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THE SIGNIFICANCE OF PERCEPTIONS AND FEEDBACKS FOR EFFECTIVELY MANAGING WOOD IN RIVERS

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ABSTRACT

This article reports a survey of 196 river managers in seven states across the USA assessing their perceptions of in-stream wood. This survey followed corresponding questionnaires given to undergraduate students representing non-expert views in the same states and in 10 countries around the world. Whereas most students registered predominantly negative views of in-stream wood (i.e. not aesthetically pleasing, dangerous and needing improvement), American managers perceive rivers with wood as significantly more aesthetically pleasing, less dangerous and needing less improvement than rivers without wood. These views were consistent across different types of managers (conservation, fisheries, forestry, recreation and water), suggesting that because of education, training and field experience beyond the undergraduate degree, managers gain more positive views of in-stream wood. Analysis of manager responses grouped by years in the profession suggests that professional experience or information within professional networks plays a role. As years worked in the profession increase, managers' responses to photos with and without wood became significantly different, showing sharper discernment in viewing in-stream wood more positively. We conceptualize evolving management strategies involving wood in American rivers as a series of iterative states within changing human–landscape systems produced by interacting impacts and feedbacks. In this example application, the Interactive, Integrative, and Iterative (III) Framework for Human Landscape Change highlights the importance of public education and policy as necessary feedback linkages to close the gap between people's perceptions of wood and scientific advances that recognize the significant role of wood in rivers.

KEY WORDS: public perception; human–landscape interaction; river management; in-stream wood; river restoration; human impacts

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INTRODUCTION

Large wood is a significant component of the form and function of river systems. Wood provides mechanisms for energy dissipation (Gippel, 1995; Curran and Wohl, 2003), enhances areas of scour and deposition (Abbe and Montgomery, 1996), and promotes pool formation (Buffington *et al*., 2002). Wood provides nutrients for aquatic organisms (Anderson *et al*., 1978), cover for young fish (Bisson *et al*., 1987) and habitat throughout their life cycles (Harmon *et al*., 1986; Roni and Quinn, 2001; Gregory *et al*., 2003). In these ways, channel complexity (Abbe and Montgomery, 1996), channel stability (Montgomery *et al*., 2003) and aquatic biodiversity (Wondzell and Bisson, 2003) are often enhanced. Wood is particularly significant in river channels until the width of the channel equals or exceeds the height of the riparian trees (Gregory and Gurnell, 1988), but significant influences continue downstream as well.

Wood has played a key and changing role in river management in many parts of the world. Traditionally, management has removed wood in rivers because of perceptions that in-channel wood causes negative consequences, such as flooding, bank erosion, interruptions in navigation and damage to infrastructure (Sedell and Froggatt, 1984; Shields and Nunnaly, 1984; Diehl, 1997). In fact, although forested areas such as the Pacific Northwest in the USA had much more abundant wood historically (Collins *et al*., 2002), wood has been removed from rivers to such an extent that people's perceptions of natural landscapes have changed (Wohl and Merritts, 2007).

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Since the 1960s and 1970s, however, research into wood in rivers has demonstrated the positive role of wood, so that management focus has begun to shift toward the re-introduction of wood into river channels (Gurnell *et al*., 1995; Hilderbrand *et al*., 1997; Abbe *et al*., 1997; Reich *et al*., 2003; Brooks *et al*., 2006; Kail *et al*., 2007). For example, the addition of wood to four streams in the Basque country in northern Spain produced a twofold to 70-fold increase in the storage of organic matter (Flores *et al*., 2011). In Australia, wood re-introduction in agricultural streams did not increase flooding and erosion hazards, so that the use of wood as a stream restoration technique is supported (Lester and Wright, 2009). In a meta-analysis of river restoration projects, the addition of large wood had the most consistent response in increasing habitat heterogeneity (Miller *et al*., 2010), although individual streams could exhibit variable responses (Entrekin *et al*., 2009). Large wood was also demonstrated to aid spawning Chinook salmon in marginal habitats on a regulated river in California (Senter and Pasternack, 2011). Small wood is as effective as large wood in contributing to available habitat for macroinvertebrate communities (Lester *et al*., 2009).

Yet, despite increasing calls from researchers for using wood in stream restoration (e.g. Senter and Pasternack, 2011), and scientific evidence that has continued to demonstrate negative effects of removing wood (e.g. Mellina and Hinch, 2009), the public has yet to fully understand and accept this restoration strategy. Part of the challenge lies in the long-held negative perceptions of wood that linger in the general public despite scientific advances. For example, a study of harvested and mature forests in the US Pacific Northwest found that perceptions of the scenic beauty of forests increased with less down wood (Ribe, 2009). For wood in river channels, an international survey of students in 10 countries around the world—France, Germany, India, China, Italy, Poland, Russia, Spain, Sweden and the USA (Oregon and Texas)—found largely traditional and negative perceptions of wood (Piégay *et al*., 2005; Le Lay *et al*., 2008). Except in Sweden, Germany and Oregon (USA), students viewed rivers with wood as less aesthetically pleasing, more dangerous and needing more improvement than rivers without wood. These views were also borne out in additional surveys of students in Colorado, Connecticut, Georgia, Iowa, Illinois and Missouri (Chin *et al*., 2008), using the same set of photographs to express a range of scenes with and without wood. These results provide a clear picture of the prevailing views of wood in rivers by the general non-expert public across the USA and around the world. They also suggest challenges for successfully using wood in managing and restoring river channels, as recently advocated, because the success of restoration strategies depends on the extent to which scientific advances are translated to policymakers and, in turn, on the public support for decisions made (Rhoads *et al*., 1999).

Despite the acknowledged importance of in-stream wood and the recognition for two decades (Gregory and Davis, 1993) of how significantly perception might affect decision-making, the influence of the views of managers has been insufficiently explored. In this article, we expand upon the studies of Chin *et al*. (2008) and Piégay *et al*. (2005) by examining the reactions to wood in riverscapes of a corresponding group of river managers across the USA. First, we outline the background to the initial surveys of students across the USA and around the world with a summary of the main results providing the backdrop to the present investigation. Second, the rationale, methods, study sites and results of surveys of river managers conducted in seven states of the USA are presented to show the extent to which the perceptions of river professionals accord with those of students in the USA, as representing the general public. Third, we discuss the results in an effort to isolate the factors and feedback linkages essential for the effective management of wood and restoration of rivers using wood. We illustrate such linkages with a framework for human–andscape change recently developed.

STUDENTS' PERCEPTIONS IN THE USA AND ACROSS THE WORLD

In 2004–2005, we surveyed 376 students in eight states of the USA to assess their views of river landscapes with and without wood. The students represented non-expert views and were drawn from undergraduate geography/environmental science classes in Colorado (Colorado State University), Connecticut (University of Connecticut), Georgia (Valdosta State University), Illinois (Southern Illinois University), Iowa (Central College), Missouri (University of Missouri), Oregon (Oregon State University and Portland State University) and Texas (Texas A&M University). We administered questionnaires to these volunteer respondents in groups of 30–50 students and asked them to view a set of 20 photographs of streams and rivers—10 with wood and 10 without wood (Figure 1). These students scored the photographs according to four characteristics: how aesthetically pleasing the photographs look, how natural the scenes appear, how dangerous they feel the rivers are and the extent to which they perceived a need for improvement within the channels. Students recorded their reactions to landscape scenes, projected on a screen in colour and printed on sheets in black and white, using tick marks on a graded scale from 1 to 10. We then converted the tick-mark responses into numerical scores with a ruler scale for statistical analysis.

The results showed that, except in Oregon (within two campuses in Corvallis and Portland), students consistently rated photographs with wood to be less aesthetically pleasing, more hazardous and needing more improvement (such as dredging and removing obstructions), even though statistical

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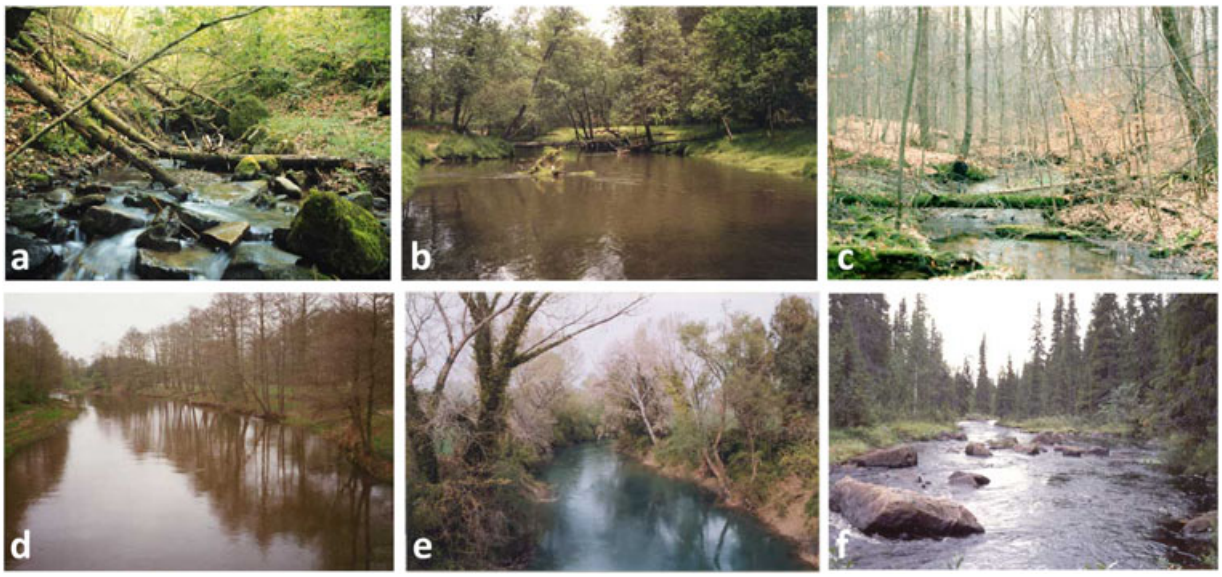

Figure 1. Example photographs used in survey: with wood (a–c), without wood (d–f). Piégay *et al*. (2005) shows the complete set of 20 photographs. This figure is available in colour online at wileyonlinelibrary.com/journal/rra

significance was not achieved in all cases (Figure 2; Chin *et al*., 2008). These results corroborate earlier international surveys conducted between 2003 and 2004 by members of the research team, using identical methodological procedures, which revealed prevailing negative views of wood by students around the world (Figure 3; Piégay *et al*., 2005). Among nearly 2000 undergraduate students in 10 countries, only those in Germany, Sweden and in Oregon (Oregon State University in Corvallis) recorded positive views of wood—that is, these students considered rivers with wood to be more aesthetically pleasing, less dangerous and needing less improvement than rivers without wood. In the USA, the unusual initial results from one location in Oregon prompted the additional survey of students from Portland State University, which confirmed the generally favourable views of wood in rivers by students in Oregon. Presumably, these views reflect a more advanced environmental consciousness that is likely influenced by the pioneering research conducted since the 1970s in the region (for example, Swanson *et al*., 1976). In Germany and in Sweden (Le Lay *et al*., 2008), a similar emphasis has been given to environmental research and education (Reich *et al*., 2003; Mutz *et al*., 2006). The prevailing negative perceptions of wood in rivers by students elsewhere in the USA and around the world—as exemplified in students in China, France, India, Italy, Poland, Russia and Spain, and in Colorado, Connecticut, Georgia, Illinois, Iowa, Missouri and Texas—underscore the need for more aggressive environmental education and professional training (e.g. Wyżga *et al*., 2009). As advocated by Chin *et al*. (2008), a three-pronged approach is therefore needed toward an integrated program of research, education and policy.

SURVEYS OF RIVER MANAGERS IN THE USA

In the USA, results of the student surveys prompted questions regarding where the critical gaps arise between public perceptions and the scientific understanding of the important role of wood in fluvial systems. In other words, what are the outstanding needs in terms of how to convey the importance of in-stream wood to students, to the general public and to those making policy decisions? In Poland, for example, the length of university and professional training was found to correlate with more positive views of wood in riverscapes (Wyżga *et al*., 2009). In this paper, we partly address the question for the USA of where along the continuum of public–students–professionals–policymakers we need to place greatest focus in our education and communication efforts. Isolating this focus would facilitate efforts to improve positive perceptions of in-stream wood, to expedite acceptance of wood in rivers and ultimately to develop a national perspective on effective management of rivers with wood.

To that end, we administered the same questionnaire described earlier to 196 river managers in seven states where students were surveyed in 2005–2006: Colorado, Connecticut, Illinois, Iowa, Missouri, Oregon and Texas. We pursued multiple hypotheses. On the one hand, we hypothesize (*H1*) that the views of river professionals would accord with those of students in the respective states studied, so that persisting regional variations in perceptions of wood would need to be addressed in developing national strategies for education and river management. On the other hand, we hypothesize (*H2*) that, because of further education, information and training, river managers in general would hold positive views of wood in rivers, in

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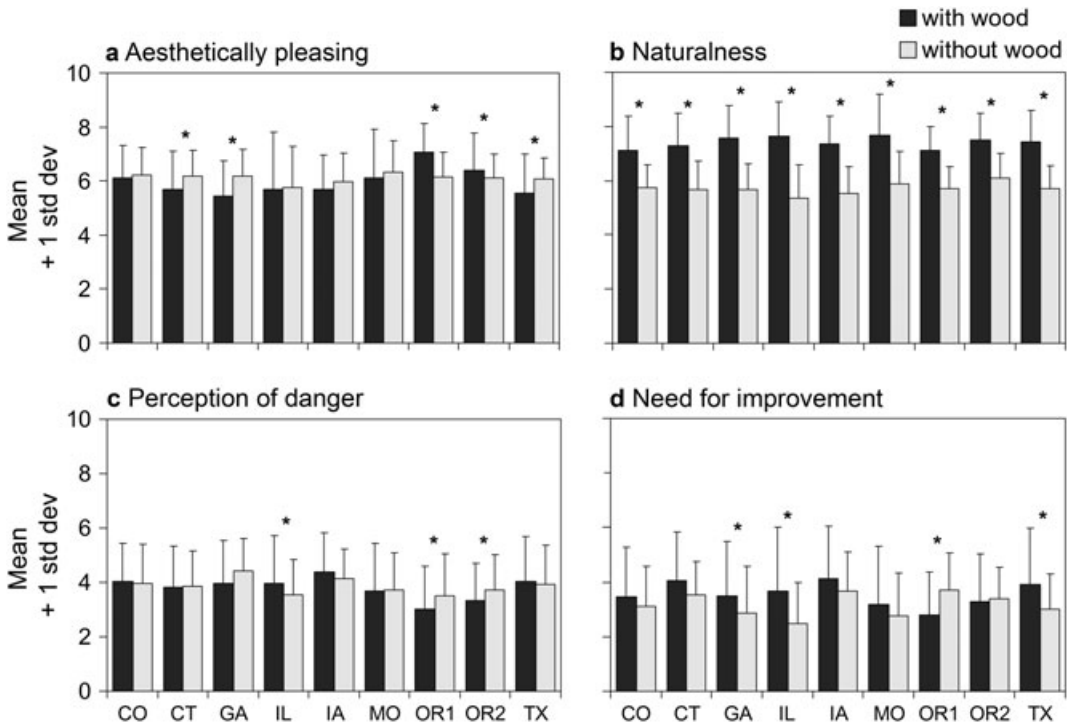

Figure 2. Perceptions of American students for photographs with and without wood regarding (a) aesthetics, (b) naturalness, (c) danger and (d) need for improvement (after Chin *et al*., 2008). Bars indicate mean scores given by students for photographs. Asterisks denote significant difference at the 0.05 level. Sample sizes for each state are as follows: Colorado (CO), $n = 33$; Connecticut (CT), $n = 40$; Georgia (GA), $n = 20$; Illinois (IL), $n = 42$; Iowa (IA), $n = 46$; Missouri (MO), $n = 58$; Oregon 1 (OR1), $n = 54$; Oregon 2 (OR2), $n = 31$; Texas (TX), $n = 53$. Data for Oregon 2, from Portland State University, were collected to corroborate the results from Oregon State University (Oregon 1), which consistently showed opposite trends

contrast to most students. In addition, we further hypothesize (*H3*) that river managers may acquire particular perceptions of wood in rivers on the basis of their job responsibilities, such as conservation versus aspects of human recreation or safety.

In each of the study states, we sought as large a respondent pool as possible through an exhaustive online and person-to-person research process to identify all regionally relevant river managers. We initially reached out to these contacts during spring and summer of 2006 by e-mail and telephone to invite them to participate. Respondents then participated in the online survey anonymously, voluntarily and without compensation, similar to student respondents in the previous surveys. Our response rates varied widely among states, even after sending reminders three times in each case. For example, managers in Connecticut and Oregon completed 27 and 33 questionnaires out of 36 and 79 individuals contacted for 75% and 42% response rates, respectively. On the other hand, we contacted 109 and 180 managers in Colorado and Texas but received 24 and 32 completed questionnaires for response rates of 22% and 18%, respectively. In Missouri, only 20 managers responded with completed questionnaires out of 150 contacted, for a response rate of 13%. The variability in response rates across states is difficult to explain.

Table I shows demographic characteristics of the respondents by state. Of the 196 total participants, 72% were male and 28% were female. The majority of respondents were between the ages of 30 and 59 years, with only 5% in the 20–29 years age group, and 6% were older than 59 years. When asked about the highest educational degree obtained; 12% indicated PhD, 49% masters degree, 33% bachelors degree, 2% associates and 2% high school diploma. We also asked the managers to categorize their occupational fields into six broad categories: water (e.g. US Army Corps of Engineers, US Department of Agriculture NRCS and State Water Board), recreation/land manager (e.g. National Park Service, local parks and recreation department), fisheries (e.g. US Fish and Wildlife Service, State Fisheries Department), forestry (e.g. US Forest Service, State Forestry Department), other governmental agencies, and conservation organization (e.g. fish and anglers groups, such as Trout Unlimited and National Wildlife Federation; general interest groups such as Nature Conservancy and watershed associations; and other non-governmental groups). Of the respondents, 40% identified with the water category, 28% with other governmental agencies, 22% with fisheries and 10% with recreation/land manager.

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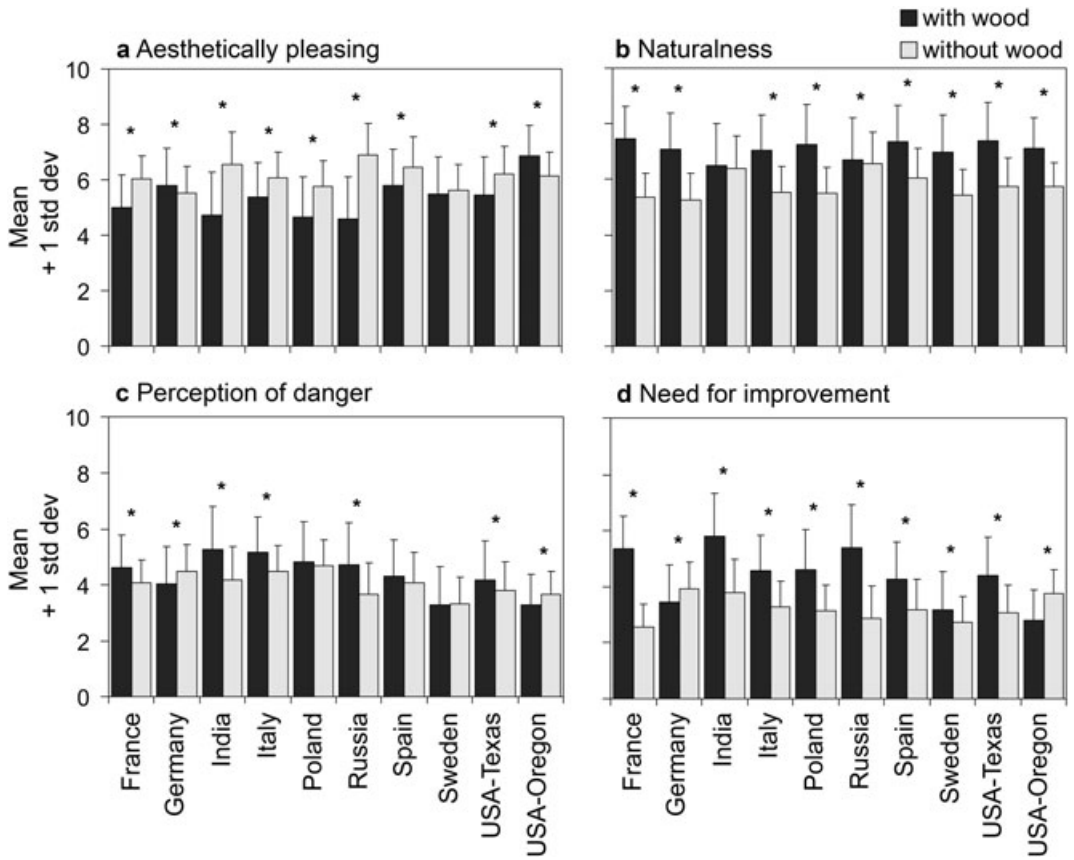

Figure 3. Results from original international survey of students conducted in nine countries, for the four characteristics evaluated in photographs with and without wood. Asterisks denote statistical significance at the 0.05 level, as in Figure 2 (after Piégay *et al*., 2005). Subsequent survey given to students in China is reported in Le Lay *et al.* (2008)

To ensure consistency across survey instruments, this questionnaire included the same four central questions asked of student participants in the previous international and national studies—regarding the aesthetics, naturalness, perception of danger and need for improvement with respect to images of stream and river landscapes. We followed as closely as possible the procedures of the previous surveys of students and translated them into an online format using a web survey provider (SurveyMonkey). Upon entering the survey, participants were presented with basic information and instructions regarding the survey. In keeping with the student surveys, river managers were not told that the study focused on perceptions of large wood in stream channels. Images of river and stream landscapes with and without wood were then presented to the respondents in colour. Matching procedures followed for the student surveys, managers were then asked to print black and white copies of the images and use them as references to answer the survey questions. Participants were asked to record their responses to the images of river and stream landscapes using a graded scale from 1 to 10 by selecting the appropriate number on the scale (Figure 4). At the end of the survey, respondents were asked several demographic questions that produced the data in Table I, to help us understand the manager population sampled.

PERCEPTIONS OF AMERICAN RIVER MANAGERS

Grouped together, results indicate that river managers uniformly keyed on the presence or absence of wood when assigning values to the streams and rivers in the photographs (Figure 5). Respondents considered rivers and streams with wood to be significantly more aesthetically pleasing than those without wood (average score of 6.6 compared with 5.7, respectively). They also appraised photos of riverscapes with wood as more natural (mean score of 7.3) than those without wood (average of 5.5). Managers articulated streams and rivers with wood as less dangerous than those without wood (3.2 versus 3.8), and they identified river landscapes with in-stream wood as less in need of improvement (average score 2.7) than those without wood (average score 3.7).

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Table I. Demographic characteristics of respondents

	CO	CT	IL	IA	MO	OR	TX	Total
Total no. of respondents	24	27	14	46	20	33	32	196
(In % for each variable below)								
Gender								
Male	58	59	71	78	80	79	72	72
Female	42	41	29	22	20	21	28	28
Age (years)								
20–29	0	0	14	11	5	3	3	5
30–39	25	30	14	33	30	15	28	26
40–49	29	44	29	20	30	21	47	31
50–59	46	22	36	30	25	52	19	33
>59	0	4	7	7	10	9	3	6
Manager type								
Conservation	33	30	29	26	30	21	16	26
Fisheries	8	0	0	17	20	15	34	15
Forestry	21	0	7	7	10	21	3	10
Recreation/land	8	11	7	7	0	6	9	7
Water	21	56	29	22	25	15	25	27
Other	8	4	29	22	15	21	13	16
Highest educational degree								
Bachelors	13	33	43	48	25	33	25	33
Masters	58	56	36	35	60	48	56	49
Doctorate	21	7	0	11	15	12	13	12
Other	8	4	21	7	0	6	6	7
Years worked in a profession related to streams/rivers								
0–5	8	22	43	20	15	6	16	17
5–10	21	19	14	22	30	6	22	19
10–15	25	22	7	22	10	12	16	17
>15	46	37	36	37	45	76	47	47

These views were consistent across all seven states (Figure 6), even though greater variability was found in scores concerning perception of danger (for all photographs) and the need for improvement (for landscapes with wood). This scenario contrasts with the regional variations found in student responses earlier (Figure 2). In other words, river managers across the USA participating in this study hold predominantly positive views of streams having visible accumulations of wood, unlike the situation with students in which only those in Oregon perceived in-stream wood favourably.

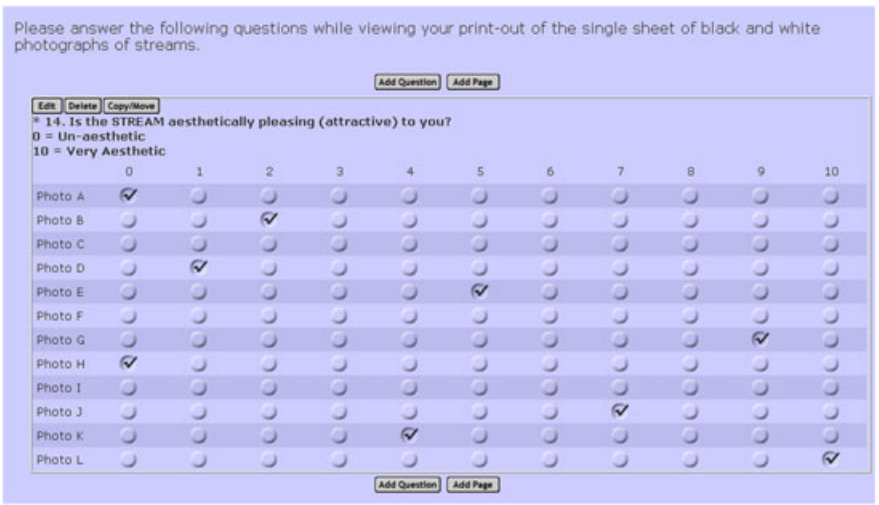

Figure 4. Example of the online survey format. This figure is available in colour online at wileyonlinelibrary.com/journal/rra

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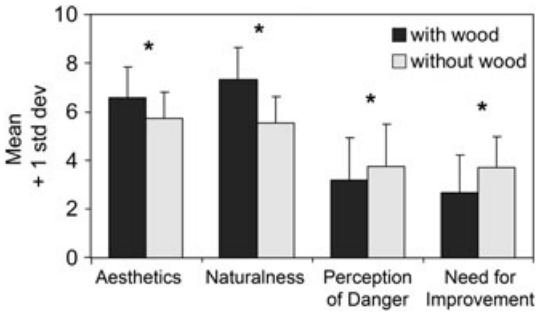

Figure 5. Combined mean responses of river managers across seven states ($n = 196$). Asterisks indicate statistically significant difference at the 0.05 level

The hypothesized (*H1*) regional differences in wood perception among managers do not exist in the sample population when responses are stratified by location (Figure 6), even though managers in Oregon seem more reactive with respect to improving rivers without wood (Figure 6(d)). Assuming no significant generational bias, this indicates that somewhere between their undergraduate training and professional experiences, practising river managers across the USA develop more positive perceptions of the role of in-stream wood in rivers.

COMPARISON BETWEEN MANAGERS AND STUDENTS

With the exception of Oregon, the views of managers queried in all locations run counter to student perception (Table II). Differences between the manager and student populations in Oregon are less distinguishable, as students similarly hold favourable views of rivers and streams with in-stream wood, similar to those of managers. These results would seem to support our second hypothesis that, because of education, training and field experience beyond the undergraduate degree, managers hold more positive views of in-stream wood than do students.

The exact source of this shift in perception is unclear. These changes could potentially be derived from (i) more specialized graduate training; (ii) interactions with other professionals involved in studying and managing rivers, such as at practitioner conferences; (iii) personal observations of, and experiences with, rivers with and without wood; or (iv) some combination of the aforementioned. Analysis of how river managers perceive in-stream wood grouped by education level showed inconclusive results, partly because of low sample sizes in some of the groups (high school and associate degrees). For groups with large sample sizes (bachelors, masters and doctorate degrees),

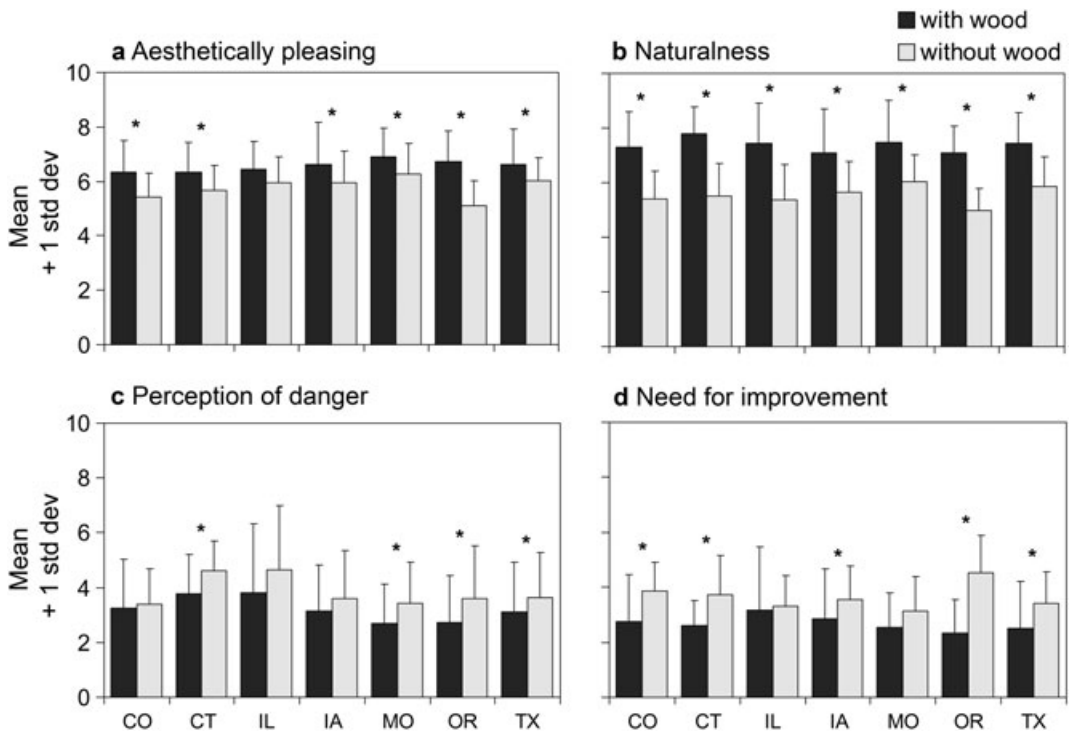

Figure 6. Perceptions of American managers by state. Asterisks indicate statistical significance at the 0.05 level. Sample sizes for each state are as follows: Colorado (CO), $n = 24$; Connecticut (CT), $n = 27$; Illinois (IL), $n = 14$; Iowa (IA), $n = 46$; Missouri (MO), $n = 20$; Oregon (OR), $n = 33$; Texas (TX), $n = 32$

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Table II. Mean scores given by managers and students for photographs with and without large wood for the four characteristics evaluated

	CO		CT		IL		IA		MO		OR		TX	
	With	Without	With	Without	With	Without	With	Without	With	Without	With	Without	With	Without
Aesthetics														
Managers	6.3	*5.4*	6.3	*5.7*	6.4	5.9	*6.6*	5.9	6.9	6.3	6.7	*5.1*	*6.6*	6.0
Students	6.1	*6.2*	5.7	*6.2*	5.7	5.8	*5.7*	6.0	6.1	6.3	7.1	*6.2*	*5.6*	6.1
Naturalness														
Managers	7.3	5.4	7.8	5.5	7.4	5.4	7.1	5.7	7.5	6.1	7.1	*5.0*	7.4	5.8
Students	7.1	5.7	7.3	5.7	7.6	5.4	7.4	5.5	7.7	5.9	7.1	*5.7*	7.4	5.7
Danger														
Managers	3.3	3.4	3.8	*4.6*	3.8	4.6	*3.2*	3.6	*2.7*	3.4	2.7	3.6	*3.1*	3.6
Students	4.0	4.0	3.8	*3.9*	4.0	3.6	*4.4*	4.2	*3.7*	3.7	3.0	3.5	*4.0*	3.9
Need for improvement														
Managers	2.8	3.9	*2.6*	3.7	3.2	*3.3*	*2.9*	3.5	2.5	3.1	2.3	*4.5*	*2.5*	3.4
Students	3.5	3.1	*4.0*	3.5	3.7	*2.5*	*4.1*	3.7	3.2	2.8	2.8	*3.7*	*3.9*	3.0

Italicized pairs of managers/students are significantly different (0.05 level) on the basis of the Mann–Whitney test.

perceptions of streams with and without wood were significantly different for all four characteristics regardless of degree (Wilcoxon test, $p = 0.05$). With increasingly advanced degrees, however, managers saw less need for improvement for channels with wood (Kruskal–Wallis, $p = 0.006$).

This trend is suggested in further analysis of the responses from managers grouped by years in the profession (Table III). For rivers with wood, the Kruskal–Wallis test detected a significant difference in managers' perceptions of improvement needs. That is, managers working in the profession for less than 5 years saw greater need for improving channels with wood.

What is also apparent is that, as professional experience increases, the managers' responses show more differentiation (significant differences) between streams with and without wood. Whereas managers with less than 5 years of experience viewed rivers with wood and without wood similarly, managers working in the profession for more than 10 years gave significantly different responses for streams with wood and without wood for all parameters scored. These results suggest that professional experience or information within professional networks plays a role.

Although these findings indicate a clear appreciation of the value of in-stream wood to management objectives related to aesthetics, ecological function, human health and safety, and the need for direct modification of stream channel morphology, less clear is where the source of this increased level of appreciation lies. Possible sources of the shift in perception between students queried earlier and the river managers at the focus of the current study may be related to a better fundamental understanding of how wood

Table III. Mean scores given by managers for photos with and without wood for the four characteristics evaluated, by years worked in a profession related to streams/rivers

		Years worked in a profession related to streams/rivers				
		0–5 years	5–10 years	10–15 years	>15 years	
Feature evaluated	Type of riverscape	$n = 33$	$n = 37$	$n = 34$	$n = 92$	Kruskal–Wallis p-value
Aesthetics	Wood	6.1	*6.6*	*6.8*	*6.7*	0.066
	No wood	5.9	*5.8*	*5.8*	*5.6*	0.818
Naturalness	Wood	*7.6*	*7.3*	*7.6*	*7.2*	0.212
	No wood	*5.4*	*5.6*	*5.8*	*5.5*	0.561
Danger	Wood	3.9	3.2	*3.3*	*2.8*	0.052
	No wood	4.4	3.6	*4.0*	*3.5*	0.221
Need for improvement	Wood	3.5	*2.5*	*2.6*	*2.5*	0.035*
	No wood	3.9	*3.5*	*3.6*	*3.7*	0.323

Italicized pairs are significantly different (0.05 level) on the basis of the Wilcoxon test. Results of a Kruskal–Wallis test show differences in the perception of riverscapes among manager groups.
*$p < 0.05$.

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relates to geomorphologic and ecologic process, familiarity with the scientific literature or simply more extensive first-hand experience working with impacted streams and rivers, influenced by technical debates from professional workshops and the literature. It also means that student-level education does not provide such knowledge even in disciplines relevant to rivers, whereas it is likely acquired later by practitioners. Whatever the source of the increased awareness of the positive benefits of in-stream wood, these findings indicate an important gap in perception between those without specialized training in river management (represented here by the undergraduate student surveys) and professional managers. This gap suggests that increased levels of education, training and exposure to fluvial systems (or to the fluvial technical community) are needed to change the long-held perceptions of wood in river channels by people who will never professionally manage rivers. Ideally, these educational goals would be met outside of existing graduate training to reach a broader and less specialized population. Public information campaigns on the physical and ecological benefits of in-stream wood could promote acceptance of wood-rich rivers. Such campaigns could also reduce levels of opposition to management and restoration strategies where wood is an essential component.

Analysis of responses rationalizing the need for channel improvement also highlights basic differences in thinking between river managers and the general student non-expert population. Figure 7(a) shows that, for river landscapes with wood visibly present, students (excepting Oregon) reported a greater need for improvement to clean channels because of flood risk management (19%) and landscape quality (21%). Only 6% of those students were concerned with faunal habitat.

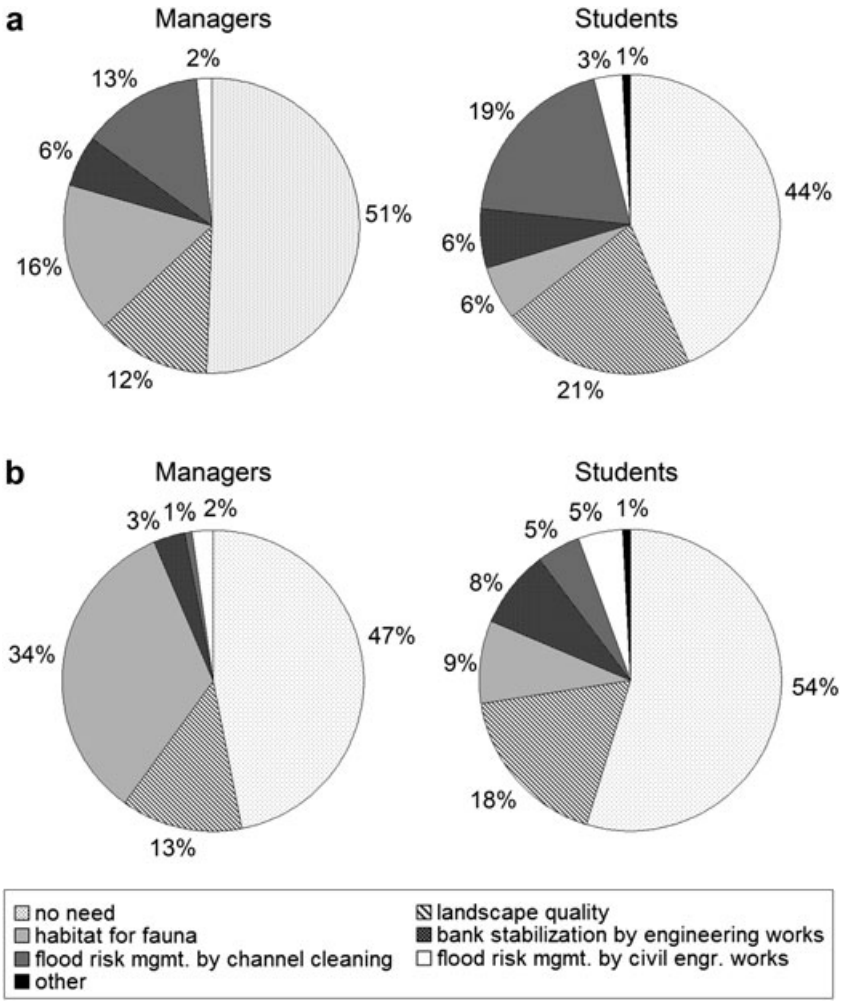

Figure 7. Reasons for improvement needs for riverscapes given by managers and by students across the USA except Oregon. (a) With wood, (b) without wood. The sample sizes for managers and students (shown) are 196 and 272, respectively. The data for students comprised only those states where data for managers were also collected

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For the same streams, a substantially larger proportion of responses by river managers indicated improvement needs for faunal habitat (16%), whereas they focused less on the need to clean channels (13%). A larger proportion of the manager responses also indicated no apparent need for channel improvement in these streams (51%).

Differences in responses between managers and non-Oregonian students became clearer when summarizing the reasons for necessitating channel improvements in riverscapes without wood (Figure 7(b)). River managers across the USA expressed even more concern for improving faunal habitat in rivers and streams without visible wood in the channels (34% of respondents compared with 9% of non-Oregon students). On the other hand, a larger proportion of student responses (54%) indicated no need for improvement in these channels (compared with 47% for river managers). These students do not see the restoration challenge revealed by American managers and underlined in the international context by Le Lay *et al*. (2008). Presumably, river managers understand that cleaning channels could reduce local flood and recreational hazards, but probably consider this effect to be undesirable or unnecessary given the likely ecological costs.

VARIATIONS AMONG TYPES OF RIVER MANAGERS

Analyzing scores on the basis of type of river managers responding revealed notable trends in the perceptions of manager groups (Table IV). First, the responses from managers showed differences for rivers with wood and without wood for the four parameters studied, regardless of the type of river manager giving the response. All river managers viewed rivers with wood as significantly more aesthetic, more natural, less dangerous and needing less improvement than those without wood (displayed also in Figure 5 as grouped results). These views were consistent regardless of whether the manager worked for a fisheries organization (such as the US Fish and Wildlife Service), a forestry agency (such as the US Forest Service), a water agency (such as the US Army Corps of Engineers) or other governmental agencies. These views also resonated with recreation/land managers (such as those employed by the National Park Service and other local parks and recreation departments), as well as by those affiliated with conservation organizations (including fish and angler groups such as Trout Unlimited and The National Wildlife Federation, general interest groups such as The Nature Conservancy, and watershed associations).

Subtle differences emerge, however, when considering the insignificant results for recreation/land managers (for the parameters of aesthetics and danger) and managers working in conservation (for perception of danger). Regarding the perception of danger, the Wilcoxon signed rank test did not detect significant differences between channels with and without wood in responses for the recreation/land manager group and the conservation group, as it did for the other manager groups (Table IV). Although the recreation/land managers and managers working in conservation organizations still seemed to view riverscapes with wood to be less dangerous than those without wood (as reflected in mean scores of 4.0 compared with 4.2 and 3.7 versus 4.0, respectively), these differences were more subtle and statistically insignificant. This situation is perhaps not surprising given that the job responsibilities of these managers may affect how they view rivers and streams. For example, managers working for local parks and recreation departments whose mandate is, in part, to consider recreational safety in their job may be more sensitive to perceiving streams with in-stream accumulations of wood as dangerous. Similarly, managers employed in conservation organizations such as fish and angler groups may also relate the potential danger of streams and rivers with wood to other aspects of human recreation for which in-stream wood can pose a hazard, such as boating.

Table IV. Mean scores given by managers for photos with and without wood for the four characteristics evaluated, by type of manager

		Fisheries	Forestry	Recreation/land	Water	Other	Conservation	
Feature evaluated	Type of riverscape	$n = 30$	$n = 19$	$n = 14$	$n = 52$	$n = 31$	$n = 50$	Kruskal–Wallis p-value
Aesthetics	Wood	*6.7*	*6.4*	6.7	*6.4*	*7.0*	*6.5*	0.365
	No wood	*5.3*	*5.3*	5.9	*6.0*	*6.1*	*5.7*	0.011*
Naturalness	Wood	*7.2*	*6.8*	*7.3*	*7.3*	*7.3*	*7.7*	0.228
	No wood	*5.4*	*5.0*	*5.7*	*5.7*	*5.5*	*5.6*	0.150
Danger	Wood	*2.4*	*2.9*	4.0	*3.1*	*3.1*	3.7	0.021*
	No wood	*3.5*	*3.6*	4.2	*3.6*	*3.8*	4.0	0.784
Need for improvement	Wood	*2.2*	*2.7*	*2.6*	*2.6*	*2.5*	*3.1*	0.217
	No wood	*3.7*	*4.1*	*3.8*	*3.3*	*3.8*	*3.9*	0.370

Italicized pairs are significantly different (0.05 level) on the basis of the Wilcoxon test. Results of a Kruskal–Wallis test show differences in the perception of riverscapes with and without wood among manager groups.
*$p < 0.05$.

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On the other end of the spectrum, perceptions of danger for river landscapes with and without wood differed greatly for river managers in fisheries and forestry organizations. River managers affiliated with state fisheries departments or state forestry departments in which the focus is fish or forest resources may reasonably view streams with wood as posing little threat to those resources as opposed to streams without wood. Such differences in perspective and the exact nature of the managerial goals within their respective organizations may explain the subtle variations in responses among manager groups for the perception of danger in river landscapes.

The Kruskal–Wallis test detected similar variations in perceptions among river manager groups. Statistically significant results for the parameter of aesthetics (no wood) and danger (wood) suggest that river managers viewed rivers without wood differently, depending on where they worked (Table IV). Water and recreation/land managers perceive rivers without wood more favourably than fisheries and "forestry" managers (mean scores of 6.0 and 5.9, versus 5.3 and 5.3, respectively). Similarly, recreation/land managers and conservation managers considered rivers with wood to be more dangerous (mean score of 4.0) than fisheries and forestry managers (2.4 and 2.9, respectively). These differences, as noted earlier, likely reflect variations in foci within the respective work organizations. Such interpretations, however, might be considered preliminary considering the small sample sizes of the groups of recreation/land managers ($n = 14$) and forestry managers ($n = 19$).

Nevertheless, the fundamental message is clear that river managers in the USA overall view rivers with wood as more aesthetically pleasing, more natural, less dangerous and needing less improvement than those without wood. This trend differs from those of students across the country, except in Oregon. The subtle variations among manager types further suggest that, in addition to education and professional experience, job responsibilities may also influence how river managers perceive in-stream wood.

PERCEPTIONS, FEEDBACK LINKAGES AND EFFECTIVE MANAGEMENT OF WOOD IN RIVERS

Evolving management strategies involving wood in rivers in the USA can be illustrated as a series of iterative states within changing human–landscape systems produced by interacting impacts and feedbacks. Building upon the work of Kondolf *et al*. (2003, Figure 21.1), these states are conceptualized within a framework for human–landscape change recently developed from an interdisciplinary workshop focused on integrative human–landscape systems, sponsored by the US National Science Foundation (Chin *et al*., 2010). The Interactive, Integrative, and Iterative (III) Framework for Human–Landscape Change focuses on the core interactions among physical, biological and social processes resulting from perturbations in the landscape (Figure 8)—such as installing or removing dams, human-induced soil erosion, or deforestation. The interactions alter conditions of bio-physical and human systems, which elicit environmental responses and possible changes in human actions that potentially feed back to the original causes (the bottom arc of Figure 8). Feedback responses at the micro level include mitigation and adaptation strategies to environmental stress as well as behavioural changes. Macro responses occur through policy along with technology, media, education and communication.

In the case of wood in river management, the initial removal of wood changes the interactions among physical, biological and social processes, such as reducing roughness, decreasing habitats and increasing recreational opportunities (eventually also reducing flood risk and permitting navigation; Figure 9(a)). These interactions result in degraded stream and riparian ecosystems (State 1), increasing their vulnerability and decreasing resilience, setting up responses including changes in landforms, species and hydrological regimes. Feedback responses also include mitigation (e.g. stopping the continual removal of wood from the channel and/or managing forested riparian zones specifically for long-term recruitment of wood to the channel) and adaptation strategies (e.g. adapting to a changed regime with no wood). As scientific knowledge advances regarding the positive role of wood in streams, education and media campaigns could spread the message that 'wood is good' (Chin *et al*., 2008), negatively feeding back to the original strategy of removing wood.

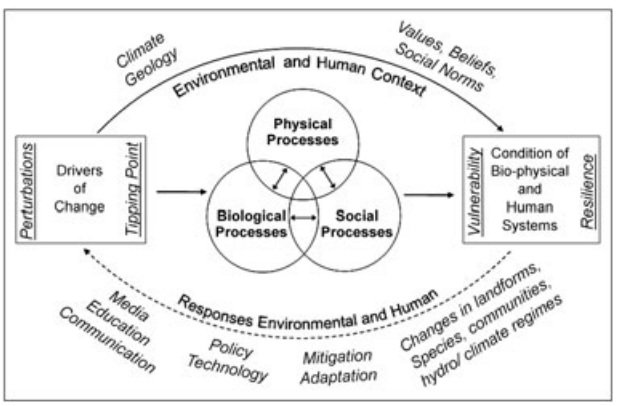

Figure 8. The Interactive, Integrative, and Iterative (III) Framework for Human–Landscape Change integrates impacts with feedbacks through bio-physical and human processes. Multiple interacting impact-feedback loops are likely at a range of scales and not necessarily in sequential order. When applied iteratively (i.e. in succession), the framework is useful for articulating and understanding changing human–landscapes

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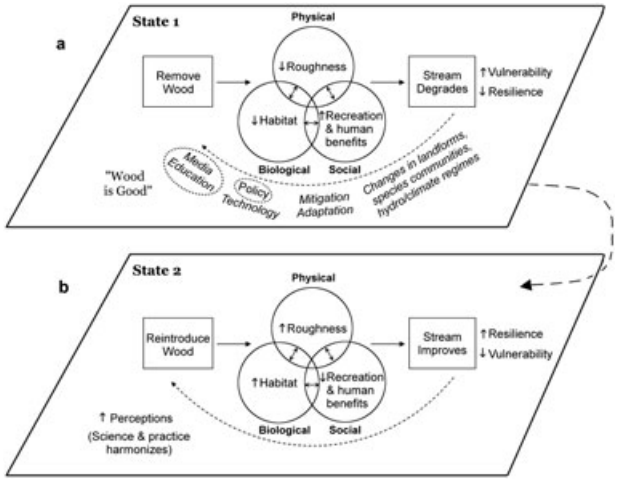

Figure 9. Iterative states within human–landscape systems for removing (a: State 1) and re-introducing (b: State 2) wood with subsequent interacting impact and feedback loops. Up and down arrows indicate increase and decrease, respectively

In State 2, scientific advances prompt the re-introduction of wood in river management. In-stream wood improves faunal habitats and increases hydraulic roughness, although some human benefits may be reduced, such as recreational opportunities (Figure 9(b)). These interactions ultimately improve stream and riparian ecosystems, resulting in further feedback responses. Presumably, continuing education efforts and consistent policies that promote in-stream wood improve public perceptions toward congruence with scientific knowledge. Such iterative states could continue until science and practice are harmonious, although we do not expect that achieving such harmony will be quick or easy. Nevertheless, understanding the interacting feedbacks could enable science to guide management decisions while maximizing human benefits (Piégay and Landon, 1997). Management could remove wood, for example, if security or navigation is needed, or preserve or re-introduce wood if other benefits are more important, such as fish resources and conservation.

An additional complication in re-introducing wood to streams, or simply allowing wood to accumulate rather than actively removing it, is the possibility that rivers from which all wood has been removed for many years may reach an alternative stable state. This can result when removal of wood decreases the hydraulic roughness of a channel sufficiently to limit retention of any subsequently recruited wood (Wohl and Beckman,). Under natural conditions, wood load in a river can fluctuate through time as a result of occurrences such as wildfire or floods, but the river typically retains at least some wood. This wood creates congestion in the channel that can help to trap and store subsequently recruited wood. Wood in a river also creates blockages that trap and store sediment. The stored sediment provides sites for trees to mature over hundreds of years in valley bottoms where the average cycle of floodplain turnover is much shorter, thus ensuring a future supply of large wood and creating a physically complex and biodiverse floodplain (Collins *et al*., 2012; Gurnell *et al*., 2012). When wood is removed from the channel, these effects are lost, and the floodplain gradually stabilizes in a simpler and less diverse form. The persistence of these wood-poor alternative stable states also creates a changing baseline of perception in which people come to think of such conditions as the natural or expected condition. Such is the case for Chinese and Indian students who considered rivers with wood as less natural than rivers without wood (Le Lay *et al*., 2008). This situation increases the challenge of educating the public regarding the physical and ecological benefits of wood, as well as the formerly very different characteristics of wood-rich rivers and valley bottoms.

In-stream accumulations of wood have been repeatedly identified in the scientific literature as having a number of discrete geomorphic and ecological benefits coinciding with the management goals of public agencies and private interests. The degree of dissonance, however, between the scientific benefits and utility of wood in managing streams and the antipathy of the general public to in-stream wood may inevitably lead to conflict and uncertainty in implementing management strategies. Managing rivers in the USA effectively, using wood, may hinge on the ability of scientists to convey formal knowledge and research results to the general non-expert public as well as policymakers.

Our results indicate that the crux of the problem in the USA lies in the fact that much of the general public has a fundamentally different perception of what an ideal stream actually looks like than river managers who likely have a greater depth of technical knowledge and professional experience with stream systems. Public acceptance or resistance to management strategies may rely on the distance between their perceptions of an idealized environment and the scientific basis for what works. Changing the perceptions of these individuals regarding the role of wood is the first step toward successful re-introduction of wood for managing rivers. It is only when the potential benefits of using wood as a part of the management process are understood that relational conflicts arising because of different strategies and management goals can be identified and addressed, such as the ecological benefits of wood versus the potential hazards that wood creates for recreation.

The presence of wood in rivers is one example of what Jones *et al*. (1994) characterized as ecosystem engineers, later exemplified as riparian engineers for the Tagliamento River in Italy (Gurnell and Petts, 2006). Although research has focused upon the pertinence of such features in modifying the physical environment of river channels, recognizing

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that our perceptions of such features affect how we act upon them is now increasingly important (Kondolf and Piégay, 2011). Variations can also occur according to cultural distinctions (Gregory, 2006). It will now be possible to investigate how sub-cultures affect perceptions which in themselves can exert a significant influence on decision-making concerning river management and restoration.

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