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Resource selection by an ancient taxon (Onychophora) in a modern urban landscape: A multi-scale analysis approach to assist in the conservation of an animal phylum

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HIGHLIGHTS

- Onychophora selected habitat fragments with moist, dark, and decayed cover objects.
- Onychophora were also found in disturbed habitat with non-native vegetation.
- Habitat selection was influenced by urban matrix conditions.
- Protecting Onychophora habitat, even in urban areas, is important for conservation.

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ABSTRACT

Invertebrates are a neglected but important component of urban ecosystems. Although cities are a heterogeneous landscape most studies of urban invertebrates focus on specific habitat fragment types. We modeled the resource selection of an undescribed species of Onychophora – the Dunedin peripatus – at multiple scales across an urban gradient in the city of Dunedin, New Zealand. We aimed to identify habitat variables that influence the presence of the species in a modified urban environment, to assist in management strategies focused on conserving Onychophora as a phylum. We modeled resource selection at micro-and macro-scales within selected parks and habitat fragments using resource selection probability functions (RSPF), and using maximum entropy (Maxent) models at the landscape-scale. We identified 12 relevant environmental variables within habitat fragments and the surrounding urban matrix. The Dunedin peripatus was positively associated with shaded, moist sites with an abundance of large decayed cover objects, including living native tree fuchsia (*Fuchsia excorticata*) and downed woody material. Dunedin peripatus persisted in fragments dominated by exotic vegetation and a history of disturbance, including urban gardens and forest plantations, although the period between disturbances necessary to maintain peripatus populations remains unclear. Our results highlight the importance of studying habitat use at multiple scales within urban areas for biodiversity conservation proposes, even for relatively sessile invertebrates such as onychophorans. We also demonstrate the need for researching and conserving Onychophora populations in terrain that is traditionally discounted as being inhospitable due to disturbance.

1. Introduction

Urban areas are characterized by high spatial heterogeneity due to variably sized patches and diverse land uses, creating a mosaic of habitats for native and exotic species (Niemelä, 1999).

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Responses to urbanization vary due to complex interactions between non-linear and unpredictable habitat disturbances, and the ecological idiosyncrasies of individual species (McKinney, 2008). Cities typically have multiple cores of growth and disturbance, and ecological investigations require extensive measurements of environmental as well as demographic variables. Because species select for resources at multiple scales, it is also important to account for scale when conducting urban research (McCleery, Moorman, Wallace, & Drake, 2012). For invertebrates, a neglected but important component of urban ecosystems, there are differing approaches to defining scales of habitat use in disturbed habitats (Dennis, Shreeve, & van Dyck, 2006). On one hand it has been suggested that the hierarchical order of selection for vertebrates, which describes the scale at which animals select resources (Johnson, 1980), does not apply to flightless invertebrates because they are "marooned on a terrestrial island or patch" (Jamieson, 2003). Unused habitat immediately surrounding the "terrestrial island" can be considered available, but it cannot be assumed that dispersal is possible to sites distant from the island (Jamieson, 2003). A contrasting approach views the city as a "continuum of overlapping resource distributions," without arbitrary habitat boundaries, and treats the urban matrix as an additional resource type that must be included in the analysis (Dennis et al., 2006).

Most studies of urban impacts on invertebrates examine species richness or diversity within specific habitat types, such as habitat fragments (e.g. Bolger, Suarez, Crooks, Morrison, & Case, 2000) or gardens (e.g. Smith, Gaston, Warren, & Thompson, 2006; Smith, Warren, Thompson, & Gaston, 2006). Here we investigate habitat selection across an urban area by an enigmatic saproxylic invertebrate, the Onychophora. Onychophora, commonly known as "peripatus" or "velvet worm", constitute their own phylum, and are an ancient lineage, having changed little since the Cambrian explosion approximately 550 million years ago (Gleeson & Ruhberg, 2010). Due to their unique phylogenetic position they are the focus of extensive evolutionary, reproductive and taxonomic studies; and have been the subject of debate about mechanisms of evolution (e.g. Williamson, 2009 and responses). From the standpoint of phylogenetic diversity their evolutionary distinctiveness should translate to a high conservation priority, yet, despite the entire phylum being classified as "vulnerable" by the IUCN (Wells, Pyle, & Collins, 1983), there has been relatively little focus on managing their populations (New, 1995).

The IUCN Invertebrate Red Book identifies habitat disturbance as the greatest threat to Onychophora populations (Wells et al., 1983), yet quantitative research on onychophoran response to disturbance is lacking. As predatory soft-bodied invertebrates, prone to desiccation due to their inability to close their tracheal spiracles, Onychophora are likely to have specific habitat requirements. Habitat modeling in Australia and Costa Rica demonstrated that their presence was predicted by prey presence, characteristics of fallen logs and soil, moisture levels, and vegetation cover (Barclay, Ash, & Rowell, 2000; McGlynn & Kelley, 1999; Monge-Najera & Alfaro, 1995). Although it has been previously stated that onychophorans prefer indigenous primary forest (Wells et al., 1983) there are currently no records of Onychophora being associated with specific vegetation types, and they are not exclusively found in native forests (Monge-Najera, 1994). In fact, records of Onychophora in exotic plantations (Pawson, Ecroyd, Seaton, Shaw, & Brockerhoff, 2010), harvested forest (Bonham, Mesibov, & Bashford, 2002), and following post-harvest regeneration burns (Yee, Grove, & Closs, 2007) suggest they can exist in modified habitats.

Urbanization has been implicated in the decline of certain Onychophora species, such as the South African *Peripatopsis claveriga* (Purcell, 1899), after road construction and development destroyed much of its habitat (Hamer, 2003). Another South African species, *Peripatopsis leonina* (Purcell, 1899), has not been observed since 1900 when its habitat was converted to housing developments (Hamer, Samways, & Ruhberg, 1997). Many of the impacts of urbanization, such as reduced humidity, deforestation, and removal of decaying wood were thought to preclude the presence of Onychophora in the developed urban matrix. However some species of Onychophora have been reported to occur in urban forested fragments (Cupul-Magaña & Navarette-Heredia, 2008; Harris, 1991; Trewick, 1999). With the rapid international trend toward city growth (United Nations, 2011), an understanding of habitat requirements is necessary to conserve urban populations of this remarkable taxon.

In the present study we investigated the use of urban habitat at multiple scales by a single undescribed species of Onychophora in an urban area of New Zealand. Though the Dunedin peripatus is still unclassified, Trewick (1999) concluded that the Onychophora within Dunedin conformed to a, "single-species level taxon." The Dunedin peripatus has been observed in forested parks and private gardens within the city (Trewick, 1999; Harris, personal communication), including a noteworthy population consisting of thousands of individuals (Harris, 1991). We build upon known important ecological variables derived from Onychophora populations in forest habitats, and focus on their habitat selection within city reserves as well as the adjacent urban matrix. We hypothesize that the presence or absence of Onychophora in urban areas is primarily affected by the structure of living and dead vegetation within forest fragments, which ensures the presence of cover objects that provide refuge and humid conditions, and not by large scale features such as fragment size and shape, or landscape-scale features of the developed urban matrix. Our objective was to improve the understanding of onychophoran ecology across a variety of urban habitats, thus facilitating decision-making for peripatus management and conservation in modified habitats.

Table 1
Features of the three sample parks and reserves. Includes: sample area size, distance to city center, and average housing density in a 0.25 km^2 buffer around the sample area.

	Town belt	Fraser gully	Ross creek
Sample area size (ha)	7.4	50	13
Distance to city center (km)	0.9	3	3.5
Housing density (homes/ha)	8.4 ± 4.3 (S.D.)	5.5 ± 3.3 (S.D.)	1.6 ± 1.7 (S.D.)

2. Materials and methods

2.1. Study area and scale

The research was conducted in the city of Dunedin, New Zealand (population ~120 000). Dunedin has a warm temperate climate without a distinct wet season. Habitat selection by the Dunedin peripatus was assessed at three scales: (1) micro- and (2) macro-scale selection measured in three parks and reserves, and (3) landscape-scale selection measured at points throughout the city. The three parks and reserves at which micro- and macro-scale selection were measured were: the Town Belt, Frasers Gully, and Ross Creek plantation (Table 1). The sample areas were selected according to reported Onychophora presence, the presence of a representative range of habitat types, and the sites' location along a gradient of urbanization from the city center (Fig. 1). The Town Belt sample area was intersected and completed bounded by paved roads. Dominant vegetation was exotic evergreen and deciduous trees, mowed turf grass, and native understory herbs. The Fraser Gully sample area included regenerating and mature native species, exotic trees and shrubs, harvested plantation forest, pasture, and mowed turf grass. The Ross Creek plantation sample area was a mixed-use plantation at the boundary of the central city. Dominant