Assessing the Effects of Human Activities on Wildlife

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Human activities that affect wildlife and their habitats are pervasive and increasing. Effects of these activities are manifested at all ecological scales, from short-term changes in the behavior of an individual animal through local extirpations and global extinctions (Pimm et al. 1995; Chapin et al. 2000). Consequently, understanding the effects of humans on wildlife and wildlife populations, as well as devising strategies to ameliorate these effects, is an increasing challenge for resource managers. Given the conflicting mandate to both encourage human use and to protect sensitive natural resources in national parks, developing reliable strategies for assessing and monitoring the effects of human activities on natural resources is essential to ensuring appropriate stewardship of these resources.

Given the breadth of relevant human activities, the diversity of wildlife species potentially affected, and the multitude of ways they may be affected, scientists and resource managers planning to assess the effects of human activities on wildlife must be careful to state their study objectives explicitly. In all cases, these objectives should specify the human activity of interest; the timing, intensity (frequency, duration) and spatial extent of the activity; the focal wildlife species of interest; and the range of ways that species might respond to the activity—that is, the objectives should define the "disturbance context" in which the human–wildlife interaction occurs (Steidl and Anthony 2000). Given well-defined objectives and a clear disturbance context, a measure that gauges the response of the wildlife species of interest to the human activity must be selected carefully.

In this paper, we provide a general classification for the ways in which human activities can affect wildlife, distinguish among general types of relevant studies based on different objectives, and identify appropriate measures for gauging wildlife response for different types of studies. Our goal is to provide a conceptual framework to guide studying and monitoring human–wildlife interactions, specifically those deriving from non-consumptive recreational activities.

Classifying human activities

Virtually all human activities can affect wildlife populations either positively or negatively. Those activities that are likely to have adverse effects can be divided into those that function primarily by altering the physical environment in a relatively permanent way and those that cause changes to an animal's behavior. Activities that alter the physical environment change the amount or the suitability of habitat for a species. Widespread and large-scale examples include activities that directly alter the structure and composition of the landscape, such agriculture, forestry, livestock grazing, and unregulated off-road vehicle use. In general, these are land use or land management practices that change the trajectory of ecological succession, including altering the dominant plant communities and the abiotic features of a site. The ecological effects of these activities on vertebrates are readily apparent and have been relatively well studied (e.g., Blair 1996; Spies et al. 1996; Lichstein et al. 2002).

Perhaps less obvious in their ecological impacts are those non-consumptive human activities that do not appreciably alter the physical environment but nonetheless can affect wildlife adversely. Examples include recreational activities such as hiking, wildlife viewing, and boating—all common activities for visitors in parks. As recreational use increases in wilderness and other protected areas, sensitive wildlife species may be increasingly affected by these activities (Steidl and Anthony 2000). The magnitude of effects of recreational activities on wildlife is influenced by many factors, including the type, duration, frequency, magnitude, location, and timing of the disturbance, as well as the particular species of interest. Although effects of these activities are typically of short duration, cumulatively they can effect wildlife populations adversely in both the short- and long-term (Burger 1981; Henson and Grant 1991; Fernandez and Azkona 1993; Holmes et al. 1994; Steidl and Anthony 1996, 2000; Swarthout and Steidl 2001, 2003; Mann et al. 2002; Johnson et al. 2005). Observed effects include increased energetic stresses (Bélanger and Bédard 1990), changes in activity budgets (Steidl and Anthony 2000; Mann et al. 2002; Swarthout and Steidl 2001, 2003), displacement from preferred environments (McGarigal et al. 1991), and reduced productivity through abandonment and decreased survival of young (Tremblay and Ellison 1979; White and Thurow 1985).

Although there are human activities that cause physical changes to park environments, such as construction of building and roads, or vegetation destruction resulting from overuse of particular areas, most wildlife-related impacts away from these areas likely result from short-term recreational pursuits of visitors. We focus the remainder of our discussion on these types of activities.

Types of studies

Given the wide range of potential information needs and study objectives, we distinguish between two fundamentally different kinds of studies: research and monitoring. These can be classified primarily based on their different objectives and secondarily based on different durations. *Research studies* include an objective related to answering specific questions and are usually of relatively short duration (1–3 years). An example would be a study conceived to assess the distance at which a population of birds flushes in response to a particular visitor activity, such as hiking or mountain biking (e.g., Swarthout and Steidl 2001). The goal for this type of study might be to reliably establish the distance at which birds flush in response to the activity so that the activity can be restricted in particular areas to reduce disturbance frequency and minimize adverse effects. In contrast, *monitoring studies* involve quantifying changes in characteristics of resources over time, are usually not driven by particular questions, and are always intended to be undertaken over long-time periods (Steidl 2001). The goal for monitoring studies is almost always related to quantifying changes in characteristics of resources over time. A third kind of study, which we only mention here, is a hybrid between research and monitoring studies. *Impact assessment studies* are designed to measure the effects of a planned activity or action within the context of a previously established monitoring program. These are often large-scale studies where the fundamental approach is to establish a monitoring program based on a series of sampling sites, a subset of which is eventually subject to being affected by the impact. The effect of the impact is estimated by comparing how sites subject to the impact change relative to control or reference sites over time (Green 1979). The application of these studies is useful to natural resource managers interested in assessing the effects of management actions, such as opening or closing particular trails or other facilities, especially when replication of the impact is impossible.

All types of studies benefit from careful application of the basic tools of research design, which include randomization, replication, reduction of error, incorporation of adequate controls, and understanding how the scope of inference for any study is dictated in part by the way study units are selected (Ramsey and Shafer 2001).

Research studies. Specific resource management questions about human–wildlife interactions are best answered through well-designed research studies, either experimental or observational. Questions that can be answered experimentally, which always involves some type of manipulation by the investigators, are more powerful than observational studies because they provide strong evidence of a causal link between the activity and the response measure. Observational studies cannot establish cause-and-effect inferences because of the potential for confounding by additional factors that may have influenced the response measure. Observational studies, therefore, provide only correlative inferences, yet can offer strong evidence when designed carefully. There is a vast literature on conceiving and designing effective research studies on wildlife populations (e.g., Morrison et al. 2001).

Monitoring. Ecological monitoring studies almost always focus on quantifying changes in characteristics of resources over time. Consequently, monitoring studies are correlative and can therefore quantify patterns and associations but cannot establish causal links between changes in the resource of interest and changes in levels of human activity or other environmental characteristics. For example, if we observe a decline in abundance of a species in an area over time concurrent with an increase in a particular type of human activity, we cannot claim that the increase in human activity caused the decrease in abundance. Despite their limited inference relative to randomized experiments, monitoring studies can still provide information that is valuable for understanding and reducing human–wildlife conflicts (Burger et al. 2004) especially when designed as part of an integrated monitoring program that encompasses a range of biotic and abiotic resources. Specifically, by measuring other environmental characteristics that are thought to affect changes in the wildlife response measure of interest (e.g., vegetation structure, food resources, rainfall), the ability to detect temporal and spatial changes in the resource is increased and the likelihood that the observed change was driven by a confounding variable is reduced. Lastly, the information provided by monitoring studies can be increased if they are designed to be comparative—that is, designed to contrast wildlife responses in areas of concern or impact with those in control or reference areas (e.g., Romero and Wikelski 2002).

Monitoring visitor impacts on wildlife is different than most observational studies because changes in parameters of interest are designed to be measured for long time periods, usually spanning multiple generations. Therefore, well-designed monitoring programs should provide sufficient temporal and spatial coverage as well as the flexibility to address a range of potential impacts, the nature and extent of which may be unknown when the program is being designed.

Choosing an appropriate wildlife response measure

Understanding both the short- and long-term consequences of interactions between humans and wildlife requires that a response measure be chosen that reflects the temporal and spatial scales appropriate to the human activity being assessed (Table 1). Many attempts to understand the effects of human activities on wildlife have focused on measures that are most appropriate for long-term assessment (i.e., 5–10 years or more) such as abundance (e.g., Mathisen 1968; Fraser et al. 1985; Westmoreland and Best 1985), reproductive success (e.g., Fernandez-Juricic 2000), and species diversity (e.g., Francl and Schnell 2002). Although these are clearly important measures, they are not appropriate for assessing all types of human activities because changes in behavior and space use are often overlooked, both of which can have long-term consequences for populations (Holthuijzen 1989; Anthony et al. 1995; Gill et al. 2001). Changes in behavior are consequential because they can ultimately affect reproductive success, survival, and habitat occupancy, which in turn can reduce population viability, especially for rare, threatened, or endangered species. Response measures that include aspects of behavior, such as activity budgets or space use, are most appropriate for short-duration human activities such as hiking.

As a general guideline, wildlife response measures should reflect the temporal and spatial scales of the human activity of interest, including the type of activity, its daily and seasonal timing, duration, and frequency, especially during initial investigations. The choice of the species or population to study is also critical, because species vary widely in their responses to human activities as do different populations of the

Table 1. Potential response measures for assessing effects of human activity on wildlife and wildlife populations.

Appropriate study period	Measure
Short-term	Physiological responses — heart rate, stress hormones
	Behavior and activity budgets
	Space and habitat-use
Long-term	Reproductive success and productivity
	Survival or mortality rates
	Abundance or density
	Distribution or occupancy rates
	Species richness
	Species diversity

same species, which can depend on their previous exposure to the human activity of interest. Assuming the choice of species and populations has been made or was mandated by legislation, the response measure should match the disturbance context, which is defined, in part, by the time scale of the human activity of interest. For most research studies, short-term responses seem most appropriate, whereas for most monitoring studies, long-term responses seem most appropriate (Table 1).

Effects of human activities on bald eagles *(Haliaeetus leucocephalus)* have been relatively well studied, so we'll use this species to illustrate the importance of choosing appropriate response measures. Many research studies have used reproductive success as the response measure and have reported no relationship between the level of human activity and reproductive success (e.g., Mathisen 1968; Fraser et al. 1985). In some cases, these negative results may reflect two fundamental problems: a disconnection between the scale of human activity being studied and the response measured (a short-term study and a long-term response measure) and a likely potential problem assessing impacts that have been in place for years.

With regard to the disconnection between the scale of the human activity and the response measure, the nesting season for bald eagles is long (>120 days), so short-term activities are unlikely to effect reproduction unless the activity is very intense. In most studies where bald eagles were disturbed by researchers approaching nests, the activities were of short duration (usually less than an hour) relative to the nesting period (Grier 1969; Fraser et al. 1985). Once a pair has made the decision to breed and has invested energy into producing offspring, they are more difficult to displace with such short-duration impacts relative to a pair that has not yet nested or to individuals that are not breeding (Trivers 1974). This investment may explain why some species abandon nesting sites the year after, rather than the year of, a short but intense disturbance near the nest (Platt 1977).

Populations that have long been exposed to a particular human activity may have already responded to the activity or may have become habituated. Because many studies are initiated well after the human activity was established, a conclusion of "no effect" may be misleading because consequential effects may have already occurred. For example, changes in distribution of bald eagle territories away from a new source of human activity did not occur until several years after the activity was established (Gerrard et al. 1992). If the eagles that are most sensitive to human activities abandon their nests after the level of human activity exceeds some threshold level but before a study is initiated, the chances of observing any residual effects would be low. These "time lags" may obscure changes in site occupancy unless viewed on longer time scales (Wiens 1986). And although the conclusion of no effect is likely appropriate for the specific locations where these data were collected, applying management recommendations to other areas based on information gleaned from these kinds of biased samples could have adverse consequences. Without thinking carefully about the contextual issue of previous exposure, activities affecting wildlife may be classified incorrectly or inappropriate management recommendations made.

Planning monitoring studies that include human–wildlife issues

Monitoring studies that include an objective to assess changes in wildlife populations in response to changes in visitor activities will need to quantify human activities carefully. Sampling should be designed to capture the amount, types, and intensity of the human activity as well as how the activity varies spatially and temporally (Gregoire and Buhyoff 1999; Watson et al. 2000). Carefully quantifying these elements will increase the ability to relate trends in the resource with changes in levels and types of human activity. As we mentioned previously, monitoring changes in wildlife populations is more efficient when integrated into a broader program that includes measuring additional biotic and abiotic parameters, especially those that might be directly affected by human activities of particular interest.

There are a number of tools for designing studies that can be used to increase the success of a monitoring program while balancing the interrelationships and trade-offs among sampling effort, cost, and the overall ability of the program to detect trends in resources (e.g., www.pwrc.usgs.gov/monmanual/). In general, sampling designs that include elements to reduce sampling variability, such as stratified or cluster sampling, tend to be more efficient than those that do not account for heterogeneity of the response measure across the study area (Thompson 2002). Power analysis can guide some of the more challenging design questions, such as how many samples are necessary to meet study objectives, how large a trend is likely to be detected with a given amount of sampling effort, and what the probability of detecting a particular trend that is considered biologically meaningful might be (Gerrodette 1987; Steidl and Thomas 2001).

Monitoring changes in natural resources requires a detailed statement of goals and a careful choice of parameters to measure. To link monitoring to management, a threshold in the response measure should be identified such that when the threshold is reached, managers are alerted that resource levels have reached an unacceptable level and some sort of action needs to be taken. A tight integration between monitoring and management is critical, as monitoring programs often fail because they were established without involvement of managers (Noon 2003). Those programs that are linked clearly to management objectives and are designed to provide regular updates on the status and trends of natural resources and human activities will be most useful and therefore will have the highest chances of persisting over the long term.

References

Anthony, R.G., R.J. Steidl, and K. McGarigal. 1995. Recreation and bald eagles in the Pacific Northwest. In *Wildlife and Recreationists: Coexistence through Management and Research*. R.L. Knight and K.J. Gutzwiller, eds. Washington, D.C.: Island Press, 223–242.

Bélanger, L., and J. Bédard. 1990. Energetic cost of man-induced disturbance to staging snow geese. *Journal of Wildlife Management* 54, 36–41.

Blair, R.B. 1996. Land-use and avian species diversity along an urban gradient. *Ecological Applications* 6, 506–519.

Boyle, S.A., and F.B. Sampson. 1985. Effects of nonconsumptive outdoor recreation on wildlife: A review. *Wildlife Society Bulletin* 13, 110–116.

Burger, J. 1981. The effect of human activity on birds at a coastal bay. *Biological Conservation* 21, 231–241.

Burger, J., C. Jeitner, K. Clark, and L.J. Niles. 2004. The effects of human activities on migrant shorebirds: successful adaptive management. *Environmental Conservation* 31, 283–288.

Chapin, F.S. III, E.S. Zaveleta, V.T. Eviner, R.L. Naylor, P.T. Vitousek, H.L. Reynolds, D.U. Hooper, S. Lavorel, O.E. Sala, S.E. Hobbie, M.C. Mack, and S. Diaz. 2000. Consequences of changing biodiversity. *Nature* 405, 234–242.

Fernandez, C., and P. Azkona. 1993. Human disturbance affects parental car of marsh harriers and nutritional status of nestlings. *Journal of Wildlife Management* 57, 602–608.

Fernandez-Juricic, E. 2000. Local and regional effects of pedestrians on forest birds in a fragmented landscape. *Condor* 102, 247–255.

Francl, K.E., and G.D. Schnell. 2002. Relationships of human disturbance, bird communities, and plant communities along the land-water interface of a large reservoir. *Environmental Monitoring and Assessment* 73, 67–93.

Fraser, J.D., L.D. Frenzel, and J.E. Mathisen. 1985. The impact of human activities on breeding bald eagles in north-central Minnesota. *Journal of Wildlife Management* 49, 585–592.

Gerrard, J.M., P.N. Gerrard, P.N. Gerrard, G.R. Bortolotti, and E.H. Dzus. 1992. A 24-year study of bald eagles on Besnard Lake, Saskatchewan. *Journal of Raptor Research* 26, 159–166.

Gerrodette, T. 1987. A power analysis for detecting trends. *Ecology* 68, 1364–1372.

Gill, J.A., K. Norris, and W.J. Sutherland. 2001. Why behavioural responses may not reflect the population consequences of human disturbance. *Biological Conservation* 97, 265–268.

Grier, J.W. 1969. Bald eagle behavior and productivity responses to climbing to nests. *Journal of Wildlife Management* 33, 961–966.

Gregoire, T.G., and G.J. Buhyoff. 1999. *Sampling and Estimating Recreational Use.* General Technical Report PNW-GTR-456. Portland, Ore.: U.S. Department of Agriculture–Forest Service, Pacific Northwest Research Station.

Green, R.H. 1979. *Sampling Design and Statistical Methods for Environmental Biologists*. New York: Wiley.

Henson, P., and T.A. Grant. 1991. The effects of human disturbance on trumpeter swan breeding behavior. *Wildlife Society Bulletin* 19, 248–257.

Holmes, T.L., R.L. Knight, L. Stegall, and G.R. Craig. 1994. Responses of wintering grassland raptors to human disturbance. *Wildlife Society Bulletin* 21, 461–468.

Holthuijzen, A.M.A. 1989. *Behavior and Productivity of Nesting Prairie Falcons in Relation to Construction Activities at Swan Falls Dam*. Boise: Idaho Power Co.

Johnson, C.J., M.S. Boyce, R.L. Case, H.D. Cliff, R.J. Gau, A. Gunn, and R. Mulders. 2005. Cumulative effects of human developments on arctic wildlife. *Wildlife Monographs* 160.

Lichstein, J.W., T.R. Simons, and K.E. Franzreb. 2002. Landscape effects on breeding songbird abundance in managed forests. *Ecological Applications* 12, 836–857.

Mann, S.L., R.J. Steidl, and V.M. Dalton. 2002. Effects of cave tours on breeding cave myotis. *Journal of Wildlife Management* 66, 618–624.

Mathisen, J. E. 1968. Effects of human disturbance on nesting of bald eagles. *Journal of Wildlife Management* 32, 1–6.

McGarigal, K., R.G. Anthony, and F.B. Isaacs. 1991. Interactions of human and bald eagles on the Columbia River estuary. *Wildlife Monographs* 115.

Morrison, M.L., W.M. Block, M.D. Strickland, and W.L. Kendall. 2001. *Wildlife Study Design*. New York: Springer-Verlag.

Noon, B.R. 2003. Conceptual issues in monitoring ecological resources. In *Monitoring Ecosystems: Interdisciplinary Approaches for Evaluating Ecoregional Initiatives*. D.E. Busch and J.C. Trexler, eds. Washington, D.C.: Island Press, 27–72.

Pimm, S.L., G.J. Russell, J.L. Gittleman, and T.M. Brooks. 1995. The future of biodiversity. *Science* 269, 347–350.

Platt, J.B. 1977. The breeding behavior of wild and captive gyrfalcons in relation to their environment and human disturbance. Ph.D. dissertation, Cornell University, Ithaca, New York.

Ramsey, F.L. and D.W. Schafer. 2001. *The Statistical Sleuth: A Course in Methods of Data Analysis*. 2nd ed. Pacific Grove, Calif.: Duxbury Press.

Romero, L.M., and M. Wikelski. 2002. Exposure to tourism reduces stress-induced corticosterone levels in Galápagos marine iguanas. *Biological Conservation* 108, 371–374.

Spies, R.B., S.D. Rice, D.A. Wolfe, and B.A. Wright. 1996. The effects of the *Exxon Valdez* oil spill on the Alaskan coastal environment. *American Fisheries Society Symposium* 18, 1–16.

Steidl, R.J. 2001. Practical and statistical considerations for designing population monitoring programs. In *Wildlife, Land and People: Priorities for the 21st Century*. R. Field, R.J. Warren, H. Okarma, and P.R. Sievert, eds. Proceedings of the Second International Wildlife Management Congress. Bethesda, Md.: The Wildlife Society, 284–288.

Steidl, R.J., and R.G. Anthony. 1996. Responses of bald eagles to human activity during the summer in interior Alaska. *Ecological Applications* 6, 482–491.

———. 2000. Experimental effects of human activity on breeding bald eagles. *Ecological Applications* 10, 258–268.

Steidl, R.J., and L. Thomas. 2001. Power analysis and experimental design. In *Design and Analysis of Ecological Experiments*. 2nd ed. S. Scheiner and J. Gurevitch, eds. Oxford, U.K.: Oxford University Press, 14–36.

Swarthout, E., and R.J. Steidl. 2001. Flush responses of Mexican spotted owls to recreationists. *Journal of Wildlife Management* 65, 312–317.

———. 2003. Experimental effects of hiking on Mexican spotted owls. *Conservation Biology* 17, 307–315.

Thompson, S.K. 2002. *Sampling*. 2nd ed. New York: Wiley.

Tremblay, J., and L.N. Ellison. 1979. Effects of human disturbance on breeding of black-crowned night herons. *Auk* 96, 364–369.

Trivers, R.L. 1972. Parental investment and sexual selection. In *Sexual Selection and the*

Descent of Man, 1871–1971. B. Campbell, ed. Chicago: Aldine, 136–179.

Watson, A.E., D.N. Cole, D.L. Turner, and P.S. Reynolds. 2000. *Wilderness Recreation Use Estimation: A Handbook of Methods and Systems.* General Technical Report RMRS-GTR-56. Ogden, Utah: U.S. Department of Agriculture–Forest Service, Rocky Mountain Research Station.

Westmoreland, D., and L.B. Best. 1985. The effect of disturbance on mourning dove nesting success. *Auk* 102, 774–780.

Weins, J.A. 1986. Spatial scale and temporal variation in studies of shrubsteppe birds. In *Community Ecology*. J. Diamond and T. J. Case, eds. New York: Harper and Row, 154–172.

White, C.M., and T.L. Thurow. 1985. Reproduction of ferruginous hawks exposed to controlled disturbance. *Condor* 87, 14–22.

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