Wildlife Society Bulletin 38(4):672–681; 2014; DOI: 10.1002/wsb.459

Original Article

Barriers to Climate-Adaptive Management: A Survey of Wildlife Researchers and Managers in Wisconsin

SUZANNE HAGELL,[1] *Department of Forest and Wildlife Ecology, University of Wisconsin, Madison, WI 53706, USA*
CHRISTINE A. RIBIC, *United States Geological Survey, Wisconsin Cooperative Wildlife Research Unit, University of Wisconsin, Madison, WI 53706, USA*

ABSTRACT Resource management agencies must be able to integrate current research into their decision-making to effectively address climate change impacts. In this study, we investigated the capacity for climate-adaptive management by surveying the community of researchers, administrators, and field managers who are responsible for wildlife conservation in the state of Wisconsin, USA. We specifically measured differences in how these sectors perceive climate change risk, communicate, and make decisions to represent barriers in how they transmit and use research. We frame these barriers within the literature on evidence-based and adaptive management and risk psychology, as principles that underlie climate change adaptation. Almost all respondents agreed that the climate is changing (223/224), but 22% of the respondents were unsure whether climate change is negative for wildlife and field managers dominated this group (68%). Field managers also reported using components of adaptive management more frequently than did other sectors, but all three questioned the importance of one specific component: predicting the consequence of management before implementation. When seeking information, researchers preferred communicating via published literature, but managers and administrators reported a preference for in-person communication. Although only 29% of the respondents were currently involved in climate change work, 77% said they would get involved without additional incentives or direction at work. These results confirm a common pattern of barriers between research and management sectors across all scales of decision-making. Overall, results suggest that in-person and problem-based communication that is focused on real decisions and that utilizes social networks are a way to enable resource management communities to effectively confront these barriers. Published 2014. This article is a U.S. Government work and is in the public domain in the USA.

KEY WORDS adaptive management, climate change, decision-making, information sharing, risk perception, wildlife management.

Making conservation decisions under climate change is akin to setting one's sights on a moving target; we can no longer rely on ecological systems to be stationary (Nichols et al. 2011) and the public's opinion of climate change and willingness to adapt are also highly changeable (Brulle et al. 2012, Scruggs and Benegal 2012). Organizations that are involved in wildlife conservation are hence confronted with a "wicked" management problem, or a problem for which there is no optimal solution (Balint et al. 2011). Not only must these organizations negotiate difficult trade-offs, but they must do so while facing multiple sources of uncertainty and risk. Given these difficulties, it is not surprising that our systems for making management decisions appear insufficient for adapting to climate change and protecting natural resources for the public good (Berrang-Ford et al. 2010).

This study seeks to identify barriers to climate-adaptive wildlife management, which we define as the capacity for the management system to make informed decisions while reducing critical sources of uncertainty. There are multiple constraints on natural resource management that inhibit informed decision-making, including limited budgets and lack of guidance (Archie et al. 2012). Here we focus on the barriers between information production and decision-making that have been widely discussed within 3 conceptual frameworks: evidence-based practice, adaptive management, and climate change psychology.

Received: 20 July 2013; Accepted: 8 March 2014
Published: 21 July 2014

[1]*E-mail: seh222@nau.edu*

Evidenced-Based Practice

Evidence-based management or conservation in its simplest form refers to decision-making that relies on research over personal experience (Sutherland et al. 2004, Pullin and Knight 2009). The use of these reasoning shortcuts, or heuristics, that are based on personal experience can lead to systematic errors in decision-making. For example, reliance on information that is easily recalled could cause a decision-maker to consider a future event unlikely (Tversky and Kahneman 1982). The effect of heuristics on climate change adaptation could be potentially severe because future conditions will be novel and personal experience is less informative.

Evidence-based practices may be particularly relevant for making decisions in the context of dynamic systems, as in the case of non-stationarity under climate change. Using evidence may be the best solution to counteract personal biases and ensure that decision-makers use updated information, so long as the evidence used accurately represents the system being managed. Despite the recognition that evidence is important, when management systems have been analyzed evidence is only applied inconsistently (e.g., Cook et al. 2010). Recent authors have suggested that not only do decision-makers need "evidence," but evidence should be accompanied by guidance on how to correctly apply it; otherwise, it will be used selectively (Holmes and Clark 2008) and filtered based on belief systems (Kahan et al. 2012).

Adaptive Management

An additional limitation of evidence-based management is that the best available information may be insufficient if significant uncertainty remains. Adaptive management has been used to describe a wide spectrum of activities intended to improve management by integrating learning to reduce uncertainty (Williams 2011). As such, it has been recommended for wildlife management (Welch 2005, Fontaine 2011), for management under uncertainty (Runge et al. 2011), and for climate change adaptation specifically (Lawler et al. 2010). However, it has also been recognized as overly difficult to implement and unlikely to succeed (Lee 1999, Allan and Curtis 2005, Allen and Gunderson 2010), particularly at the scales necessary for climate change planning (National Research Council 2009). One commonly cited criticism is that carrying out a scientifically rigorous monitoring design is overly difficult and too costly for agencies, but it is also necessary for adaptive management to be effective (the "active" vs. "passive" debate; Gregory et al. 2006). Secondly, as with evidence-based management, the results from monitoring are also frequently inaccessible or irrelevant to decision-makers and stakeholders (McNie 2007, Tribbia and Moser 2008) because they do not address all of the uncertainties that undermine management success (Gregory et al. 2006, 2012) or are treated as stand-alone activities that are not integrated into the larger management process (Nichols and Williams 2006).

These and other issues are addressed by the form of adaptive management currently used by the U.S. Department of the Interior (Williams et al. 2009, Williams 2011), also defined as "structured decision making for recurrent decisions in which uncertainty is an impediment" (Runge 2011: #220). Structured Decision Making (SDM) has been used to integrate decision analytic tools into resource management for decades. Briefly, by sequentially working through the 5 basic components of a decision (problem, objectives, alternatives, consequences, and trade-offs), decision-makers are able to compare alternative management actions by predicting their consequences on management objectives. When the decision-maker will be revisiting the same problem in the future, they can choose to recursively reduce uncertainties along the way. This approach ensures that monitoring is relevant because it is designed to feed into a prescribed decision process (Nichols and Williams 2006, Lyons et al. 2008). In the context of climate change, agencies that have the capacity to carry out SDM will be able to produce information that is most relevant to decision-makers; including changing system dynamics, pubic values, and outcomes of different management actions.

Climate Change Psychology and Risk

In addition to the barriers to evidence-based and adaptive management, there are also psychological factors that could affect decision-making under climate change. Of primary interest is how individuals perceive and are tolerant of the risks from climate change, or their "risk attitudes." Risk attitudes are individual and domain-specific and an individual's willingness to take action is partially determined by their perception of outcomes (in terms of costs or benefits; Weber et al. 2002). As such, it may be possible to address climate change and improve decision-making by identifying underlying perceptions of the public as well as natural resource agency staff (Weber et al. 2002, Marx and Weber 2012) or the risk attitudes of decision makers (Runge 2011).

Study Objectives and Conceptual Model

We evaluated the capacity for climate-adaptive management, and searched for ways to improve it, by surveying the community of wildlife research and management professionals in the state of Wisconsin, USA. We designed a survey to meet the following objectives related to climate change psychology, adaptive management, and evidence-based practice: 1) evaluate the risk attitudes of these professionals regarding climate change; 2) assess how they currently make decisions; and 3) clarify their information needs and communication styles.

To further expand on our objectives above, we used a simplified conceptual model of how information is currently transmitted between 3 sectors: 1) Research as conducted by accredited scientists, 2) Field Operations as conducted by managers implementing policy on the ground, and 3) Administration and/or Policy (including "central office" staff) who plan and oversee policy. Most organizations that manage wildlife or wildlife habitats employ staff in all 3 sectors, and although each sector makes decisions, managers in the field interpret policy and research to make the decisions that directly impact wildlife. We can summarize their decision-making process in 3 steps: making a decision, implementing the decision, and monitoring the outcome. Researchers, administrators, and numerous stakeholder groups impact wildlife indirectly through their effect on managers. In an optimal scenario, each of these sectors has access to the information they need to support good decision-making. We make the assumption that, in practice, the majority of information produced by Research is communicated through peer-reviewed journals or "gray" literature (e.g., agency reports) and both resources are extensive, diffuse, technical, and frequently inaccessible to agency staff (McNie 2007).

METHODS

Survey Instrument

We targeted all individuals who are actively involved in wildlife management and research in Wisconsin, USA, specifically by searching online directories of institutions that manage protected lands or baccalaureate colleges that support relevant research (resulting in 40% State, 30% Federal, 25% Academic, and 5% Private and Tribal staff). We also added the state chapter of The Wildlife Society to represent relevant individuals who were missed using the method above. The sample of multiple organizations was designed to encompass diverse opinions and institutional cultures.

We implemented e-mail solicitations and questionnaires in Qualtrics (Qualtrics Labs, Inc., Provo, UT), as approved by the University of Wisconsin Institutional Review Board for Human Subjects (protocol 2012–0083). We sent invitations and one reminder to 1,041 e-mail addresses. In the web-bases survey (Supporting Information, SI 1, available online), respondents self-selected their agency affiliation, regional focus, and sector (i.e., the primary type of decision they make at work: Research, Management—Field Operations, or Management—Administration or Policy). All respondents were then presented the same questions with the exception of one section described below.

Objective 1) Evaluate Climate-Change Risk Attitudes

We measured attitudinal differences in terms of the perceived severity and immediacy of risk to wildlife, an individual's confidence in their assessment, and their tolerance for taking adaptive action. This is comparable to "dread" as used in climate change psychology (Loewenstein et al. 2001, Marx and Weber 2012). We asked one question to initially differentiate the sample, "Do you think that climate change will have negative impacts on Wisconsin's wildlife?" Respondents selected "no," "yes," or "not sure." To further clarify, we then asked the first subset (no or not sure), whether they agreed that climate change is happening globally or in Wisconsin. We also asked this group whether restoration based on historical reference conditions or "adaptation to environmental change" should guide wildlife management. We hypothesized that managers were most likely to support the continued use of tried, retrospective management practices, which would affect their receptivity to climate change adaptation. The second subset (yes or not sure) was asked to rank risk severity over 3 time periods (<5, 5–25, and 25–100 years in the future). All respondents ranked their confidence in each answer (low = 1, medium = 2, or high = 3).

To establish risk tolerance, we asked all respondents whether they currently participate in climate change adaptation and the likelihood that they would participate without incentives or direction at work. As a measure of self-efficacy, we asked whether the decisions they make "could affect climate change impacts on wildlife," (similar to "powerlessness" as in Aitken et al. 2011). We defined risk aversion by comparing these behaviors with the perception of risk. We hypothesized that wildlife professionals will not be risk-averse when confronted with threats to wildlife, and that individuals who are most confident about negative impacts will also be most willing to act. We expected field managers to have the weakest self-efficacy because they may consider administrative authorization and collective action as necessary. In other words, those who are most directly responsible for wildlife may not recognize the criticality of an individual's role in decision-making.

Objective 2) Assess Decision-Making

We used 3 approaches to measure decision-making and provided them with animal translocation as an example of a management activity. We used translocation as an example because it would be familiar to all respondents, is widely advocated as a strategy in the climate change adaptation literature (e.g., Hoegh-Guldberg et al. 2008, Sutherland et al. 2009), and is popular with the public (McLachlan et al. 2007). First, to compare motivations, we asked respondents whether translocation is best justified if it is used for basic research, species conservation, and/or public access. We expected the applied sectors (managers and administrators) to be more motivated by public concerns than researchers. Second, to measure the use of heuristics versus evidence-based processes, the participants ranked factors that might cause them to recommend translocation to a colleague (4-point scale). Because most respondents are trained biologists, we expected them to rank research as the strongest basis for making recommendations.

Finally, we compared how different sectors define good decision-making using the components of successful adaptive management as outlined by Williams et al. (2009), rephrased and organized for clarity (Table 1). The respondents selected those components, referred to as "actions," that they consider necessary for reaching their goals and described how often they think these are used in practice (5-point scale). We did not define these actions as originating from adaptive management or SDM, because the respondents were only asked to provide their opinion of each action. We hypothesized that respondents would, in general, consider the components to be important but under-utilized and that components that originated from SDM would be considered least important because this framework is relatively new to this audience.

Objective 3) Clarify Communication Preferences

To assess communication preferences and barriers to information exchange among the sectors in our conceptual model, we asked respondents to rank information sources based on frequency of use, information quality, and bias (also termed salience, bias, and legitimacy; Cash and Buizer 2005). They were then asked to identify their preferred methods and types of information that would be useful to them. We also asked them whether specific types of outreach materials (prepared slides, factsheets, or talking points) would be useful for communicating with colleagues, students, or the public about climate change. We finally asked the respondents whether they had heard of the Wisconsin Initiative on Climate Change Impacts (WICCI), the regional "boundary organization" (Tribbia and Moser 2008), and related

Table 1. Ten components of adaptive management based on the U.S. Department of Interior Adaptive Management Technical Guide (Williams et al. 2009). Components that are unique to a Structured Decision Making version of adaptive management are indicated with "*." Text in quotes refers to wording used in the survey of wildlife professionals in Wisconsin (Jun–Sep 2012).

Component	Relevance to adaptive management (AM)
"*Involve stakeholders (like landowners)*"	Stakeholders are important for the articulation of public values, successful implementation, and the process of mutual learning
"*Make sure policy is in place that supports [translocation]*"	Management decisions should comply with relevant regulations
"*Commit adequate resources in the beginning*"	Resources should be committed to cover the life of the project so that monitoring is not discontinued and learning can take place
"*Review previous research*"	Decisions should be grounded in the understanding of ecological processes and the consequences of previous interventions
"*Set measurable, specific objectives*"*	Objectives should be identified and stated explicitly, capture values, and be measurable
"*Consider alternative choices [like not translocating]*"*	Decision-makers should compare the consequences of multiple alternatives.
"*Predict the outcome of different choices (using models)*"*	Testing model assumptions and predictions forms the foundation for learning in AM
"*Oversee implementation on the ground*"	Management is most likely to succeed under high controllability
"*Evaluate your progress*"	Progress in understanding and improving management must be recognizable
"*Change a course of action if progress is unsatisfactory*"	There must be flexibility to adjust management strategies

assessment reports, as an example of freely available, easily accessible, and publicly funded climate change research. We expected field managers to have a stronger preference for in-person communication and locally relevant subject matter than researchers (as found in previous surveys; e.g., Tribbia and Moser 2008) as well as a relatively less familiarity with the WICCI reports as an indication of a relatively weak connection to climate change research.

Analysis

To assess differences among the 3 sectors, we performed cross-tabulations, Cochran–Mantel–Haenszel association tests, and Kruskal–Wallis rank-sum non-parametric analysis of variance followed by *post hoc* multiple-comparison tests. We used R version 2.11.1 (packages: coin 1–22, Hothorn et al. 2006; gmodels 2.15.4, Warnes 2012; pgirmess v1.4.7, Giraudoux 2010; reshape2 v1.1 and ggplot2 v0.8.9, Wickham 2007, 2009; vcdExtra 0.5–7; Friendly 2013) for all analyses.

RESULTS

Survey Response

We retained completed surveys from 224 respondents (22% of the targeted population), with response rates exceeding 87% for all questions. The sample includes 14 individuals who identified as "other" (e.g., from out-of-state universities), but the actual representation of these groups in the population is unknown. Only 4 of 34 individuals from tribal organizations responded to the survey. There was no strong locational bias: 66% of respondents had no preference and the remaining split between northern (42%), southern (33%), or other areas of Wisconsin (25%). Respondents self-identified as Field Operations (42%), Research (33%), or Administration and/or Policy (24%). Overall, we over-sampled state employees and field managers, but this may be expected because state-level managers are most directly involved in wildlife management. This subset was also most important for this survey, because in much of the Midwest the state agency manages the largest amount of protected land (212,322 acres [85,923.7 ha], 1998–2011; Trust For Public Land 2013), in addition to being statutorily responsible for wildlife protection.

Risk Attitudes

There was strong agreement within this sample that climate change will negatively impact wildlife (Yes 77.7%; No 2.7%; Not Sure 19.6%). Field managers differed significantly from the other sectors in their perception of impacts ($\chi^2 = 17.3$, $P < 0.001$), because 36% replied "no or not sure" when asked whether climate change imposes negative impacts on wildlife, compared with 11% of researchers, and 15% of administrators (managers comprised 68% of the no or not sure group). However, 49/50 of that subset agreed nonetheless that climate change is happening globally and in Wisconsin. Put another way, 23% of respondents to this survey agreed that climate change is happening but were unsure of its negative impacts on wildlife. This subset also strongly supported management that is adaptive (98%), but not restoration based on historical reference conditions (41%). Mean confidence in restoration was also significantly lower (a mean score of 2 compared with 2.4–2.5 for the previous statements [with 1 as lowest and 3 as highest]; $\chi^2 = 10.0$, $P = 0.006$).

Any temporal discounting that could affect decision-making could be occurring at a low rate. Respondents strongly agreed that the severity of impacts would increase with time (Fig. 1; $\chi^2 = 338$, $P < 0.001$). They also showed a consistently moderate level of confidence across all time periods ($\bar{x} = 2.2$–2.3, $P = 0.170$). In other words, confidence was not time-dependent.

Despite their confidence that the most severe risks from climate change will occur in the future, the respondents showed a strong interest in taking action now: 76% and 77% considered themselves likely or very likely to participate in adaptation even if there is no direction or incentive to do so. This was true for all sectors, with researchers slightly more inclined (83%). Participation and self-efficacy were comparatively low: 29% reported that they currently include climate change adaptation in their annual work plan, and 34% believed that their decisions could affect the impacts of climate change (28% replied "no," 38% were "not sure"). Contrary to expectation, field managers reported self-efficacy at a higher rate than the other sectors (42% vs. 26–29% of administrators or researchers), regardless of having the lowest rate of current participation in adaptation (Table 2).

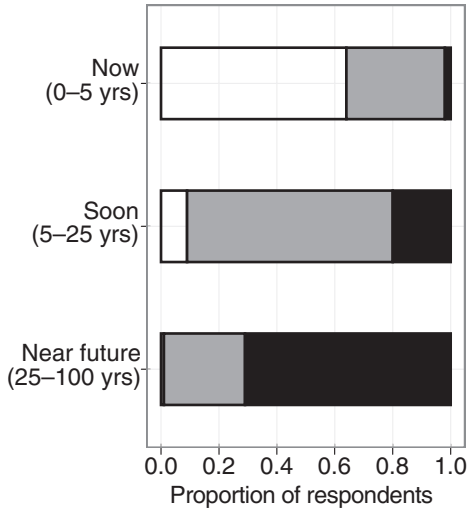

Figure 1. The severity of climate change impacts to wildlife (white = low, gray = medium, black = high) over 3 time periods as ranked by 224 wildlife professionals in Wisconsin, USA (Jun–Sep 2012).

Table 2. Cross-tabulation of self-efficacy and participation in climate change adaptation among 224 wildlife professionals in Wisconsin, USA, within 3 decision-making sectors (Jun–Sep 2012).

Wildlife management sector	Decisions have an impact		Currently participating	
	Yes	No	Yes	No
Research (%)	22 (29)	53 (71)	28 (38)	45 (62)
Field Operations (%)	40 (42)	55 (58)	22 (23)	72 (77)
Administration and/or Policy (%)	14 (26)	40 (74)	13 (25)	40 (75)

Researchers reported the highest current rate of participation (38%).

Decision-Making

All sectors displayed similar opinions of translocation and would rely on a variety of information when recommending its use (Fig. 2). All of the sectors selected "preserving a population" as the primary reason for translocation and were less motivated by research or public interest. Two respondents each commented that they would support translocation for biological control or to mitigate human–wildlife conflict. More than 60% of the respondents were willing to rely on heuristics and 74–78% on personal experience when deciding whether to recommend this technique to colleagues.

Respondents acknowledged the importance of the 10 components of adaptive management for decision-making, even if "adaptive management" was not mentioned by name: 65% of the respondents considered all of the components important and 6 components were selected by >90% (Fig. 3). However, all of these components or activities were reported as used in practice at a comparatively lower rate ($\chi^2 = 73.2$, $P < 0.001$), except to "oversee implementation," which was scored equally for use and importance (88%; Fig. 3). One activity derived from SDM, to "predict the outcome of different choices (using models)," was selected at the lowest rate for both measures (75% considered it necessary and 49% reported it as used sometimes or often). "Committing adequate resources at the beginning" had the weakest use relative to its importance, or a difference of 40%, which is nearly double the difference found in the next weakest activities, "predicting the outcome" (23% difference) and "changing a course of action if progress is unsatisfactory" (28% difference). Agreement was high among sectors ($\bar{x}$ difference < 10%), but field managers viewed the frequency of use in their agency differently from the other sectors ($\chi^2 = 18.3$, $P < 0.001$) and reported higher usage in 8/10 activities. This includes "predicting the outcome" as mentioned above, which 62% of managers considered to be used in practice compared with 42–49% of researchers and administrators. Finally, 20% fewer administrators felt that having adequate resources is necessary for success (78% vs. 95–98% of managers and researchers).

Communication Preferences

When asked about the sources of information used when making decisions, the respondents gave "published research

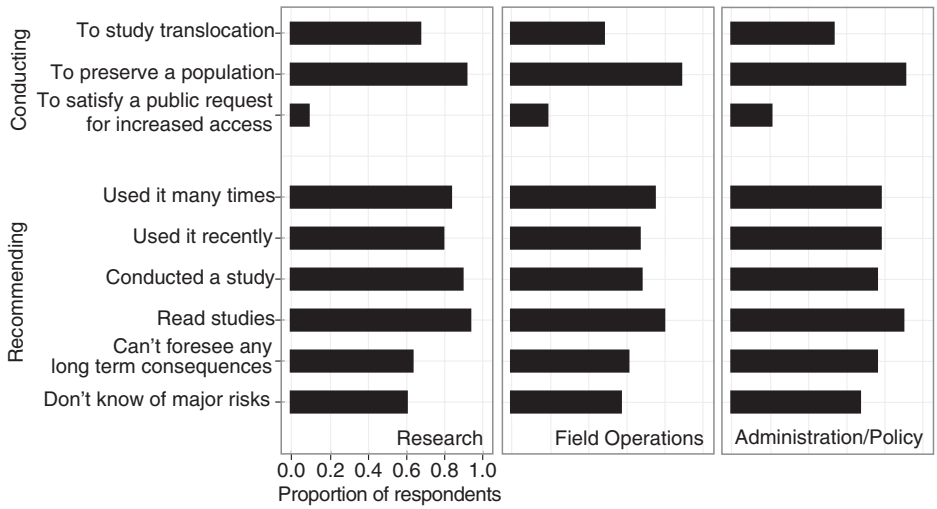

Figure 2. Motivations for using translocation of wildlife and justifications for recommending its use to colleagues by 224 wildlife professionals in Wisconsin, USA (Jun–Sep 2012).

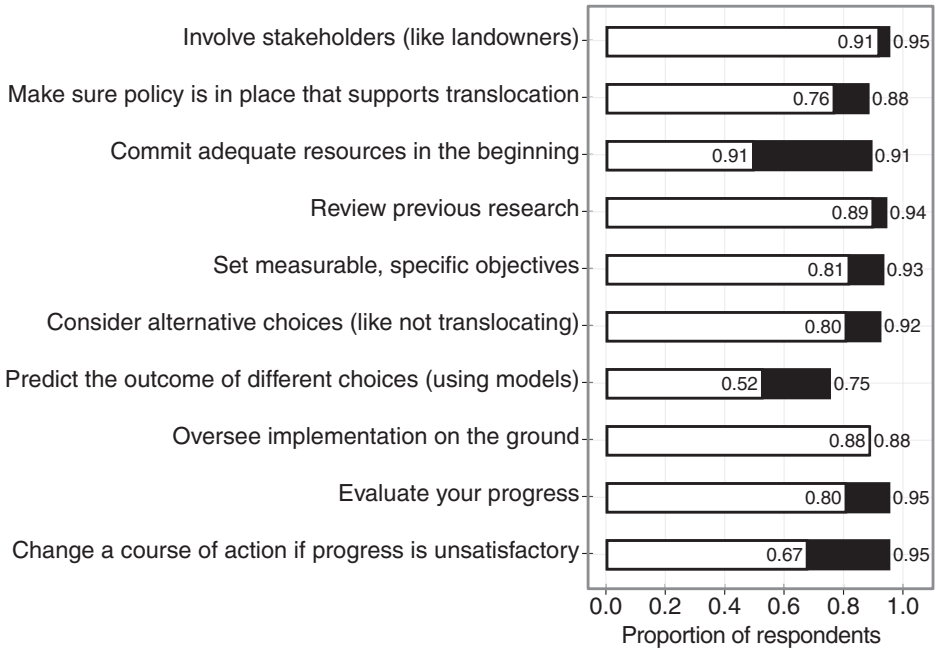

Figure 3. Importance (black) versus current frequency of use (white) of 10 requirements for Adaptive Management (from Williams et al. 2009), as ranked by 224 wildlife professionals in Wisconsin, USA (Jun–Sep 2012).

articles" the highest composite score (Table 3), or highest use, quality, and lack of bias. Researchers reported using published articles at a significantly higher frequency than the other sectors ($\chi^2 = 34.4$, $P < 0.001$). Field managers and administrators used "colleagues" as a resource more frequently than research articles, but scored colleagues as having lower quality and greater bias, resulting in a lower composite score. News ranked lowest according to all criteria. All sectors scored reports from governmental agencies better than environmental organizations according to all criteria. Published research and research reviews were the 2 most preferred resources for information and webinars were the lowest, regardless of sector (Fig. 4). The research sector showed an almost exclusive preference for publications and reviews, whereas the other sectors also selected resources that are communicated in person. For example, "workshops" were the first choice for 16% of field managers (third-highest preference overall), but this was not selected as a first choice by any researcher. Researchers were the only sector that selected "climate change science" as preferred subject area (Fig. 4), which combined with "wildlife impacts" totaled 59% of their first choice selections. Field managers preferred locally relevant information and management recommendations (84% of first choice selections). "Decision-making under climate change" was only of interest to administrators (15% of their first-choice selections). "Climate change policy" was the lowest ranked subject for all sectors (Fig. 4). Approximately half of the respondents would find prepared presentations, fact-sheets, or talking-points helpful for preparing them to discuss climate change with constituents, students, or colleagues (43–49% of the sample). The respondents also offered suggestions, including the following: summarized research or bibliographies on local issues, a resource or contact person to answer questions or supply materials (via social media, websites, or phone), posters for public events, standardized monitoring protocols, and training on effective communication. The need for improved access to research was also mentioned; one respondent wrote "Because my position is not "research," I don't have access to this because of the expense I suppose. This is kind of silly because if one is working on permitting and reviewing development projects on the "front line" we are making decisions that would benefit by being able to use this information." The WICCI reports had been read by 39% of respondents and this group was dominated by researchers (47%; $\chi^2 = 14.0$, $P < 0.001$). Only one-quarter of field managers reported reading the reports and 46% had not heard of them. Roughly half of researchers and admin-

Table 3. Composite ranking (mean score weighted by sample size) of information sources used when making wildlife management decisions, and individual scores (frequency of use [3 = highest frequency], quality [3 = highest quality], and bias [3 = lowest bias]) as reported by 224 individuals within 3 sectors of wildlife management in Wisconsin, USA (Jun–Sep 2012).

Information source	Research	Field operations	Administration and/or policy	$\bar{x}$
Colleagues	2.41 (2.66,2.6,1.94)	2.54 (2.84,2.66,2.1)	2.40 (2.85,2.54,1.89)	2.45
Published research articles	2.83 (2.93,2.95,2.72)	2.60 (2.45,2.82,2.52)	2.60 (2.56,2.77,2.44)	2.68
Reports from governmental agencies	2.45 (2.47,2.56,2.28)	2.45 (2.49,2.57,2.28)	2.34 (2.44,2.4,2.17)	2.41
Reports from environmental organizations	2.03 (2.16,2.15,1.79)	2.14 (2.22,2.33,1.92)	2.20 (2.33,2.31,1.94)	2.12
News media	1.34 (1.56,1.19,1.24)	1.34 (1.64,1.18,1.2)	1.44 (1.65,1.21,1.46)	1.37

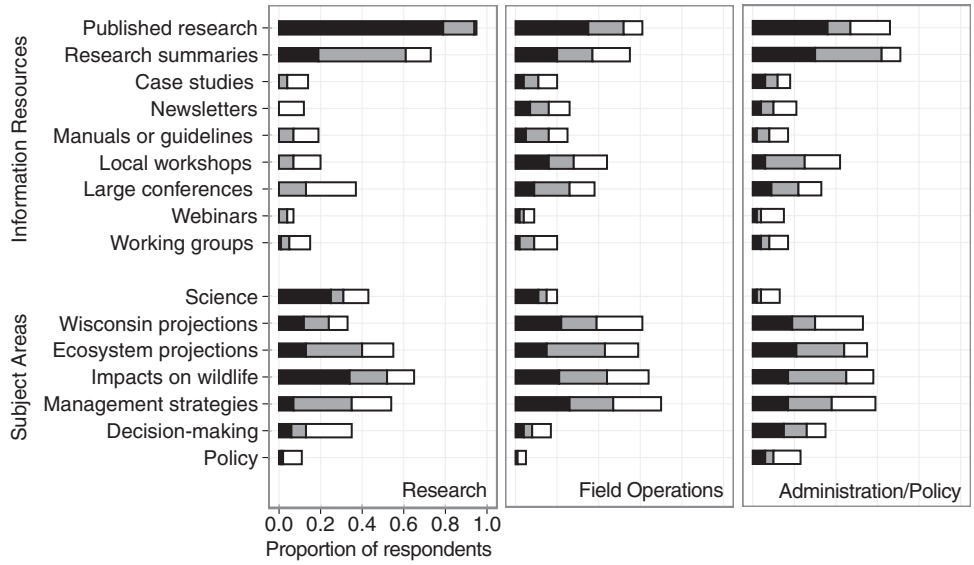

Figure 4. Preferred information resources and climate-change subject areas among 224 individuals in 3 sectors of wildlife management in Wisconsin, USA (Jun–Sep 2012). Black indicates first choice, gray second choice, and white third choice.

istrators (55% and 45%) reported reading the reports but 25% and 27%, respectively, had not heard of them.

DISCUSSION

Our survey results and related studies suggest that natural resource professionals are more aware of climate change risks than the U.S. population on average. Similar to our survey, a Fall 2010 census of employees of the state agency in Minnesota, USA, that included the sectors described here, found that 7.7% disagreed and 18.3% were unsure that climate change is happening (MNDNR unpublished report). U.S. residents surveyed during the same period show substantially higher disagreement: 26% disagreed and 16% were unsure of climate change (Borick and Rabe 2012). Other surveys of managers have found another common pattern: at least two-thirds agree that climate change is occurring now. This includes 76% of federal managers (Archie et al. 2012), 74% of state employees (MNDNR unpublished report), 76% of refuge managers (Magness et al. 2012), and all but one respondent in this survey. The greater acceptance by resource professionals might be explained by their acceptance of scientific data and their close connection to the resources affected by climate change, making it comparatively difficult to become psychologically "distant" (Spence et al. 2012).

The Status of Risk Attitudes Regarding Climate Change and Adaptation

Our results suggest an important difference in how sectors within resource management perceive the risks from climate change because a large subset of primarily field managers was unsure of the impacts to wildlife. This may support the suggestion that managers need more specific guidance relating climate change to their work (Tribbia and Moser 2008, Jantarasami et al. 2010). Many wildlife professionals may be aware of climate change but believe that the net effect will be positive, neutral, or at least unlikely to change the way they manage. This suggests that increasing climate "literacy" alone may not change behavior. Instead, agencies may also need to address underlying risk attitudes (Weber and Stern 2011). Contrary to our findings, a high percentage of federal managers surveyed by Archie et al. (2012) considered climate change risk to be immediately severe (>65%) and this individual perception of risk was less predictive of the willingness to act than agency affiliation. This suggests that agencies are already influencing participation. Similarly, Safi et al. (2012) found that risk perception in ranchers was not predicted by actual vulnerabilities to climate change impacts, but it was affected by the belief that their management actions could influence these impacts.

Despite the critical roles that research, field operations, and administration and/or policy play in resource management, they may all suffer from low self-efficacy that could limit their integration of climate change into decision-making. Our respondents were not averse to revising management strategies based on new information and were more in favor of, and more confident in, management that is "adaptive to environmental change" than they were of historical reference conditions. Regardless, their self-efficacy was low, which suggests that some individuals consider adaptation important but not their responsibility. Individuals may have believed that sectors other than their own have a greater responsibility; for example, they may believe field managers have more direct impact or policymakers have more top-down control. Managers may also be waiting for specific guidance before they make climate change a priority over other issues (Archie et al. 2012). However, if adaptive and evidence-based wildlife management relies on all of these sectors, then more individuals from all of the sectors should consider their decisions to be important. Outreach to address literacy and risk attitudes could be also used to define the role of specific sectors in decision-making and climate change adaptation.

Use of Adaptive Management and Evidence-Based Decision-Making

Despite the growing demand for evidence-based decision-making, managers and administrators and/or policymakers in particular may struggle to define "evidence" and to balance multiple competing demands, such as political constraints (Jennings and Hall 2012). Previous surveys suggest that conservation plans and planners are influenced more by experience than evidence, and are biased toward traditional practices (Pullin et al. 2004). Our survey showed equal reliance on experience and heuristics among all 3 sectors of wildlife professionals. Our assessment may have been biased by using translocation as the example activity because its use is controversial (McLachlan et al. 2007).

Because researchers and managers make different decisions, it might be expected for them to disagree as to the importance and use of decision components. However, all 3 sectors in this survey strongly supported the components we listed and questioned how reliably they are used in practice. Similarly, managers in Colorado and South Dakota (USA) strongly agreed with the importance of 16 attributes of adaptive capacity for climate change and also reported agency usage as poor (Lemieux et al. 2012). This included support for adaptive management and "safe to fail" policies. Given the high degree of support shown in both studies, the components of adaptive management could be treated as characteristics of "good" decision-making and as a metric to judge decision success. Having such a metric could aid climate change adaptation by providing a means to measure immediate decision "success" separate from outcomes that will take place over long time-frames (National Research Council 2009).

Budgetary constraints are also frequently cited as a primary barrier to climate change adaptation (Tribbia and Moser 2008, Archie et al. 2012, Lemieux et al. 2012), but there is a difference between sectors in the types of funding they need. In this survey, the administrators considered "having adequate resources at the beginning" less important than other sectors, possibly because they plan budgets differently (e.g., rely less on variable, high, and short-term costs such as field staff or equipment). As such, when assessing the importance of budgetary constraints, future surveys should also deduce what types of funding the respondents consider important.

The respondents in this survey repeated a common sentiment—that incorporating stakeholders is important for project success and is preferable to litigation (Balint et al. 2011). Improving this practice could help align resource agencies with the public (Nie 2004, Jacobson and Decker 2006) and avoid future conflicts over strategies such as translocation. Wildlife professionals may be facing a strong within-group cultural aversion to animal translocation, as well as regulatory mechanisms that limit translocation, and managers may even consider climate change adaptation infeasible if it requires translocation (Jantarasami et al. 2010). However, the public may be less risk-averse and may be willing to circumvent restrictions to conserve popular species (McLachlan et al. 2007). As such, although wildlife biologists may be resistant to translocation and less motivated by public demands (as shown in this study), advocates from the public could apply pressure in the future via political measures (Nie 2004).

Differences in Communication Styles and Outreach Needs

Our results re-emphasize the barrier in information sharing that undermines the effective use of research in decision-making. We found that although managers may trust researchers more than other sources of information (Tribbia and Moser 2008), they use research literature less than in-person communication (MNDNR unpublished report). Furthermore, although the individuals we sampled may be more informed about climate change than the public, their lack of familiarity with the WICCI reports suggests that making information available is not enough to ensure its use. Similarly, federal managers have mentioned that they need help synthesizing research articles and agency reports (Archie et al. 2012), and guidance on how to interpret adaptation plans (Jantarasami et al. 2010).

Unsurprisingly, resource professionals want information that will inform the decisions that they make at work. Multiple surveys have found that managers prefer "hands-on training" over other options (e.g., Tribbia and Moser 2008) and possibly over large conferences (this survey). Reports on scenario-based training suggest that managers benefit from practice and want to learn from realistic examples (Crimmins et al. 2007). For these reasons, training in climate change science is not enough. Similarly, complex models can also be perceived as overly uncertain and unreliable by policymakers (Webler et al. 2011). As an alternative, exercises that help users conceptualize the impact of climate change on their decisions could help groups learn collaboratively (LeDee et al. 2011). Better integration of decision-makers in model building could also remedy misinterpretation and improve communication (Webler et al. 2011).

MANAGEMENT IMPLICATIONS

We found that the sectors differ in their risk attitudes and information needs, but agree with the need for better management. These findings are consistent with other surveys of resource professionals. Many of the barriers to adaptive and evidence-based management could be addressed through improved communication between researchers and applied sectors. The results of our survey suggest 2 possible tools for this.

Problem-Based Management

Many of the field managers in this survey were not yet aware of the local boundary organization, WICCI. It may be that in order for boundary organizations to function, they must also build in decision-makers when designing deliverables. Decision-makers could also seek assistance on a problem-by-problem basis using decision support frameworks such as Structured Decision Making (SDM), and our results show

potential support from agency administrators. As the number of trained staff increases nationally, managers will be able to access this support through their local network of colleagues, on whom they already rely for informal decision support.

Early Adopters and Social Networks

Managers report using colleagues and direct forms of information exchange; and as such, one approach for increasing adaptive capacity would be to connect early adopters with decision-makers. The resulting resources saved by avoiding future losses to ecosystem services and litigation could more than compensate agencies for the time and effort spent now.

ACKNOWLEDGMENTS

We thank the Wisconsin Initiative on Climate Change Impacts Wildlife Working Group, particularly co-chairs K. Martin and M. Meyer for many insightful comments, as well as O. LeDee, M. Larson, and organizers and participants of the Ecological Society of America, 2nd Emerging Issues Conference: Developing Ecologically-Based Conservation Targets Under Global Change. Funding for the survey was provided by the Wisconsin Department of Natural Resources. We thank T. Knoot, C. Boal, and 2 anonymous reviewers for comments on previous drafts of this manuscript. The U.S. Fish and Wildlife Service (Wisconsin Ecological Services Field Office) supported data analysis through a Research Work Order with the U.S. Geological Survey Wisconsin Cooperative Wildlife Research Unit. Mention of trade names or products does not constitute endorsement by the U.S. government. We thank the Department of Forest and Wildlife Ecology, University of Wisconsin, Madison, for assistance with publication expenses.

LITERATURE CITED

Aitken, C., R. Chapman, and J. McClure. 2011. Climate change, powerlessness and the commons dilemma: assessing New Zealanders' preparedness to act. Global Environmental Change 21:752–760.

Allan, C., and A. Curtis. 2005. Nipped in the bud: why regional scale adaptive management is not blooming. Environmental Management 36:414–425.

Allen, C., and L. Gunderson. 2010. Pathology and failure in the design and implementation of adaptive management. Journal of Environmental Management 92:1379–1384.

Archie, K. M., L. Dilling, J. Milford, and F. Pampet. 2012. Climate change and western public lands: a survey of US federal land managers on the status of adaptation efforts. Ecology and Society 17:20.

Balint, P. J., R. E. Stewart, A. Desai, and L. C. Walters. 2011. Wicked environmental problems. Island Press, Washington, DC, USA.

Berrang-Ford, L., J. Ford, and J. Paterson. 2010. Are we adapting to climate change? Global Environmental Change 21:25–33.

Borick, C., and G. Rabe. 2012. Fall 2011 national survey of American public opinion on climate change: belief in global warming on the rebound. Issues in Governance Studies 45:1–8.

Brulle, R., J. Carmichael, and J. Jenkins. 2012. Shifting public opinion on climate change: an empirical assessment of factors influencing concern over climate change in the US, 2002–2010. Climatic Change 114:169–188.

Cash, D., and J. Buizer. 2005. Knowledge–action systems for seasonal to interannual climate forecasting: summary of a workshop, report to the Roundtable on Science and Technology for Sustainability, Policy and Global Affairs. The National Academies Press, Washington, DC, USA.

Cook, C., M. Hockings, and R. W. Carter. 2010. Conservation in the dark? The information used to support management decisions. Frontiers in Ecology and the Environment 8:181–186.

Crimmins, M., G. Zaimes, N. Haas, C. Jones, G. Garfin, and T. Crimmins. 2007. Changes on the range: exploring climate change with range managers. Journal of Natural Resources & Life Sciences Education 36: 76–86.

Fontaine, J. 2011. Improving our legacy: incorporation of adaptive management into state wildlife action plans. Journal of Environmental Management 92:1403–1408.

Friendly, M. M. 2013. Package 'vcdExtra'. <http://CRAN.R-project.org/package=vcdExtra>. Accessed 16 Jul 2013.

Giraudoux, P. 2010. pgirmess: data analysis in ecology. <http://CRAN.R-project.org/package=pgirmess>. Accessed 16 Jul 2013.

Gregory, R., L. Failing, M. Harstone, G. Long, T. McDaniels, and D. Ohlson. 2012. Incorporating uncertainty. Pages 122–149 *in* Structured decision making: a practical guide to environmental management choices. Wiley-Blackwell, Hoboken, New Jersey, USA.

Gregory, R., D. Ohlson, and J. Arvai. 2006. Deconstructing adaptive management: criteria for applications to environmental management. Ecological Applications 16:2411–2425.

Hoegh-Guldberg, O., L. Hughes, S. McIntyre, D. B. Lindenmayer, C. Parmesan, H. P. Possingham, and C. D. Thomas. 2008. Assisted colonization and rapid climate change. Science 321:345–346.

Holmes, J., and R. Clark. 2008. Enhancing the use of science in environmental policy-making and regulation. Environmental Science and Policy 8:702–711.

Hothorn, T., K. Hornik, M. A. Van De Wiel, and A. Zeileis. 2006. A Lego system for conditional inference. The American Statistician 60:257–263.

Jacobson, C. A., and D. J. Decker. 2006. Ensuring the future of state wildlife management: understanding challenges for institutional change. Wildlife Society Bulletin 34:531–536.

Jantarasami, L., J. Lawler, and C. Thomas. 2010. Institutional barriers to climate change adaptation in US national parks and forests. Ecology and Society 15:33.

Jennings, E., and J. Hall. 2012. Evidence-based practice and the use of information in state agency decision making. Journal of Public Administration Research and Theory 22:245–266.

Kahan, D. M., E. Peters, M. Wittlin, P. Slovic, L. L. Ouellette, D. Braman, and G. Mandel. 2012. The polarizing impact of science literacy and numeracy on perceived climate change risks. Nature Climate Change 2:732–735.

Lawler, J. J., T. H. Tear, C. Pyke, M. R. Shaw, P. Gonzalez, P. Kareiva, L. Hansen, L. Hannah, K. Klausmeyer, A. Aldous, C. Bienz, and S. Pearsall. 2010. Resource management in a changing and uncertain climate. Frontiers in Ecology and the Environment 8:35–43.

LeDee, O., W. H. Karasov, K. J. Martin, M. W. Meyer, C. A. Ribic, and T. R. Van Deelen. 2011. Envisioning the future of wildlife in a changing climate: collaborative learning for adaptation planning. Wildlife Society Bulletin 35:508–513.

Lee, K. 1999. Appraising adaptive management. Conservation Ecology 3:3.

Lemieux, C. J., J. L. Thompson, J. Dawson, and R. Schuster. 2012. Natural resource manager perceptions of agency performance on climate change. Journal of Environmental Management 114:178–189.

Loewenstein, G. F., E. U. Weber, C. K. Hsee, and E. S. Welch. 2001. Risk as feelings. Psychology Bulletin 127:267–286.

Lyons, J. E., M. C. Runge, H. P. Laskowski, and W. L. Kendall. 2008. Monitoring in the context of structured decision-making and adaptive management. Journal of Wildlife Management 72:1683–1692.

Magness, D., A. Lovecraft, and J. M. Morton. 2012. Factors influencing individual management preferences for facilitating adaptation to climate change within the National Wildlife Refuge System. Wildlife Society Bulletin 36:457–468.

Marx, S. M., and E. U. Weber. 2012. Decision making under climate uncertainty: the power of understanding judgment and decision processes. Pages 99–128 *in* T. Dietz, and D. C. Bidwell, editors. Climate change in the Great Lakes. Michigan State University Press, East Lansing, USA.

McLachlan, J. S., J. J. Hellmann, and M. W. Schwartz. 2007. A framework for debate of assisted migration in an era of climate change. Conservation Biology 21:297–302.

McNie, E. C. 2007. Reconciling the supply of scientific information with user demands: an analysis of the problem and review of the literature. Environmental Science and Policy 10:17–38.
National Research Council. 2009. Informing decisions in a changing climate. Panel on Strategies and Methods for Climate-related Decision Support, Committee on the Human Dimensions of Global Change. Division of Behavioral and Social Sciences and Education. The National Academies Press, Washington, DC, USA.
Nichols, J. D., M. D. Koneff, P. J. Heglund, M. G. Knutson, M. E. Seamans, J. E. Lyons, J. M. Morton, M. T. Jones, G. S. Boomer, and B. K. Williams. 2011. Climate change, uncertainty, and natural resource management. Journal of Wildlife Management 75:6–18.
Nichols, J. D., and B. K. Williams. 2006. Monitoring for conservation. Trends in Ecology and Evolution 21:668–673.
Nie, M. 2004. State wildlife policy and management: the scope and bias of political conflict. Public Administration Review 64:221–233.
Pullin, A., and T. Knight 2009. Doing more good than harm-building an evidence-base for conservation and environmental management. Biological Conservation 142:931–934.
Pullin, A., T. Knight, D. Stone, and K. Charman. 2004. Do conservation managers use scientific evidence to support their decision-making? Biological Conservation 119:245–252.
Runge, M. 2011. An introduction to adaptive management for threatened and endangered species. Journal of Fish and Wildlife Management 2: 220–233.
Runge, M., S. Converse, and J. Lyons. 2011. Which uncertainty? Using expert elicitation and expected value of information to design an adaptive program. Biological Conservation 144:1214–1223.
Safi, A. S., W. J. Smith, and Z. Liu. 2012. Rural Nevada and climate change: vulnerability, beliefs, and risk perception. Risk Analysis 32:1041–1059.
Scruggs, L., and S. Benegal. 2012. Declining public concern about climate change: can we blame the great recession? Global Environmental Change 22:505–515.
Spence, A., W. Poortinga, and N. Pidgeon. 2012. The psychological distance of climate change. Risk Analysis 32:957–972.
Sutherland, W. J., M. Clout, I. M. Côté, P. Daszak, M. H. Depledge, L. Fellman, E. Fleishman, R. Garthwaite, D. W. Gibbons, J. De Lurio, A. J. Impey, F. Lickorish, D. Lindenmayer, J. Madgwick, C. Margerison, T. Maynard, L. S. Peck, J. Pretty, S. Prior, K. H. Redford, J. P. W. Scharlemann, M. Spalding, and A. R. Watkinson. 2009. A horizon scan of global conservation issues for 2010. Trends in Ecology and Evolution 25:1–7.
Sutherland, W. J., A. Pullin, P. Dolman, and T. Knight. 2004. The need for evidence-based conservation. Trends in Ecology and Evolution 19:305–308.
Tribbia, J., and S. C. Moser. 2008. More than information: what coastal managers need to plan for climate change. Environmental Science and Policy 11:315–328.
Trust for Public Land. 2013. Conservation almanac. <www.conservationalmanac.org>. Accessed 14 Feb 2013.
Tversky, A., and D. Kahneman. 1982. Judgments of and by representativeness. Pages 3–20 *in* D. Kahneman, P. Slovic, and A. Tversky, editors. Judgment under uncertainty: heuristics and biases. Cambridge University Press, New York, New York, USA.
Warnes, G. R. 2012. gmodels: various R programming tools for model fitting. <http://CRAN.R-project.org/package=gmodels>. Accessed 16 Jul 2013.
Weber, E. U., A. Blais, and N. E. Betz. 2002. A domain-specific risk-attitude scale: measuring risk perceptions and risk behaviors. Journal of Behavioral Decision Making 15:263–290.
Weber, E. U., and P. C. Stern. 2011. Public understanding of climate change in the United States. American Psychologist 66:315–328.
Webler, T., S. Tuler, and T. Dietz. 2011. Modellers' and outreach professionals' view on the role of models in watershed management. Environmental Policy and Governance 21:472–486.
Welch, D. 2005. What should protected areas managers do in the face of climate change? The George Wright Forum 22:75–93.
Wickham, H. 2007. Reshaping data with the reshape package. Journal of Statistical Software 21:1–20.
Wickham, H. 2009. ggplot2: elegant graphics for data analysis. Springer, New York, New York, USA.
Williams, B. K. 2011. Adaptive management of natural resources—framework and issues. Journal of Environmental Management 92:1346–1353.
Williams, B. K., R. C. Szaro, and C. D. Shapiro. 2009. Adaptive management: the U. S. Department of the Interior technical guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC, USA.

Associate Editor: Boal.

SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article at the publisher's web-site.

SI 1. Survey Questionnaire taken by 224 wildlife professionals in Wisconsin, USA (Jun–Sep 2012).