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Supplemental Information: Goals-based species selection process for connectivity modeling and planning

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Appendix A: Metro habitat connectivity toolkit - Metropolitan area focus

This case study explains how we applied our approach in a medium-sized metropolitan area and surrounding habitats to determine surrogate species for connectivity mapping. Below we detail each step of the process for implementation of this mid-scale project.

Project synopsis and background

Habitat loss and fragmentation is a serious threat to maintaining biodiversity, particularly in urbanizing areas. The greater metropolitan area of Portland, Oregon, which is maintained by the government body, 'Metro', has many large natural areas in and around its urban growth boundary. These natural areas provide habitat that can support a diversity of organisms. As the human population of the area grows, open space within and surrounding the metropolitan area is at greatest risk of development. In order to protect and enhance habitat connectivity in these development-prone areas Metro has set a goal to first identify and establish potential habitat corridors and assess their condition. In a joint project with collaborators from Metro's natural resources staff, we employed a surrogate species approach to address connectivity needs of the wildlife community in a way that could incorporate empirical data.

Articulating project goals

The Metro regional government, headquartered in Portland, Oregon, researchers from Portland State University, and Samara Group LLC developed a partnership in order to quantify and describe connectivity in a dynamic urban and urbanizing environment. The goal of this project was to establish an approach to assess connectivity for native species at a fine scale between metro holdings and other natural areas across urban landscapes. The overarching project goals helped establish boundaries for ultimately selecting species that best support those project goals. The species selection goals aligned with and supported the project goals. For example, the urban nature of the project and its goals required species that aren't urban avoiders. In addition, species that are synanthropic would be too common and generalist in habitat use to be able to be used to indicate habitat quality. Based on existing efforts and conservation objectives of the region, partners established four primary habitats of interest: forest, wetland, oak woodland, and prairie (The Intertwine Alliance, 2012b). One constraint of the effort was to limit species selection to 8-10 species to represent connectivity for native wildlife, excluding fish, across and within these habitat types.

Data acquisition

Vertebrate species known to the region, composed of 229 birds, 78 mammals, 16 reptiles, and 20 amphibians, were provided by the Biodiversity Guide for the greater Portland-Vancouver Region (The Intertwine Alliance, 2012a), a companion document to the Regional Conservation Strategy (The Intertwine Alliance, 2012b). Species-habitat associations and eight habitat types used by these species were determined using the data provided by Wildlife-Habitat Relationships in Oregon and Washington (Johnson and O'Neil, 2001). Habitat types used in this analysis, as defined by Johnson and O'Neil, included Westside Lowlands Conifer-Hardwood Forest; Westside Oak and Dry Douglas-fir Forest and Woodlands; Westside Upland Grasslands; Agricultural Lands; Urban and Mixed Environs; Open Water – Lakes, Rivers, and Streams; Herbaceous Wetlands; and Westside Riparian-wetlands. We then used the Biodiversity Guide species list and associated Johnson and O'Neil habitat associations as the input data for cluster analysis.

Cluster analysis

Hierarchical cluster analysis helps identify what other species each surrogate may represent and can help detect if separate groups of species are needed to represent more refined habitat groups (e.g., two types of forest rather than lumping all forest into one group). We included all species in our dataset, along with their specific habitat associations, for use in a cluster analysis to identify surrogate species and which other species they represent. Ten groups were initially selected for the hierarchical cluster analysis output as this was the maximum number of species we ultimately planned to select. These groups included all habitats a given species was associated with as described by Johnson and O'Neil (2001). The resulting groups were reviewed with a goal of reducing the number of clusters until each one included a variety of habitat-specific taxa as they pertained to the four habitat types of interest, as established in project goals (forest, wetland, oak woodland, and prairie), or subgroupings of those habitats. For example, the initial output included a large cluster group of 85 species that were associated with all possible habitat types and primarily comprised generalist species. As the goals did not include selecting a surrogate for generalist species using all habitat types, we reduced the number of clusters. After re-running with just seven clusters, we manually reduced the number of clusters a final time because one group was associated with herbaceous wetland, open water, and agricultural lands, and was composed entirely of waterfowl and marshland birds. Because of the lack of diversity in taxa, this waterfowl group was combined with another group to represent herbaceous wetland habitats. Hence, we identified six groups from which we continued the process of selecting surrogate species.

Filter/interpretation and refinement

Once the final species and habitat association groups were compiled that best represented the four habitats of interest, we further refined the potential candidates for selection as surrogate species to

narrow the candidate pool to the targeted 8-10 species representing the key habitat types. We removed non-native species as well as those species known to be highly adapted to urban and agricultural habitats. Non-native species were removed from consideration as surrogates given the project objectives of representing connectivity for native species in addition to the fact that most non-native species are generalists and adaptable to multiple habitat types. Species highly adapted to urban and agricultural habitats were also not considered because we can infer that the lack of sensitivity to these matrix habitats would mean agricultural and urban- adapted species would not be particularly good habitat indicators for more sensitive species.

Initial identification of potential surrogate species

The remaining species were further categorized within each habitat association by taxa in order to best consider mobility types. Project partners, Metro, and Portland State University, reviewed the remaining species and aimed to select species that are typically found in or are obligate to a given habitat type of good quality and are neither very rare (which would require more species-specific information) or overly common (indicating habitat generalists). The proposed species selections intentionally highlighted a range of mobility types but primarily focused on species most susceptible to barriers. The group of surrogate species selected represents the different regional habitats and of the different classes of native terrestrial vertebrates. The primary focus was on species' needs and ability to move between patches to access quality habitat areas. Extensive literature reviews were conducted for each proposed species and a report was drafted detailing habitat associations, home range and expected movement needs, as well as additional species expected to be represented by each of the surrogates.

Feedback and literature review

Once the project partners compiled a final list of proposed surrogates, several local species experts were contacted to provide peer review of the overall project goals and process as well as the proposed surrogate species. These reviewers were contacted based on their careers contributing to local knowledge of species and associated habitat connectivity challenges. Eight reviewers provided comments that were incorporated with associated justifications, and this justified feedback led to some change in the surrogate species selection. The reviewers suggested alternatives to some species due to habituation to human feeding (Anna's hummingbird [*Calypte anna*]), status as an agricultural pest (gray-tailed vole [*Microtus canicaudus*]), and extremely limited mobility (western red-backed salamander [*Plethodon vehiculum*]). These species were replaced by newly selected surrogate species from the same hierarchical clusters while maintaining the overall taxonomic breadth.

Final selections

The proposed final species selections were discussed once more by project partners and peer reviewers. A final list of eight species were ultimately selected to represent connectivity needs and provide the framework for assessing connectivity within and across habitats of interest using modeling and field assessments that address habitat quality and barrier strength (Table S1). American beaver, one of the surrogates, was considered particularly impactful given it is a keystone species (Stoffyn-Egli and Willison, 2011). Parallel efforts by the USFWS to identify surrogate species in the Willamette Valley (USFWS, 2014) provided opportunities for collaboration and several species selected for the Metro Toolkit project overlap with the USFWS effort.

Table S1. Metro Connectivity Toolkit Project Final Species Selections & Associated Habitats. Species selected as surrogates to represent the habitat connectivity needs of most species in the Metro region. American beaver, red-legged frog and southern alligator lizard require or are closely associated with multiple habitat types and are therefore listed under more than one habitat type. Forested habitats are more variable; and in order to best represent them, each vertebrate group was represented.

Vertebrate Group	**Forested Habitats (*Includes upland forest, upland shrub, riparian & wetland forest*)**	**Wetlands (*Includes willow/shrub wetland and emergent wetland*)**	**Oak (*Includes savannah and woodlands*)**	**Prairie and Grassland**
Amphibians	Red-legged Frog (*Rana aurora*)	Red-legged Frog (*Rana aurora*)		
Reptiles	Rubber Boa (*Charina bottae*)		Southern Alligator Lizard (*Elgaria multicarinata*)	Southern Alligator Lizard (*Elgaria multicarinata*)
Birds	Swainson's Thrush (*Catharus ustulatus*)		Slender-Billed Nuthatch (*Sitta carolinensis aculeata*)	Western Meadowlark (*Sturnella neglecta*)
Small Mammal	Douglas' Squirrel (*Tamiasciurus douglasii*)		Western Gray Squirrel (*Sciurus griseus*)	
Medium Mammal	Beaver (*Castor canadensis*)	Beaver (*Castor canadensis*)		

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