Planning Trails for People and Wildlife – Literature Review

Compiled by New Hampshire Fish and Game Department, November 2017

Summary

NH Fish and Game staff reviewed 67 articles, published studies, regulations, handbooks, or BMP manuals (not restricted to peer-reviewed journals).

Recreational trails have three levels of impact on wildlife:

- Collision (direct injury/mortality)
- Stress from disturbance
- Alteration of habitat

Wildlife responses are short in duration but can have long term effects, such as breeding birds being flushed from nests leaving eggs or chicks vulnerable to predation. Response is also species dependent and not correlated with conservation status (Rodríguez-Prieto 2014). Behavioral response can be observed and measured. The "alert" distance, when animal first becomes aware of human presence, is greater than the "flight" distance, when animal is disturbed and moves from its position. However, physiological response can occur at lower level of disturbance than behavioral response (Snetsinger 2009). Physiological responses include increased heart rate, and increased levels of stress hormones. With repeated disturbance these responses can impact health of the individual, survivorship from decreased foraging, and lower reproductive success.

Trail type should also be considered. While hiking trails are not perceived (by marten) as edge habitat given their narrow width, snowmobiles using high elevation roads will compact snow, resulting in increased access to competing carnivores (Sirén 2017). Trail type also reflects differences in the speed of the recreational activity. Larson et al (2016) conclude that non-motorized activities show more evidence for negative effects than motorized. Spahr (1990) found that eagles, for example, are more likely to flush when observers move slowly or stop to view or photograph the bird. Studies comparing hiking and mountain biking found these two activities are not significantly different in their impact on wildlife (Thurston & Reader 2001; Taylor & Knight 2003). However, motorized and mountain biking activities cover larger spatial extents in the same amount of time, and incur an increased risk of direct mortality or injury. Mountain bike activity in particular has potential to rapidly approach animals without being detected (Quinn & Chernoff, 2010). Bear-human interactions, for example, are disproportionately higher with bikers due to speed, travel more quietly, and bikers pay closer attention to tread than hikers (Herrero & Herrero 2000). Cow moose are protective during spring, a bull moose can be unpredictable in fall; and moose in general have been known to follow trails. To avoid this potential conflict, Steinholz & Vachowski (2007) recommend trail design that avoids abrupt curves and maintains a 75-100ft line of sight.

Humans are perceived as greater risk than coyotes, and that perception increased with presence of dog (Parsons 2016). Dogs not properly vaccinated also risk transmission of rabies, distemper, and parasites (Olliff 1999). Regardless of humans accompanied by a dog, or without a dog, wildlife reacted most strongly to off-trail recreation (Taylor & Knight 2003). Most studies concluded that wildlife can acclimate to recreation along designated trails, as human presence occurs in a predictable location.

Larson et al (2016) and Marzano & Dandy (2012) provide management recommendations:

- Spatial restrictions = trail-free areas; buffer zones (min. approach distances to animals)
- Visitor education
- Cap visitation = visitor frequency and trail use important factors (Rodríguez-Prieto)
- Temporal restrictions = limit activity at critical times - nesting, fledging
- Rule change = prohibit feeding
- Physical improvements = restore habitat; fencing; veg. screening; designated viewing
- Enforcement = leash laws
- Staff training = recognize signs of animal disturbance

Trail design may help minimize impact on wildlife and reduce maintenance requirements. The U.S. Forest Service recommends using Coweeta dips or rolling grade dips, in place of water bars; and to design trails that provide the experience trail users seek. This should help prevent recreationists improperly building informal trails in locations that negatively impact wildlife. Marion & Olive (2006) recognized that soil loss was greater on equestrian/ohrv trails than bike/hike trails, and suggested trails be located on side-hills. IMBA (2006) further defines five sustainable trail principles: half rule, 10% avg, max 15% grade, grade reversals, outslope
-from Designing and Building Sustainable Trails (IMBA 2006) http://www.imba.com

Ferguson et al (2017) concluded that local-scale covariates (the pattern of development on the landsape) are a stronger influence on wildlife populations than site-scale covariates. As development increases, with our growing human population, the amount of trail free habitat maintained will have most positive influence (Thompson 2015). Yet recreational trails are an important means of providing opportunities to discover and appreciate wildlife and natural resources. New trails, or relocations, can be designed to help maintain unfragmented habitat and not disrupt wildlife travel corridors. The NH Fish & Game Department, in consultation with state trail and wildlife experts, has developed a geospatial tool to help plan trails that minimize impacts to wildlife. Online URL: http://www.wildlife.state.nh.us/habitat/trails.html Nov. 2017.

Literature Review

Aust, M.W., Marion, J.L., and Kyle, K. 2005. Research for the Development of Best Management Practices to Minimize Horse Trail Impacts on the Hoosier National Forest. U.S. Forest Service Research Report, Virginia Tech, Dept. of Forestry.

The researchers surveyed existing trails to identify factors that could be manipulated by land managers to minimize horse trail impacts. Primary findings were to install additional water bars, relocate or close trails on steep slopes, and harden trail sections with gravel to eliminate muddiness. Horse trail grades should not exceed 15% maximum. Trail segments with direct slope alignments (0-22^{o}) should be rerouted/avoided. Consider temporary closures during wet season on non-graveled trails. Loamy soils have higher erodibility.

Bennett, V.J., Beard, M., Zollner, P.A., Fernández-Juricic, E., Westphal, L., & LeBlanc, C.L. 2009. Understanding Wildlife Responses to Human Disturbance through Simulation Modeling: A Management Tool. *Ecological Complexity* 6(2009): 113-134

Presents two case studies where a Simulation of Disturbance Activities (SODA) model was used to assess the impact of recreational activities and compare different proposed park designs. Yellow-headed blackbirds nesting and foraging near trails were disturbed, particularly within 10-15 meters of the marsh, but no nest failures. Female barbastelle bats were significantly disturbed but researchers were unable to establish a threshold value for identifying a zone of influence around the breeding colony site since response varied with visitor numbers. The greatest disturbance would be visitors with unrestricted movement.

Bennett, V.J., Zollner, P.A, Quinn, V.S. Simulating the implications of recreational disturbance on Karner blue butterflies at the Indiana Dunes National Lakeshore. Technical Report. IISEA Project: Implications of recreational Disturbance on the Karner Blue. Purdue University

Disturbance of female Karners decreased with increased habitat width from the trail. Within 20m oviposition concentrated furthest from trail. Habitat patches should extend min. 25 m from trail.

Blumstein, D.T., Anthony, L.L., Harcourt, R., and Ross, G. 2003. Testing a key assumption of wildlife buffer zones: is flight initiation distance a species-specific trait? *Biological Conservation* 110(1): 97-100

Tested flight initiation distances (FID) for shorebirds in Australia. Primary finding was that FID is species-specific, with great variability between species regardless of site charactersitics.

Borgmann, K.L. 2012. A Review of Human Disturbance Impacts on Waterbirds. Audubon California report for San Francisco Bay Joint Venture.

Reviewed 110 studies on disturbance to waterbirds by persons on foot and in boats. Flush distance may not indicate sensitivity, birds in good condition may be more likely to respond.

Chase, V., Deming, L., & Latawiec, F. 1997. Buffers for Wetlands and Surface Waters: A Guidebook for New Hampshire Municipalities. Audubon Society of New Hampshire.

Nearly one-third of New Hampshire's native wildlife depends on riparian habitat. Provides a table of buffer widths by species based on literature. Recommend a minimum 100-ft buffer, recognizing that many species require larger buffers.

Colescott, J.H. & Gillingham, M.P. 1998. Reaction of moose (Alces alces) to snowmobile traffic in the Greys River Valley, Wyoming. *Alces* 34(2):120–125.

Moose change behavior in response to snowmobiles: 150m foraging, 300m when bedding

Coppes, J. and Braunisch, V. 2013. Managing Visitors in Nature Areas: Where do they leave the trails? A Spatial Model. *Wildlife Biology* 19(1): 1-11

Researchers used winter recreation field data to predict where people leave marked trails and move into winter wildlife habitat. Study looked at impact to disturbance sensitive species: capercaillie and red deer. Increased canopy cover decreased the probability of people leaving the marked trails. Sign-posts or information panels may be solutions to reducing off-trail travel in areas sensitive to snow compaction or other disturbance.

DeGraaf, R.M., Yamasaki, M., Leak, W.B., & Lanier, J.W. 1992. New England Wildlife: Management of Forested Habitats. Gen. Tech. Rep. NE-144. U.S. Department of Agriculture, Forest Service, Northeast Forest Experiment Station.

Lists average home-range size (acres) in New England for wildlife species, by taxonomic class. Describes structural habitat needs and use of different forest size classes. Lists wetlands, seeps, gravel pits/bare ground, woods roads, slash piles as habitat important to several species. Over 90% of vertebrates in the northeast use riparian habitat, 40% preferred. Does not include recommended buffers, nor impacts of traveled roads.

Deluca, W.V. and King, D.I. 2014. Influence of Hiking Trails on Montane Birds. *Journal of Wildlife Management* 78(3): 494-502

Study looked at effect of hiking trails on five montane bird populations in the White Mountains, New Hampshire, while accounting for imperfect detection probabilities. Found that recent increases in hiking traffic are unlikely to have caused population declines, and nest survival of blackpoll warblers was not influenced by distance from trail.

Ewacha, M.V., Roth, J.D., Anderson, W.G., Brannen, D.C., & Dupont, D.L. 2017. Disturbance and Chronic Levels of Cortisol in Boreal Woodland Caribou. *Journal of Wildlife Management* 81(7):1266-1275

Study found cortisol concentrations, a measure of chronic stress, increased with decreasing home range size from disturbances (roads, transmission lines, development and logging). However the consequences of increased cortisol on survival are unknown.

Ferguson, P.F., Conroy, M.J., & Hepinstall-Cymerman, J. 2017. Assessing Conservation Lands for Forest Birds in an Exurban Landscape. *Journal of Wildlife Management* 81(7):1308-1321

Exurban development fragments wildlife habitat. Conducted an occupancy model for six forest-dwelling songbirds in North Carolina. Study found the black-throated blue warbler and wood thrush may need particular conservation attention. Results found that landscape and local scale covariates were stronger influence than site-scale covariates.

Fernández-Juricic, E., Jimenez, M.D. and Lucas, E. 2002. Factors affecting intra- and inter-specific variations in the difference between alert distances and flight distances for birds in forested habitats. *Canadian Journal of Zoology* 80(7): 1212-1220.

Measured buffer distances (difference between alert versus flee distances) for four ground-feeding bird species in forested habitats. Buffer distances increased with group size and temparture. Decreased with shrub cover (increased visual obstruction). Increased with tree height. Varied between species in grassland habitat. Larger species showed greater buffer distances.

Fernández-Juricic, E. 2005. Sensitivity of wildlife to spatial patterns of recreationist behavior: A critical assessment of minimum approaching distances and buffer areas for grassland birds. *Biological Conservation* 125(2): 225-235

Studied sensitivity of disturbance of five grassland birds in Argentina. Four showed greater flight initiation distance in response to direct approach by humans, compared to tangential direction of approach. Cautions that buffers calculated from direct approaches may not necessarily eliminate disturbance.

Ferrarini, A., Rossi, G., Parolo, G., & Ferloni, M. 2008. Planning low-impact tourist paths within a Site of Community Importance through the optimisation of biological and logistic criteria. *Biological Conservation* 141(2008): 1067-1077.

Chose biological and logistic constraints and factors and applied fuzzy-scoring to standardize and weight criteria. Applied least-cost modeling to resulting surface to plan tourist paths that minimize impact to habitats, plants and animal species.

Gaines, W.L., Singleton, P.H., & Ross, R.C. 2002. Assessing the Cumulative Effects of Linear Recreation Routes on Wildlife Habitats on the Okanogan and Wenatchee National Forests. Gen. Tech. Rep. PNW-GTR-XXX. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Conducted a literature review of 238 articles to document the effects of roads, motorized trails, and non-motorized trails and from that developed a GIS assessment process. Focal species were chosen to represent six groups: wide-ranging carnivores, ungulates, late-successional forest habitat species, riparian-associated species, waterfowl and colonial nesting birds, primary cavity excavators. Motorized trails: longer displacement, avoidance. Non-motorized trails: some species more sensitive. Snowmobile/groomed ski trails: trapping facilitated by access, compaction of subnivian sites used by small mammals, altered competitor/predator communities. Applied a GIS cumulative effects assessment by combining focal species models and estimating what proportion of each management unit was rated as a high level of human disturbance.

Hamilton, N. 1997. A partial literature review of the effects of various human activities on wildlife. Bureau of Land Management.

Moose temporarily displaced when skiers used trails, returned after activity stopped. Mule deer habituated to snowmobiles but not to persons on foot.

Hennings, L. 2010. Wildlife corridors and permeability - a literature review. Metro Sustainability Center, Portland, OR.

Suggests methods to map and improve connectivity for wildlife.

Hennings, L. 2016. The Impacts of Dogs on Wildlife and Water Quality: A Literature Review. Metro Parks and Nature

Found that people with dogs disturb wildlife more than people alone, causing spatial (birds) and temporal (bobcats) displacement. Deer were impacted within 100m of trails, small mammals within 50m. Negative effects increased when dogs and people venture off trails (perceived by wildlife as less predictable). Cites studies quantifying direct/indirect mortality by off-leash dogs.

Horizons Engineering, PLLC. 2007. Jericho Mountain State Park Riding Area Master Trail Development Plan. NH Division of Parks and Recreation, Bureau of Trails.

Plan covers proposed development of OHRV riding area in northern NH, on approx.. 7500 acres with 136 miles of trails and a peak carrying capacity of 670 ATVs. Project designed to meet coarse and fine filter criteria found in NH Statute 215-A, specifically Section 215-A:43. Interesting to note: on the proposed trail layout map not all first order streams were buffered, nor steep slopes identified.

IMBA. 2006. Designing and Building Sustainable Trails http://www.imba.com

Presentation at the 2006 IMBA Summit/World Mountain Bike Conference. Goals 1.) limit environmental impacts, 2.) minimum maintenance requirements, 3.) avoid user conflicts Build "Sustainable Contour Trails", surf the hillside. Five principles:

- The Half Rule (grade shouldn't exceed half the grade of the sideslope)
- 10% average guideline (avg grade should stay under 10%)
- Maximum sustainable grade (only exceed 15% on natural or built rock structures)
- Grade reversals = surf the hillside, avoid the fall line
- Outslope (bench-cut construction)

Kays, R., Parsons, A.W., Baker, M.C., Kalies, E.L., Forrester, T., Costello, R., Rota, C.T., Millspaugh, J.J., & McShea, W.J. 2017. Does hunting or hiking affect wildlife communities in protected areas? *Journal of Applied Ecology* 2017, 54, 242–252.

Evaluated the effect of managed hunting and recreation on 12 terrestrial wildlife species by employing a large citizen science camera trapping survey at 1947 sites stratified across different levels of human activities in 32 protected forests in the eastern USA. Three cameras per station placed on-trail, at 50m and 200m; moved every three weeks. Found that hunting and recreation had measureable affects but habitat/landscape covariates, especially the amount of large continuous forest and local housing density, were more important than recreation for affecting the distribution of most species.

Klein, M.L. 1993. Waterbird Behavioral Responses to Human Disturbance. *Wildlife Society Bulletin* 21:31-39.

Trials conducted at the J.N. "Ding" Darling NWR, Sanibel Island, FL comparing bird responses to visitors approaching in-vehicle, motorcycles/mopeds, bicycles, pedestrians along the main route through the refuge. Out-of-vehicle activity was more disruptive than vehicle traffic. Approaching birds on foot had greatest impact on alert/alarm/flight responses. Photographers were most likely to approach birds – recommended observation blinds to reduce disturbance.

Larson, C.L., Reed, S.E., Merenlender, A.M., & Crooks, K.R. 2016. Effects of Recreation on Animals Revealed as Widespread through a Global Systematic Review. PLoS ONE 11(12): e0167259

Analyzed 274 articles on the effects of recreation on animals, worldwide, by activity (all non-consumptive). Non-motorized activities had more evidence for a negative effect than motorized activities (1.2 times), however studies did not compare across multiple scales/distances. Snow-based activities had more disturbance (1.3 times). Provides (Fig. 4, Page 11) evidence for effect of recreation by taxonomic group. Found few articles for reptiles, amphibians, and insects.

Lomas, E., Larsen, K.W., & Bishop, C.A. 2015. Persistence of Northern Pacific Rattlesnakes masks impact of human disturbance on weight and body condition. *Anim. Conserv*. 18: 548–556.

10 meters rattlesnake. Consequences of animals occupying disturbed habitats, even when changes in behavior and density are not detected.

Maine Department of Inland Fisheries and Wildlife. 2012. Beginning with Habitat Manual, Appendix 12B. http://www.beginningwithhabitat.org

Includes table of recommended riparian management zones from ecological forestry-based initiatives, by stream order, water body size, wetlands, and vernal pools. Critical distance (no-cut) was 25 feet. Recommends guidelines for siting new roads with wildlife in mind <40 ft width with little/no verge clearance, and use road closures/or limit access (gates), to maintain unfragmented forest.

Marion, J.L. and Olive, N. 2006. Assessing and Understanding Trail Degradation: Results from Big South Fork National River and Recreational Area. USGS Patuxent Wildlife Research Center

Describes trail impact assessment and monitoring methods to identify factors contributing to erosion by horses and ORV/ATV use: trail design factors (trail topographic position, soil texture, grade and slope alignment angle), use-related factors (type and amount of use), and maintenance factors (water drainage). Trail width increased with decreasing slope alignment. Impacts to the trail resource have both ecological effects and social effects. Estimate 46,518 yd^3 or 4,651 dump trucks of soil loss for the entire trail system, 227 miles of single and multi-use primitive roads and trails. (20 dump trucks per mile of trail)

Marion, J.L. and Wimpey, J. 2007. Environmental Impacts of Mountain Biking: Science Review and Best Practices. International Mountain Bicycling Association.

Relevant to impacts to wildlife: avoid wetlands and riparian areas, discourage/or restrict access during sensitive times in breeding/wintering areas.

Marion, J.L. 2008. Guidance for Managing Informal Trails. http://www.americantrails.org

Descriptive Trail Condition Classes

Class 0: Trail barely distinguishable; no or minimal disturbance of vegetation and/or organic litter.
Class 1: Trail distinguishable; slight loss of vegetation cover and/or minimal disturbance of organic litter.
Class 2: Trail obvious; vegetation cover lost and/or organic litter pulverized in primary use areas.
Class 3: Vegetation cover lost, organic litter pulverized in the center of the tread, some bare soil exposed.
Class 4: Nearly complete loss of vegetation cover and organic litter within the tread, bare soil widespread.
Class 5: Soil erosion obvious, as indicated by exposed roots and rocks and/or gullying

Marzano, M. & Dandy, N. 2012. Recreational use of forests and disturbance of wildlife - a literature review. Forestry Commission Research Report, Edinburgh, Scotland

Study focused on review of 450 publications relative to wildlife and habitat disturbances from recreational activities in UK forests. Recommended categories of access restriction: buffer zones, time and site restrictions, and visual screens. Suggested a weak relationship between visitor education and actual behavior. Classified disturbance as Type 1 transient, Type 2 permanent, Type 3 consumptive but described considerable variation in this range, and each type can be direct or indirect.

MA DCR Massachusetts Department of Conservation and Recreation. 2014. Trails Guidelines and Best Practices Manual.

Different range of trail densities depending on parcel type (refuge vs state park). New trails should Avoid: sensitive ecological areas, riparian areas, public water supplies, steep slopes, unique or important geologic features, cultural or historic resources. Develop trails in already disturbed areas, consider multi-use. Maximum grade may vary 15% to 25%.
Document includes USFS Trail Design Parameters by recreation type.

Miller, S.G., Knight, R.L., & Miller, C.K. 1998. Influence of Recreational Trails on Breeding Bird Communities. *Ecological Applications*, Vol 8, issue 1, pp. 162-169

Study looked at impacts of recreational trails on breeding birds in forest and grassland habitat in an urban/suburban setting in Bolder County, CO. Bird abundance measured at 0, 50 and 100 meters from trails, compared with control transects. Generalist bird species more common near trails, specialist species less common. Nest predation was greater near trails, but brood parasitism was not influenced by trails. Zone of influence of trails appeared to be 75 meters.

Miller, S.G., Knight, R.L., & Miller, C.K. 2001. Wildlife Responses to Pedestrians and Dogs. *Wildlife Society Bulletin*, Vol. 29, No. 1, pp. 124-132

Measured responses of two grassland songbirds, one forest songbird, and mule deer to pedestrians, pedestrain with dog on-leash, and dog alone; both on and away from trails. Grassland birds were most influenced by the pedestrian and dog on-leash, than the dog-alone treatment. Response by American robins did not differ by treatement. Mule deer were more impacted by presence of dogs than pedestrians alone.

NH Fish and Game Department. 2005. GIS Procedures for the Coarse Filter Wildlife Habitat Analysis.

Established minimum unfragmented habitat block size classes and assigned point values based on published findings of species home range requirements.

Olliff, T., Legg, K., & Kaeding, B., editors. 1999. Effects of Winter Recreation on Wildlife of the Greater Yellowstrone Area: A Literature Review and Assessment. Report to the Greater Yellowstone Coordinating Committee. Yellowstone National Park, Wyoming.

- Lynx: snowmobiling occurs when animals are in poorer condition due to winter stress. Snowmobiling may be dispersed (not confined to roads); may occur at night when lynx are active; and may later distribution and abundance of snowshoe hare. Lynx may adapt behaviorally to repeated exposure to human activity that is predictable in time and space.
- Mid-sized carnivores: Access to remote areas may increase disturbance/harassment and direct/accidental mortality from trapping. Compaction of snowfields may increase mortality of small mammals. Fisher are more tolerant of human activity.
- Moose: energy cost when disturbed, especially when the source is unpredictable and in close proximity. Moose may travel groomed trails, increased disturbance/harassment.
- Subnivean fauna: Skiers may do more damage than snowmobiles due to greater footload. Restrict activity to trails.
- Bald eagles: Strong fidelity to breeding area and often specific nest. Nest Site ¼ mile radius no disturbance from first occupancy until 2 weeks after fledging. Primary Use Area within ½ mile habitat alterations should be carefully designed to ensure nesting/foraging habitat is not degraded. Recommend 1,300 feet buffer of critical roosts late October 15-April 15.

- Energetic costs of displacement: Vegetation is effective at absorbing sound. Sound levels of 45-60db are at point of animal toleration, reported in some snowmobile studies. Energy cost changes seasonally, as energy stores drop flight initiation distances shorten, must be able to increase food intake. Recommend escape breaks in snow berms. Trails in close proximity to ungulate wintering areas should be screened behind ridgelines or vegetative cover. Lower speed limits in winter ranges.
- Impacts of two-stroke engines on aquatic resources: even low levels of hydrocarbon pollution cause chromosomal damage, reduced growth and development, and reduced stamina. Trout spawning in early spring, exposing developing embryos.
- Habituated wildlife: ravens and crows habituate to human presence and benefit from it. Bears, coyotes, red foxes, martens, red squirrels, magpies and gray jays may also seek human food sources (trash along trail or at camp sites).

- Harassment by pets: Domestic pets may transmit diseases to wildlife. Canine distemper - aerosol transmission to canids and mustelids. Parvovirus killed 25 wolves. Transmission is only a problem in dogs not properly vaccinated.

Owen, D. 2005. Studying impacts of visitor use on the Appalachian Trail. http://www.americantrails.org

In 2000 surveyed AT hikers 79% stayed at huts, shelters, designated camp sites, 12% camped nearby shelters, 9% camped elsewhere – bootleg sites have most potential to cause significant damage to AT resource values. Kahdahl (1999, unpublished) documented 402 unauthorized bootleg camp sites along a 131 mile section of the AT in New Hampshire. Poor sanitation leads to direct and indirect water contamination.

Parsons, A.W. 2016. The ecological impact of humans and dogs on wildlife in protected areas in eastern North America. *Biological Conservation*, Vol. 203, November 2016, Pages 75-88

Citizen-science camera survey found most dogs were on-trail and 89% of off-trail dogs were accompanied by humans. Humans were perceived as greater risk than coyotes, which increased with presence of dog. Responsible management of dog behavior greatly reduced their impact.

Pelletier, S.K., Flatebo, G., and Foss, C.R. 1999. Land-Use Issues: Public Access and Roads. *Biodiversity in the Forests of Maine: Guidelines for Management.* University of Maine Cooperative Extension Bulletin #7147. Pp. 125-130.

Narrow trails that do not break the canopy have less affect. Three acres of forest are directly converted for every mile of 24-ft road with cleared right-of-way. Edge habitat benefits some species, while having negative effects (disturbance or predator pressure) on other species. Amphibians are susceptible during seasonal migrations. New trails near previously inaccessible shorelines and to remote ponds may increase disturbance, camping, fishing pressure, and accidental or intentional introduction of exotic fish. Gates or blocking not always successful in deterring access by motorized vehicles.

Quinn, M. & Chernoff, G. 2010. Mountain Biking: A Review of the Ecological Effects. A Literature Review for Parks Canada, Final Report, Miistakis Institute - University of Calgary.

A review of recreational ecology literature. Speed and silence are significant characteristic of the impact of mountain biking on wildlife (range of detectability). Animal may not detect until well within the flight response distance, and severe startle may prompt aggressive response (by wildlife and dogs). Research need: cumulative effects of human recreational activity in protected areas to identify thresholds for numbers, timing, type and distribution of use. Many environmental effects vary by regional geophysical traits – research may not be applicable.

Reed, S.E., & Merenlender, A.M. 2008. Quiet, Nonconsumptive Recreation Reduces Protected Area Effectiveness. *Conservation Letters* 1 (2008) 146–154

Paired comparisons of parks in northern California with and without recreation revealed a five-fold decline in density of native carnivores. Landscape characteristics similar between pairs. Bobcats in particular were detected more frequently in areas without recreation.

Reilly, M.L. 2017. Spatial and temporal response of wildlife to recreational activities in the San Francisco Bay ecoregion. *Biological Conservation*, Vol. 207, March 2017, Pages 117-126

Used camera traps to quantify habitat use and activity of wild mammals and human recreationists. Species habitat use more closely associated with environmental covariates, recreation had less influence.

Rodgers, J.A., & Smith, H.T. 1997. Buffer zone distances to protect foraging and loafing waterbirds from human disturbance in Florida. *Wildlife Society Bulletin* 1997, 25(1):139-145

Sixteen species of waterbirds in Florida exposed to human approach by: walking, ATV, automobile, boat. A 100-ft buffer would minimize most disturbance.

Rodríguez-Prieto, I., Bennett, V.J., Zollner, P.A., Mycroft, M., List, M., & Fernández-Juricic, E. 2014. Simulating the responses of forest bird species to multi-use recreational trails. *Landscape and Urban Planning* 127 (2014) 164–172

Non-consumptive recreation can promote wildlife preservation and add socio-economic value to protected areas; but can displace wildlife, influence breeding success and reduce survival. This study used a modeling simulation to compare effects of different trail designs and use rates on forest birds in Indiana. Birds experienced 3 to 17 times more disturbance in all trail designs. Highly species dependent, even among species of concern (not correlated with conservation status). Visitor frequency is an important factor, even on existing trails.

Rudd, B. & Bateman, H. 2015. Reptile use of trails in the Phoenix Mountain Parks. *Herpetological Review*, 2015, 46(1), 15–17

Lizards did not avoid, and some species may prefer, areas with trails. Lining trails with fallen trees to discourage people from leaving the trail may have contributed to habitat structure used.

Shriver, G., et al. 2005. Appalachian Trail Vital Signs. Technical Report NPS/NER/NRTR--2005/026, National Park Service

Visitor use includes the footpath itself, overnight use areas (designated and bootleg), and human waste management. Locations of migratory breeding birds, esp. those with declining population trends (BBS), should be buffered. Mountain birds may be residents or migrants. Bicknell's Thrush known to use forest edges adjacent to ski trails and other clearings; but destruction of habitat is greatest short-term threat.

Sirén, A.P.K., Pekins, P., Kilborn, J.R., Kanter, J.J., & Sutherland, C.S. 2017. Potential Influence of High-Elevation Wind Farms on Carnivore Mobility. *Journal of Wildlife Management*. 2017

Study counted marten, red fox, and coyote tracks along roads, snowmobile and hiking trails in northern New Hampshire. Compacted snow increased access for canids to high-elevation forest, which may increase competition for marten.

Smith-Castro, J.R. 2008. Impacts of Recreational Trails on Breeding Birds in Forested Urban Parks. Masters Thesis. Ohio State University

Determined extent to which trails affect nest predation on breeding birds in Ohio, even urban-adapted species (Northern Cardinal). No reproductive consequences to human disturbance.

Snetsinger, S. & White, K. 2009. Recreational Trail Impacts on Wildlife Species of Interest in Mount Spokane State Park. Pacific Biodiversity Institute, Winthrop, Washington.

Study assessed impacts of recreation (snowmobiling, hiking, biking, skiing, horseback riding) on carnivores, ungulates, the Western toad, and a butterfly species. For most species the effects of recreation were secondary compared to habitat loss or degradation. However recreational disturbance should be considered in cumulative impact.

1. Trapping, legal and illegal/poaching – particular risk with snowmobile and ORV trails
2. Stress/physiological response – heart rates and fecal glucocorticoid levels, chronic stress reduces individual fitness and susceptibility to illness
3. Breeding/rearing disturbance – even in species generally tolerant of humans
4. Displacement/avoidance (temporal or spatial) – most common response
5. Disease – transmitted from domestic dogs
6. Animal collection – uncommon but trails can increase vulnerability
7. Habitat fragmentation/edge effects – depends on width of trail
8. Predator/competitor increased accessibility – snowmobile trails in particular
9. Snag/coarse woody debris reduction – remove of hazard trees, firewood collection
10. Incidental mortality – direct collision or compaction of snow
11. Habituation – undesirable behaviors, poor nutrition

Observed behaviors: alert distance, flight initiation distance, and distance moved.
New trails should avoid separating mature closed-canopy forest in marten foraging habitat.
Flight response of ungulates greater toward human than dog; and greater off-trail than on.
Moose appear unalert because often can approach closer, but even a raised ear = alert
Moose response changes depending on individuals, season and situation
Trails should not separate bedding and feeding areas.
Snowmobiles seems to cause less response than humans on foot.
Early spring deer at lowest physical condition, animals may succumb to stress that would consider minor at other times of the year.
White-tailed deer variety of responses to snowmobiles from potential benefit to stress/avoidance.

Steckler, P., Glode, J., & Flanagan, S. 2016. Land Conservation Priorities for the Protection of Coastal Water Resources: A Supplement to The Land Conservation Plan for New Hampshire's Coastal Watersheds. The Nature Conservancy. Technical Report prepared for the NH Department of Environmental Services Coastal Program, Concord, NH.

A conservation plan to primarily address water quality, focused protection on natural or restorable riparian buffers. Relative to trails because reducing disturbance in these buffers helps remove polluntants. A 30-meter buffer (100ft) removes >80% of nitrogen and phosphorus and the majority >75% of sediment.

Steinholz, R.T. & Vachowski, B. 2007. Wetland Trail Design and Construction. 8E82A3 Trail Treatment for Wet Areas, U.S. Forest Service, Missoula, MT.

A trail designed and built in the dry season may be unsuitable during the wet season.
Cow moose protective during spring, a bull moose can be unpredictable in fall.
Moose have been known to follow trails – avoid abrupt curves/maintain 75-100ft line of sight.
If wetland is attraction – consider building an overlook.
Beavers may raise water level above the trail (maintenance and reconstruction).

Steven, R., Pickering, C., & Castley, J.G. 2011. A review of the impacts of nature based recreation on birds. *Journal of Environmental Management* 92, 2287-2294

A review of 69 papers on impact of recreation on birds, included only original research in peer-reviewed publications. Negative effects (88%), no effect-seven papers, one positive (corvids).
Stokowski, P.A., & LaPointe, C.B. 2000. Environmental and Social Effects of ATVs and ORVs: an Annotated Bibliography and Research Assessment. University of Vermont, School of Natural Resources

Paper briefly addresses impacts to wildlife. Negative correlation of number of white-tailed deer on trails and number of snowmobiles; and cite incidents in Canada of snowmobilers chasing wildlife. Populations and diversity of small mammals inversely related to level of ORV use; ORV trails may alter drainage patterns (bog environments); and snow compaction. Mean distance moved by radio-collared elk in Colorado was twice distance in response to ATVs compared with pedestrians.

Taylor, A.R., & Knight, R.L. 2003. Wildlife Responses to Recreation and Associated Visitor Perceptions. Ecological Applications, 13(4), 2003, pp. 951–963

Examined responses of bison, mule deer, and pronghorn antelope to hiking and mountain biking at Antelope Island State Park, Utah. The study reported a 70% probability of flushing from on-trail recreationists within 100 m from trails. Results indicated little difference in wildlife response to hikers vs. mountain bikers. Reacted most strongly to off-trail activity.

Thompson, B. 2015. Recreational Trails Reduce the Density of Ground-Dwelling Birds in Protected Areas. *Environmental Management* (2015) 55:1181–1190

Examined impacts of trails on forest-dwelling birds in Ontario, Canada. Species that nest or forage on the ground exhibited the greatest response to trails and were significantly positively influenced by the amount of trail-free refuge habitat. Little effect to birds that nest or forage in the canopy. Trail network was buffered by 15 meters (songbirds initiated flight). Trail density

did not impact breeding birds, more important to minimize the extent to which trails fragment habitat.

Trip, N.V. and Wiersma, Y.F. 2015. A Comparison of All-Terrain Vehicle (ATV) Trail Impacts on Boreal Habitats Across Scales. *Natural Areas Journal* 35(2): 266-278

This study looked at ATV trails in Newfoundland, Canada. Direct on-trail erosion and off-trail vegetation impacts differed in different habitat types. Dry forest was more resistant to on-trail erosion but less resistant to off-trail vegetation impacts, heath sites were the reverse. Bog sites had low resistance to both impacts.

Underhill, Town of, VT. 2011. Trail Handbook.

Includes table of recommended trail width, cleared width, maximum grade 15% (25% for short stretches), by trail type. Trails should follow the contour and use grade reversals. Avoid fall line. Vermont recommends 20-ft setback from adjoining private property, final siting will be the landowners decision. 100-ft riparian buffers protect water resources, provide bank stabilization. VT Greenways recommends 330-ft riparian buffer.

U.S. Forest Service. 2010. Final Environmental Impact Statement: Three Trails Off-Highway Vehicle Project and Forest Plan Amendments. U.S.F.S., Crescent Ranger District, Oregon.

Compared alternatives for a 143-mile OHRV/mixed use trail system. Increased disturbance from motorized recreation can alter migration patterns, affect hiding cover, residential development, and poaching. OHV travel off designated trails would not be permitted for any reason including big game retrieval during hunting season. No trail construction or maintenance within ¼ mile of raptor or heron nests during the breeding season, nor May 1- June 30 (deer/elk fawning/calving).

U.S. Forest Service. 2014. Final Environmental Impact Statement: Ochoco Summit Trail System Project, Environmental Consequences - Wildlife (Chapter 3). U.S. Forest Service.

Animals can become habituated to recreational activity when it is restrained to on-trail. Report states 200 meters as the road effect zone (disturbance associated with noise). Noise and disturbance impacts drop to the ambient level at 1-mile distance from motorized trails. Lists “special habitats”: springs, bogs, meadows, riparian woodlands, shrublands, rocky sites.

U.S. Forest Service. 2016. Tracy Ridge Shared Use Trails and Forest Plan Amendment Project Environmental Assessment. U.S. Forest Service, Bradford Ranger District, Pennsylvania.

Reviewed proposal to convert 12.5 miles of the 34-mile system from hiking-only to shared use open to hiking and bicycling.

Valliere, W. 2011. Literature Review for the Vermont Trail Collaborative: Summary of findings and annotated bibliography. Vermont Trail Collaborative, Green Mountain National Forest.

Reviewed current research related to trails on the Green Mtn National Forest. Ungulates show greater response to hiking than to motorized recreation (year-round). Snow compaction will impact survival and activity of small mammals, but studies of snowmobile impacts on wildlife in eastern U.S. are limited.

Wake County, CO. 2006. Design Guidelines. appendix to: Wake County Open Space Plan.

Recommend prescriptive riparian buffers varied by ecological features of the watershed (slope, soil, hydrology, vegetation, water quality, impervious surface). 100-ft buffer with flexibility for smaller buffers if the slope is less than 10 percent and water quality still protected.

Whiteman, J.P. & Buskirk, S.W. 2013. Footload influences wildlife use of compacted trails in the snow. *Wildlife Biology*, 19:156-164.

Footload of mammals positively influenced their following distance along compacted trails.