Conservation Design and Stewardship Guidelines for Local Land-Use Regulations

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Open space should be configured in one or very few large parcels to reduce negative edge effects from adjacent development.

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Executive summary

Our goal is to support and encourage land-use planners, decision makers and conservation scientists and practitioners to participate in local land-use policy by providing them with guidelines that translate their scientific knowledge into a planning and development decision-making context.

Sprawling development is a leading driver of habitat loss and fragmentation in the United States, Canada, and around the world. Private lands provide a disproportionate amount of high-quality habitat for wildlife species and ecosystem services that are essential for human well-being. Adjacent private properties in various stages of development may provide opportunities for species to meet multiple needs such as access to key habitats or connectivity from one area to another especially when situated near existing protected areas (Franklin et al. 2009). However, most local land-use zoning or codes lack scientific guidance based on conservation science for residential design, construction, or stewardship. In addition, many communities have limited capacity or resources to implement new planning tools and development incentives, in part due to historical segregation by socio-economic status and race coupled with a legacy of policies that have resulted in inequitable access to resources. Best-practices guidelines are needed to improve the outcomes of local land-use decisions in ways that meet conservation and social justice objectives.

To address these challenges, the Wildlife Conservation Society (WCS) and the Conservation Development Working Group at Colorado State University (CSU) convened a workshop of eight leading biological experts to generate science-based recommendations for how residential design, construction, and stewardship could be improved to protect wildlife habitats on private lands. We collaboratively identified six themes for which to recommend guidelines, compiled scientific evidence to support our choice of guidelines, and identified resources to support implementation of our recommendations:

◊ **Expert Consultation.** Consult biological expert(s), defined as professional biologists, ecologists, or conservation scientists, as well as experts on environmental justice and equitable land-use planning, for local land-use policy and during the design, construction, and stewardship phases of individual development projects.

◊ **Ecological Site Analysis**. Require an ecological site analysis to inventory and map ecological resources on a development property and to provide a baseline for long-term monitoring to ensure that conservation objectives are achieved.

◊ **Clustering**. Allow, encourage, or require clustering of housing in residential developments to enable the conservation of contiguous open space.

◊ **Open Space.** Establish standards for the amount, location, configuration, and stewardship of protected habitats or undeveloped land in residential developments. This should include consideration of the ability of wildlife to move across adjacent lands, i.e., permeability, including opportunities for enhancing wildlife movements and use of private lands as core habitat.

◊ **Sustainable Construction.** Minimize disturbances to ecological resources during the construction phase of development and having the plan to reduce impacts reviewed by a biological expert. .

◊ **Stewardship & Education.** Require a long-term plan for active stewardship of ecological resources and monitoring of conservation outcomes that engages and educates residents and other stakeholders.

We write this report for two audiences. First, we intend it as a resource for land-use planners and decision-makers seeking to modify local land-use ordinances and zoning codes in the U.S. context, or legislation and local bylaws in the Canadian context, where there is a need for science-based guidance

Subdivisions are built on lands important to wildlife. © Sarah Reed/WCS

about how to achieve conservation in residential developments. Second, we write to an audience of our peers—conservation scientists who are concerned about the effects of expanding residential development on wildlife and wildlife habitat and have valuable knowledge about biological communities and ecosystem functions to contribute. Our goal is to support and encourage these experts to participate in local land-use policy by providing them with guidelines that translate their scientific knowledge into a planning and development decision-making context. We expect that our work will encourage rigorous standards in local land-use zoning or codes, development incentives, state or province enabling legislation for local planning, and third-party development certification programs, as well as lead to improved land stewardship practices by developers and homeowners. By identifying and targeting the policies best equipped to sustain the lands and diverse communities where people live and work, we will achieve what Aldo Leopold (1938) called "the oldest task in human history: to live on a piece of land without spoiling it."

Introduction

"Take care of the land as if our lives and the lives of all of our relatives depend on it. Because they do." - Robin Wall Kimmerer

Private lands play a critical role in conservation, providing a disproportionate amount of high-quality habitat for wildlife species (Scott et al. 2001) and ecosystem services essential for human well-being (Kroeger & Casey 2007). One out of every four acres of private land in the U.S. (Brown et al. 2005) and nearly half of Canada peri-urban areas have been converted to housing development (Czekajlo et al 2021), with extraordinary consequences for nature and society. Structural changes to ecological communities are occurring (Glennon and Kretser 2021), specialist species are being replaced with human-adapted generalists (Glennon & Kretser 2013), human-wildlife conflicts are increasing (Kretser et al. 2008), and fragmented landscapes inhibit ecosystem processes (Haddad et al. 2015) and impede migrating species (Goad et al. 2014). Although sometimes referred to as 'matrix' lands or non-habitat, many private lands are now widely recognized as providing critical habitat. In the U.S., private lands are the most biologically productive and support the greatest number of wildlife species (Scott et al. 2001), and yet they are also the most threatened. In Canada, the southernmost parts of the provinces are home to the greatest diversity of species and ecosystems, whilst presenting the highest density of private lands and human population and being the most threatened by development (Boucher & Fontaine, 2010; CRRNT Estrie 2010; CRRNT Montérégie Est, 2010; Ying et al. 2010; Gratton et al. 2011).

Although private land conservation efforts have increased rapidly, the total area of developed land in the U.S.

Between 2001 and 2019, new development in the United States consumed an area over five times the size of Delaware.

remains 10 times that of privately-conserved lands (NRCS 2007), and private lands are being converted to residential and urban development at twice the rate that they are being protected (Chang 2010). Between 2001 and 2019, new development in the United States consumed an area over five times the size of Delaware (Levitt and Eng 2021). Funding for land conservation is inadequate to assemble an inclusive and ecologically viable network of conservation areas (Lerner et al. 2007), and existing protected areas are unlikely to accommodate shifts in species' ranges due to climate change (Hannah et al. 2007, Berteaux et al. 2014). Additionally, the acquisition of land for conservation has been historically fraught with injustices against vulnerable communities. The continued conversion of land to residential development and limited funding available for conservation make this a critical time to examine innovative policies and incentives for integrating biological science with land-use planning and development to facilitate wildlife benefits on private lands. This should include thinking about private protected lands and the role of the adjacent properties in the surrounding landscape in providing movement corridors to other protected areas and as well as core habitat. To consider all of these aspects, approaches should consider the best ways to engage private landowners along various gradients of development to participate in wildlife-friendly practices at multiple scales ranging from the yard to the landscape (Tallamy 2019); to do so effectively requires having the appropriate scientific guidance regarding conservation design and stewardship.

Most land-use codes lack scientific guidance on residential design, construction, or stewardship (Kretser and Reed 2012, Reed et al. 2014). In addition, many communities have limited capacity or resources to implement new planning tools and development incentives (Miller et al. 2009). Some urban and suburban ordinances and regulations focus on yard management for landscape sustainability (Larson et al. 2020), however these tools are useful only after a development has been built. Although model ordinances proposed by land-use planning and legal experts are important resources for communities seeking to incorporate conservation into their development codes or by-laws (e.g., Arendt 1996, McElfish 2004), they typically emphasize the design phase of development and are applicable to a broader set of community goals beyond biodiversity conservation (e.g., preservation of open space or agricultural lands). Although several guidebooks and reports communicate general aspects of ecology and conservation biology for planners and developers (e.g., Perlman & Milder 2005, Boucher & Fontaine 2010, Hostetler 2012), there is a need for model guidelines that are designed specifically for adoption or revision of local land-use regulations.

To address these challenges, the Wildlife Conservation Society (WCS) and the Conservation Development Working Group at Colorado State University (CSU) convened a workshop of eight leading biological experts to collaboratively generate science-based recommendations for how residential design and stewardship guidelines could be improved to protect wildlife habitat on private lands. The workshop's participants included scientists and planners from universities, natural resource management agencies, and non-profit organizations who have conducted research on the effects of residential development on biological communities and who have experience applying the results of their research in an applied land-use planning context. Participants represented a range of species and ecosystem expertise from across the U.S. to ensure that the report accounts for taxonomic diversity and context-specific considerations associated with implementing the recommendations in different regions.

As a group, we collaboratively identified six themes on which to focus the workshop: (1) *Expert Consultation;* (2) *Ecological Site Analysis;* (3) *Clustering;* (4) *Open Space;* (5) *Sustainable Construction;* and (6) *Stewardship & Education*. At the workshop, we held facilitated discussions to generate a proposed list of guidelines for each theme. We compiled scientific evidence to support our choice of guidelines, and we identified resources to support implementation of our recommendations. Since the workshop, we shared drafts of these recommendations with individuals who support communities in their land-use planning processes (Reed and Kretser 2017) and added several co-authors with expertise on land-use planning in Canada. We have worked together to expand the geographic scope and enhance the practical relevance of the guidelines presented in this report.

This report is organized around the six themes listed above, and each section contains:

- ◊ Overall recommendation(s) for each theme;
- ◊ A narrative explaining the background and providing supporting scientific evidence for the recommendations;
- ◊ A bulleted list of specific guidelines for adoption or revision of local land-use regulations; and
- ◊ Tables containing quantitative guidelines, examples, and other resources to support implementation of the recommendations.

The workshop's participants included scientists and planners from universities, natural resource management agencies, and non-profit organizations who have conducted research on the effects of residential development on biological communities and who have experience applying the results of their research in an applied land-use planning context.

There are two main audiences for this report. First, this report is intended as a resource for land-use planners and policy makers seeking to undertake comprehensive planning, modify local ordinances and land-use zoning, codes, regulations and by-laws, update state or province enabling legislation for local land-use planning or create third-party development certification programs; collectively we refer to these terms as local land-use policy. In particular, we are writing for an audience of local land-use planners—especially those planners who work in rural communities with abundant natural resources and expanding amenity-driven residential development (e.g., counties in the Rocky Mountains in the U.S. and Canada, towns in the Northern Forest of New York, Vermont, New Hampshire and Maine as well as southern Ontario and Quebec and parts of the Atlantic Provinces) but we note that all of the concepts apply in more suburban/peri-urban and urban environments. Rural areas are often the places most in need of new tools and strategies to balance conservation and development, but which lack financial capacity or technical resources to incorporate biological conservation into land-use planning in ways that are equitable and achieve conservation and social justice objectives (Miller et al. 2009). Our goal is to provide local planners with general guidelines and supporting scientific evidence that they can adapt and apply in their planning and development decisions. This report complements existing model ordinances with design and stewardship guidelines that are focused more specifically on functional protection and stewardship of biodiversity and natural resources over time.

Second, we write to an audience of our peers—conservation scientists who are concerned about the effects of expanding residential development on plants and animals, have valuable knowledge about ecological communities and ecosystem functions to contribute, and who are already or may wish to become involved in land-use planning or development processes in local communities. These include scientists and managers from state/provincial and federal natural resource agencies, universities, industry, and conservation organizations who play a variety of roles to influence local land-use policy, such as best-practices advisors, technical consultants, elected officials, municipal board members, expert witnesses, or local non-profit organization leaders. Our goal is to support and encourage these experts to participate in local land-use policy by providing them with guidelines that translate their scientific knowledge to a planning and development context.

We recognize that science will evolve, as will our understanding of the complex interactions between humans and wildlife as well as how we center justice and equity in the discussions of land-use policy and planning. We hope that future iterations of this report will be able to incorporate revisions and additional thematic sections. We additionally hope this report can be integrated with resources from more contextualized, regional workshops developing steps to address wildlife-friendly land-use in a particular site (e.g., Kretser & Reed 2017).

From our prior experience working with audiences of land-use planners, developers, and conservation organizations, we know there is a strong need for and willingness to use science-based guidance on how to achieve conservation and development goals across all landscapes and

Participants in the 2015 workshop collaboratively developed science-based recommendations for how residential design, construction, and stewardship. © USFS

especially in rural, under-resourced places. We expect that our work will encourage rigorous standards in state or province enabling legislation, local land-use codes or by-laws, development incentives, and third-party certification programs, as well as improved stewardship practices by developers and homeowners. Because land-use planning and policy are a function of local community governance, policy changes will take time. We recognize that many communities motivated by issues of development pressure also require capacity, as in an individual or organization, to support the integration of such concepts into land-use regulations and certification programs (Kretser et al. 2019). The positive influence on development patterns from such work may take from several years to a decade, as communities deliberate through democratic processes, negotiate elected official turnovers, and maintain a coalition of voters who will promote, accept, and implement these changes. That said, with increasing pressures on land and the recognition of the increasing impacts of climate change (e.g., water shortages, fires, floods, or other episodic events) such conservation design and stewardship policies will likely provide co-benefits to other climate- and water-friendly and disaster-prepared policies for communities grappling with uncertain futures. We advocate that governments and funding organizations consider opportunities to direct long-term support (3-10 years) for capacity at the most devolved level of land-use decision-making within Town, County, and Municipalities to adopt and implement these policy recommendations. It is at this local level of governance where decision-makers can respond to the specific equity and justice issues affecting communities and take actions that will ultimately lead to improved and durable conservation outcomes for private lands.

Conservation Design and Stewardship Guidelines

Expert Consultation

Consult biological expert(s), defined as professional biologists, ecologists, or conservation scientists, as well as experts on environmental justice and equitable land-use planning, for local land-use policy and during the design, construction, and stewardship phases of individual development projects.

Local land-use planning rarely incorporates the best available biodiversity data. For example, a survey of Natural Heritage Data (NHD) programs in the U.S. found that local government planners were ranked last among users of NHD data, whether for comprehensive planning or review of proposed projects (Cort 1996). This is likely due to weak standards for biodiversity protection, infrequent requirements for local plans to incorporate natural ecosystems, and inconsistent quality and availability of biodiversity data. Some local planning agencies devote little staff time to biodiversity conservation; although some states, provinces, and cities do have strong programs that could serve as models (e.g., Maine, British Columbia). Few jurisdictions have in-house biological experts (Miller et al. 2009), and many planning staff members report that they lack time or do not know where to find the biodiversity information they need (Davis et al. 2014). Furthermore, many agencies fail to assess how conservation decisions may affect communities historically marginalized or excluded from the planning process, including low-income communities and communities of color.

These gaps in expertise and biological information could be addressed by having planning departments consult with external biological experts as well as experts in environmental justice and housing equity during the public processes of comprehensive planning, land-use code updates (e.g., subdivision regulations, zoning ordinances, floodplain management regulations), and individual development project reviews (*Table 1*). A review of 11 western states and over 700 towns in 4 northeast states revealed few land-use regulations specifically require consultation with a biological expert in planning and development decisions (Reed et al. 2014; Kretser and Reed 2012). One possible solution is to develop linkages among academic conservation science programs, environmental justice programs, and municipalities through internships and graduate student research (e.g., Levesque et al. 2016). In one study, planners commented that such linkages, if employed regularly and consistently, would be welcomed in most jurisdictions (Stokes et al. 2010). Additionally, state, provincial, or federal agencies and non-governmental organizations (NGOs) can assist local governments with the mapping of natural resources, setting priorities for protection, and making land-use decisions (Underwood et al. 2011). These relationships could be strengthened by expanding requirements and opportunities for resource management agencies to provide technical guidance on wildlife conservation issues (Azerrad & Nilon 2006).

A review of 11 western states and over 700 towns in 4 northeast states revealed few land-use regulations specifically require consultation with a biological expert in planning and development decisions.

Ideally, when informing conservation policies at the community level, the consulting biological and environmental justice expert(s) should be independent of the development process. For example, an important factor that contributed to the success of the Sonoran Desert Conservation Plan was the creation of a scientific advisory team that was insulated from political and economic pressures (Hess et al. 2014). The City of Calgary has a thirteen-member public BiodiverCity Advisory Committee to provide review and advice regarding the application of biodiversity policies (City of Calgary 2022).

The conservation outcomes of planning and development decisions could also be improved by requiring planning agencies and developers to coordinate their activities with a regional conservation plan, where one exists. For example, in Quebec, Regional County Municipalities (RCMs) manage their territories by preparing a Regional Land-use and Development Plan; municipalities within that territory must then follow the "rule of conformity" with the Regional Plan when writing and implementing their own Urban Plan (MAMOT 2010, MAMH 2022). Owing to a 2017 provincial law protecting wetlands and aquatic habitats in Quebec, RCMs must write Regional Conservation Plan for Wetlands & Aquatic Habitats (including the identification of wetlands of high ecological value); municipalities then must take these ecosystems into consideration in their Urban Plan and enforce specific restrictions regarding new developments potentially affecting wetlands or aquatic habitats (MELCCFP 2022). In the Adirondack Park of Northern New York State, the Adirondack Park Agency provides an overall Land-Use and Development Plan which gives oversight to certain types of development within 110 towns. Any town wishing to adopt a local land-use plan must meet or exceed the regulations within the regional land-use plan (New York State 2022).

The conservation outcomes of planning and development decisions could also be improved by requiring planning agencies and developers to coordinate their activities with a regional conservation plan, where one exists.

Historically, many land-use mechanisms (e.g., zoning ordinances, deed restrictions, neighborhood covenants) have afforded whiter and wealthier neighborhoods with disproportionate environmental benefits while protecting them from environmental injustices at the expense people of color and low-income communities. If a community has identified disparities in access to nature or exposure to environmental disamenities, it is additionally important for planning decisions to close environmental equity gaps while addressing other issues such as affordable housing. For example, several large U.S. cities, including Baltimore, Minneapolis, and Seattle, have implemented budget equity analyses to assess their communities' capital investments in amenities such as public spaces and recreation by neighborhoods' racial and economic composition. These analyses encourage consistent and equitable distribution of public funding and opportunities among communities and ensure the greatest investments to sustain biodiversity are made in communities with proportionately fewer environmental amenities (Cashin 2021).

A broader-scale conservation strategy could provide the framework for planning at more local scales (Beatley 2000) and establish the landscape context for development decisions that typically occur at the site-level (Perlman 2007). Where possible, the data and tools used to integrate conservation planning with land-use planning should be simple and straightforward, given that planners are often required to balance biodiversity conservation with the potentially competing goals of housing, transportation, public services, and other local priorities (Underwood et al. 2011). Incorporating conservation planning information into planning and development decisions also requires

Houses in Conservation Developments often cost more than traditional development, raising issues of affordable housing and access to nature for many segments of society. © Heidi Kretser/WCS human interpretation and application (Stein 2007) and engaging with the broader community on values related to biodiversity conservation as well as justice, equity, and access to nature and affordable housing for all community residents. Conservation scientists could contribute to these objectives by educating planning staff and government officials, volunteering for their local planning boards, or consulting on development reviews (Broberg 2003).

Once conservation planning policies and strategies have been created, we recommend developers hire a biological consultant that can help integrate biodiversity conservation principles into all phases of development planning: site assessment and selection, early and final design, construction, post-construction, and monitoring. This role may include, but not be limited to, biological consultants who work as contractors for land developers to address environmental regulations. These biological consultants are not simply there to meet regulations but to explore unique solutions for a particular site, which may also include working with experts in environmental justice to balance equity issues facing the broader community related to how that particular development may affect affordable housing and access to nature. This is critical as each site is unique and planning documents cannot offer the best solutions given the various local site ecological and social conditions.

Guidelines

For conservation planning at the town, city, or county level:

◊ Involve biological experts who advise on the development or updating of comprehensive plans, regional conservation plans, natural heritage plans, comprehensive community plans, and land-use zoning, bylaws, or codes;

◊ Engage biological experts to advise at every stage of the process, including setting of goals and objectives, mapping and analysis of ecological resources, identification and evaluation of alternatives, creation of conservation policies and strategies, review of draft document, and implementation of plan or code;

◊ Ensure conservation policies and strategies address all phases of development, including ecological site analysis, design of protected lands, site preparation and construction, and stewardship and monitoring of protected and built areas; and

◊ Select consulting individuals or organizations who are independent of the development process.

◊ Ensure conservation outcomes are balanced with access, affordable housing and other equity issues by collaborating with experts in environmental justice.

Despite maintaining natural vegetation, the effects of development can extend up to 250m away from the house © Heidi Kretser/WCS

For individual development projects:

◊ Require consultation with biological experts in the ecological site analysis, design of protected lands, site preparation and construction, and stewardship and monitoring of nearby protected and built areas;

◊ Involve consulting individuals or agencies from the start of the project, beginning with site selection;

◊ Encourage consulting individuals to evaluate how ecological considerations of a development may influence equity and justice issues within the broader community.

◊ Require consulting individuals or agencies to conduct and/or review the ecological assessment (see *Ecological Site Analysis*) and participate in the site design process (see *Clustering and Open Space*);

◊ Instruct consulting individuals or agencies to advise the project's construction manager during site preparation and construction of buildings and infrastructure (see *Sustainable Construction*); and

◊ Ensure consulting individuals or agencies develop, implement, and/or review the plan for long-term monitoring and stewardship of the property (see *Stewardship & Education*).

Table 1. Examples of organizations, agencies, programs, and resources that could augment biological consultation on comprehensive planning, land-use code updates, development reviews, and consultation with developers. Not an exhaustive list

Biological Expert	Example	URL
University		
Cooperative Extension	National: Community Planning and Zoning – associated with Land Grant Universities	https://community-planning.extension.org/
	State: Michigan State University Extension Land Use Services	https://www.canr.msu.edu/land_use_education_servic
	Local: Cornell University Cooperative Extension, Dutchess County Rural and Community Development Program	http://ccedutchess.org/environment/natural-resources/land-use-planning
USGS Cooperative Fish and Wildlife Research Units		https://www1.usgs.gov/coopunits/
Research Groups	Colorado State University, Conservation Development Working Group	https://sustainability.colostate.edu/research/conservation-development-working-
	University of British Columbia, Biodiversity Research Center	https://biodiversity.ubc.ca/
	University of Florida: Program for Resource Efficient Communities	http://www.buildgreen.ufl.edu/about.htm
	University of Guelph, Biodiversity Institute of Ontario	https://biodiversity.uoguelph.ca/
	University of Montana Land Use & Resources Clinic	https://www.umt.edu/law/academics/clinics/
	University of Montréal, Biodiversity Centre	http://www.irbv.umontreal.ca/
	Utah State University Gateway and Natural Amenity Region Initiative	https://www.usu.edu/gnar/

Table 1—continued.

Biological Expert	Example	URL
Natural resource management agency		
Natural Resources Conservation Service		http://www.nrcs.usda.gov/
State Wildlife Agency	Western Association of Fish and Wildlife Agencies – Crucial Habitat Assessment Tool	http://www.wafwachat.org
	Maine Department of Inland Fisheries and Wildlife – Beginning with Habitat Program	http://www.beginningwithhabitat.org/
	Vermont Agency of Natural Resources – BioFinder Program	http://biofinder.vt.gov/
	New York State Department of Environmental Conservation, Hudson River Estuary Program – Conservation and Land Use Program	https://www.dec.ny.gov/lands/5094.html
	North Carolina Green Growth Toolbox	http://www.ncwildlife.org/Conserving/Programs/GreenGrowthToolbox.aspx
US Fish & Wildlife Service	North Atlantic Landscape Conservation Cooperative Conservation Planning Atlas	http://nalcc.databasin.org/
	Urban Bird Treaty	https://www.fws.gov/program/urban-bird-treaty
Environment and Climate Change Canada		https://www.ec.gc.ca
Ontario Nature	Greenway	https://ontarionature.org/programs/greenway/
	Best Practices Guide to Natural Heritage Systems Planning	https://ontarionature.org/campaigns/natural-heritage-systems-planning/

Table 1—continued.

Biological Expert	Example	URL
Conservation organization - US		
Land Trust Alliance		http://www.landtrustalliance.org/
NatureServe	Conservation Planning Services and Software	http://www.natureserve.org/conservation-tools/conservation-planning-services
The Nature Conservancy		http://www.tnc.org/
The Wildlife Society	Certified Wildlife Biologist Program	http://wildlife.org/learn/professional-development-certification/
Wildlife Conservation Society	Make Room for Wildlife – Resource for Local Planners and Communities	https://doi.org/10.19121/2020.Report.54950
	Make Room for Wildlife – Resource for Landowners	https://doi.org/10.19121/2020.Report.14061
Environmental Defense	Livable Communities	https://environmentaldefence.ca/campaign/livable-communities/

Table 1—continued.

Biological Expert	Example	URL
Conservation organization – Canada		
Appalachian Corridor	Cohabiter avec la nature!	http://www.corridorappalachien.ca/wp-content/uploads/2016/10/Cohabiter_avec_la_nature_WEB-ENG.pdf
Canada Parks and Wilderness Society - Yukon	Land Use Planning	https://cpawsyukon.org/land-use-planning/
Land Use Planning Hub	Alberta Land Use Planning Resources	https://landusehub.ca/
Nature-Action Québec		http://nature-action.qc.ca/site/service/PADD
Nature Conservancy Canada		http://www.natureconservancy.ca/en/
Nature Conservancy Canada, Appalachian Corridor, Nature-Action Québec and 7 other conservation organizations from Quebec	Tools box for local municipalities and Regional County Municipalities (RCMs) to implement land planning approaches that benefit ecological connectivity	https://connectiviteecologique.com/boite-a-outils
Stewardship Centre of BC	Green Shores program	https://stewardshipcentrebc.ca/

Table 1—continued.

Biological Expert	Example	URL
City Resources		
City of Austin, TX	Wildlife Austin	https://www.austintexas.gov/department/wildlife-austin
City of Coquitlam, BC	Guide to Best Site Development Practices	https://www.coquitlam.ca/DocumentCenter/View/317/Guide-to-Best-Site-Development-Practises-PDF?bidId=
City of Edmonton, AB	Wildlife Passage Engineering Design Guidelines	https://www.edmonton.ca/city_government/documents/WPEDG_FINAL_Aug_2010.pdf
City of Fort Collins, CO	Nature in the City	https://www.fcgov.com/natureinthecity/
Other		
Building for Birds		http://wec.ifas.ufl.edu/
HoloScene Wildlife Services	Wild Planner Tool	http://www.holoscenewild.com/tools-for-conservation-planning/
ICLEI Canada		http://www.icleicanada.org/programs/biodiversity
Urban Biodiversity Hub	BiodiverCities Methodology	http://ubhub.org
Salmon Safe	Salmon Safe Urban Standards	http://salmonsafe.org/
Sustainable Sites Initiative		http://www.sustainablesites.org/

Ecological Site Analysis

Require an ecological site analysis to inventory and map ecological resources on a development property and to provide a baseline for long-term monitoring to ensure that conservation objectives are achieved.

An ecological site analysis can provide the basis for the design and configuration of protected open space within a developed property (see Open Space) and also help to guide the location of housing clusters and associated infrastructure.

In the late 1960s, American urbanist William H. Whyte and Scottish landscape architect Ian McHarg first proposed the idea of using an ecological site analysis to guide the design of residential development. In his book, *The Last Landscape* (1968), Whyte argued that "planning should take its cue from the patterns of nature itself—the water table, the flood plains, the ridges, the woods, and above all, the streams." Methods for how to plan a development with consideration of the natural landscape appeared in McHarg's *Design with Nature* (1969). McHarg suggested a process of "ecological design," or an approach that first inventories the physical and biological features of a site and incorporates them into the design of the built environment.

An ecological site analysis can provide the basis for the design and configuration of protected open space within a developed property (see *Open Space*) and also help to guide the location of housing clusters and associated infrastructure (see *Clustering*). This process will ensure that protected open space successfully represents the native plants, wildlife, ecological communities, or other conservation targets of a region, separates sensitive biophysical resources from human disturbances that threaten their persistence, and contributes effectively to a network of reasonably connected protected lands in the surrounding landscape. In many cases, areas that historically have the least amount of human disturbance (e.g., forestry, agriculture, or urban uses) are the areas with the highest ecological value, and often it is best to redevelop areas already altered by buildings and roads or other human land uses. That said, improving the quality of the matrix of adjacent land cover that is often considered unsuitable for wildlife may be even more important than conserving isolated high quality patches as wildlife move about across the landscape (Prugh et al. 2008). Thus a component of the ecological site analysis needs to consider how the surrounding matrix on adjacent properties contributes to the overall ecological condition on the site.

The scientific literature on conservation planning provides useful guidelines for how to design protected areas, how to select a network of lands for protection based on locally-defined conservation objectives (e.g., imperiled species ranges or habitat connectivity), and how to maintain their persistence and ecological function over time (Margules & Pressey 2000). The first step of systematic conservation planning is to measure and map the locations of species, habitats, and communities. Conservation planners then

The habitat value of protected open space is reduced when it is fragmented by roads, fences, or other infrastructure. © Cooper Farr apply expert knowledge or quantitative assessments to rank or prioritize the relative ecological value of these biophysical resources and the quality of the matrix. Although rare (Knight et al. 2008), implementing a scientifically robust conservation plan in the context of a practical planning process can make vital contributions towards the successful protection of conservation targets (e.g., Arlettaz et al. 2010). Looking outside the boundary of an individual development project will assist the community with conserving large habitat patches, maintaining landscape connectivity, and understanding the relative importance of the site within the larger eco-regional context, now and into the future (Beier et al. 2015).

Guidelines

The ecological site analysis should:

◊ Be a collaborative process involving the developer, planner, biologists (see *Expert Consultation*), and other relevant local experts;

◊ Be initiated prior to the design of the developed area and continue in parallel with the design phase;

◊ Make use of local or regional databases of physical features, habitat elements, species occurrences, ecosystem processes, existing human infrastructure, nearby protected lands, matrix quality, and the general ecological and conservation context within which the development will occur (*Table 2*);

◊ Identify seasonal and year-round uses of the biophysical resources of the development property; and

◊ Make a spatially-explicit map and rank the most ecologically valuable areas of the property;

◊ Evaluate potential impacts of alternative design scenarios, in terms of both immediate and long-term impacts to biophysical resources.

In addition to the design and stewardship guidelines recommended above, requirements for ecological site analysis will be more effective when they specify methods for merging and ranking diverse biophysical resources.

Wildlife may use private lands with different levels of development as movement corridors.
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Although there are many possible approaches to conservation planning (e.g., expert ranking or qualitative assessment), the complex nature of most projects and the desire for accountability and transparency has encouraged the use of systematic conservation planning tools and approaches by governments and non-profit organizations around the world. A variety of decision-support software tools have been developed and evaluated for systematic conservation planning (Sarkar et al. 2006), and many of these are suitable for application to land-use planning and development decisions (Baldwin et al. 2014). Examples include Marxan (Ball et al. 2009), Miradi (2007) NatureServe Vista (Riordan and Barker 2003), Open Standards (http://www.conservationmeasures.org/CMP/), and new methods that incorporate consideration of habitat connectivity (Minor and Urban 2008). Use of a decision-support tool can help to ensure the transparency of prioritization decisions (e.g., weighting one species relative to another) and provide a quantitative basis for classifying areas based on their relative ecological value.

In many cases, conducting a detailed site analysis or using decision-support software may be infeasible for small development projects, and so guidelines for ecological site analysis should be adjusted for different scales of development (e.g., parcel size or number of lots).

Table 2. Elements of an ecological site analysis. Physical features, habitat elements, species occurrences, disturbance processes, existing human infrastructure, and nearby protected lands that should be included in the ecological site analysis and examples of database sources that provide information on these site and landscape resources. This list is not exhaustive.

Landscape Feature	Example of Source	URL
Biophysical features		
Geology	U.S. Geological Survey	http://mrdata.usgs.gov/geology/state/
Hydrography	National Hydrography Dataset	http://nhd.usgs.gov/
Soils	Web Soil Survey	http://websoilsurvey.sc.egov.usda.gov/
Topography	National Elevation Dataset	https://www.usgs.gov/3d-elevation-program
Geoscience	Natural Resources Canada	http://gdr.agg.nrcan.gc.ca/
Vegetation	LandFire	http://landfire.cr.usgs.gov/
Land cover	USGS Gap Analysis Project	https://www.usgs.gov/programs/gap-analysis-project
Climate	Climate Change Resource Center	http://fs.usda.gov/ccrc
	Climate Data Canada	https://climatedata.ca/
	Climate Change Knowledge Portal	https://climateknowledgeportal.worldbank.org/
	Climate Data Online	https://www.ncei.noaa.gov/cdo-web/
Species occurrences		
Bird observations	eBird	http://ebird.org/
Plant and animal locations	California Natural Diversity Database (CNDDB)	https://wildlife.ca.gov/Data/CNDDB
Plant and animal locations	National Species Dataseti	http://www.natureserve.org/conservation-tools/national-species-dataset
Plant and animal observations	Naturalist	https://www.inaturalist.org/

Table 2—continued.

Landscape Feature	Example of Source	URL
Disturbance processes		
Fire regime	LandFire	http://landfire.cr.usgs.gov/
Fire history	Monitoring Trends in Burn Severity	http://www.mtbs.gov/
Human infrastructure		
Land cover	Southwestern Regional Gap Analysis (SWReGAP)	https://swregap.org/
Roads	TIGER Line Shapefiles	https://www.census.gov/geo/maps-data/data/tiger-line.html
Protected lands		
Public protected lands	Protected Areas Database of the United States (PAD-US)	http://gapanalysis.usgs.gov/padus/
	California Protected Areas Database (CPAD)	http://www.calands.org/
	Colorado Ownership, Management & Protection (COMap)	https://comap.cnhp.colostate.edu/
	Canada's Conserved Areas	https://open.canada.ca/data/en/dataset/2888ff57-a21c-448c-a4fa-570c4cabd956
	Canadian Protected and Conserved Areas Database (CPCAD)	https://www.canada.ca/en/environment-climate-change/services/national-wildlife-areas/protected-conserved-areas-database.html
Private protected lands	National Conservation Easements Database (NCED)	http://conservationeasement.us/
	California Conservation Easement Database (CCED)	http://www.calands.org/
	Quebec's Directory of Conservation Sites on Private Land (Répertoire des sites de conservation volontaire du Québec)	www.lerepertoire.org

Table 2—continued.

Landscape Feature	Example of Source	URL
Composite datasets		
Canadian GIS data	Canadian GIS & Geomatics	https://canadiangis.com/data.php
Conservation planning atlas	North Atlantic Landscape Conservation Cooperative (NALCC)	http://nalcc.databasin.org
Geogratis	Canadian GIS including the National Topographic Dataset	http://www.geogratis.gc.ca/
Open Government Portal Canada		https://open.canada.ca/data/en/dataset?organization=nrcan-rncan
Quebec Geospatial Data		https://www.donneesquebec.ca/

Clustering

Allow, encourage, or require clustering of housing in residential developments.

Clustering is a common technique used to conserve land within residential subdivisions and minimize the negative ecological impacts of housing and associated infrastructure. In a cluster subdivision, homes are built on smaller lots and clustered together, allowing for the remainder of the property to be protected as open space (Natural Land Trusts 2001, Milder 2007, Pejchar et al. 2007). In theory, clustering homes should reduce the ecological impacts of residential development because the disturbance zones, or the area within which the wildlife community is affected, around individual homes would overlap and the total disturbance zone would be smaller (Theobald et al. 1997, Odell et al. 2003). However, few empirical studies have compared the ecological effects of clustered versus dispersed residential development, and the

Clustering houses in the least ecologically valuable areas of a property will increase the amount and connectivity of quality habitat for many species.© Cooper Farr results of those studies have been mixed. In alternative development scenarios in the northeastern U.S., clustered subdivisions were more effective at protecting threatened ecological resources than dispersed developments (Milder et al. 2008). In one Colorado study, clustered and dispersed housing developments did not differ in the composition of songbirds, mammals, or non-native plants (Lenth et al. 2006). However, in two other Colorado studies, avian and small mammal densities were higher in undeveloped areas farther away from housing development (Odell and Knight 2001), and sensitive birds and mammals were detected more frequently in conservation developments with a greater proportion or total area of protected open space (Farr et al. 2017). In Missouri, clustered housing developments supported fewer forest interior bird species than dispersed developments (Nilon et al. 1995). Working in Ottawa, Ontario and Gatineau, Quebec, Gagné and Fahrig (2010a and b) found that compact housing developments minimized impacts to bird and beetle fauna in comparison to dispersed housing.

These mixed results may be attributable to the design of cluster subdivisions (i.e., the size of the subdivision, area of protected open space, and configuration of lots and home sites within the subdivision) or to their landscape context (i.e., proximity to other protected or undeveloped lands). Poorly designed or located housing clusters can counteract the benefits of clustering. For example, if housing clusters are located near ecologically sensitive areas to facilitate views or resident access to open space (e.g., Gonzalez-Abraham et al. 2007), then disturbances associated with housing may negatively affect species in the open space. In addition, the quality of the protected open space is important; a clustered design may not adequately protect species if the open space is poor quality or fragmented (see *Ecological Site Analysis* and *Open Space*). The mixed results of research studies may also be attributable to disturbances associated with the human use and stewardship of the protected open space—for example, the presence of humans and domestic animals and maintenance or restoration of native plant species (Lenth et

Where possible, housing should be located at the edge of the property or near existing development.
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al. 2006; see *Open Space* and *Stewardship and Education*).

Although clustering homes holds promise for meeting conservation objectives, there are few examples of such developments that are designed to advance equity goals. In fact, cluster developments are often critiqued for being accessible primarily to wealthy residents; they tend to have higher home values relative to comparable homes in conventional developments (Hannum et al. 2012). However, cluster developments could be required to include affordable units or designed with the intention of making environmental benefits accessible to historically marginalized communities.

When clustering is done properly, it is a strategy that can reduce fragmentation and increase the amount and connectivity of quality habitat for many species. Clustering is one of the most common tools available for protecting native wildlife species and their habitats on private lands. Recent studies demonstrate that clustering and associated techniques (i.e., conservation development) have been adopted into local land-use regulations by 32% of counties in 11 western states (Reed et al. 2014) and guide development decisions in 51% of towns in four northeastern states (Reed & Kretser, unpublished data). Nearly all (96%) of these ordinances are intended to encourage but do not require clustering; they are commonly adopted alongside incentives (e.g., density bonus or streamlined review) to encourage use of the ordinance's voluntary clustering guidelines (Reed et al. 2014).

When clustering is done properly, it is a strategy that can reduce fragmentation and increase the amount and connectivity of quality habitat for many species.

Guidelines

- ◊ Locate clusters of housing and associated infrastructure on the least ecologically valuable areas of the property, including areas that were previously disturbed or altered (see *Ecological Site Analysis*);
- ◊ Locate clusters of housing at the edge of the property and near existing development on adjacent properties;
- ◊ Minimize the development footprint of housing clusters and associated infrastructure to keep the edge to area ratio of housing clusters to the smallest amount possible;
- ◊ Prohibit the use of "linear clusters";
- ◊ Within clusters, locate home sites close enough together such that their disturbance zones overlap;
- ◊ Limit the density of housing clusters if building near ecologically sensitive areas of the property is unavoidable; and
- ◊ Buffers should be established between housing clusters and adjacent open space.

In addition to the design guidelines recommended above, a clustering ordinance will be more effective when it specifies quantitative standards regarding the total area and density of housing clusters in relation to the size of the development property. Ideally, these quantitative standards would be based on the distance at which houses or roads negatively impact wildlife or natural resources (i.e., effect-distance or disturbance zone). *Table 3* summarizes distances reported in the scientific literature for effects of residential development on several groups of birds, mammals, and amphibians. In addition, several governments and organizations have established thresholds or buffer distances for locating housing development in relation to specific natural resources (e.g., ELI 2003, MRNF 2006, MTFWP 2012, SI 2013) and usually require underlying scientific research to support those distances (e.g., Arvisais et al. 2002).

The effect-distances for the species or natural resources targeted by the clustering ordinance could be translated to quantitative standards for the area and density of housing clusters. For example, in hypothetical subdivisions of a 640 ac section into 16 lots, Theobald et al. (1997) demonstrated that the proportion of the property that occurred within an effect-distance of 100 m was the same (19%) in clustered and dispersed development scenarios. However, effect-distances vary among species or seasons, and the area impacted was much greater for larger effect-distances in the dispersed scenarios. At 200 m, housing impacted 74% of the property in the dispersed scenario, compared to 31% in the clustered scenario. At 400 m, housing impacted the entire property in the dispersed scenario, compared to less than half (46%) in the clustered scenario.

Table 3. Examples of published scientific studies that quantified the distance at which housing negatively impacts wildlife.

Species or Taxonomic Group	Location of Study	Effect-distance	Source
Birds			
Forest birds	Forest and Vilas Counties, WI	300 m (984 ft)	Flaspohler et al. (2001)
Migrant birds	Cincinnati, OH	250 m (820 ft)	Pennington et al. (2008)
Riparian birds	Boulder and Larimer Counties, CO	1308 m (4921 ft)	Miller et al. (2003)
Resident birds	San Diego County, CA	200-500 m (656-1640 ft)	Bolger et al. (1997)
Songbirds	Adirondack Park, NY	200 m (656 ft)	Glennon and Kretser (2013)
Songbirds	Eastern U.S. and international	50 m (164 ft)	Paton (1994)
Songbirds	Pitkin County, CO	180 m (591 ft)	Odell and Knight (2001)

Table 3—continued.

Species or Taxonomic Group	Location of Study	Effect-distance	Source
Mammals			
Mule deer, white-tailed deer	Gallatin Valley, MT	400 m (1312 ft)	Vogel (1989)
Rodents	Boulder County, CO	357 m (1171 ft)	Bock et al. (2002)
Bighorn sheep	Riverside, San Diego and Imperial Counties, CA	300 m (984 ft)	Rubin et al. (2002)
Coyote, red fox	Pitkin County, CO	180 m (591 ft)	Odell and Knight (2001)
White-tailed deer	Groton, CT	86 m (283 ft)	Kilpatrick and Spohr (2000)
Mule deer	Shasta County, CA	50 m (164 ft)	Smith et al. (1989)
Elk	Missoula, MT	1207 m (3960 ft)	Cleveland (2010)
Amphibians			
Ambystomatid salamaders	Mashantucket Pequot Tribal Lands, CT	370 m (1214 ft)	McDonough and Paton (2007)
Frogs	U.S. and Canada	703 m (2306 ft)	Rittenhouse and Semlitsch (2007)
Salamanders	U.S. and Canada	245 m (804 ft)	Rittenhouse and Semlitsch (2007)
Long-toed salamander	Latah and Benewah Counties, ID	2000 m (6562 ft)	Goldberg and Waits (2009)
Pacific treefrog	Latah and Benewah Counties, ID	500 m (1640 ft)	Goldberg and Waits (2009)
Columbia spotted frog	Latah and Benewah Counties, ID	500 m (1640 ft)	Goldberg and Waits (2009)
Amphibians	Baltimore, MD	500 m (1640 ft)	Simon et al. (2009)

Open Space

Establish standards for the amount, location, configuration, and stewardship of protected open space in residential developments.

Permanent protection of open space in proximity to residential development generates many benefits for people and wildlife. These include improved human health (Shin et al. 2011); increased land and home values (Geoghegan 2002); preservation of scenic resources, working landscapes, and sense of place (Cross et al. 2011); and persistence of native wildlife populations (Loss et al. 2009).

The amount, quality, and location of protected open space will influence the capacity of a residential development to support native wildlife and their habitats. Although open space areas of all sizes may benefit subdivision residents, large patches of natural land cover located close to one another in a permeable matrix are likely to support biological diversity better than small, isolated patches. Smaller patches will typically contain fewer species than larger patches (Fahrig 2003). Even among species that occur in smaller patches, negative effects of habitat loss and fragmentation on vital rates such as survival and reproduction may lead to population declines (Donovan et al. 1995). For example, many ground-nesting birds cannot reproduce successfully in small patches because of increased risk of predation and parasitism in fragmented landscapes (Morimoto et al. 2012). Studies of many wildlife species have demonstrated that negative effects of housing extend from 50-2,000 m into adjacent undeveloped areas (*Table 3*); these "edge effects" should be minimized in the size and shape of open space parcels (Paton 1994). The open space design should take into account the potential differences in impacts that physical infrastructure and actual human activities occurring near the open space, including recreation, could have on the quality of the habitat in the open space (Dertian et al.

Permanent protection of open space in proximity to residential development generates many benefits for people and wildlife .

2021). Thus, core areas of habitat, located far away or buffered from developed areas, will have greater value for wildlife than open space parcels with a high proportion of their perimeters adjacent to or influenced by infrastructure and activities happening on the developed areas.

The amount of open space needed varies for different species and taxonomic groups (*Table 4*), making a 'one-size-fits-all' recommendation challenging. Generally, larger areas of open space that are functionally connected to other undeveloped lands will best support use by many species, especially those that are sensitive to human disturbances or have large home ranges (Crooks 2002, Farr et al. 2017). The ecological value of small patches of natural habitat conserved in a residential development should not be discounted; some wildlife species can successfully utilize smaller patches to meet different needs or at different times of the year. For instance, Neotropical birds use small forest patches in urban areas as stopover sites during migration (Petit 2000, Hostetler et al. 2005).

Allowing domestic pets in open space can contribute to harassment, predation, and disease transmission to wild animals. © Sara Bombaci

Further, many species, such as arthropods and other smaller organisms, can thrive in fragmented urban landscapes, especially if the matrix between the patches provides cover and foraging resources (e.g., nectaring plants for bees and butterflies). Studies have demonstrated that over 200 bird species can utilize developed areas (i.e., the built matrix) for breeding, stopover habitat, and wintering if enough tree canopy cover and other natural vegetation exists within yards, common areas, and along roads (Buron et al. 2022, Archer et al. 2019). Additionally, the built matrix that contains sufficient vegetation structure and cover can improve connectivity so that species can move to and from open spaces and even use some elements of the more built areas to meet some habitat needs. Ecological connectivity can result as wildlife take advantage of all types of habitats on private lands and this ability to utilize these spaces is a key landscape feature in the adaptation to climate change (Berteaux et al. 2014). The beneficial habitats of the matrix are often driven by

Setbacks and vegetative buffers should be maintained along water features and other ecologically sensitive areas of protected open space. © Sara Bombaci individual landowner practices in yards coupled with local policies that encourage wildlife-friendly design and stewardship (Lerman et al 2021, Lerman and Warren 2011, Goddard et al 2010).

The design and configuration of protected open space may be just as important for wildlife as the size of open space parcels (Freeman & Bell 2011). The habitat value of protected open space is reduced when it is fragmented by roads (Fahrig & Rytwinski 2009), recreational trails (Miller et al. 1998), fences (Boone & Hobbs 2004), and other infrastructure. In addition, wildlife and plant communities in core areas can be impacted by disturbances from human activities in developed areas, such as artificial noise (Barber et al. 2009) and light (Longcore & Rich 2004). Lastly, permitted human land uses of the protected open space (e.g., recreation, domestic animals) and long-term stewardship activities (e.g., ecological restoration) will have important influences on the occurrence and persistence of native wildlife species (see *Stewardship & Education*).

Overall, the best scenario is to conserve large contiguous and undisturbed areas of protected open space, because residential developments are typically embedded in fragmented landscapes, and the mixture of large patches and small patches would provide quality habitat for the greatest number of wildlife species.

Open space requirements will be more effective when they specify quantitative standards regarding the minimum area or proportion of the development property that must be protected.

Guidelines

Open space design should:

◊ Use a collaborative process involving developers, planners, biologists, and the individual or organization that will eventually own and/or manage the protected open space from the beginning of the planning stages;

◊ Be located in the most ecologically valuable areas of the property (see *Ecological Site Analysis*);

◊ Be configured in one or very few large contiguous parcels rather than many small parcels;

◊ Protected ecologically valuable small patches if large patches are not an option;

◊ Be located near existing protected lands or other undeveloped private lands on adjacent properties, and designed to maintain functional wildlife movement corridors within the site and to adjacent lands;

◊ Minimize the edge-to-area ratio of open space parcels to increase the protection of core habitat and reduce negative edge effects from adjacent developed areas; (i.e., circular areas are best and avoid narrow strips);

◊ Maintain or create setbacks and vegetative buffers along water features and other ecologically sensitive areas of open space, especially near developed areas;

◊ Minimize fragmentation of open space by roads, trails, fences, lighting, and other human infrastructure;

◊ Open space area calculation should be made as a percentage of the *net* buildable land that is not constrained by features such as wetlands, floodplains, or steep slopes (i.e., land that is not otherwise legally restricted from development);

◊ Adopt a management plan with a dedicated funding source to support management activities, that provides guidelines for permitted human land uses and stewardship activities (see *Stewardship & Education*);

◊ Encourage or incentivize ecological restoration of degraded areas;

◊ Held in common ownership;

◊ Coordinate stewardship activities with owners of adjacent properties;

◊ Complement developed areas that provide additional habitat and connectivity for wildlife by following best practices to limit monoculture lawns and maintain more natural vegetation, especially tree canopy cover, native plants, and areas with increased vertical height structure; and

◊ Specify that design, construction, and management on adjacent developed areas minimize negative impacts that could affect the open space (e.g., spread of invasive species; see *Sustainable Construction*).

In addition to the design and stewardship guidelines recommended above, open space requirements will be more effective when they specify quantitative standards regarding the minimum area or proportion of the development property that must be protected (Farr et al. 2017). Ideally, these quantitative standards would be based on minimum patch size requirements (i.e., the area below which a species or population cannot persist; *Table 4*) or the width of the edge effect for wildlife species that are conservation targets in the local area (*Table 3*). For minimum patch sizes, estimates are typically based on statistical or simulation models that estimate at least a 50% probability that a species will occur in an area of this size or simulation models that estimate at least a 50% probability that the species will persist in an area of this size (Vance et al. 2003).

Table 4. Examples of published scientific studies that estimated the minimum area (with a 50% probability of species occurrence or population persistence) that will support various wildlife species. Not an exhaustive list.

Species or Taxonomic Group	Location of Study	Minimum Area	Source
Amphibians			
Amphibians	Northeastern U.S.	18 ha (45 ac)	Calhoun et al. (2005)
Tiger salamander	Solano County, CA	113 ha (279 ac)	Trenham & Shaffer (2005)
Reptiles			
Wood turtle	Quebec, Canada	28 ha (69 ac)	Arvisais et al. (2002)
Birds			
Grassland songbirds	Saskatchewan, Canada	25-145 ha (62-358 ac)	Davis (2004)
Golden-cheeked warbler	North-central Texas	15-20 ha (37-49 ac)	Butcher et al. (2010)
Neotropical migrant birds	Maryland, Pennsylvania, W. Virginia, Virginia	0.3–1,000 ha (0.7-2,471 ac)	Robbins et al. (1989)
Mammals			
Coyote	San Diego County, CA	1 ha (2.5 ac)	Crooks (2002)
Bobcat	San Diego County, CA	180 ha (445 ac)	Crooks (2002)
Mountain Lion	San Diego County, CA	2300 ha (5683 ac)	Crooks (2002)

Sustainable Construction

When communities plan to conserve or restore biodiversity in residential developments, most of the emphasis is placed on the design phase, and the construction and post-construction phases often receive less attention from planners and conservationists. However, the construction and post-construction phases are just as important as they impact biodiversity over the short and long term. During the construction phase, earthwork machines can compact soil, destroy understory vegetation, and introduce invasive, non-native plants that may spread into conserved wildlife habitat. Improper maintenance of silt fences can lead to stormwater pollutants (e.g., silt and nitrate) entering into waterways and degrading habitat. Even the best designs will fail to achieve conservation goals unless they are implemented well in the construction and post-construction phases (Hostetler & Reed 2014; Hostetler et al. 2011; see *Stewardship & Education*).

Soil compaction. Over 90% of soil compaction occurs within the first three passes by construction machinery (Soehne 1958), and vehicle activity can cause soil to become so compacted that little water can percolate into the ground. Trees and their root systems must be protected from damage during the construction process (Ruppert et al. 2005). Further, lowering the soil grade removes important root mass, and raising the grade with fill dirt smothers the roots and prevents oxygen from reaching them (Hostetler & Reed 2014). In addition, disposal of debris or toxic chemicals may change soil pH due to leaching of chemicals into the ground which can negatively affect trees and other vegetation (Johnson 2005; Hostetler & Drake 2009).

Aquatic impacts. Wetlands and water bodies are typically protected from construction activities by silt fences and hence they should be well-maintained. Runoff can carry large amounts of silt into a wetland reducing penetration of light and dissolved oxygen, while increasing nutrients, algal blooms and nonnative plants (EPA 2000; Lee et al.

2006; Bilottaa & Brazier 2008). Silt fences also have unintended ecological consequences by disrupting movements of amphibians, reptiles, small mammals, and invertebrates, and too often, silt fencing is left in place long after the site is stabilized, continuing to disrupt wildlife movements. Amphibians are particularly susceptible to disruption of migratory routes from silt fencing blocking foraging habitats and wetlands used for breeding. Techniques such as wood chip berms and syncopated silt fencing can achieve wetland protection while allowing for wildlife movement. Curbs and catch basins, while efficient at capturing stormwater, also capture many small animals, and these often perish in structures such as hydro-dynamic separators that remove particulates. Low Impact Development (LID) alternatives to hard engineering solutions, such as curbless roadways, swales, and stepped bio-filtration basins have the added benefits of conserving wildlife in residential developments. Many of these best development practices, including stormwater management and pre- and post-construction conservation best practices, can be found in Calhoun and Klemens (2002).

Invasive plants. Removal of native vegetation should be minimized, and introduction of invasive non-native plants should be avoided. Invasive plants thrive in disturbed post-construction landscapes, and they may be directly introduced from off-site by construction machinery or colonize over time on the disturbed soils. Thus, earthwork machines should be monitored for invasive plant material throughout the construction process

Guidelines

◊ Designate construction site access and routes that coincide with eventual streets and roads to limit soil compaction;

◊ Involve the construction site manager in planning the development and train the manager in environmental mitigation techniques; and

◊ Minimize the use of heavy equipment that compacts or disrupts the soil more than necessary, especially around conserved trees and natural buffers;

◊ Designate parking sites for vehicles, stockpiling sites for building materials, and areas that are properly managed for mixing of chemicals and materials;

◊ Minimize staging areas for the construction of buildings by locating equipment and building materials in areas that are planned for future hardscapes (e.g., pavement or patios);

◊ Avoid locating utilities within protected open space and instead place them in shared trenches near or under pavement for roadways;

◊ Place new power lines underground in ecologically sensitive areas, and where above-ground power lines are to be installed, apply best practices to prevent bird mortalities (e.g., from the Avian Power Line Interaction Committee);

Neighborhoods that conserve large trees during construction and retain tree canopy cover help to provide habitat for multiple wildlife species.© Mark Hostetler

- ◊ Install and maintain temporary fencing to protect ecologically sensitive areas and trees;
- ◊ Avoid lowering or raising the grade around ecologically sensitive areas and trees;
- ◊ Minimize removal of native vegetation, avoid introduction of invasive, exotic plant species (i.e., noxious weeds), and revegetate promptly using native seed, ideally in accordance with an ecological restoration and stewardship plan (see *Stewardship & Education*);
- ◊ Utilize stem wall construction for houses so that only the footprint of the home is raised to the required level to meet flood regulations;
- ◊ Develop environmental covenants and contracts for site construction that clearly identify ecological features and areas to be protected, and specify financial penalties for contractors that damage those areas and/or incentives for avoiding damage;
- ◊ Train contractors to manage their waste and not to feed wildlife during construction.

Not mowing dry retention ponds allows natural succession to occur, creating more wildlife habitat. © Mark Hostetler

Stewardship & Education

Require a plan for active stewardship of ecological resources and monitoring of conservation outcomes that engages and educates residents.

To achieve successful conservation of ecological resources across the development property, these areas should be actively stewarded to maintain or restore the property's conservation values, and potentially impactful human land uses and activities should be restricted.

Governance, management, and monitoring of ecological resources are critical to the long-term conservation effectiveness of land protection (Chape et al. 2005). The protected open space within residential subdivisions should be monitored regularly, not only to ensure legal compliance with the prevailing land-use regulations or conservation easement, but also to assess whether the development is meeting its conservation objectives (Kiesecker et al. 2007).

In addition to monitoring, active stewardship is frequently necessary to maintain or restore the conservation value of protected lands (Chape et al. 2005), particularly in residential landscapes (Lenth et al. 2006, Glennon & Kretser 2013). Private residential lots and common open space are often managed for a combination of values that provide human benefits (e.g., economic, aesthetic, recreational) (Farr et al. 2018a). However, to achieve successful conservation of ecological resources across the development property, these areas should be actively stewarded to maintain or restore the property's conservation values, and potentially impactful human land uses and activities should be restricted. Even passive recreational use of the protected open space could reduce its conservation value for wildlife (Reed & Merenlender 2008). Clear management guidelines (e.g., regarding domestic animals, artificial light and noise, etc.) and active stewardship (e.g., removal of invasive species, ecological restoration) should be implemented to achieve long-term conservation objectives (Farr et al. 2018a). These activities should be adjusted as needed in response to monitoring results, in an adaptive management framework that increases learning, builds stewardship capacity, and improves conservation outcomes (Salafsky et al. 2002).

Stewardship of front yards with primarily native vegetation and little turfgrass can benefit native species. © Sara Bombaci

A growing number of studies indicate that homeowners value the conservation features of residential subdivisions (Bowman et al. 2009), especially when they recognize those features within their own communities (Kaplan et al. 2004). Neighborhood environmental education programs can help residents to understand local ecology and implement conservation actions (Hostetler et al. 2008). Moreover, monitoring and management of residential landscapes could benefit from the participation of private landowners, improving the integrity of nearby protected open space (Hostetler & Drake 2008) and habitat quality for native and human-sensitive plant and animal species (Jimenez et al. 2022). In addition to improving residents' scientific literacy and ecological knowledge (Jimenez et al. 2021), engaging in stewardship and monitoring activities may also empower landowners to better manage their common open space (Danielson et al. 2009) and coordinate their independent land-use decisions towards the common conservation goals of the community (Cooper et al. 2007). For example, participants in a Neighborhood Nestwatch program reported changes in perceptions of their own properties and increased motivation to improve the habitat value of their yards (Evans et al. 2005). Similarly, participants in a watershed monitoring program were inspired to coordinate restoration and management activities across multiple private properties (Flitcroft et al. 2009).

To be successful, the monitoring, stewardship, and education activities described above will require leadership, an integrated plan, and a dedicated funding source (Hockings 2003, Farr et al. 2018a). Potential sources of funding to support plan implementation could include homeowners' association (HOA) dues, special lot sales, property tax assessment, and hunting or agricultural leases.

Guidelines

The stewardship and monitoring plan should:

◊ Link directly to the conservation objectives of the development project and results of the ecological site assessment (see *Ecological Site Analysis*);

◊ Be co-developed with developers, residents and appropriate conservation or science experts (see *Biological Consultation*)

◊ Provide guidelines for management of private residential lots as well as for common open space;

◊ Specify permitted and prohibited land uses in the protected open space (*Table 5*) and provide guidelines for stewardship and restoration activities (*Table 6*);

◊ Include strategies for actively engaging and providing current educational information to residents (*Table 7*);

◊ Specify a clear organizational and/or individual lead to coordinate stewardship and monitoring activities, with a strong preference for involving motivated residents where appropriate;

◊ Ensure stewardship and monitoring activities are coordinated with activities on adjacent properties and/or nearby protected lands and specify how that coordination will occur;

◊ Be adaptive, with a process for adjusting resident or open space management practices in response to monitoring results;

◊ Establish a dedicated and reliable funding source to support ongoing stewardship, monitoring, and education activities.

Table 5. Examples of human land uses or activities (drawn from existing plans) that could be considered for permitting, limiting (e.g., seasonally), or prohibiting in the protected open space when developing the stewardship and monitoring plan. Not an exhaustive list.

Land use or activity
Access
Access for residents
Access for domestic pets
Public access
Extractive land uses
Agriculture
Grazing
Hunting and fishing
Hydrological development
Oil and natural gas extraction
Mining
Renewable energy production
Timber harvest
Infrastructure
Airstrip or helicopter pad
Buildings (permanent or temporary)
Fences
Garbage dump
Parking lots
Roads
Septic system or leach field
Utilities
Recreation facilities and activities
Camping
Campfires
Golf course
Non-motorized recreation (including cycling, horse-riding, canoeing, climbing, hiking, etc.)
Motorized recreation on land or water
Park or playground
Shooting range
Sports fields
Swimming pool
Tennis court

Table 6. Examples of stewardship and restoration activities to consider recommending or requiring for private residential lots and/or protected open space. Not an exhaustive list.

Activity	Potential benefits	Examples and resources
Stewardship		
Install wildlife-friendly fencing	Facilitate wildlife movement, reduce wildlife mortality	Paige (2012)
Restrict wild animal feeding, particularly nuisance wildlife (e.g., coyotes, raccoons)	Reduce human-wildlife conflicts	Hanophy (2009). MT Fish, Wildlife & Parks (2012)
Establish guidelines for trash management	Reduce human-wildlife conflicts	MT Fish, Wildlife & Parks (2012) WildSafeBC https://wildsafebc.com/bear-smart/
Guide appropriate provision of artificial resources (e.g., bird feeders, water features)	Reduce human-wildlife conflicts	Gardening For Wildlife by Merilees 2000 https://gardenforwildlife.com/
Minimize artificial lights and provide shielded lights	Minimize disruption of animal movement, foraging, and reproduction	Darksky program http://darksky.org/ Guide de L'Éclairage (2022) https://en.cieletoilemontmegantic.org/
Minimize artificial noise	Minimize disruption of animal communication and foraging	Francis & Barber (2013)
Limit pet access (e.g., cats indoors, dogs on leashes)	Minimize population declines of small mammals, birds, amphibians and reptiles; reduce disease transmission from outdoor cat to owner; limit pet waste	Loss et al. (2013)

Table 6—continued.

Activity	Potential benefits	Examples and resources
Stewardship		
Landscape yards for wildlife habitat using native plants	Maintain, restore, enhance ecological processes Create connectivity and habitat for animals to forage and to move through built areas	Lerman et al. (2021) Lerman and Warren (2011) www.wildones.org
Establish guidelines for extractive uses	Ensure best management practices to limit disruption of wildlife are adhered to in the open space	Beattie et al 1983 – Working with your Woodland, Hansen et al 2011 Managing your woods
Install bird-friendly windows, particularly for large windows	Reduce the number of bird deaths associated with window collisions	https://www.audubon.org/news/reducing-collisions-glass
*Restoration**		
Restore riparian areas Restore wetlands	Maintain, restore, enhance ecological processes.	USEPA (2000) Dooley and Stelk (2021)
Control invasive plant species		https://www.fs.usda.gov/managing-land/invasive-species
Restore native plant species		National Seed Strategy (2015)
Restore natural disturbance regimes (e.g., fire, water/flood)		

*Restoration activities should be undertaken jointly with qualified professionals with prior authorization from all relevant authorities.

Table 7. Examples of strategies for actively engaging and educating subdivision residents. Not an exhaustive list.

Strategy
Education
Install educational signage regarding management of yards and protected open space
Host nature walks in protected open space with local naturalists
Build a neighborhood website with fact sheets on best management practices
Distribute fact sheets on best management practices
Host educational workshops on wildlife species, habitats, and ways to enhance subdivisions for wildlife
Build model homes and yards to demonstrate best management practices for design and stewardship
Engagement
Establish a conservation committee, including representatives of neighboring parcels and protected areas
Establish a participatory monitoring program for biodiversity
Organize neighborhood bio blitzes
Engage residents in monitoring and stewardship activities (e.g., WildPaths, Stop-Caracasses on iNaturalist)
Train and empower a resident to become the lead coordinator of stewardship and monitoring activities
Recognize leading residents with certifications or awards (e.g., "steward of the year")
Adopt a master naturalist/master gardener model
Encourage residents to "adopt" stewardship of critical ecological areas
Encourage resident participation in social networks to share stewardship activities (e.g., YardMap Network).

Discussion

"The human race is challenged more than ever before to demonstrate our mastery, not over nature, but ourselves" - Rachel Carson

Community engagement

To successfully incorporate the biological recommendations summarized in this report into land-use planning and development decisions, we recognize the importance of engaging communities early in the process. The process takes time and requires flexible and open leadership. This is particularly important for communities that may have important natural assets but lack time or monetary resources for planning or have been historically marginalized and excluded from land-use decisions. Early engagement enables the community to participate in collective visioning within the planning process, the coproduction of knowledge about local natural resources through citizen science or values mapping exercises, and in setting goals and defining outcomes for the community. Early engagement also provides time to identify stakeholders who need to be involved in the process. This may include partnering with an early adopter, someone who is sympathetic to wildlife, to create the first 'green' development as a model, or simply working with existing community groups such as 4H, religious institutions, or local scouts to participate in the inventory and assessment phase of a community's resources. Especially in smaller communities, the implementation of private land conservation strategies is often undertaken by a few key players, and engagement efforts can be targeted toward these individuals (Farr et al. 2018b).

Government-to-government dialogue with Indigenous Peoples is a crucial step in the early phases of planning and development. Indigenous Peoples have particular knowledge about local ecology and traditional management, as well as cultural contributions, interests, sensitivities and rights relevant to local decisions. In some jurisdictions of Canada, consultation or other levels of engagement with Indigenous' leaders may be mandated. Guidelines for involving Indigenous Peoples are available for British Columbia (Province of British Columbia, 2014) as well as several other Provinces.

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Getting people to the table may be challenging, and thus picking the right place and time are just as important as incentives to encourage collaboration. Incentives may include opportunities for education, awards or recognition of leaders in developing wildlife-friendly designs, mini-grant programs to support innovative development projects, or the opportunity to collaborate on a demonstration project. For example, the Lawns to Legumes program in Minnesota offers mini-grants for planting pollinator habitat and the Audubon Habitat Heroes Program awards heroes as having bronze, silver or gold habitats contributing to regional flyways. To underscore the importance of the biological recommendations, we recommend combining engagement with shared learning opportunities. These may include social events or nature walks with developers and planners, field trips with collaborators, tours of model developments, or any number of other ways to engage people outside the typical meeting setting. Other possibilities include hosting a lecture series on wildlife in the region, developing a demonstration project (e.g., a home or subdivision built according to the guidelines in this report), or engaging residents of a community through social media. In all of these processes, it is important to use a diverse set of techniques to solicit and collect input from the relevant players. This can be done through facilitated or informal discussions, one-on-one or in a group. Engagement must be sustained through the community visioning, the shared learning, the adoption of modified or new ordinances, and the implementation phases. To this end, recognizing and celebrating small successes will be important for maintaining interest.

Of particular importance to the audience of our peers in the biological sciences, we recognize that integration and implementation of these recommendations will be successful only when biologists have the appropriate training and resources to engage in these land-use planning processes. We recommend creating educational materials on land-use and development processes and how to contribute to community planning for professional biologists. Biologists should be encouraged, starting as early as the undergraduate level, to learn about the planning process and to serve on local planning boards, given that habitat fragmentation due to residential development is one of the most pressing threats to wildlife and biodiversity. Students should also be encouraged to participate in interdisciplinary working groups and partner as students and throughout their careers with social scientists and planners to address these issues related to the stewardship of private lands. Students pursuing post-graduate wildlife management degrees should enroll in service-learning courses that help them develop skills in how to engage local communities, and empower those that have been traditionally excluded from decision making processes.. Scientists working at universities and natural resource management agencies should be evaluated and rewarded for their involvement in local policy discussions and collaborations with social scientists and land-use planners.

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Regional context

The guidelines proposed in this report were designed to be general enough to be applicable at a national level, and to target conservation of a variety of species and ecosystems. However, we recognize that our recommendations may need to be tailored to regional, social, and ecological contexts to be successfully adopted and implemented by local communities. In addition, although we had a preliminary discussion of the land-use planning tools (e.g., overlay district), development incentives (e.g., density bonus), and third-party certification programs (e.g., Sustainable Sites Initiative) that could be used to implement our recommendations (*Table 8*), we did not have sufficient time or appropriate expertise to review relevant examples or generate model code language. Thus, we believe that a key next step to ensure successful adoption and implementation at the local level is to convene regional workshops to adapt our recommendations to the regional context and generate models of specific planning and development tools. WCS recently tested this approach by convening a 2-day meeting of researchers, planners and technical experts from the four-state Northern Forest region (New York, Vermont, New Hampshire and Maine) (Kretser & Reed 2017), and we hope to repeat this model in other areas of the U.S. and Canada that are experiencing rapid residential development.

We intend for this report to be a living document. We recognize that science and societal values will evolve, as will our understanding of the complex interactions between humans and wildlife. We have produced the report to be flexible for incorporating revisions and additional thematic sections in the future, and to integrate it with resources from more focused, regional workshops (Kretser & Reed 2017).

Empowering local communities to decide how to incorporate conservation into comprehensive land-use planning leads to stronger conservation outcomes. © Heidi Kretser/WCS

Conclusion

Private lands harbor important wildlife habitats and other natural resources threatened by sprawling housing development across the United States and Canada. Incorporating explicit biological components into local land use plans will improve the conservation value of private lands for wildlife and people. This report provides science-based guidelines for how residential design, construction, and stewardship could be improved to protect wildlife habitats on private lands. These recommendations and guidelines result from collaboration among leading biological experts to compile scientific evidence for the guidelines and identify resources to support implementation. Successful integration of these recommendations into land-use zoning or codes requires dedication from biologists, experts in environmental justice, and a diverse and representative group of citizens to engage in the land-use planning and development process This engagement will enable dialogue among scientists and the planning community to facilitate understanding of what information planners need to make development decisions, to translate the guidelines for the benefit of specific regions, habitats and species, and to communicate to local voters, who elect public officials with the ultimate decision-making power over billions of acres of private lands in the United States and Canada.

Table 8. Land-use planning tools and development incentives for conservation. Not an exhaustive list.

Tool	Definition	References
Conservation Development (CD)	An approach to the design, construction, and stewardship of a development that achieves functional protection of natural resources, while also providing social and economic benefits to human communities. Homes in CD subdivisions are built on smaller lots and clustered together, allowing for a substantial portion of the property (typically >50%) to be permanently protected for conservation purposes. Further, CD subdivisions could contribute to equity goals by including affordable units or providing historically marginalized communities with access to environmental benefits.	Pejchar et al. (2007); Milder (2007); Milder & Clark (2011); Reed et al. (2014)
Purchase of Development Rights (PDR)	A voluntary program in which a landowner sells or donates their development rights to a land trust or local government and can be eligible for compensation from public funds and/or tax credits. A permanent deed restriction, often a conservation easement in the U.S. and most of Canada (or a conservation servitude in Quebec), is placed on the property which restricts in perpetuity the types of activities which may take place on the property to protect its conservation values.	Daniels (1991); Daniels & Lapping (2005); see also https://www.alberta.ca/assets/documents/ep-environmental-tools-purchase-of-development-rights.pdf
Transfer of Development Rights (TDR)	A program that allows landowners to buy, sell, or transfer development rights from one property to another. TDR programs are intended to reduce or eliminate development potential in areas that are a high priority for conservation, while directing future growth to areas where infrastructure and services already exist. TDR can also be used to preserve affordable housing and generate revenue for operations.	Machemer & Kaplowitz (2002); Kaplowitz et al. (2008); Pruetz & Standridge (2008); Nelson et al. (2012); see also https://www.alberta.ca/assets/documents/ep-environmental-tools-transfer-of-development-rights.pdf

Table 8—continued.

Tool	Definition	References
Overlay District [US]/ Conservation-Designated Area [CA]	A mapped zoning designation that identifies conservation targets and supplements the underlying zoning standards with additional requirements that are designed to protect those targets. For example, developers of properties within overlay districts may be required to preserve certain natural features or conduct environmental assessments to avoid or mitigate potential impacts. Overlay districts may also be used to advance housing equity goals, and conservation and affordable housing overlays could be implemented together to ensure that affordable units are located near environmental benefits.	McElfish (2004); Duerkson & Snyder (2005); Tziganuk et al. (2022); See also Ecological Connectivity in French and English at https://ecologicalconnectivity.com/node/69?_ga=2.165021055.1520820272.1664392791-459923652.1664392791
Environmental Analysis	A required review of development proposals for potential impacts on conservation targets.	Mandelik et al. (2005)
Payments for Ecosystem Services (PES)	A program in which landowners are compensated, by a local government or private organization, for the environmental services generated by their lands (e.g., clean water, reduced flooding risk, or carbon sequestration).	Goldstein et al. (2011)
Sustainable Design Certification	A system of voluntary guidelines and performance standards for sustainable design, construction, and stewardship of a development and/or associated open space. A third-party (typically non-profit) organization reviews projects and certifies them according to the level of standards achieved.	Sustainable Sites Initiative (SITES); LEED for Neighborhood Development (LEED-ND)

Table 8—continued.

Tool	Definition	References
Conservation Easement	A statutorily created interest in land whereby a landowner voluntarily relinquishes certain rights or opportunities in order to protect the conservation values of all or part of their land. That "interest in the land" is granted to an eligible conservation organization or government agency. Once registered properly, conservation easements run with the land and develop-	Kwasniak (2009); Good and Michalsky (2008); Greenway (2017)
Conservation Land Securement	"the legal acquisition of natural areas or natural heritage lands through a range of securement methods to facilitate permanent protection of land 'in perpetuity.'" Source: Conservation Land Securement Strategy by the City of Vaughn, Ontario.	
Agricultural Land Reserve	Public or private land permanently designated by the government to prioritize agricultural use and preserve rich soils and that restricts other types of development. These lands may be vacant, managed for forestry, or used for agriculture.	City of Vaughan (2014); See also https://www.alc.gov.bc.ca/
Greenbelt	Permanent legislative protection along the urban edges to preserve ecological, agricultural, and hydrological function from development pressures.	Ontario's Greenbelt Plan (2017)

Participant Biographies

Sarah Reed *(Principal Investigator and Workshop Leader)*

Dr. Sarah Reed is Executive Director of the Robert and Patricia Switzer Foundation, a results-driven family foundation that supports a network of over 700 Switzer Fellows who are emerging leaders in environmental science, policy, and justice. Sarah is also an affiliate faculty member at Colorado State University, where she works with communities and government agencies to apply conservation science to land-use planning and natural resource management decisions. In her free time, she enjoys growing and cooking food, traveling and recreating with her spouse and dogs, and serving as a mentor and foster parent for teenagers.

Aram JK Calhoun *(Workshop Participant)*

Dr. Aram JK Calhoun is a Professor Emerita of Wetland Ecology and Conservation from the University of Maine. Her research focuses on wetland and vernal pool ecosystems as landscape features requiring landscape-scale, locally driven conservations and she is active in local conservation planning and state and federal wetland policy.

Caroline Daguet *(Canada Consultant)*

Caroline Daguet is a Conservation Biologist who worked for Nature Conservancy Canada – Quebec Region and Appalachian Corridor for almost 12 years, where she completed ecological surveys and contributed to Natural Area Conservation Plans, specialized on ecological connectivity in the Green Mountains of southern Quebec, and provided advice to municipalities, Regional County Municipalities and other partners about conservation planning.

Cooper Farr *(Graduate Research Assistant)*

Cooper Farr is the Director of Conservation at Tracy Aviary, where she coordinates the Aviary's conservation initiatives and implements a number of community science projects throughout the region. Cooper received her M.S. in Ecology from Colorado State University, where she investigated the effectiveness of conservation development as a private land conservation strategy. She specializes in designing and implementing community science efforts that generate information on pressing conservation issues, inform bird-friendly restoration and management, and build community support for conservation efforts.

Doris Fischer *(Workshop Participant)*

Doris Fisher retired in 2013 as a Land-Use Planner of 35 years. Her career included serving as a Planning Director for Madison County, Montana handling projects as diverse as rangeland subdivisions and ski resort condominiums in high-value wildlife habitat. Notably, Doris served as a Land Use Planner for Montana Fish, Wildlife & Parks mapping Crucial Areas for fish and wildlife across the state. She led the collaborative effort to assemble Fish and Wildlife Recommendations for Subdivision Development in Montana. Doris received a Master's in Planning from the University of Wisconsin-Madison.

Michale Glennon *(Workshop Participant)*

Dr. Michale Glennon is a Senior Research Scientist at the Paul Smith's College Adirondack Watershed Institute. She is an ecologist and uses wildlife as a tool for understanding threats to ecological integrity and watershed health. She has authored more than 30 publications on issues ranging from land use management to climate change and has collaborated with Dr. Heidi Kretser for 20 years to investigate the impacts of exurban development on wildlife. She is a member of the editorial board for the Journal of Field Ecology as well as a board member for the Adirondack Council and Traditional Arts in Upstate New York. Michale obtained her B.S. in Environmental and Evolutionary Biology from Dartmouth College, and her M.S.

and Ph.D. in Environmental and Forest Biology from the State University of New York, College of Environmental Science and Forestry.

Mark Hostetler *(Workshop Participant)*

Dr. Mark Hostetler is a Professor, Department of Wildlife Ecology & Conservation, University of Florida (UF). With over twenty years of experience in urban wildlife and green development issues, Dr. Hostetler conducts research and outreach on how urban landscapes could be designed and managed, from small to large scales, to conserve biodiversity. Dr. Hostetler co-founded UF's Program for Resource Efficient Communities (PREC) and collaborates with an interdisciplinary team of scientists and graduate students to foster green development projects nationally and internationally. He serves on the advisory board of URBIO, is the author of The Green Leap: Conserving Biodiversity in Subdivision Development, and he has produced and directed an award-winning TV series titled Living Green. Dr. Hostetler has a Bachelor of Science in Biology from Purdue University and his Master of Science and Ph.D. in Zoology are both from University of Florida.

Heidi Kretser *(Workshop Facilitator)*

Dr. Heidi Kretser is the Director of Rights + Communities for the Wildlife Conservation Society's Global Conservation Program. Heidi has worked in conservation for over 25 years focusing on incorporating tools and perspectives from the social sciences into applied conservation research, planning, practice, and decision-making. She has devoted nearly two decades of applied science and practical experience to devising strategies for reducing the impacts of private lands development on wildlife. Heidi has a Ph.D. from Cornell University and holds a master's degree from the Yale School of Forestry. Heidi also serves as an Adjunct Associate Professor at Cornell University's Department of Natural Resources and the Environment.

Susannah Lerman *(Workshop Participant)*

Dr. Susannah Lerman is a Research Ecologist with the USDA Forest Service Northern Research Station. Her research assesses how wildlife communities respond to different management practices, with a focus on birds and bees, and how people interact with nearby nature. Her research emphasis is on private lands, which provide opportunities for the public to participate in science, conservation, and shared stewardship. Her research also assesses how to ensure equitable access to biodiversity. Susannah proudly mentors a diverse and exceptional group of young and early career scholars.

Charlie Nilon *(Workshop Participant)*

Dr. Charles Nilon is the William J. Rucker Professor in the School of Natural Resources at the University of Missouri. Charlie's research considers the impact of urbanization on wildlife habitats, populations, and communities. From 1997 –2020, he was a co-principal investigator on the Baltimore Ecosystem Study (BES)—one of two urban ecosystems included in the National Science Foundation's Long-Term Ecological Research program. Charlie's work with the BES focused on understanding how ecological and socioeconomic factors influence bird species composition and abundance. Charlie's research also considers the role of nature as part of an individual's day-to-day environment and environmental justice issues associated with access to nature. He has a doctorate in ecology and wildlife ecology from the State University of New York College of Environmental Science and Forestry. He earned a master's of forest science with an emphasis on wildlife from Yale University.

Liba Pejchar *(Workshop Participant)*

Dr. Liba Pejchar is a Professor in the Department of Fish, Wildlife and Conservation Biology at Colorado State University. Her interdisciplinary research focuses on restoring biodiversity and ecosystem services in the places where people live and work. Among other projects, she and her terrific students study the loss and recovery of birds on invasion-prone pacific islands, bison reintroduction in western North America, and innovative and equitable ways to sustain nature and human well-being in agroecosystems and areas undergoing residential and energy development.

Jennifer Rae Pierce *(Canada Consultant)*

Jennifer Rae Pierce (she/her) is Co-Founder and Head of Partnerships and Research of the Urban Biodiversity Hub (UBHub). She is a political ecologist with a planning and design background, holding graduate degrees in Environmental Science and Policy from CEU and also in Community and Regional Planning from Cornell University. Her research focuses on how local governments around the world navigate their relationship with nature and people, including measurement and monitoring, justice, engagement, and framing of biodiversity conservation and sustainable lifestyles. She co-leads the Urban Ecosystems Working Group for the IUCN Commission of Ecosystem Management. She is the technical lead on the IUCN knowledge product, the Urban Nature Indices, as part of the consulting team for IUCN. She is now earning her PhD in Community and Regional Planning from University of British Columbia on urban biodiversity plans and engagement while also working as a Senior Planning Analyst for the Ministry of Municipal Affairs of British Columbia.

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