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Using TreeNet for Identifying Management Thresholds of Mantled Howling Monkeys' Habitat Preferences on Ometepe Island, Nicaragua, on a Tree and Home Range Scale

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Abstract

Numerous studies have been conducted on mantled howling monkeys (*Alouatta palliata*). However, very few of the studies have dealt with explicitly quantifying spatial and habitat preferences. Thus, the exact used and unused habitats of howling monkeys remain neither fully investigated nor quantified. Thus, crucial thresholds for science-based sustainable management programs continue to be unknown. Therefore, in this paper, the presence and absence of two howling monkey groups in different forest types on the island of Ometepe, Nicaragua were examined. Data were collected on several variables including the focal animal's tree location and measurements of that tree. These data were linked with landscape features such as proximity to man-made and natural edges. In order to assess the generalizability and robustness of the findings, the data were analyzed on two scales: (i) the trees the monkeys used were compared to random (pseudo-absence) trees and (ii) home ranges were estimated based on the animals' locations and compared to unused ('absence') areas. Resource Selection Functions (RSFs), which are widely utilized for comparing localities used by wildlife to unused locations, were employed. The powerful TreeNet (Salford Systems Ltd.) algorithm was applied to obtain the resource functions and thresholds. The results indicate that tree Diameter at Breast Height (DBH) and its derivatives were the most relevant variable explaining where the howling monkeys occurred in the island forest habitats.

This study uses a powerful TreeNet algorithm to determine resource selection functions and thresholds of the mantled howling monkey on two habitat scales in order to contribute to their conservation.

Key words:
Mantled Howling Monkey (*Alouatta palliata*), Habitat Preferences, Resource Selection Functions (RSF), TreeNet, Conservation Management Thresholds, Ometepe, Nicaragua

Introduction

An understanding of the habitat preferences of animals is key to their conservation management (Johnson, 1980; Manly *et al*., 2002). For example, for species preferring big trees, relevant trees and habitats that support them need to be protected (Jones, 2001; Braun, 2005). The mantled howling monkey (*Alouatta palliata)* is a relatively large arboreal New World primate belonging to the family Atelinae (Rowe, 1996; Fleagle, 1999). As a heavy primate, it may be restricted to the middle or upper strata of the forest canopy (Fleagle, 1980; Neville *et al*., 1988). The mantled howling monkey is a generalist herbivore, foraging mostly on young leaves (Rickwood & Kenneth, 1979; Milton, 1980; Estrada, 1984). Currently, *A. palliata* is listed as an endangered species by the USDA (United States Department of Agriculture http://www.usda.gov/wps/portal/usdahome) and CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora http://www.cites.org; Nowack & Paradiso, 1983), yet we have little explicitly quantified data on spatial and habitat preferences for howler monkeys.

A crucial component of wildlife research and management is the investigation of the quantity and quality of vegetation within a habitat (Braun, 2005), and how the animals exploit it. Although howling monkeys (*Alouatta spp*.) occupy a wide range of habitats (Crockett & Eisenberg, 1987), they are found in greater densities in riverine and flood-plain forests (Freese *et al*., 1982). However, water can limit them somewhat because rivers can act as barriers for primates (Reed & Bidner, 2004). Howlers also inhabit forests in all stages of growth, with the highest densities apparently occurring in secondary forests (Scott *et al.*, 1976). In addition, howling monkeys are found in fair numbers in tropical dry forests in Costa Rica (Clarke & Zucker, 1994) and in many areas of Honduras, Panama, and Nicaragua (Crockett & Eisenberg, 1987). *Alouatta* even can be observed in small patches where it utilizes forests with low to moderate levels of destruction and of all ages (Horwich, 1998). Notwithstanding, howlers do not occur in open country areas without forests (Wolfheim, 1983).

Of the many howler species, *A. palliata* has the widest range of habitats (Crockett, 1998) and thus, a relatively large ecological niche (see Winkler *et al*., 2004 for genetic diversity). In Costa Rica, *A. palliata* abundance was estimated to be between 7 and 15 howlers/km^2 (Stoner, 1994). The average home range size for *A. palliata* falls between 9.9 ha and 60 ha (Estrada, 1984; Estrada & Coates-Estrada, 1984), and the monkeys usually pass through an area every three to ten days (Baldwin & Baldwin, 1972). In relation to their long resting and digesting times, mantled howlers have relatively small day ranges (10 m – 800 m: Estrada & Coates-Estrada, 1984; Neville *et al*., 1988) and are able to decrease their range when threatened (Horwich, 1998).

According to Horwich (1998), the most serious threats to nonhuman primates are logging, agricultural disturbances, and hunting for bush meat (http://en.wikipedia.org/wiki/Bushmeat). Most disturbances are caused by forest destruction, of which 200,000km^2 occurs annually (Myers, 1987). Worldwide, tropical forests are declining by 0.8% annually (Pucci, 2004). Although exact tree thresholds are not known, it can be presumed that the disappearance of old growth forests will affect howler populations as they appear to show a general preference for 'larger' trees (Fedigan & Jack, 2001). Destruction of howling monkey habitat results in immediate decreased social interactions and increased travel times (Clarke *et al.,* 2002). Long-term effects include decreases in group sizes (Clarke *et al.,* 2002).

Selective logging removes the most valuable timber trees, and usually these are the larger ones (Dale & Slembe, 2005). Because of the howlers' ability to exploit a wide range of habitats, they can somewhat adapt to logging as long as a specific gradient of forest remains available (Horwich, 1998). Further, they can tolerate considerable habitat fragmentation (Crockett, 1998), and are known to inhabit small forest patches such as those on cattle ranches (Bonvicino, 1989). Although exact habitat thresholds serve as crucial metrics for efficient habitat management, they have not been calculated for howler monkeys (Betts *et al*., in press). Moreover, it is not known how 'scale' (*e.g.* Boyce *et al.*, 2003) affects these thresholds. These are fundamental questions for predicting survival probabilities of wildlife, including howlers (Caughley & Sinclair, 1994; Braun, 2005).

In order to gather such information, the quantitative habitat preferences and thresholds of howling monkeys on Ometepe Island were determined using a progressive resource selection function (RSF) approach across two major biological scales. A RSF provides the probability of the use of different available resource units (Manly *et al.,* 2002). It can be used with any algorithm such as habitat or food, and can be combined with many forms of data including those from Geographic Information Systems (GIS). RSFs usually are based on Generalized Linear Models (GLMs) (McCullagh & Nelder, 1989), but in this study, a more convenient and powerful algorithm called TreeNet (Salford Systems Ltd.) was applied. Similar techniques are increasingly being used and provide convincing results (Onyeahialam *et al.,* 2005; Elith *et al.*, 2006; Prasad *et al.,* 2006).

Since it is known that habitat models are generally affected by scale (Bowyer and Kie, 2006; Huettmann and Diamond, 2006), two different approaches were employed in this study. The first examined various aspects of tree preferences by comparing random used and unused monkey trees within the available area. The second approach involved investigating similar tree variables using day ranges. The application of scale is a rather new approach in primate ecology (*e.g.*, Chapman *et al*., 2002a, b), and the results of this study can contribute to a quantified understanding of howling monkey habitat preferences and their conservation management. For example, presence-absence data can be used in detailed management action plans that predict the sustainability of resources. In addition, different influences of natural resources and/or anthropogenic factors can be captured and investigated. RSFs allow the quantitative identification of habitats of high value to a species, and can further assist in conservation mapping (MacKenzie, 2005) and predictive modeling (Onyeahialam *et al.,* 2005). These approaches have been widely employed (*e.g.* Manly *et al.,* 2002; Yen *et al.,* 2004; Sodeikat *et al.,* unpublished; see Johnson *et al.*, 2004 for an exemplary analysis of the distribution of mountain caribou at multiple spatial scales). RSFs also have been helpful in determining the habitat preferences of wildlife exposed to changing environments such as moose (Osko *et al.,* 2004). Although these studies demonstrate that RSFs work (*e.g.* Huettmann & Diamond, 2001; Yen *et al.,* 2004), they have never been used on howling monkey data nor for the study area in Nicaragua. Thus, the Island of Ometepe in Nicaragua was chosen because it provided infrastructure, afforded convenient access, and was home to a group of wild howling monkeys accustomed to humans (see Garber *et al*., 1999; Peter *et al*., 1999; Winkler 1999; Huettmann, 1999; Bezanson *et al*., 2002; Belt, 2006 for more details).

Methods

Study Area

This study was conducted on Ometepe Island, Nicaragua, at the base of the dormant Maderas Volcano. The study area was situated close to Point San Ramon Village. The habitat consisted of two forest areas that were separated by a road. Both were comprised of secondary tropical dry forest containing old growth forest remnants (see Garber *et al*., 1999 and Huettmann, 1999 for further description). Several groups of habituated howling monkeys inhabited the forests. Data for the day range scale were collected from December 28, 2004 to January 6, 2005. Data for the tree scale resource selection functions were collected from December 28, 2005 to January 6, 2006. All observations were made between 06:00 h and 11:00 h.

RSF Tree Scale

The mantled howling monkeys usually were detected by sound or sight by following male calls during early morning hours. The monkeys often were found in the forest along or near man-made marked trails. The howlers at Ometepe lived in fission-fusion groups (see Bezanson *et al*., 2002), typically consisting of seven individuals per group. In order to obtain independent samples, if the first group of monkeys detected was in a tree that already was included in this study, the next group along the trail was followed.

Once the group was located, each tree encountered in which there were monkeys, served as focal trees. The time, date, and the location of the focal trees from the trail were recorded. In addition, the number of monkeys in the tree as well as their gender, maturity, and activity at the moment of observation were recorded. However, this information was not used in this study but kept for future research. Other researchers were in the area studying various aspects of the behavior and ecology of the mantled howling monkey groups (the results are also reported elsewhere).

Several measurements were taken on all of the focal trees. These measurements included: maximum tree height (estimated visually); diameter at breast height (DBH), for which a tape measure was used to measure the circumference of the tree 1.3m above the ground: *cf*. Husch *et al*., 2003); the presence or absence of leaves; canopy length (the maximum distance between the two furthest points of the crown); canopy width (measured from the ground with a tape measure spread between the two furthest canopy points perpendicular to canopy length); canopy depth (estimated visually as the distance between the first major branch of the tree and maximum tree height); and the percent of canopy cover (determined with a spherical densitometer). Thirty trees were measured for this portion of the study.

Because confirmed absence data is crucial for understanding habitat preferences and subsequent resource selection analyses, data also were collected on trees not used by the monkeys ('absence' trees). For every tree used by the monkeys that was measured, two confirmed unused or 'absence' trees were measured. Although such a design results in an uneven sample size skewed toward absence trees, it allows the quantification of unused habitat in a more representative fashion. This not only is justified, but is an established procedure in RSF research (Manly *et al.,* 2002).

Absence trees were chosen in available habitat by selecting a random number for distance (within 100 m of the used tree) and another random number for angle. The trees closest to the locale of the random distance and random angle from the focal tree served as the absence trees. To be included in this study, and for a fair comparison, trees had to reach the forest canopy. The same measurements that were taken on the used trees, were taken on the unused trees. In total, 60 unused trees were sampled.

In addition to tree measurements, the distance of the trees to the nearest edge were recorded. An edge (Forman, 1995) was defined as a span of space that howling monkeys could not cross without coming down to the ground (which they rarely do in continuous forest at Ometepe: pers. obs.). The type of edge was noted as being an agricultural field, river bed, man-made trail, and/or gap between the trees.

RSF Day Range Scale

The 'daily' range was quantified by observing the howler monkeys for part of the day, during the morning hours. In order to estimate the day range, we applied a robust and commonly used method, the minimum convex polygon (MCP) (Braun, 2005; see also P. Hooge's Animal Movement extension in ArcView; Hooge & Eichenlaub, 1997). The MCP can be used to estimate areas even when some unused areas are included. Here we focus on the whole 'home' range area and not only on the concentrated area. (Note: In this short study, 'home' range was defined as areas used by the animals when they were being observed). The day-'home' ranges covered approximately 0.29 ha (0.74 acres; based on n=2*2*10, used and unused trees in two forests).

In order to determine the available habitat in a representative fashion, trees within the area the monkey's used – the day-home range – were randomly sampled. Data on these trees, as well as the overall landscape structure within the day-home range (or 'presence') area, were recorded. In addition, the area that bordered the day-home range was used as the 'confirmed absence' area. The MCP method was employed here as well. As was done for the day-home ranges, ten trees were chosen randomly and evaluated as a representative sub-sample for the 'non-home' range (or 'absence') area. For both the presence and absence home areas, measurements of trees were taken in a fashion similar to the measurements of trees taken and described previously in the RSF tree scale methods section. Briefly, the measurements included: maximum tree height; DBH; canopy length, width, and depth; and the percent of canopy cover. In addition, also as described in the RSF tree scale methods section, the distance from and type of edge were noted.

RSF Analysis using TreeNet

A multiple regression was computed. The TreeNet algorithm (note that 'tree' refers here to a computational algorithm not to be confused with a biological tree) was used because it is fast, convenient, and can handle data without any prior assumptions. In addition, it affords easy interpretation of Resource Selection Functions. TreeNet also can be used with model selection (*sensu* Burnham & Anderson, 2002) and works well with complex and correlated data sets. Salford Systems Ltd. (http://www.salford-systems.com; see also Pittman and Huettmann, 2006; Elith *et al*., 2006) provided the TreeNet algorithm.

Data were imported into TreeNet from MS Excel via ASCII Textfiles, and analyzed for the two scales using identical settings. In addition to the default standards, we used the following settings in order to obtain the best possible model fits and prediction accuracies for comparisons across scales and data sets: Classification Tree, 30-fold cross-validation, tree size of 6, 400 trees, best model chosen by ROC, and balanced sample weights.

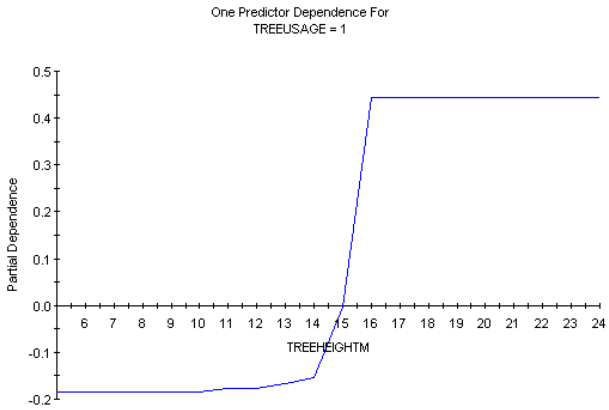
Results

RSF Tree Scale

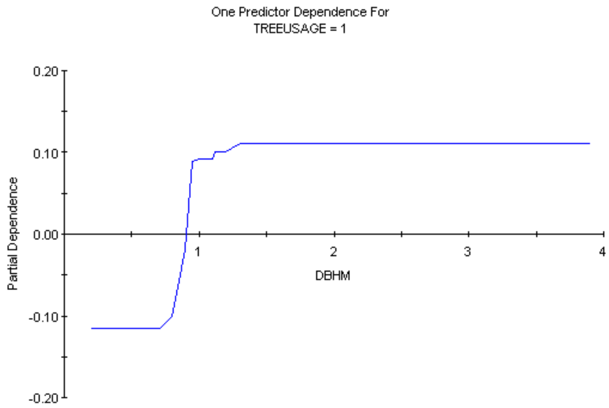
TreeNet runs small sample sizes such as used here within a few seconds. The 'optimum' was found when 87 'trees' were created. The best accuracy is given in Table 1 and demonstrates high accuracy values for testing data (70% correct presence, 88% correct absence). The importance values of predictors for this model are shown in Table 1 also. Importance values from TreeNet describe the individual contribution of each predictor in explaining the response variable. By far, tree height received the highest ranking. Tree DBH ranked second, followed by crown volume. This means that of the six tree scale predictors, tall trees with large DBHs and crown volumes were the most important features determining the presence and absence of monkeys. The detailed RSFs for the predictors are shown in Figure 1 (the top three predictors are shown; others are available upon request).

Habitat thresholds for the predictors are identified where the Y-axis crosses the X-axis (summarized in Table 2). When features are smaller than these threshold values, monkeys appeared to avoid such habitats. It is of interest that virtually all RSFs have clear step-functions with robust thresholds, to be identified without many doubts.

a) Tree Height



b) DBH



c) Crown Volume

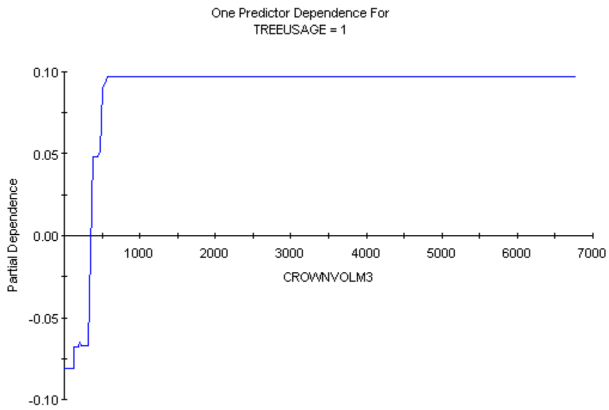


Figure 1. Resource Selection Functions for the top 3 predictors of Howler Monkey habitat measured on the tree scale (positive Partial Dependence indicates preference, negative values indicate avoidance in relative units; a. Tree Height, b. DBH, c. Crown Volume)

RSF Day Range Scale

The best accuracy for RSF day-home range scale is given in Table 1. It is based on 56 trees in TreeNet and shows high predictive values (80% correct absences and 65% correct presences). The importance values of predictors for this model are shown in Table 1 as well. Of the six day-home range scale predictors, edge, tree size (DBH), and canopy were ranked the highest. This means that trees with large diameters and mid-range canopy covers near water were the habitat features of most important in predicting the presence of monkeys at the day range scale. The detailed RSFs for the top three predictors are shown in Figure 2. Table 2 shows the specific management thresholds for the predictors (again, thresholds identified where the Y-axis crosses the X-axis).

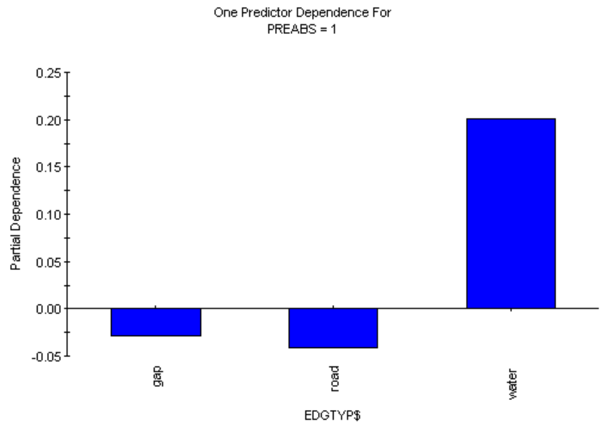
Table 1. Ranking of Importance Values for Predictors on two scales for Howling Monkeys

Tree Scale Model		Day Range Model	
Predictor	Importance Value	Predictor	Importance Value
Tree Height	100	Edge Type	100
DBH	53	DBH	84
Crown Volume	49	Canopy Cover	62
Canopy Cover	38	Tree Height	58
Edge Type	30	Crown Volume	49
Nearest Edge	19	Nearest Edge	10

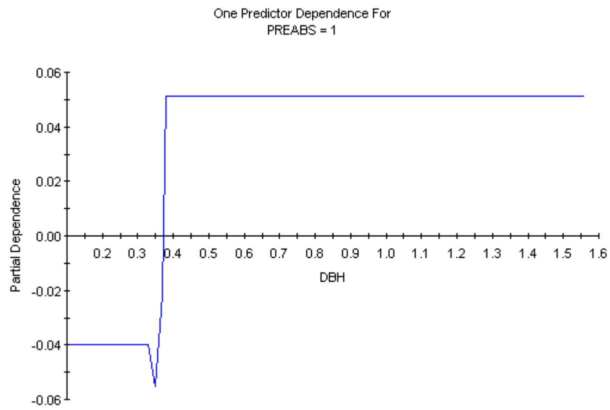
Table 2. Thresholds of predictors across two scales (Tree and Day range) for Howling Monkeys

Tree Scale		Day Range Scale	
Explainatory Variable	Threshold Value	Explainatory Variable	Threshold Value
Tree Height (m)	15	Edge Type	+ water - road, gap
DBH (m)	0.9	DBH (m)	0.37
Crown Volume (m^3)	400	Canopy Cover (%)	10
Canopy Cover (%)	68	Tree Height (m)	12.5
Edge Type	+ gap, none - river, field	Canopy Volume (m^3)	67
Nearest Edge (m)	13	Nearest Edge (m)	7

a) Edge Type



b) DBH



c) Canopy Cover

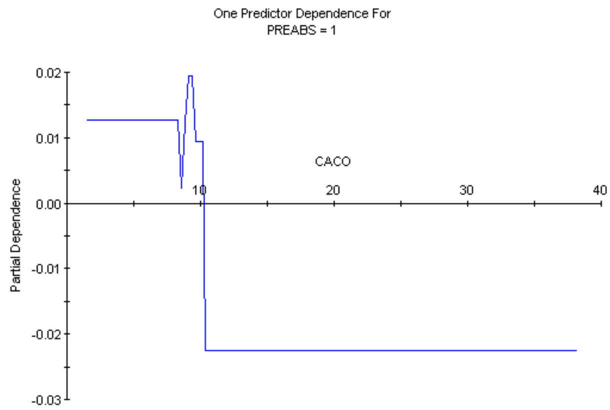


Figure 2. Resource Selection Functions for the top 3 predictors of Howler Monkey habitat measured on the day range scale (positive Partial Dependence indicates preference, negative values indicate avoidance in relative units; a. Edge Type, b. DBH, c. Canopy Cover CACO)

Discussion

Overall, as can be seen in Figures 1 and 2, large tree structures seem to be of key importance to the animals' presence. The monkeys appear to prefer trees that are large – in height, DBH, and crowns. This makes sense in light of previous research demonstrating that howling monkeys feed on young leaves from, as well as rest on, large branches and tree trunks (*e.g.*, Milton, 1980; Garber *et al*., 1999). Our findings quantify these associations for the first time.

Interestingly, the tree scale model results reveal that the monkeys preferred larger trees than the model for the day range scale shows. This may be due to greater variability in habitat during daily ranging, which consisted of a mixture of tree characteristics including smaller trees for comparison. In addition, this is not out of the ordinary considering that habitat preferences can change across scales (Bowyer & Kie, 2006; Huettmann & Diamond, 2006). The main point is that for both scales, fairly consistent models were identified, especially where the most important predictors, resource functions and thresholds were concerned. This means that the results of this study can be generalized.

Another finding is that the monkeys did not choose trees or areas with young open forests or completely closed canopies (see for instance Figure 2c). This probably was not influenced by antipredator strategies, which seem to be relatively unimportant on Ometepe. Observations and experience on the islands indicate that the monkeys are not hunted and are well habituated to the presence of humans (R. Molina pers. com.; also see Huettmann, 1999 for lack of predation events by large avian predators).

Several steps could be undertaken to improve this study. First, increasing the sample sizes for both the tree and home range data would be beneficial. Data on more groups of monkeys and/or extending the study area would increase the data pool as well. Also, sampling during different seasons (*e.g.*, dry and wet) would clarify whether or not tree and habitat preferences change throughout the year. Additional variables could be included also such as the locations of other howler groups in the study area and how these affect the positioning of the focal groups and dispersed individuals. In addition, behavioural information such as the use of trees for specific activities such as feeding, resting, travelling, *etc*. would be interesting to investigate further. Moreover, incorporating these data with information on habitat preferences and demographics of mantled howling monkeys in other areas could contribute toward a PVA (Population Viability Analysis; Morris & Doak, 2002) and science-based conservation management.

Regarding the analyses used, TreeNet provided a quick and convenient output that allowed for rapid assessment of the data, plus afforded a robust research design. GLMs (*e.g.*, Johnson *et al.*, 2004) may not yield results as quickly (Ritter, 2007) or with similar accuracy (also compare with Elith *et al.*, 2005, 2006). It is also likely that GLMs would not have provided very stable models for these data because linear models might not be able to handle such a complex dataset and its underlying non-linear structure. This is further supported by the fact that most RSFs actually summarize complex, multidimensional ecological relationships and interactions, none of which fit well with strictly linear functions such as those used in GLMs.

This is the first time that resource selection functions using a non-linear, TreeNet algorithm were applied to data on mantled howling monkeys in Nicaragua. Furthermore, RSFs were used with data on two scales relevant to the biology of the monkeys – tree and home range (Milton, 1980). In addition, the raw data for this study were 'published' digitally as an online Metadata file (Hubley *et al*., 2006: http://mercury.ornl.gov/nbii). This not only adds to the transparency of the study and results reported, but appears to be an unusual and rather novel procedure in primatology (Huettmann 2005).

Using the Island of Ometepe, Nicaragua as a case study, we have demonstrated the usefulness of a quick and reliable alternative method for analyzing data on the most important resources (*e.g.*, trees and habitat) of howling monkeys. The TreeNet algorithm allows rapid data-mining and quantitative assessment of information that can be used to make more prompt decisions regarding safeguarding crucial biodiversity components. Quantitative forest habitat thresholds of the main predictors of occurrence of animals comprise an essential component of sound conservation management planning.

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Appendix 1

Metadata are presented online with the NBII Metadata Server
http://mercury.ornl.gov/nbii/

Raw Data are stored on a CD-ROM and available from the authors on request.