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Determining Climate Change Management Priorities: A Case Study from Wisconsin

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ABSTRACT: A burgeoning dialogue exists regarding how to allocate resources to maximize the likelihood of long-term biodiversity conservation within the context of climate change. To make effective decisions in natural resource management, an iterative, collaborative, and learning-based decision process may be more successful than a strictly consultative approach. One important, early step in a decision process is to identify priority species or systems. Although this promotes the conservation of select species or systems, it may inadvertently alter the future of non-target species and systems. We describe a process to screen terrestrial wildlife for potential sensitivity to climate change and then use the results to engage natural resource professionals in a process of identifying priorities for monitoring, research, and adaptation strategy implementation. We demonstrate this approach using a case study from Wisconsin. In Wisconsin, experts identified 23 out of 353 species with sufficient empirical research and management understanding to inform targeted action. Habitat management and management of hydrological conditions were the common strategies for targeted action. Although there may be an interest in adaptation strategy implementation for many species and systems, experts considered existing information inadequate to inform targeted action. According to experts, 40% of the vertebrate species in Wisconsin will require near-term intervention for climate adaptation. These results will inform state-wide conservation planning as well as regional efforts.

Keywords: climate, sensitivity, decision framework, vertebrates, priority

INTRODUCTION

The conservation of biodiversity will require increasing intervention by natural resource professionals (Vitousek et al. 1997) as global climate change challenges the ability of managers to protect species from extinction and the loss of ecosystem function (Thomas et al. 2004; Urban et al. 2012). Currently, to achieve conservation goals, managers utilize a multitude of tools, from land acquisition to captive breeding. Although beneficial for many species, in some cases these interventions merely delay near-term extinction (Snyder et al. 1996; Wilcove and Chen 1998). Global climate change exacerbates this tension between resource investment and long-term conservation success (Ruhl 2010; Wilson et al. 2011). As a result, a burgeoning dialogue exists regarding how to allocate resources to maximize the likelihood of long-term biodiversity conservation within the context of climate change (West et al. 2009; Bardsley and Sweney 2010). A common suggestion from scientists and managers is to improve decision support for natural resource professionals (Hagerman et al. 2010; Nichols et al. 2011).

To make effective decisions in natural resource management, the integration of biological and social information is essential (Soulé 1985). In addition, iterative, collaborative, and learning-based decision processes are the model for success (Holling 1978; Williams et al. 2009). Such processes, integrating monitoring, research, and management, are often time and resource intensive. Because funds for natural resource science and management are limited, agencies often face a difficult exercise. One step in a decision process is to proactively identify priority species or systems. This selection, implicitly or explicitly, alters the future of non-priority species and systems. Because this is a difficult and influential choice, many tools exist to guide priority-setting in conservation (e.g., “gap analysis”, Scott et al. 1993; “hot spots”, Reid 1998; “ecoregion”, Olson and Dinerstein 1998; “systematic conservation planning”, Margules and Pressey 2000). Despite the major challenge of global climate change, the conversation on how to integrate this stressor into priority-setting for the conservation of biological diversity is just emerging.

One potential approach is triage: a systematic process that considers urgency, sensitivity, and available resources to determine management priority (Millar et al. 2007). In brief, triage is the concept that, under scarce resources, interventions determined unlikely to succeed should be abandoned (Watt 1984). Although some natural resource professionals find the concept problematic (Noss 1996; Pimm 2000; Jachowski and Kesler 2009; Parr et al. 2009), triage is implicitly a widespread practice (Bottrill et al. 2008) and is increasingly an acceptable conversation topic among scientists and managers (Hagerman et al. 2010; Rudd 2011).

A second potential approach is based on ecological resilience. Ecological resilience is the capacity for a system to absorb a disturbance yet maintain its structure and function (Walker et al. 2004). The population or system’s resistance and resilience may be attributable to intrinsic (e.g., behavioral plasticity) or extrinsic (e.g., minimal temperature changes) factors. In natural resource planning, a resilience-based approach would dictate investment in populations or areas with high survivability and resilience to climate change (West and Salm 2003; Baskett et al. 2010). Although resilience is an ecological concept with a long theoretical history (Holling 1973), its quantification is problematic (Carpenter et al. 2001). Many have identified potential surrogates for resilience (see Carpenter et al. 2005) and implementation may be impractical (e.g., relationships change over time) and inaccurate. Thus, the ability to make or monitor resilience-based management decisions is often limited.

A third potential approach is based on climate change vulnerability (reviewed in Füssel and Klein 2006, Carter et al. 2007). Vulnerability refers to the level of susceptibility to harm to a system due to a stressor; it is a measure of exposure, sensitivity, and adaptive capacity (Turner et al. 2003). In contrast to a resilience-based approach, a vulnerability-based approach would favor actions to reduce the climate vulnerability of species (e.g., identifying climate refugia) (e.g., Crossman et al. 2012). Many indices and analytical methods are available to scientists and managers to identify vulnerable species (e.g., Rowland et al. 2011).

Triage, resilience, and vulnerability are major areas of dialogue in the climate change and biodiversity conservation community; however, for implementation, the operationalization of these concepts in a decision framework is essential. Although some large-scale vulnerability-based approaches achieve this goal, they may be subject to taxonomic, economic, cultural, or geographic bias (Martín-López et al. 2011). We outline a proactive approach to prioritize the conservation and management of terrestrial animal species under climate change that can be used to inform planning to help determine climate change-based management actions. We describe a process to screen terrestrial wildlife for potential sensitivity to climate change, which engages natural resource professionals in a structured process to identify priorities for climate adaptation planning. We will demonstrate this process using a case study from Wisconsin.

METHODS

Screening Process

The screening process was composed of defining criteria for sensitivity to a changing climate, including identifying species characteristics that indicate potential sensitivity, and expert review of a resulting database. For the criteria, we considered any physiological, morphological, ecological, or behavioral traits responsive to climate-linked stimuli (Turner et al. 2003; Williams et al. 2008). We used five trait groups (Foden et al. 2008), common to many indices of climate vulnerability (Rowland et al. 2011), to indicate sensitivity and added two additional categories, disease and behavior (Table 1). We considered potential sensitivity to a changing climate for all regularly occurring native vertebrate species: mammals, reptiles, amphibians, and birds (year-round residents and migratory species). This was done in order to obtain a holistic picture of the potential climate change impacts to vertebrates in a defined geographic area – in our case, the state of Wisconsin. In Wisconsin, there are 236 avian, 62 mammalian, 36 reptilian, and 19 amphibian species.

To identify species characteristics indicating potential climate sensitivity, we conducted an extensive literature search on the species. To organize and analyze information, we built a database with a unique record for

Table 1. Trait groups used to categorize species sensitivity to climate change in Wisconsin.

Trait Group	Description	Example
Specialized habitat and/or microhabitat requirements	Narrow niche breadth during any life stage	American golden-plover nests on arctic and subarctic tundra (Johnson and Conners 2010).
Narrow environmental thresholds likely to be exceeded	Narrow abiotic thresholds (e.g., pH, temperature, precipitation)	Sensitivity to hydrological regime during nesting in black tern (Gilbert and Servello 2005).
Dependence on an environmental cue	Abiotic cue prompts physiological or behavioral response	Temperature-dependent sex determination in Blanding's turtles (Harding 1997).
Dependence on inter-specific interaction likely to be altered	Interactions influential to population trend (predation, herbivory, competition, mutualism)	Canada lynx population is closely tied to abundance of snowshoe hare (InfoNatura 2007).
Poor dispersal ability	Intrinsic or extrinsic barriers to dispersal	High genetic differentiation in eastern massasauga across fine spatial scales, likely indicating limited dispersal (Gibbs and others 1997)
Disease	Established susceptibility to infectious agents	Common loon susceptible to avian botulism with erratic, but extensive die-offs (McIntyre and Barr 1997)
Maladaptive behavior	Behavioral traits ill-suited for future climate conditions	Pied-billed grebes utilize detritus to increase amount of heat in nest (Muller and Storer 1999).

each species which included fields for each predefined trait group. We used online resources (taxa-specific and general biological databases) and comprehensive state-specific books to review the ecology and life history of each species. We searched both common and scientific names because preliminary searches with the scientific name produced few results. We examined titles and abstracts of all results to identify research papers with potential information on climate sensitivity. We reviewed those papers for physiological, morphological, ecological, or behavioral research relevant to the climate-sensitive trait groups and added this information to the database fields. We linked each record to supporting references and noted the total number of peer-reviewed articles extracted in the search. To ensure consistency, two researchers evaluated an assigned set of species and then reviewed the entries of their colleague; a third individual reviewed all database entries. We did not attempt to categorize the strength of the climate effect (e.g., strong or weak). We used the number of climate-sensitive traits for a species as a climate sensitivity score; the score ranged from 0 to 7. The last step, review of the database, was included in workshops to identify priorities for climate adaptation planning.

For the Wisconsin study, the literature search was done September 2009 to December 2010. We used the following taxa-specific online resources: NatureServe Explorer v7.1 (NatureServe 2010), Birds of North America (Cornell Lab of Ornithology 2005), and AmphibiaWeb (AmphibiaWeb 2011). We then used the Wildlife and Ecology Studies Worldwide Database (EBSCO Publishing 2010) where we searched on common name, limited to abstracts, in scholarly (peer-reviewed) journals over the complete database period (1935-2011).

Climate Adaptation Planning

We convened natural resource professionals (i.e., taxonomic experts and site-level managers) from state and federal agencies, universities, and non-governmental organizations in taxa-specific workshops (reptiles and amphibians, mammals, and birds) to review the database results and prioritize species for climate adaptation planning. The participants were members of or identified by the Wisconsin Initiative on Climate Change Impacts Wildlife Working Group (Wisconsin Initiative on Climate Change Impacts 2009). The goals of the workshops and role of the participants were to: 1) review the database results and available resources, 2) deliberate as a group, and 3) determine an exclusive, climate change-based management recommendation for each species. Prior to the workshop, participants received a packet with the list of objectives, a detailed description of trait groups, a species list with climate sensitivity scores, and supporting information on climate change in Wisconsin. At the start of each workshop, we reviewed the goals of the workshop and the role of the participants. We also described the literature search, provided the database results, and reviewed additional resources (e.g., range maps) that were available to participants. The participants were asked to choose among four recommendations: targeted action, research, monitoring, and hold action. The participants were asked to consider the actions as mutually exclusive. A targeted action was defined as the design and implementation of a management tactic to minimize negative changes or enhance beneficial changes as a result of climate change in an animal population, or biotic and abiotic surroundings. Research referred to the development and execution of a distinct ecological study to determine the direct or indirect impact of climate change on an animal population. Monitoring referred to the design and implementation of a monitoring program to measure an animal population, or biotic and abiotic conditions, specified as indicators of climate change or sensitivity. Finally, hold action was chosen if no climate change monitoring, research, or management tactic should be taken for this species now or in the near future. It is important to note that our working assumption was that resources for wildlife conservation and management in the states will continue to be limited in the future. Although not restricted to a predetermined financial sum, the group was asked to broadly consider the limited availability of resources in their deliberation. To prompt conversation, we provided a preliminary categorization of the species based on the database results and scientific knowledge. As the participants deliberated, two facilitators with expertise in ecology and natural resource management aided the process, clarified definitions, provided additional information, ensured consensus, and documented rationale. For the Wisconsin workshops, there were 14 participants for birds, 10 participants for amphibians and reptiles, and 6 participants for mammals.

Post-workshop Analysis

To understand if specific species were chosen because of some type of special interest, we categorized the status of species after the workshops using the following groups: harvested species (species that are hunted, trapped, or collected), policy-concern (federal/state threatened or endangered species, state species of management concern), nuisance species (species that can be removed by landowner or designee), and no special concern. We used the regulations as posted on the Wisconsin Department of Natural Resources website in January-February 2012 (Wisconsin Department of Natural Resources 2012) to determine harvest, policy-concern, and nuisance species. Species not falling into any of these categories were put into the no-special-concern category. Species were put into one category only. If a species was in more than one category, the category taking legal precedence was used. For example, amphibian species can be legally collected (harvested species category) even if the species is a state species of management concern (policy-concern category) so the species was counted as a harvested species. Two wildlife extension specialists at the University of Wisconsin-Madison confirmed the species categorizations. We used analysis of variance to determine differences among taxa given the amount of available information, and differences among taxa and among climate sensitivity scores in relation to the number of peer-reviewed articles. Number of peer-reviewed articles per species was log-transformed to stabilize variances. We used contingency tables with residual analysis (Lloyd 1999) to determine if there were any patterns among the taxa having to do with sensitivity to climate change and participants' management recommendations.

RESULTS

Screening Process

In our literature search for species in Wisconsin, the number of peer-reviewed studies varied widely by taxa (F = 31.5, $df_1 = 3$, $df_2 = 349$, $P < 0.001$). The lowest amount was for reptiles (mean = 22 studies/spp, SD = 36, n = 36 spp). Birds and amphibians had similar and moderate amounts of information (amphibians: mean = 70 studies/spp, SD = 73, n = 19 spp; birds: mean = 81 studies/spp, SD = 100.1, n = 236 spp). Mammals had the most information per species (mean = 206 studies/spp, SD = 307.8, n = 62 spp).

Sensitivity to climate change varied by taxa both for the specific trait ($X^2 = 71.0$, $P < 0.001$) and for the number of trait groups ($X^2 = 27.0$, $P = 0.036$). For specific traits, amphibians and reptiles were more likely to be sensitive via specialized habitat/microhabitat requirements (94.7% of amphibians and 50% of reptiles) (Table 2). Reptiles were also sensitive due to dependence on an environmental cue (36.1% of species).

Table 2. Categorization of Wisconsin terrestrial vertebrate species according to traits sensitive to climate change. Species can have more than one climate-sensitive trait (n = number of species).

Trait Group	Amphibia (n=19)	Aves (n=236)	Mammalia (n=62)	Reptilia (n=36)	All Species (n=353)
Narrow environmental thresholds likely to be exceeded	6	171	29	3	209
Specialized habitat and/or microhabitat requirements	18	69	20	18	125
Disease	11	69	36	6	122
Dependence on an environmental cue	12	76	11	13	112
Dependence on inter-specific interaction likely to be altered	1	42	10	6	59
Maladaptive behavior	0	14	4	1	19
Poor dispersal ability	1	5	2	1	9

Birds were primarily affected by climate due to narrow environmental thresholds likely to be exceeded (72.5% of species) while mammals were likely to be affected by changing climate due to disease/parasitism issues (58.1% of species).

For climate sensitivity scores, birds and mammals were similar (Table 3); these taxa were primarily sensitive to climate due to 1 (32.6%, SD = 4.1%), 2 (31.8%, SD = 1.7%), or 3 (19.6%, SD = 0.4%) trait groups. Amphibians had more climate sensitive traits than the other taxa; species were sensitive due to 2 (47.4%), 3 (31.6%), or 4 (15.8%) trait groups.

Reptiles had the fewest climate sensitive traits; 25% of species were not sensitive to climate change, 33.3% were sensitive to 1, and 30.6% were sensitive to 2 trait groups. Within taxa, species with more information did not have higher climate sensitivity scores – for mammals (F = 0.41, df = 4, 57, P = 0.80), amphibians, (F = 1.23, df = 3, 15, P = 0.33) and reptiles (F = 0.41, df = 4, 31, P = 0.14). For birds, species with more information were more likely to be scored sensitive to 3 or 4 trait groups compared to 0, 1 or 2 (F = 4.05, df = 5, 230, P = 0.001) (Table 3).

Climate Adaptation Planning

For each workshop, participants often used personal knowledge of species and ecosystems in Wisconsin to inform the discussion. Participants routinely deferred to the attendee with the most experience with the species or system in question. The time required to review each species varied widely. In particular, two strategies, research and monitoring, often required considerably more time to reach consensus.

Recommended management by taxa differed from the uniform distribution of no preference ($X^2 = 278.8$, $P < 0.001$) (Table 4). Participants were more likely to recommend hold action for birds (62.7% of species) and mammals (69.3%), and research for reptiles (50% of species). Participants did not have any action preferences for amphibians.

Table 3. Climate sensitivity score (number of climate sensitive traits) and average amount of information with standard deviation (SD) for Wisconsin terrestrial vertebrates (n = number of species).

Total Sensitivity Score	Amphibia (n=19)	Amphibia-Average (SD) number of peer-reviewed articles	Aves (n=236)	Aves-Average (SD) number of peer-reviewed articles	Mammalia (n=62)	Mammalia-Average (SD) number of peer-reviewed articles	Reptilia (n=36)	Reptilia-Average (SD) number of peer-reviewed articles	All Species (n=353)	All Species-Average (SD) number of peer-reviewed articles
0	0	-	22	63 (91)	5	82 (57)	9	12 (16)	36	53 (78)
1	1	6	70	54 (53)	22	183 (242)	12	18 (32)	105	76 (130)
2	9	54 (62)	78	94 (134)	19	260 (423)	11	18 (17)	117	111 (212)
3	6	75 (65)	47	96 (95)	12	220 (316)	3	79 (95)	68	115 (160)
4	3	132 (116)	17	109 (79)	4	189 (148)	0	-	24	125 (96)
5	0	-	1	103	0	-	1	21	2	62 (58)
6	0	-	1	117	0	-	0	-	1	117
7	0	-	0	-	0	-	0	-	0	

Table 4. Categorization of Wisconsin terrestrial vertebrates by climate change-based management strategy (n = number of species).

Climate change-based management strategy	Amphibia (n=19)	Aves (n=236)	Mammalia (n=62)	Reptilia (n=36)	All Species (n=353)
Targeted Action (design and implementation of climate change management action)	6	12	2	3	23
Research (implement climate change-focused research)	2	35	14	18	69
Monitoring (implement program to measure populations of species considered to be indicators of climate change or sensitivity)	4	41	3	3	51
Hold Action (no near-term management action necessary)	7	148	43	12	210

When hold action was chosen for the climate-based management strategy, five, non-exclusive criteria were common to the participants' determination for nearly half of the species: range (n = 53, 24%), population size (n = 33, 15%), niche breath (n = 28, 13%), perceived benefit due to climate change (n = 19, 9%) and importance of other stressors (n = 15, 7%). For 74% of species selected for climate change-based research, participants identified habitat and/or species interactions as information gaps. Other commonly identified research gaps included population dynamics (15%), distribution patterns (15%), movement/dispersal (13%), and thermal preferences (7%). For species identified as targets for monitoring, changes in hydrology (29%) and habitat (14%) were common concerns. Across the four workshops, participants identified 23 species (7%) as appropriate targets for targeted action. Habitat management was the most commonly recommended targeted action (81%); management of hydrological conditions or regime was also a common strategy for targeted action (35%).

Post-workshop Analysis

Recommended climate change-based management action for the different status categories varied by taxa. Amphibians were not considered, as the majority of species was in one category; 16 of the 19 species could be harvested. For reptiles, there was no evidence that species status (harvested or policy-concern) influenced the recommended action ($X^2 = 3.25$, $P = 0.40$). This also held for mammals ($X^2 = 10.6$, $P = 0.22$). In contrast, for birds ($X^2 = 19.3$, $P = 0.005$), harvested and policy-concern species had more targeted actions recommended than no-special-concern species (10.3% of harvested species and 9.1% of policy-concern species compared to 0.08% of no-special-concern species). Bird species of no-special-concern had more hold actions recommended (74% compared to 58.6% of harvested birds and 48.9% of policy-concern).

DISCUSSION

Climate change is an expansive threat to natural resources; moreover, lack of quality data and high uncertainty reduce the predictability of our management interventions. Limited resources exacerbate this challenge. When priority species or areas are already identified, undertaking climate change vulnerability assessments (e.g., Aubrey et al. 2011, Bagne et al. 2011, DuBois et al. 2011) can be useful. However, when planning for integrating climate change into management strategies is at the initial stages, a preliminary assessment, such as demonstrated in this Wisconsin example, may be useful for guiding groups through an informed, proactive, systematic process to identify priorities and allocate sparse resources to monitoring, research (e.g., quantitative vulnerability assessment), or adaptation strategy implementation. Because law dictates many planning and management efforts, it is important for such work to easily integrate into an organization or agency's framework. The results of this work are first being integrated into the Wisconsin Department of Natural Resources Species Guidance; these documents inform managers of risk and threats to species, in particular in environmental review and the issuance of permits. The results of this work are also informing the development of the Wisconsin State Wildlife Action Plan – a comprehensive strategic plan to conserve species and their habitats. As a multi-year planning process, managers have already used the results to identify species of concern. The next steps will use the expert review to select species-specific management actions and priorities.

The process described in this paper is an explicit demonstration of conservation triage; in this open discussion, we know how and why the decisions are made (Marris 2007). There is frank discussion on mandates, stakeholder interests, resource impacts and likelihood of success (Botrill et al. 2008). As Summers et al. (2012) note, there are "inherent trade-offs between a focus on sensitive species and the representation of other species." A follow-up to our process would be to further refine management options, calculate costs for each action, estimate biodiversity benefits, and then rank the management actions (Botrill et al. 2008).

An important strength of this priority-setting approach is the cross-sector, cross-agency participation of natural resource professionals. As a trans-boundary problem with high resource demands, such collaboration is essential for success (Hannah et al. 2002). A second strength is its orientation to proactive management action. Experts are a valuable resource for data-poor problems; they can evaluate available information to develop a management response (Sutherland 2006). For example, Gardali et al. (2012) used experts to evaluate available information on climate risk for birds of special concern in California; the process is also closely linked to policy implications (i.e., implementation is linked to lists of at-risk species). Like Gardali et al. (2012), we used a combination of available information and expert opinion; however, rather than score climate sensitivity, we used the evaluation to determine next steps: monitor, acquire more information, or implement an adaptation strategy. This not only provides managers with priorities (Gardali et al. [2012]), but also the next steps to advance management action in response to climate change. A third strength is that we considered all vertebrate species in the state; this allowed us to avoid the "trap" of focusing only on threatened and endangered species (Martín-López et al. 2011). This is an important distinction of this study. For example, reptiles in Wisconsin scored lowest in terms of climate-affected traits; however, because of concern for their sensitivity but low available information, natural resource professionals prioritized research for reptiles.

Yet, our approach has limitations; these include the rapid nature of the process, lack of explicit input from policy makers, and unacknowledged biases. Natural resource professionals have high workloads and little time available for collaboration (Schuett et al. 2001). To gather a diverse set of individuals, time was a constraint. Where possible, allocating more time for the evaluation and deliberation process would be useful. To address the second limitation, requesting the participation of senior managers, who deal explicitly with budgeting and policy implementation, would more effectively link information and management needs with key decision-makers. Finally, potential biases should be acknowledged by the participants. State natural resource professionals were more likely to recommend targeted action for birds that were harvested or of policy concern compared to bird species that were not of concern. This bias may not be too surprising given the focus on coordinated state-federal (U.S.) management of harvested species and conservation of policy concern bird species (Van Horn and Benton 2007, North American Bird Conservation Initiative 2009). Renewed efforts to identify representative species (e.g., umbrella, keystone, flagship) or "keep common species common" (e.g., State and Tribal Wildlife Grants Program) may minimize this historical research and management bias.

Given the potential for abrupt climate change (Alley et al. 2003) and the increasing evidence for high frequency extreme weather events (Field et al. 2012), there is a pressing need for natural resource professionals to participate in processes to help inform evidence-based, iterative, collaborative decision-making to develop effective management actions with respect to climate change. The process we have developed starts to address these needs, is straightforward to implement, and is adaptable to other scales of planning. For example, it informed the development of a species list for regional prioritization in the Midwestern United States (LeDee et al. 2012). Furthermore, because it could inform decision frameworks (i.e., strategy implementation, research, monitoring) (Allen et al. 2011), it is widely compatible with federal (U.S.) and state-level management plans. Finally, it promotes collaboration, from people to resources, across institutional boundaries that will be increasingly vital to natural resource management and conservation.

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