Focal Nodes Identification Using Habitat Availability Concept for Simulation of Ecological Connectivity Network of Quezon City, Philippines

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Abstract. Anthropocentric orientation of urban development processes leads to deficiency of areas with significant environmental values in the urban landscapes. As landscape planners try to increase the quality of living in the urban environment, efforts are focused only on the hot spots which often cater only to the recreational needs of urban dwellers. In Quezon City, the local government unit plans to create the Green Lung Network featuring a chain of developments linking La Mesa Nature Reserve, the largest green space in Metro Manila, to all the open spaces and parks in the city. However, the chosen areas to be connected are based only on area size of green spaces and opportunities for economic development. To support and enhance the connectivity plan of the city government, this study aims to identify the focal nodes which represent the key habitat patches of interest on the landscape between which flows are modelled in circuit analysis for simulating an ecological connectivity network. Parameters are based on empirical habitat-use data on the preference of biological indicators/focal species. For computational feasibility, instead of treating every occurrence of suitable habitat on the landscape as a focal node, this study applies the Habitat Availability (reachability) concept using the GIS tool Conesnode. This allows ranking habitat patches (patches prioritization) by their contribution to landscape connectivity, which provides objective criteria for the selection of the most critical habitat areas for conservation planning purposes. Not only the spatial arrangement of the habitat is considered (structural connectivity), but also the dispersal distances and the behavioural response of species to the physical structure of the landscape (functional connectivity) is taken into account in the analysis. The results revealed that focal nodes of Quezon City include not only the ecological cores but also other tiny patches of green spaces. Moreover, a more surprising result is that some highly vegetated nodes did not qualify as priority nodes for conservation.

Keywords: Focal Nodes, Landscape Ecology, Ecological Connectivity, GIS, Focal Species, Habitat Availability, Urban birds

1. Introduction
Quezon City (QC) is one of the most developed cities in the Philippines. It is the most competitive city in 2018, first in economic dynamism and second in infrastructures.[2] As a result, its habitat patches are significantly affected by urbanization. The removal of 1,858 trees to pave way for the MRT 7 line in QC [3] can possibly lead to loss of natural habitats and further landscape fragmentation which will go against the goal of the city government in creating a garden city. In the longer term, reduced gene flow as a result of habitat fragmentation can lead to loss of genetic diversity and thus to decreased fitness, reduced adaptability to environmental changes or even extinction of the populations which have survived.[4] Along with the new transportation system, the city government made a Comprehensive Land Use Plan for 2030.
which includes the Green Lung Network featuring a chain of developments linking all the open spaces and parks in the city.[5] However, it does not address the functional and structural connectivity of green spaces and is focused solely on creating green corridors for human mobility and the areas linked are only the largest public green spaces.

Thirtysix percent of QC’s green spaces is in the northernmost part of the city - the La Mesa Nature Reserve which functions as an important breeding and roosting area for a variety of wildlife species including birds.[6] It acts as the mother node in a metapopulation zone that has significant influence on the surrounding area.[7] However, it is separated from other ecological cores by the MRT 7 line and wide highways traversing the city. Thus, it is a challenge to connect this area to other green spaces of the city to create an ecological network that can distribute the biodiversity all over the city. The main priority at present is not to conserve rare or endangered species but rather to stop the process of biotic impoverishment to enhance future possibilities of habitat restoration.

To ensure viable species populations in fragmented landscapes, individuals must be able to move between suitable habitat patches. To maintain or restore connectivity, planners must identify the best habitat and potential corridors by quantifying the landscape characteristics such as distances, size, and density, and consider landscape resistance and the barriers between habitats posed by the landscape and land use.[8] The first step to understanding the role of habitat connectivity in urban ecology is the challenging task of assessing connectivity in the complex patchwork of contrasting habitats found in cities.[9] As a way of preserving the biological integrity of a landscape, well-planned corridors and habitat matrices must be in place to allow dispersal between green spaces. But before paths of corridors can be strategically placed, the nodes to connect must be identified first. Hence, this study aims to identify parameters for movement along green spaces using empirical habitat-use data on the preference of biological indicators/focal species and with GIS technique, identify the priority nodes for the simulation of ecological connectivity network.

2. Methodology

Nodes represent the differentiated spatial units (green spaces) that are considered for analysing connectivity. The focal nodes are the habitat patches of interest in the landscape between which flows are modelled in circuit analysis.[10] For computational feasibility, instead of treating every occurrence of suitable habitat on the landscape as a focal node, this study uses the Habitat Availability (reachability) concept which is based on considering a patch itself as a space where connectivity occurs, integrating patch attributes and connections between different patches in a single measure.[11] For a habitat being easily available (reachable) for an animal, it should be both abundant and well connected; therefore, habitat availability for a species may be low if habitat patches are poorly connected, but also if the habitat is highly scarce even if the patches are highly connected.

The tool used in this study to identify the focal nodes was Conefor Sensinode 2.6 which is a spatial ecology tool that can be used for analyses and decision-making support in conservation planning through the identification and prioritization of critical sites for habitat and landscape connectivity.[12] It is a program for quantifying the importance of habitat patches for maintaining landscape connectivity through graph structures and habitat availability indices. This allows prioritizing habitat patches based on their contribution to landscape connectivity, providing objective criteria for the selection of the most critical habitat areas for conservation planning purposes. Not only the spatial arrangement of the habitat is considered (structural connectivity), but also the dispersal distances and the behavioural response of individuals or species to the physical structure of the landscape (functional connectivity) is taken into account in the analysis.[13,14]
Table 1: Parameters for identification of focal nodes for *Passer montanus* [15]

| Parameter          | Weight                  | Justification [15]                                                                 |
|--------------------|-------------------------|-----------------------------------------------------------------------------------|
| **Patch Size**     | **Minimum Area Of 2 Hectares** | Bird Nesting Site: Most species successfully colonised large patches more than smaller ones. Population density decreased with smaller habitat patch area. |
| **Patch Distance** | **Maximum Distance Of 1000 Meters** | Seed Dispersal: Larger parks tend to support more diverse habitats and tree species, and have reduced edge effects, which help birds to establish larger, and thus more stable populations. |
|                    |                          | Diet/Feeding/Foraging: Non-random preferences for foraging habitats. Lower found in larger areas of lawns under the canopy because of more intensive human management and disturbance. |
|                    |                          | Breeding: The area covered with bush layer, tree layer and pond, >0.05 ha. Larger parks with more visitors could support more omnivores in the breeding season. Increasing random extinction with decreasing habitat size. |
|                    |                          | Seed food within 1 km of the nest site influenced nest-site choice or affected productivity. |
|                    |                          | All tree fractions equally suitable; avoids gaps. |
|                    |                          | Birds choose the least-cost (optimum) path, encounter fewer hazards, would spend less time in traveling, and travel through habitat with higher probability of containing food and cover. |
|                    |                          | The importance of seed and food resources to the persistence of eurasian tree sparrow populations. Operates on a larger spatial scale due to the greater mobility in the nonbreeding season. |
Table 2: Parameters for identification of focal nodes for *Pycnonotus goiavier* [15]

| Parameter          | Weight | Description                                                                 | Bird Nesting Site | Seed Dispersal          | Diet/Feeding/Foraging                      | Breeding                                                                 |
|--------------------|--------|------------------------------------------------------------------------------|-------------------|--------------------------|--------------------------------------------|--------------------------------------------------------------------------|
| Vegetation Density |        |                                                                              |                   |                          |                                            |                                                                          |
| 10                 | Closed Forest | More than 2000sqm, greater than 70% canopy cover                             | Nest in urban gardens; arboreal and make untidy, cup-shaped nests in trees. Hole nester (versatile). Strong preference for nest sites adjacent to wetland habitats, woody vegetation and farmland sites | Fruit 8 to 10 mm, seed deposition, seeds defecated or regurgitated at open sites is limited by perch availability in terms of height, diameter and branching | Forage within tree foliage, which typically take fruits and berries from a perch and swallow them whole, defecating viable seed. High abundance in high vegetation density (woodland) | Adjusting their breeding activities and/or foraging areas by tracking food resources |
| 9                  | Medium Closed Forest | More than 2000sqm, 40-70% canopy cover                                    |                   |                          |                                            |                                                                          |
| 8                  | Open Forest | More than 2000sqm, 10-40% canopy cover                                    |                   |                          |                                            |                                                                          |
| 7                  | Agricultural Land | Distinctive geometric fields and road patterns                            |                   |                          |                                            |                                                                          |
| 6                  | Grassland | Predominantly vegetated with grasses                                        |                   |                          |                                            |                                                                          |
| 5                  | Lawn     | Planted grass                                                               |                   |                          |                                            |                                                                          |
| Patch Distance     |        |                                                                              |                   |                          |                                            |                                                                          |
| Maximum Distance: 1000 Meters | Nesting site on the trees | All tree fractions equally suitable; avoids gaps within 500-m intervals at distances 10, 20, & 40m from the border with urban forest to the fringe and 10, 20, 40 & 65m from urban forest | Birds are assumed to choose the least-cost path, encounter fewer hazards, would spend less time in traveling, & travel through habitat with a higher probability of containing food and cover | Small highly isolated patches of forest adversely affect some bird. Nearest distance to waterbody, grassland and trees |                                            |
The patch attributes used for identifying the focal nodes are based on the habitat preferences of the focal species which are the top two urban birds in QC. Tables 1 and 2, shows the justification of the parameters based on the collected literature by Nor et al. [15] on the habitat preferences. The larger green patch size has higher number of Eurasian tree sparrow (*Passer montanus*) during the breeding season and is easier to move within. However, the patch size has little impact on the seed dispersal of Yellow-vented bulbul (*Pycnonotus goiavier*). The species richness of *Pycnonotus goiavier* was positively correlated with vegetation density while *Passer montanus* showed an inverse correlation. Hence, for the *Passer montanus* the focal nodes are based on patch size (in unit ha), while for *Pycnonotus goiavier*, the focal nodes are based on vegetation density (type of green space). Both species have a dispersal capability of about 1000 meters as both seed density and number of species were significantly affected by distance from vegetation area.

Conefor Sensinode 2.6 uses connectivity indices for computation of node importance. Based on the study of Pascual-Hortal and Saura [11], the best binary index for the type of connectivity analysis is the Integral Index of Connectivity (IIC) which is sensitive to all types of negative changes that can affect the habitat mosaic and is effective in detecting which of those changes are more critical for its conservation. The IIC values allow identifying the most critical nodes for the maintenance or improvement of landscape connectivity, in which conservation or restoration efforts should concentrate. [16] In this index, two patches are linked (directly connected) if the distance between them is below a certain threshold dispersal distance. [16] IIC ranges from 0 to 1 and increases with improved connectivity. It is given by:

\[
IIC = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} a_i \cdot a_j}{A_L^2 + n_L}
\]

where \( n \) is the total number of nodes in the landscape, \( a_i \) and \( a_j \) are the attributes of nodes \( i \) and \( j \), \( n_L \) is the number of links in the shortest path (topological distance) between patches \( i \) and \( j \), and \( A_L \) is the maximum landscape attribute (MLA).

To obtain the final index value that characterizes the degree of habitat connectivity for the whole landscape (mosaic of habitat patches), MLA value was entered in Conefor. This is the value that would correspond to a patch covering all the landscape with the best possible habitat. In the first run, since the attribute used for *Passer montanus* is patch area, the MLA value was the total landscape area of Quezon City, comprising both habitat and non-habitat patches. In the second run, since the attribute for *Pycnonotus goiavier* is a quality-weighted area of green space land cover type, the MLA was equal to highest value of the weight attribute multiplied by total area in hectares of the study area.

Conefor Sensinode 2.6 calculates the importance of every node as the decrease in the connectivity metric value caused by the removal of that individual node from the landscape. [17] In this study, the importance of a node according to IIC metric was expressed in relative terms (delta).

\[
dM(\%) = 100 \cdot \frac{M - M_{after}}{M}
\]

Where \( M \) is the IICnum value when all the nodes are present in the landscape (i.e. the metric value for the initial, intact, undisturbed landscape) and \( M_{after} \) is the IICnum after the removal of that individual node from the landscape. Therefore, \( dM \) quantifies the relative variation in the overall IIC value for the whole landscape (\( M \)) after the loss of a particular node/patch.

The importance values for the IIC metrics were partitioned in three different fractions (*intra*, *flux*, *connector*) considering the different ways in which a habitat patch (node) can
contribute to overall habitat connectivity and availability in the landscape.[17] Conefor automatically calculated for each node the values of these three fractions. The total of the three is the final importance value for each node. Only positive or zero values are possible. The higher the value, the more important that node is for maintaining landscape connectivity.[17]

2.1 Data Preparation in Google Earth Pro and ArcGIS Desktop 10.3
First, the polygons of green spaces of QC were created using Google Earth Pro. All clustered vegetation in a minimum area of 2 hectares were considered as green space and categorized by the author to six different land cover types as shown in Table 2. The kmz file from Google Earth Pro was then transferred to ArcGIS Desktop 10.3 and converted to a shapefile.

2.2 Pre-processing using Conefor Inputs 10 (ArcGIS extension)
There are two parts of Conefor tools: the GIS extension (Conefor Inputs 10 tool) and the standalone tool (Conefor Sensinode 2.6). The polygon shapefile of QC’s Green Spaces was analysed using the GIS extension to produce the input files to be used in Conefor Sensinode for calculating the focal nodes and patch distance. The tool was ran twice: first, using patch size as attribute value, second using green space land cover type. In both runs, the distance threshold was 1000 meters, the maximum dispersal distance of the focal species. For each run, there are two ASCII text file outputs: first was the “distances to each feature” (Euclidian distance between nodes) and second had the nodes containing the attribute value to be used as another parameter for identifying the focal nodes.

2.3 Node Importance Processing in Conefor Sensinode 2.6 (standalone tool)
The two ASCII text files were loaded in the tool for the full binary connection modelling which considers each two nodes as either connected or not, with no intermediate modulation of the connection strength or dispersal feasibility among them.[16] The tool assigns a link between two nodes implying the potential ability of an organism to directly disperse between these two nodes, which are considered connected.[16]

The connection type selected was “Distances” and the distance threshold value was 1000 meters. All pairs of nodes separated by a distance larger than the threshold distance were considered directly unconnected (no link between them), while a link was assigned to those nodes with an internode distance below or equal to the threshold. The tool was ran twice, once for each ASCII text file of the two species. Each run produced ASCII text file containing the node importance values (dIIC) for the species. Then, arithmetic mean of each node value for the two species was obtained to produce the final node importance value. The nodes with values higher than 1 were considered the focal nodes of QC.

2.4 Creating the focal nodes shapefile in ArcGIS Desktop 10.3
The node values were joined in the attribute table of the Green Spaces polygon shapefile using ArcGIS Desktop 10.3. The focal node maps for each species as well as the final focal node map for QC were generated.

3. Results
The IIC used by Conefor Sensinode in identifying the focal nodes integrates in a single measure the habitat area made available by the connections between nodes (interpatch connectivity) and the connected area (or other node attributes) existing within the nodes themselves (intrapatch connectivity). Therefore, the importance of a particular node for a habitat availability index is the joint result of 1) its intrinsic habitat characteristics (e.g. area size and vegetation density) and 2) its topological position within the landscape network (e.g. a node acting as a stepping stone for dispersal between other habitat areas). The relative importance
of each node depends as well on the inputs of the analysis (spatial arrangement of habitat nodes in the landscape and dispersal distances).

In Figure 1, the nodes with the highest IIC values are those important both for interpatch and intrapatch connectivity. The higher the value, the more important that node is for maintaining landscape connectivity. A noteworthy difference in the two maps is the change in IIC values of QC Circle found at the center of the city and the patches in the Northern part (Bagong Silangan area and areas crossed by Mindanao Avenue) and Southern part (Camp Aguinaldo, Ugong Norte, and Horseshoe Village. For *Pycnonotus goiavier*, QC Circle has high IIC value due to its vegetation density; however, its size is relatively small compared to other nodes which is why it got lower IIC value for *Passer montanus*. On the other hand, the northern and southern nodes, has higher IIC values for *Passer montanus* due to their area sizes despite the low vegetation density which are open forests, grassland, and lawn.

Figure 2. Focal Nodes of QC based on the arithmetic mean of IIC values of the green spaces for the two focal species
When the final focal nodes for both species were generated, there were 26 nodes identified with IIC values 1 and above. The IIC value of QC Circle did not reach the cut; hence, it was not included in the final nodes (see Figure 2). Focal nodes with the highest IIC values for both species are La Mesa Nature Reserve, UP Diliman, and Culliat and New Era areas. Importance value of La Mesa Nature Reserve and UP Diliman is due to their area size and vegetation density. Even though areas in Culliat and New Era have lower vegetation density (open forest) compared to other surrounding green spaces, it got a higher IIC value due to its area size and location which is near the geographic centre of QC.

However, an interesting result shows that tiny patches in the eastern part of QC were included in the final focal nodes (Figure 3). According to Saura and Pascual-Hortal [16], areas get high IIC values larger than 1 because they serve as stepping-stone patches, such that the loss of any of them would disconnect the remaining habitat in two disconnected halves. Each of the three tiny focal nodes in QC would have a large impact on connectivity when lost. Hence, it is important that they are included in the nodes to be connected with corridors.

![Image of Figure 3](image-url)

**Figure 3. Tiny Focal Nodes of Quezon City**
Satellite Image Source: Google Earth Pro, 2018

### 4. Conclusion

As the Anthropocene activities engage in restoring the altered ecosystems and protect the existing fragments of natural systems, landscape planners must recognize that the most effective way to re-establish or maintain the viability of these systems is to ensure they exist as a part of a larger functioning system. Urban planning process should integrate ecological concepts particularly ecological networks. This study provided a framework of integrated models which were parameterised with green space structures such as patch size and vegetation density to optimise corridor effectiveness for two bird species: Eurasian tree sparrow (*Passer montanus*) and Yellow-vented bulbul (*Pycnonotus goiavier*).

This study emphasizes the importance of considering the behaviour and preferences of existing species in the landscape when developing priority corridors of ecological connectivity networks. Conserving the existing green spaces of QC and creating greenways to link them should not be just based on aesthetic reasons that affect only the populace. Using the Habitat-Availability approach can help us ensure that we are managing the linkage as a semblance of a
fully functioning ecosystem, rather than a narrow gauntlet that lets focal species pass between areas that threatens mortality rate. Connectivity modelling involves a great deal of research, data compilation, GIS analyses, and careful interpretation of results. Defining areas to connect, parameterising resistance models, and other modelling decisions are not trivial.

The identification of important habitat patches and the functional connection between them is critical for constructing ecological networks. In this study, the selection of patches for the identification of focal nodes did not only consider the vegetation density, area size, and patch distance but also the contribution of each node to the overall system. The Habitat Availability Approach used in identifying the focal nodes resulted to a surprising map. Some highly vegetated nodes with large area size were not included in the focal nodes but there were tiny patches which were surprisingly tagged as important nodes. Changes in land use can be considered as one reason leading to this effect. For example, the Arboretum forest was previously wider before UP Technohub was deducted from its patch area. If the ecological network plan was simulated before the change in land use, Arboretum forest could still be one of the focal nodes of QC. This suggests that conserving connectivity of green spaces for the focal species require different strategies than simply conserving the ecological cores.

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