Draft Report

Conservation management of recreational impacts on wildlife requires consideration of population- and community-level effects

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Abstract

Ultimately, both practical management considerations and agency missions imply that the study of recreation impacts on wildlife should connect explicitly to the population and community levels. Population and community responses integrate meaningful individual behavioral, physiological, and fitness impacts into practical metrics (e.g. population size and trend, species distribution and richness) that serve as big-picture benchmarks for on-going (long-term) change. Despite 20+ years of reviews calling for better recreation research to guide wildlife managers in developing conservation strategies, studies at population and community levels are still sparse. We

offer an ecological framework to interpret measured wildlife responses on individual, population, and community levels for management prioritization and guiding future research, and review recent studies of recreation impacts to evaluate how they correspond to levels of this framework. Of the 103 research papers published since 1995, fewer than 12% (N=13) collected data that specifically targeted recreation effects on wildlife population and/or community levels. Most of these (12/13) describe impacts on only circumscribed populations/communities local to the recreation disturbance rather than on the larger interbreeding biological population and/or interacting ecological communities. The great majority of recent studies (87%; N=90) measured how recreational impacts on wildlife led to an individual response, especially in behavior. The larger question of whether these changes translate into meaningful effects on the units of conservation focus – wildlife populations, species, or communities –is still a relatively unexplored research area in the wildlife-recreation field.

Introduction

There are both expressed mandates and public support for managing recreation's effects on wildlife, and wildlife conservation is a named priority of protected area managers as well as users (USFWS 1996; Cordell & Super 2000). Because recreation is one of the leading causes for decline of endangered species (Losos et al. 1995; Czech et al. 2000), a clear of understanding of how wildlife are being affected by recreation is essential to effective conservation management.

For 20+ years, reviews of recreation impacts on wildlife have called for better research to guide managers in developing conservation strategies (e.g. Boyle & Samson 1985; Knight & Gutzwiller 1995; Blumstein et al. 2005). These reviews have stressed scientific rigor on design elements such as experimentation, appropriate controls, confounding factors, interactive effects, replication and randomization, and time scales of responses. Reviews have also recognized the importance of choosing a research focus appropriate to managers' conservation goals. As early as 1991, Knight and Cole pointed out the need for research on population and community level effects to supplement research on individual effects and support conservation at a scale where management tends to operate (Knight & Cole 1991).

This paper repeats the call for research on the population level and community level impacts of recreation. Our goal is to strengthen the field of recreation research and its application to wildlife conservation. First, we provide an argument for understanding impacts on biological populations and ecological communities. We then offer an ecological framework to interpret measured wildlife responses on individual, population, and community levels for management prioritization and guiding future research. Next, we ask how recent studies of recreation impacts correspond to our framework and what implications those studies offer to conservation management. Finally, we identify knowledge gaps and suggest a course of action for assessing recreation impacts on wildlife species.

Management of Recreation Impacts on Wildlife Requires a Population and Community Focus

Ultimately, both practical management considerations and agency missions imply that the study of recreation impacts on wildlife should connect explicitly to the population and community levels. Population and community responses integrate meaningful individual behavioral, physiological, and fitness impacts into practical metrics (e.g. population size and trend, species distribution and richness) that serve as big-picture benchmarks for on-going (long-term) change.

For example, the recent Nobel Prize-winning Intergovernmental Panel on Climate Change (IPCC) report describes global climate change effects on wildlife in terms of how physiological and behavioral (e.g. migration timing) alterations manifest as changes in distribution, abundance, and trend of native and introduced species (Rosenzweig et al. 2007). Likewise, the World Conservation Union (IUCN) criteria for identifying threatened species and conservation priorities center predominantly around recent population trends (IUCN 2007).

Even with the responsibility of serving multiple users, including providing recreational opportunities and natural resource protection, the United States' agencies in charge of wildlife management recognize conservation of wildlife populations and ecological communities as a priority. Depending on the agency, wildlife disturbance is often regulated at the scale of individuals (e.g. the National Park Service (NPS) includes behavior and distribution in their wildlife management policies, and regulates harassment of wildlife by visitors; the Fish and Wildlife Service (USFWS) regulates species of concern at a disturbance threshold level). However, all of the agencies tend to focus their wildlife management missions and goals on higher-level ecological impacts, such as populations and communities.

An underlying principle of the National Park Service 2006 Management Policies is to 'ensure that conservation will be predominant when there is a conflict between protection of resources and their use' (NPS 2006). From the first Park Service publications on their wildlife management policies (Wright et al. 1932) to these more recently published policies (NPS 2006), the NPS priority has consistently been the "preservation of perpetuating populations of native wildlife" (from Wright et al. 1932).

The United States Fish and Wildlife Service (USFWS) also focuses their protection efforts at the higher levels as directed by the Endangered Species Act of 1973, in which they define their focus as 'any distinct population segment of any species of vertebrate fish or wildlife, which interbreeds when mature' (Endangered Species Act of 1973, Definitions, page 5; USFWS 1973).

The U.S. National Forest Service (USFS) Management Act of 1976 has an overall mandate to "provide for diversity of plant and animal communities" (Noon et al. 2005), and this commitment is reflected in more recent policies as well. The National Forest Service's 2004-2008 strategic planning mission identifies one of their top priorities as sustainable ecosystems (USFS 2004), which are dependent on the sustainability of communities and populations within them.

Thus, both ecological principles and management policies point to population and community effects as necessary focal points for studies of recreation impacts on wildlife.

A Conceptual Framework for how Human-Caused Disturbance Affects Wildlife

A rich body of ecological knowledge is available to help both researchers and managers understand how recreation may affect wildlife. Both basic ecological concepts and applied studies of other stressors such as hunting, pollutants, and habitat loss have been analyzed for wildlife for more than a century. These ecological concepts can guide the study and interpretation of recreation effects as yet another stressor on wildlife populations.

Wildlife responses to any stressor can manifest at many levels, including the individual, population, community, and ecosystem (Knight & Cole 1995:52). While research of recreation impacts on wildlife at all these levels (e.g. individual, population, and community) can provide useful information to managers, they are not equal in terms of inference value for conservation management. Next, we describe a simple ecological framework of wildlife responses to disturbance (Figure 1), emphasizing with examples from the recreation literature when available. This conceptual framework can be used to inform assessment of recreation impacts on wildlife for conservation management.

Individual Responses

Short-term studies of individual responses to recreation are common (Knight & Cole 1995; Steidl & Powell 2006). Research at this scale can identify potential mechanisms and/or guide future research at population and community levels. In addition, disturbance impacts on individuals may be important to consider morally, ethically, politically, and otherwise. Here we describe the most commonly studied individual responses to recreation: behavior, physiology, and fitness.

Behavior

Behavioral responses to human disturbance (defined in Taylor & Knight 2003) include attraction (Whittaker & Knight 1998) and avoidance, such as flight or flushing (e.g. Geist et al. 2005), increased alertness (e.g. Duchesne et al. 2000), temporal or spatial displacement (e.g. Densmore & French 2005), and even offspring abandonment (e.g. Bolduc & Guillemette 2003; other examples in Linnell et al. 2000). Another type of change in behavior resulting from human disturbance is a learned "non-response" to disturbances that once provoked behavioral changes, often called habituation (Thorpe 1963; Whittaker & Knight 1998).

While behavioral adjustments are responses that wildlife species use to protect themselves naturally, if disturbance is severe and/or frequent enough, behavioral changes in individuals may lead to negative physiological and/or fitness effects that could in turn cascade into population or community level changes. For example, ecotourism disturbance may increase escape behaviors that modify stress and/or energy budgets to a point where reproduction and/or survival are reduced (e.g. McClung et al. 2004; Müllner et al. 2004).

However, behavioral changes do not automatically lead to physiological and other higher-level effects, especially in the short term (e.g. Janis & Clark 2002; Parent & Weatherhead 2000; habituation: e.g. Walker et al. 2006; Griffin et al. 2007). Therefore, changes in behaviors such as flushing, alertness, or habituation should not be assumed to cause negative impacts at the physiological levels and higher unless these are explicitly investigated.

Physiology

Human disturbance can directly impact the physiology of wild animals by increasing stress hormones (often measured using corticosteroids) (e.g. Creel et al. 2002; Ellenberg et al. 2007; other examples in Wingfield & Ramenofsky 1999), as well as indirectly, through altered behaviors that reduce energetic intake and/or increase energetic expenditures (examples in Gabrielsen & Smith 1995). As with behavioral effects, physiological responses to disturbance may (e.g. Holmes et al. 2005; McClung et al. 2004) or may not (e.g. Walker et al. 2005; Rode et al. 2007) manifest at higher levels (Fig. 1).

Fitness

Individual fitness can be defined as the ability of an individual to contribute to the gene pool in future generations. Disturbance may affect individual fitness attributes (survival and reproduction) directly or indirectly through behavioral and physiological responses as described above. Reductions in survival and/or reproduction have been correlated with recreational activity (e.g. Thiel et al. 1998; Phillips & Alldredge 2000; Beale & Monaghan 2005) and have also been demonstrated as manifestations of behavioral and physiological responses to recreation disturbance (e.g. Bolduc & Guillemette 2003; O'Leary & Jones 2006; other examples in Linnell et al. 2000).

Although changes to individual fitness attributes (survival and reproduction) are often referred to as "fitness effects" in the literature, we should caution that demonstrating the actual effect on an individual's fitness requires modeling its age-specific survivorship and reproduction across its lifetime (McGraw & Caswell 1996; Crone 2001). In some cases, changes in fitness attributes may not affect an individual's fitness, as when the rate in question has no influence on an individual's lifetime fitness (e.g. increase in mortality following reproductive senescence), or when a change in one rate is compensated for by an opposing change in another (e.g. "bet hedging" trade-offs between lower reproduction and higher survival). Importantly, individual fitness attributes such as survival or reproduction may also be significantly altered by recreation and yet not translate into higher-level effects on population dynamics and community function (see next two sections).

Population Responses

In some cases, anthropogenic disturbance can have impacts that extend beyond individual responses to the population – the collection of individuals of a species in a defined area. Short-term changes in population abundance, density, and/or distribution may be demonstrated directly (e.g. Gerodette & Gilmartin 1990; Densmore & French 2005). More often, a long-term population metric of interest to conservation management is the trend in population abundance over time, otherwise known as the population growth rate.

There are two main ways to estimate population growth rates in the face of recreation or other stressors (Morris & Doak 2002; Mills 2007). The first is to measure population abundance over time, and estimate average growth, or trend, across the trajectory. The second way to estimate population growth uses the birth and death rates averaged across individuals (population vital rates), often with population models.

An important, yet non-intuitive finding that has emerged from applying such population models is that some vital rates contribute very little to population growth while others make large contributions even when changed by very small amounts. A classic case with endangered loggerhead sea turtles showed that tiny decreases in young adult mortality (through minimizing shrimp net by-catch) would efficiently increase population growth, while large decreases in mortality of newborn turtles (through managing vehicles on the beach) would have very little influence on the population growth (Crouse et al. 1987; Crowder et al. 1994).

As a general rule, for all but very short-lived species, both fitness and population growth will be affected more by survival changes than fecundity (Crone 2001), except for cases where the changes in fecundity are particularly large (Wisdom et al. 2000). The population modeling framework to evaluate whether, or how, vital rate changes translate into effects on fitness and population growth is very well established (Morris & Doak 2002; Mills 2007), though nearly completely ignored in recreation studies.

It is important to determine the relationship of interbreeding biological populations to circumscribed and politically defined populations, such as the collection of individuals that fall within a park boundary. Recreation impact research often focuses on politically defined populations because of wildlife managers' limited jurisdictions, and because study sites are often centered on the recreation location rather than the biological population per se. Although the documented changes in abundance and distribution of locally defined populations are meaningful to managers charged with maintaining wildlife populations within their protected areas, (e.g. NPS mission to maintain sustainable populations of wildlife within the parks), these impacts may or may not be meaningful to the larger biological population of which the local population is only a part. Research that aims to describe impacts of disturbance at the population scale for conservation purposes should be clear about the scope of inference relative to cumulative effects on the larger biological population.

Community and Ecosystem Responses

An ecological community is a suite of interacting species within a specified area, and an ecosystem includes the community and its associated abiotic processes (e.g. nutrient cycling, hydrology). Disturbance that affects populations may, in turn, have community level and ecosystem level effects, especially if the populations altered interact strongly with other species or processes (Mills 2007). Certain species are "strong interactors" by virtue of their dominance in biomass or numbers (e.g. Douglas fir trees in the Pacific Northwest, or prairie grasses in the U.S. Midwest); other species may have particularly strong *per capita* interaction strength (e.g. beavers). Species whose impact on its community or ecosystem is both large and disproportionately large relative to its abundance are considered keystone species (Power et al. 1996), and disturbance impacts to these species may result in large-scale cascading effects, such as entire shifts in community structure and function (Mills et al. 1993; Power et al. 1996).

Of course, it is an ecological truism that different species will respond differently – at the level of behavior, physiology, vital rates and population responses – to any natural or anthropogenic perturbation. Studies of recreation impacts on communities commonly use metrics such as species richness, composition, and diversity to compare control communities with those local to recreational disturbance (e.g. Riffell et al. 1996; Camp & Knight 1998; McMillan et al. 2003). Here again, it is useful to remind the reader that locally defined communities of species often differ from the larger ecological communities of which they are a part. It is the responsibility of the researcher to make clear the scope of inference of their research before extrapolating conservation implications of localized responses to the ecological community level.

Conceptual Framework Summary

Emerging from this discussion is that any stressor – recreation included – can be measured at several levels with potentially varying conclusions. While studies at the level of individual behavior or physiology can provide useful basic information, such responses may or may not affect the dynamics of the whole population, or its role in influencing natural area community or ecosystem properties.

Recent Papers and an Overview of Recent Studies on Recreation Effects

Having established a context for how perturbations, or stressors in general, may or may not affect wildlife at different ecological levels, we next investigated the extent to which research on recreation impacts have assimilated these ecological ideas. We searched for recently published (1995 – 2008) articles on direct impacts of recreation on wildlife in natural areas using numerous search engines (Agricola, Biological Abstracts, CSA, USDA TREEsearch, & other ad hoc searches) and various combinations of the keywords: wildlife, recreation, disturbance, impacts, anthropogenic, visitation, and response. By reviewing abstracts, we identified all research papers on direct impacts of recreation on wildlife in natural areas.

Because our target audience is managers in protected areas where recreation occurs in natural wildlife habitat, we limited our focus to non-consumptive and, for the most part, non-motorized recreational activities in protected natural areas. In a few cases, motorized recreation was included when the recreation was likely to occur in protected areas; for example, we did include some studies on snowmobile effects and boating effects in national parks (e.g. Creel et al. 2002). Also, some studies looked at impacts of human presence on non-target species when people were hunting. As long as it was human presence that was having the impact and not direct hunting, we included these papers (e.g. Janis & Clark 2002).

For all selected publications, we recorded: 1) the type of recreation, 2) the study species, 3) whether data were observational or experimental, 4) the type of response measured (above and Figure 1), 5) basic findings, and 6) how the authors described the implications of their results. We summarize the results for each category to give an overview of the research being currently conducted on the impacts of recreation on wildlife.

Summary of Recent Research

We found 103 papers published since 1995 on the direct impacts of recreation on specific wildlife species. The papers focused on >100 species of wildlife and represented 20+ different recreation types that ranged from general hiking and human presence to more specific recreation types including mountain biking, skiing, and paragliding.

Most (92%) of the papers were on birds and mammals (birds: N=55; mammals: N=40), especially focusing on ungulates and waterbirds (Table 1). And, the majority of studies (65%; N= 67) were observational (Table 1), taking advantage of natural experiments either spatially (comparison of areas with and without recreational pressure) or temporally (e.g. areas before/after recreation was allowed).

Of the 103 research papers we reviewed, fewer than 12% collected data that specifically targeted recreation effects on wildlife population and/or community levels (Fig. 2), and most of these studies (12/13) described impacts to only circumscribed populations local to the recreation disturbance. Only one of the population studies we reviewed appears to have demonstrated probable changes at a scale of an interbreeding biological population (Garber and Burger 2006).

The great majority of recent studies 89% (N=92) measured how recreational impacts on wildlife led to an individual response, most of these (68%, N=61) focusing on behavioral changes, and this was the only response measured (Fig. 2). Seventeen papers measured physiological responses to recreation disturbance, nineteen measured impacts on individuals' fitness attributes, and twenty of these measured a combination of behavioral, physiological, and/or fitness effects on individuals.

Management Implications As Reported by the Authors

All the reviewed papers included recommendations to managers for promoting conservation through minimizing the disturbance that was studied. However, fewer than half of the papers discussed how their findings would translate into population or community level effects. In 37 (35%) of the papers, some attention was made to argue that the research implications were at a higher level than what was studied, but only seven of these papers used previous studies and/or modeling to make a case for such higher-level implications. For example, four studies described and quantified physiological implications of measured behavioral responses by determining the changes in energetic expenditures that would have resulted (e.g. reindeer flushing was translated into increased energy budgets, which surpassed estimated physiological thresholds; Reimers et al. 2003). Three studies used modeling to project population level changes due to observed responses (e.g. food uneaten by geese due to disturbance was converted to biomass and then translated to the number of individuals it would have supported; Gill et al. 1996).

Discussion

For the past two decades, reviews of recreation impacts on wildlife have been calling for more well-designed and scientifically rigorous studies that can guide wildlife managers in developing conservation strategies. These suggestions have led to improved methodology, experimental approaches, and analytical techniques in demonstrating recreation effects on wildlife.

Despite these methodological improvements, the vast majority of papers we reviewed failed to address the population level and community level impacts of recreation on wildlife. Such an omission is in stark contrast to the conceptual framework established in applied ecology for the study of effects of perturbations on wildlife, where population and community level effects are recognized to be the emergent impacts that trigger management actions (e.g. listing or de-listing as threatened, prioritization of conservation funds, etc.).

We assume the goal of recreation impact studies is to inform managers of long-term problems as almost all the papers we reviewed made conservation management recommendations to mitigate the impact of recreation no matter the type of response that was observed. However, most of these papers fail to make a data-based link between the response observed and long-term population and community level effects that would result.

The simple conceptual framework in Figure 1 demonstrates types of wildlife responses studied and the corresponding inference value of those studies' results to ecosystem and wildlife managers. The responses are listed in order of inferential strength for ecologically meaningful impacts on wildlife. Behavioral responses and even physiological effects do not necessarily cause changes in fitness of individuals, or in population dynamics or community structure and function. Therefore, we encourage biologists to investigate effects of behavioral and physiological responses on fitness across many individuals and use population analysis tools (e.g. in Mills 2007) before declaring that recreation is having an effect at the population level (Gill et al. 2001).

We especially encourage more widespread recognition that individual fitness attributes can be analyzed to specifically assess whether they are likely to lead to population growth/decline over time (Morris and Doak 2002). Some of the recent research we reviewed looked at changes in individual vital rates due to negative effects from recreational disturbance (e.g. survival of chicks, reproductive success in elk, etc.). These studies could be even more useful to conservation management if they consolidated measured changes in vital rates across individuals into a population modeling framework to assess implications for population trend or abundance.

Population level effects due to recreation can also be inferred by directly measuring changes in abundance, density, or distribution. In such cases, however, it is important to make sure that the sampled population is biologically meaningful and that the implications beyond the studied population are carefully articulated. Some of the studies we reviewed suggest they have demonstrated population level and community level effects without clearly defining the population or community that they studied. Because locally defined management populations can become confused with interbreeding biological populations, we caution the use of the term population without a clear definition.

For example, displacement, or movement of an individual away from a recreational activity, is a behavioral phenomenon that could lead to reduced abundance or density and species richness or composition in a recreation area without any actual effects on mortality or species extinction across the greater biological population and ecological community (Riffell et al. 1996). Although localized changes in population may be important to managers and could signal impacts to the biological population warranting further study (e.g. a local population sink, displacement to suboptimal habitat, reduced connectivity, etc.), researchers and readers alike should be cautious about extrapolating results beyond the studied population. It is critical that a study purporting to infer long-term recreation effects on population abundance, population persistence, or community composition actually measure changes in these traits across the interbreeding biological population and/or interacting ecological community in question.

Conclusion

Recreation impacts on wildlife are a deepening concern among managers, especially with the steady increase of recreational activities in natural areas (Cordell and Super 2000) coupled with other global stressors. There is a large body of literature on human disturbances to wildlife that provide an ecological framework for interpreting effects of human perturbations and can be extended to recreation. In combination with previous suggestions to improve experimental design and species studied, increased focus on population and community level impacts will improve inferences that can guide and support conservation management of wildlife.

To date there has been a preponderance of studies that focus on lower level responses (Fig. 1) to recreation, addressing especially behavioral changes. In some cases studies of individual behavioral responses are an appropriate end in themselves, as in the case of human-wildlife conflict (e.g. food conditioned bears). Observational studies of wildlife individuals' behavioral and physiological responses to recreation can also be useful first steps in investigative research of recreation impacts. These types of studies are often inexpensive, short term, use non- (or less) invasive methods, and can make use of inexperienced field technicians to gain insights that may illuminate candidate species for future research.

However, behavioral and physiological research of individuals is not enough, and this type of research often cannot stand alone in the decision making process for recreation and wildlife management. That some wildlife individuals show change in behavior or physiology in the presence of recreating humans is not surprising given their evolutionary biology. However, whether changes in behavior or physiology translate into meaningful effects on wildlife populations, species, or communities – the primary units of conservation focus – requires specific study that targets those levels. Such studies will often occupy much larger time horizons and research effort, and as such, may have higher price tags. But, just as a bridge should not be built based on assumptions, we cannot make inferences about recreation impacts on wildlife conservation without doing the research that yields data directly relevant to population growth and viability and community structure and function.

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Table 1: Types of recreation impact studies published since 1995.

	Types	Number of studies
	Total	103
SPECIES	Birds	55
	(waterbirds)	(32)
	Mammals	40
	(ungulates)	(15)
	Other	8
	(reptiles)	(5)
	(invertebrates)	(2)
	(anurans)	(1)
METHOD	Observation	67
	Experiment	34
	Observation & Experiment	2

Figure 1: Wildlife responses to anthropogenic disturbance. Human disturbance can affect wildlife at several levels, causing behavioral, physiological, and fitness changes in individuals, changes to population dynamics/growth, as well as changes to ecological communities. These possible impacts are listed in increasing significance to long-term conservation. For simplicity, we have organized the responses linearly to show that lower level effects may cascade through steps into effects of higher management significance, recognizing that in some cases steps can be skipped to higher-level manifestations. However, it is not automatic that a lower-level impact will result in larger scale or long-term effects; the question marks remind the reader that these relationships must be tested in each case.

Figure 2: Number of recent (since 1995) recreation impact research publications that measured each type of wildlife response.