentional bias was not introduced. Overall, the largest potential source of survey error is acknowledged to be attributable to nonresponse in the By-Mail survey. Efforts to characterize nonrespondent perceptions were unsuccessful, and a discussion of potential effects follows.

We carried out an anonymous survey, believing that it was appropriate for a regulatory government agency, would result in more accurate answers (Kerin and Peterson, 1977) and, therefore, reduce measurement error. But anonymity precluded strict adherence to the five-contact TDM (Dillman, 2000), consequently reducing the number and changing the manner of our multiple contacts. Multiple contacts are one of the most effective ways to reduce nonresponse error (Dillman, 1991), although anonymity can also reduce nonresponse error (Kindra *et al.*, 1985). Response rates were comparable in eastern

TABLE 8. Summary of the On-River Survey of Recreational River Users by Residency.

Photograph	Montana Residents (n = 382)			Nonresidents (n = 181)		
	Number Desirable	Number Undesirable	Percent Desirable	Number Desirable	Number Undesirable	Percent Desirable
A	376	6	98.4	177	4	98.2
G	354	28	92.7	173	8	93.6
F	291	91	76.2	136	45	75.8
E	123	259	32.2	56	125	31.8
B	115	267	30.1	49	132	29.1
H	78	304	20.4	36	145	20.2
C	40	342	10.5	25	156	11.5
D	33	349	8.6	18	163	9.1

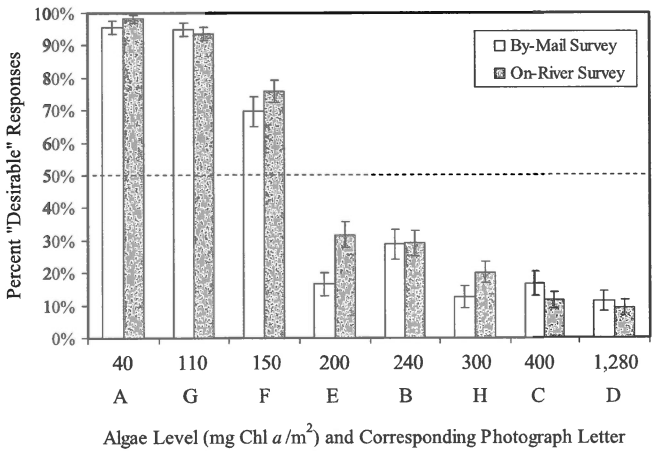

FIGURE 2. Percent Desirable Responses From the By-Mail and On-River Surveys. Letters designating the survey photographs are sequenced from lowest to highest algae level. Error bars are the 95% confidence level of each proportion, expressed as percent error.

(ca. 20%) and western (ca. 18%) Montana (each distinct geographic regions of the state; more on this below), indicating that a regional bias in nonresponse was not introduced. Overall, one can only speculate as to how nonresponse was affected by a reduced number of contacts (likely decreased response rate) *vs.* assured participant anonymity (likely increased response rate).

In general, the population represented by nonrespondents would have to exhibit a profoundly different perception of algae in wadeable rivers and streams to alter the proportions depicted in the Results at a meaningful level. Perceptions of algae by nonrespondents would have to be opposite those exhibited in the By-Mail and On-River surveys to meaningfully alter the trends observed in Figure 2. We assert that this is unlikely to occur and the fact that two different surveys – By-Mail and On-River – provide comparable results supports this assertion. A more likely outcome from the inclusion of nonrespondent perceptions would be either to shift preferences up or down (due to more or less tolerance to algae), or moderate overall preferences (due to overall indifference to algae). In either case, the proportions would still likely be significantly different than 50% (i.e., show a preference), but they would be less likely to be significant among photographs (i.e., not be distinct preferences). Overall, the same general grouping of desirable and undesirable photographs depicted in Figure 2 would likely go unchanged.

In the Introduction, we outlined some water quality regulations in the U.S. and abroad intended to protect against nuisance algal blooms and proliferations. Eutrophication of rivers and streams is a phenomenon that often leads to nuisance algae conditions. Eutrophication is the enrichment of a water body by nitrogen and phosphorus that frequently leads to increased primary productivity, i.e., increased plant growth and decay (e.g., Welch *et al.*, 1989; Chessman *et al.*, 1992; Welch, 1992; Sosiak, 2002; Dodds, 2006). So, how does the algae level found to be desirable for recreation identified in the present study (≤150 mg Chl a/m^2) compare with algae levels found in streams having varying degrees of eutrophication? Biggs (1996) reports that a group of un-enriched streams in New Zealand have a typical range of 0.5-3 mg Chl a/m^2 (median = 1.7 mg Chl a/m^2), whereas moderately enriched streams normally range from 3 to 60 mg Chl a/m^2 (median = 21 mg Chl a/m^2), and enriched streams are usually in the range of 25-260 mg Chl a/m^2 (median = 84 mg Chl a/m^2). The acceptability threshold from the present study falls within the enriched category of these streams. In Montana, Suplee *et al.* (2005) define a process for identifying reference streams and list 129 such sites around the state. Reference stream sites are, by definition, minimally impacted by human activities (Hughes *et al.*, 1986; Stoddard *et al.*, 2006) and therefore should not be

very enriched relative to natural conditions. In western Montana, a region dominated by the Rocky Mountains where most streams have gravel substrates, good gradient, and support trout fisheries, 26 reference streams had a range of mean benthic algal Chl *a* levels from 3 to 75 mg Chl a/m^2 (median = 14 mg Chl a/m^2). In contrast, in northeastern Montana, which is part of the Northern Great Plains (Hunt, 1974) and is dominated by warm-water fish species (e.g., walleye) and low-gradient prairie streams, eight reference streams had a range of mean benthic algal Chl *a* levels from 2 to 302 mg Chl a/m^2 (median = 24 mg Chl a/m^2), with 97% of the sampled reaches falling below 150 mg Chl a/m^2. So in Montana, it appears that the algae level at the recreation nuisance threshold (150 mg Chl a/m^2) is much higher than what is found in mountainous reference streams, and is only rarely found in prairie reference streams.

Dodds *et al.* (1998) present a classification scheme for rivers and streams modeled after the classic one for lakes (oligotrophic or low productivity; mesotrophic or midrange productivity; and eutrophic or productive) (Wetzel, 1975). The Dodds classification was derived from a benthic algae cumulative frequency distribution for 200 streams from North America and New Zealand of varying degrees of eutrophication, and places the breaks for the three classes at the lower, middle, and upper thirds of the dataset. Interestingly, the boundary between mesotrophic and eutrophic streams was given as 200 mg Chl a/m^2 (maximum) (Dodds *et al.*, 1998) and matches the first benthic algae level in our study considered undesirable (200 mg Chl a/m^2). Further, the cumulative frequency distribution of an enlarged version of the Dodds *et al.* (1998) dataset shows that, across a set of worldwide temperate rivers and streams of varying degrees of eutrophication, there is an inflection point around 150 mg Chl a/m^2 (mean); algae levels above this value are generally uncommon (Dodds *et al.*, 2002). Thus, benthic algae levels characterized in the literature as uncommon and representing the onset of eutrophic conditions in temperate streams worldwide correspond with what the public perceived to be, in our study, the onset of excessive algal growth.

As in our study, environmental perception studies involving streams and public waters have often focused on visual characteristics that may affect public acceptability. Studies show that river and lake water color and clarity clearly influence suitability for swimming, water clarity in particular showing a distinct threshold beyond which most feel the water is unsuitable (Smith and Davies-Colley, 1992; Smith *et al.*, 1995a,b). Public enjoyment of rivers and beaches is diminished more by solid waste contaminants (e.g., toilet paper, bottles, and cans) in the water than up on the banks (House, 1996), and varying levels of solid litter at water sites (artificially placed for a study) diminish recreational values and lead participants to incorrectly assume the water itself is polluted (Dinius, 1981). Regarding the present work, participants in the On-River survey were clear about what they did not like about some of the photographs. This is illustrated by the fact that 78% had a comment about how their recreation would be interfered with by the algae levels they deemed undesirable. Some listed several reasons, but for simplicity we tally here only their first-mentioned reason; 33% stated fishing was affected (e.g., snags lures, etc.), 23% indicated wading impacts (e.g., slippery, dangerous, and would wrap around legs), 11% cited swimming interference (e.g., looks unsuitable and would get entangled), 11% stated strictly aesthetic reasons, 2% stated boating interference (e.g., entangles paddles), and 20% had comments not readily classifiable into the aforementioned groups.

The public majority showed a high degree of consistency in our study regarding what constitutes desirable and undesirable algae levels, regardless of their location in the state. For example, the majority of citizens from Billings (i.e., eastern prairie region of Montana) found benthic algae levels greater than 150 mg Chl a/m^2 to be unacceptable, as did people in mountainous western Montana (i.e., Butte, Missoula, and Kalispell). But the geography and nature of rivers and streams of these two regions is very different, and benthic algae levels from reference streams of each region have different ranges. Due to these geographic differences we had expected significant regional differences in majority public opinion, however this was not the case; only the degree to which specific algae levels were desirable or undesirable changed. Similarly, both resident and nonresident respondents identified the same maximum threshold for a desirable algae level (150 mg Chl a/m^2). These results suggest that our findings can be applied beyond Montana to small rivers and streams in northern and southern temperate regions that are of a similar nature to those shown in Appendix A.

In conclusion, statistical analysis of responses establishes that meaningful preferences were evident for the photographs presented. Proportions of "desirable" responses (i.e., those indicating that an algae level was acceptable for recreational use of a river or stream) indicated either significant satisfaction or dissatisfaction with the levels of Chl *a* depicted; except in isolated cases, preferences between photographs were significant; and, levels of preference exhibited concordance with the algae

levels (i.e., more algae, less desirable). Furthermore, results showed that the acceptability of the algae levels depicted in each photograph were consistent among locations and between residents and nonresidents; acceptability was also consistent between the two surveys. It can be meaningfully concluded that, among Montanans and recreational users of Montana rivers and streams, benthic algae levels less than or equal to 150 mg Chl a/m^2 represent desirable levels for recreation while 200 mg Chl a/m^2 and higher levels are undesirable for recreational activities.

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APPENDIX A

The Eight Photographs Used in the Survey. The By-Mail survey form was a five page pamphlet with the text (shown below) on the front cover and the eight photographs (two per page) inside. Adjacent to each picture were two choices (desirable/undesirable) and a space for comments. Here, the photographs are lettered and shown in the same order as they appeared in the survey. The dimensions of the pictures have been slightly modified to accommodate journal publication.

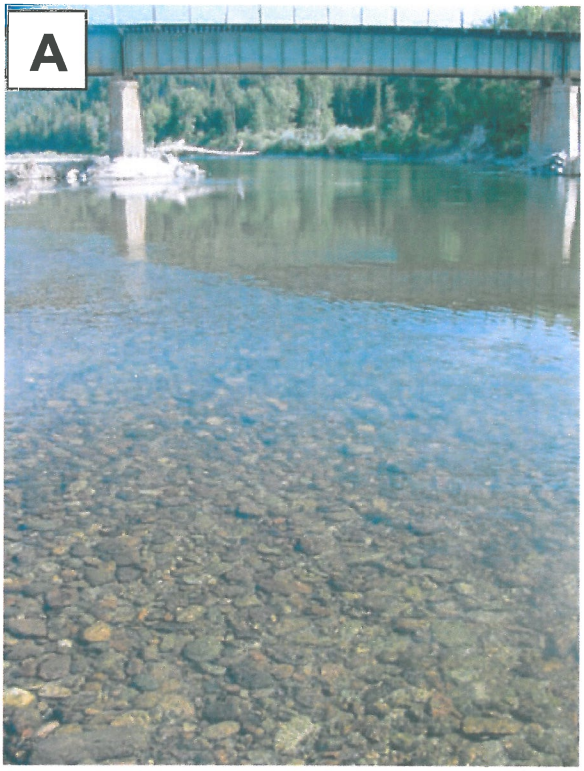
OPINION SURVEY: ALGAE LEVELS IN MONTANA RIVERS & STREAMS

Dear Montana Citizen:
Montanans recreate in and on rivers & streams in many ways, from swimming to fishing to boating. Algae are often found in our rivers & streams, and may have the potential to affect people's recreation in different ways. The Montana Department of Environmental Quality (DEQ) would like to determine if and when river & stream algae become a nuisance to water-related recreation in Montana. The University of Montana has agreed to conduct this survey.

Inside this survey booklet are some pictures that represent different types and levels of common attached algae you might encounter in Montana rivers & streams. We would like your opinion of these pictures.

As you look over each picture, please think about whether the algae level shown would be desirable or undesirable in relation to your main recreational use of rivers & streams. Then, check the appropriate box next to each picture, and write down a few words in the space provided to tell us why. Please know that you and your responses will remain anonymous.

The DEQ will use this information to determine if and when river & stream algae become a nuisance to water-related recreation. If some levels of algae are found to be undesirable to Montana river & stream users, then the DEQ would take steps to assure that pollution sources causing those levels are properly addressed. However, we would like you to know that if a river or stream's algae levels are naturally high, the DEQ would take no action.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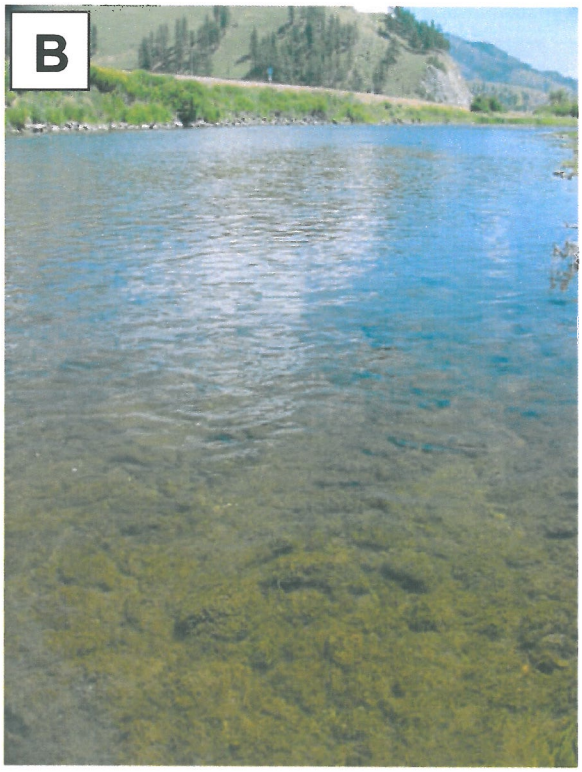
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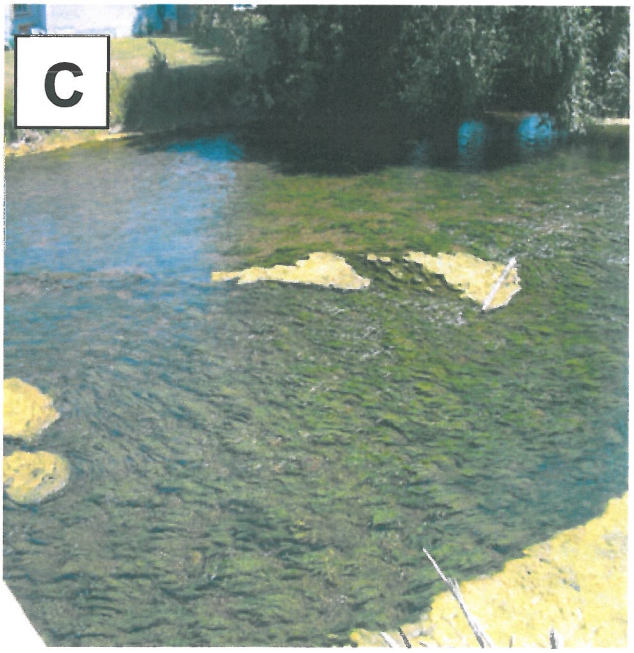
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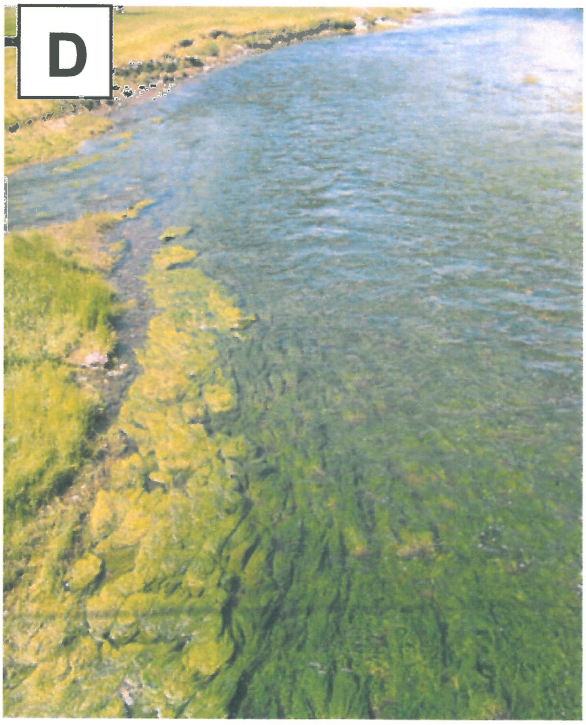
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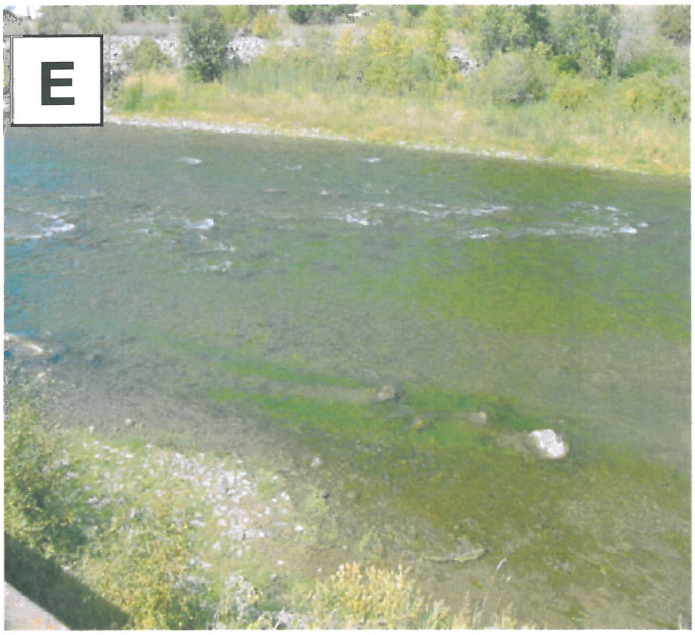
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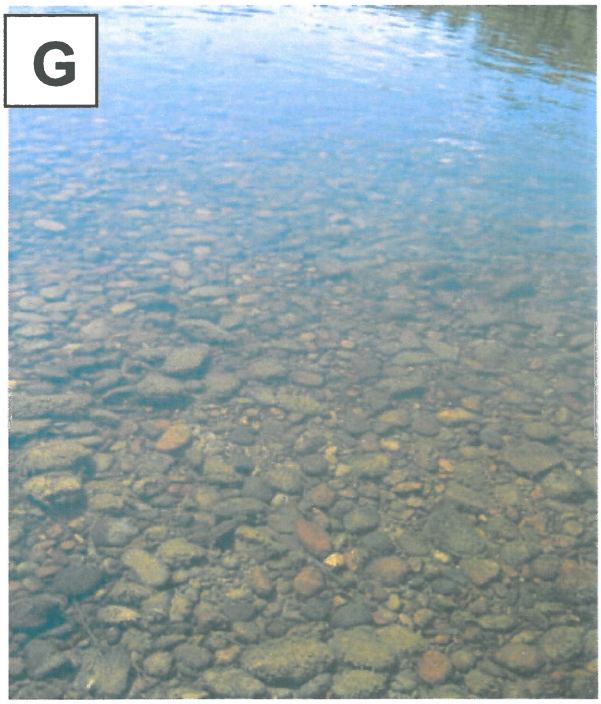
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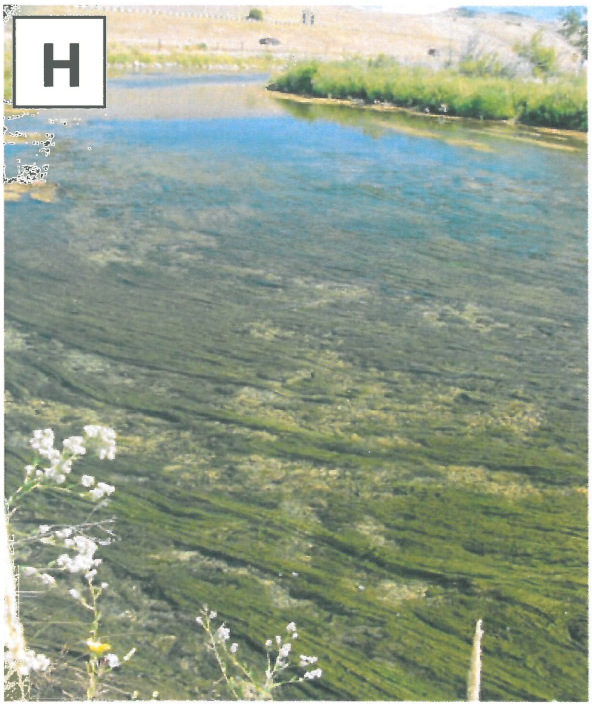
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LITERATURE CITED

Biggs, B.J.F., 1996. Patterns in Benthic Algae of Streams. *In:* Algal Ecology Freshwater Benthic Ecosystems. R.J. Stevenson, M.L. Bothwell, and R.L. Lowe (Editors). Academic Press, New York, New York, pp. 31-56.

Biggs, B.J.F., 2000. New Zealand Periphyton Guidelines: Detecting, Monitoring and Managing Enrichment in Streams. Prepared for the New Zealand Ministry of the Environment, Christchurch, 122 pp. http://www.mfe.govt.nz/publications/water/nz-periphyton-guide-june00.html, *accessed* February 15, 2006.

Biggs, B.J.F. and G.M. Price, 1987. A Survey of Filamentous Algal Proliferations in New Zealand Rivers. New Zealand Journal of Marine and Freshwater Research 21:175-191.

Brunson, M.W. and B.A. Shindler, 2004. Geographic Variation in Social Acceptability of Wildland Fuels Management in the Western United States. Society and Natural Resources 17:661-678.

Carey, R.O., G. Vellidis, R. Lowrance, and C.M. Pringle, 2007. Do Nutrients Limit Algal Periphyton in Small Blackwater Coastal Plain Streams? Journal of the American Water Resources Association 43:1183-1193.

Chessman, B.C., P.E. Hutton, and J.M. Burch, 1992. Limiting Nutrients for Periphyton Growth in Sub-Alpine, Forest, Agricultural and Urban Streams. Freshwater Biology 28:349-361.

Clesceri, L.S., A.E. Greenberg, and A.D. Eaton (Editors), 1998. Standard Methods for the Examination of Water and Wastewater (20th Edition). American Public Health Association, Washington, D.C.

Daniel, T.C. and M.M. Meitner, 2001. Representational Validity of Landscape Visualizations: The Effects of Graphical Realism on Perceived Scenic Beauty of Forest Vistas. Journal of Environmental Psychology 21:61-72.

Dillman, D.A., 1991. The Design and Administration of Mail Surveys. Annual Review of Sociology 17:225-249.

Dillman, D.A., 2000. Mail and Internet Surveys, The Tailored Design Method (Second Edition). John Wiley and Sons, Inc., New York, New York, 464 pp.

Dinius, S.H., 1981. Public Perception in Water Quality Evaluations. Water Resources Bulletin 17:116-121.

Dodds, W.K., 2006. Eutrophication and Trophic State in Rivers and Streams. Limnology and Oceanography 51:671-680.

Dodds, W.K., J.R. Jones, and E.B. Welch, 1998. Suggested Classification of Stream Trophic State: Distributions of Temperate Stream Types by Chlorophyll, Total Nitrogen, and Phosphorus. Water Research 32:1455-1462.

Dodds, W.K., V.H. Smith, and K. Lohman, 2002. Nitrogen and Phosphorus Relationships to Benthic Algal Biomass in Temperate Streams. Canadian Journal of Fisheries and Aquatic Science 59:865-874.

Dodds, W.K., V.H. Smith, and B. Zander, 1997. Developing Nutrient Targets to Control Benthic Chlorophyll Levels in Streams: A Case Study of the Clark Fork River. Water Research 31:1738-1750.

Dodds, W.K. and E.B. Welch, 2000. Establishing Nutrient Criteria in Streams. Journal of the North American Benthological Society 19:186-196.

Federal Water Pollution Control Administration, 1968. Water Quality Criteria. Report of the National Technical Advisory Committee to the Secretary of the Interior. U.S. Department of the Interior, Washington, D.C. 234 pp.

Hetherington, J., T.C. Daniel, and T.C. Brown, 1993. Is Motion More Important Than it Sounds?: The Medium of Presentation in Environmental Perception Research. Journal of Environmental Psychology 13:283-291.

Horner, R.R., E.B. Welch, and R.B. Veenstra, 1983. Development of Nuisance Periphytic Algae in Laboratory Streams in Relation to Enrichment and Velocity. *In:* Periphyton of Freshwater Ecosytems, R.G. Wetzel (Editor). Dr. W. Junk Publishers, The Hague, pp. 121-134.

House, M.A., 1996. Public Perception and Water Quality Management. Water Science and Technology 34:25-32.

Hughes, R.M., D.P. Larsen, and J.M. Omernik, 1986. Regional Reference Sites: A Method for Assessing Stream Potential. Environmental Management 5:629-635.

Hunt, C.B., 1974. Natural Regions of the United States and Canada. W. H. Freeman, San Francisco, California, 725 pp.

Kellomäki, S. and R. Savolainen, 1984. The Scenic Value of the Forest Landscape as Assessed in the Field and the Laboratory. Landscape Planning 11:97-107.

Kerin, R.A. and R.A. Peterson, 1977. Personalization, Respondent Anonymity, and Response Distortion in Mail Surveys. Journal of Applied Psychology 62:86-89.

Kindra, G.S., K.L. McGown, and M. Bougie, 1985. Stimulating Responses to Mailed Questionnaires. An Experimental Study. International Journal of Research in Marketing 2:219-226.

Manning, R.E. and W.A. Freimund, 2004. Use of Visual Research Methods to Measure Standards of Quality for Parks and Outdoor Recreation. Journal of Leisure Research 36:557-579.

McFarland, R., and D. Tarum, 2005. Montana Statewide Angling Pressure, 2003. Montana Fish Wildlife and Parks, Helena, Montana, 117 pp + appendices.

New Zealand Ministry for the Environment, 1992. Resource Management Water Quality Guidelines No. 1, Christchurch, New Zealand. 57 pp.

Nordin, R.N., 1985. Water Quality Criteria for Nutrients and Algae (Technical Appendix). Water Quality Unit, Resource Quality Section, Water Management Branch, British Columbia Ministry of the Environment, Victoria, British Columbia, 104 pp.

Quinn, J.M. and C.W. Hickey, 1990. Characterisation and Classification of Benthic Invertebrate Communities in 88 New Zealand Rivers in Relation to Environmental Factors. New Zealand Journal of Marine and Freshwater Research 24:369-392.

Ross, N.A. and S.M. Taylor, 1998. Geographical Variation in Attitudes Towards Smoking: Findings From the Commit Communities. Social Science and Medicine 46:703-717.

Sartory, D.P. and J.U. Grobbelaar, 1984. Extraction of Chlorophyll *a* From Freshwater Phytoplankton for Spectrophotometric Analysis. Hydrobiologia 114:177-187.

Sheskin, D., 1997. Handbook of Parametric and Nonparametric Statistical Procedures. CRC Press, Boca Raton, Florida, 719 pp.

Shuttleworth, S., 1980. The Use of Photographs as an Environmental Presentation Medium in Landscape Studies. Journal of Environmental Management 11:61-76.

Smith, D.G., G.F. Croker, and K. McFarlane, 1995a. Human Perception of Water Appearance 1. Clarity and Colour for Bathing and Aesthetics. New Zealand Journal of Marine and Freshwater Research 29:29-43.

Smith, D.G., G.F. Croker, and K. McFarlane, 1995b. Human Perception of Water Appearance 2. Colour Judgment, and the Influence of Perceptual Set on Perceived Water Suitability for Use. New Zealand Journal of Marine and Freshwater Research 29:45-50.

Smith, D.G. and R.J. Davies-Colley, 1992. Perception of Water Clarity and Colour in Terms of Suitability for Recreational Use. Journal of Environmental Management 36:225-235.

Sosiak, A., 2002. Long-Term Response of Periphyton and Macrophytes to Reduced Municipal Nutrient Loading to the Bow River (Alberta, Canada). Canadian Journal of Fisheries and Aquatic Sciences 59:987-1001.

Stamps, A.E., 1990. Use of Photographs to Simulate Environments: A Meta-Analysis. Perceptual and Motor Skills 71:907-913.

Stewart, T.R., P. Middleton, M. Downton, and D. Ely, 1984. Judgments of Photographs vs. Field Observations in Studies of Per-

ception and Judgment of the Visual Environment. Journal of Environmental Psychology 4:283-302.

Stoddard, J.L., D.P. Larsen, C.P. Hawkins, R.K. Johnson, and R.H. Norris, 2006. Setting Expectations for the Ecological Condition of Streams: The Concept of Reference Condition. Ecological Applications 16:1267-1276.

Suplee, M., R. Sada de Suplee, D. Feldman, and T. Laidlaw, 2005. Identification and Assessment of Montana Reference Streams: A Follow-up and Expansion of the 1992 Benchmark Biology Study. Montana Department of Environmental Quality, Helena, Montana, 41 pp. http://www.deq.mt.gov/wqinfo/Standards/Refsites_writeup_FINALPrintReady.pdf, *accessed* November 3, 2005.

Suplee, M.W., A. Varghese, and J. Cleland, 2007. Developing Nutrient Criteria for Streams: An Evaluation of the Frequency Distribution Method. Journal of the American Water Resources Association 43:453-472.

USEPA (U.S. Environmental Protection Agency), 1973. Ecological Research Series, Water Quality Criteria 1972. U.S. Environmental Protection Agency, EPA-R3-73-033, Washington, D.C. 594 pp.

USEPA (U.S. Environmental Protection Agency), 1976. Quality Criteria for Water July 1976. U.S. Environmental Protection Agency, Office of Water, Washington, D.C. 256 pp.

USEPA (U.S. Environmental Protection Agency), 1986. Quality Criteria for Water 1986. U.S. Environmental Protection Agency, Office of Water, EPA 440/5-86-001, Washington, D.C.

USEPA (U.S. Environmental Protection Agency), 2000. Nutrient Criteria Technical Guidance Manual, Rivers and Streams. U.S. Environmental Protection Agency, EPA-822-B00-002, Washington, D.C. http://www.epa.gov/waterscience/criteria/nutrient/guidance/rivers/index.html, *accessed* October 15, 2007.

Wang, L., D. Robertson, and P. Garrison, 2007. Linkages Between Nutrients and Assemblages of Macroinvertebrates and Fish in Wadeable Streams: Implication to Nutrient Criteria Development. Environmental Management 39:194-212.

Watson, V. and B. Gestring, 1996. Monitoring Algae Levels in the Clark Fork River. Intermountain Journal of Sciences 2:17-26.

Welch, E.B., 1992. Ecological Effects of Wastewater. Chapman and Hill, London, United Kingdom.

Welch, E.B., R.R. Horner, and C.R. Patmont, 1989. Prediction of Nuisance Periphytic Biomass: A Management Approach. Water Research 23:401-405.

Welch, E.B., J.M. Jacoby, R.R. Horner, and M.R. Seeley, 1988. Nuisance Biomass Levels of Periphytic Algae in Streams. Hydrobiologia 157:161-168.

Wetzel, R.G., 1975. Limnology. W.B. Saunders Co, Philadelphia, Pennsylvania, 743 pp.

Whitton, B.A., 1970. Review Paper. Biology of Cladophora in Freshwaters. Water Research 4:457-476.

Zube, E.H., 1974. Cross-Disciplinary and Intermode Agreement on the Description and Evaluation of Landscape Resources. Environment and Behavior 6:69-89.