Tools and Technology Note

Discrepancies Between Euclidean Distance and Compositional Analyses of Resource Selection Data With Known Parameters

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ABSTRACT A Euclidean distance (ED) method of wildlife habitat analysis has recently been proposed as an alternative to compositional analysis (CA). We performed simulation analyses to compare performance of ED to that of CA, using data sets with known parameters, where habitat patch size and shape remained the same. We observed extensive misclassification rates for ED but not for CA. For each of the 16 utilization permutations we modeled, of 3 avoided and 2 preferred habitats, results for CA and ED differed. Differences depended on the particular utilization permutations (i.e., juxtaposition of habitats) and did not seem to occur in any clear or predictable pattern. We recommend that ED not be used for future analyses of habitat use or resource selection until or unless these analytical problems can be rectified.

KEY WORDS compositional analysis, Euclidean distance analysis, habitat utilization, resource selection, simulations.

Investigations into resource selection are a fundamental component of wildlife science (Manly et al. 2002). The concept behind understanding resource selection has direct implications for wildlife management. If decisions about what types and kinds of habitats are to be constructed, enhanced, or expanded by management, then it is crucial that wildlife scientists use accurate and reliable methods of analyses to determine preference, avoidance, or random habitat use of particular habitat types.

Recently, a Euclidean distance (ED)-based analysis method for determining resource selection has been advocated as an alternative to compositional analysis (CA; Conner and Plowman 2001, Conner et al. 2003). Dussault et al. (2005:3119) observed, however, that the ED method provided analytical results of resource selection that "are difficult to interpret," a claim that was only partially countered by Conner et al. (2005).

During simulations to assess behavior of CA misclassification rates compared with other analytical techniques (Bingham and Brennan 2004, Bingham et al. 2007), we noted that ED analyses based on simulations using data sets with known parameters seemed to produce context-dependent conflicting results. Compared with some initial simulations using CA, which produced predictable and reliable results, ED produced wildly differing, and in most cases obviously wrong, interpretations from sets of data that had exactly the same parameters of use and availability but different juxtapositions of habitat types. This not only raises concerns about interpretability, as noted by Dussault et al. (2005), but also indicates that ED may not provide consistent or accurate results from analyses of resource selection.

Dussault et al. (2005) presented comparative analyses of empirical and simulated data based on CA and ED and illustrated that ED produced inconsistent results for habitat types with systematic differences in patch size that were often counterintuitive and difficult to interpret. Dussault et al. (2005:3123) concluded that use of ED could result in habitat preference rankings different from those obtained using CA, "… unless habitat types are randomly distributed and occur in similar sizes and shapes." We investigated, by using examples based on a series of analyses using simulated data with known parameters for habitat types of similar sizes and shapes, whether ED also generates results inconsistent with approaches based solely on relative utilization and availability of habitats. Our objective was to perform simulations that were fundamentally different from those presented by Dussault et al. (2005), in that we kept habitat patch sizes and shapes constant throughout all analyses and only varied juxtaposition of habitat patches, a point directly analogous to the above-mentioned statement from Dussault et al. (2005:3123). Our motives for taking this approach were based on the suppositions that 1) variation in patch size and shape might have been in some way responsible for the strange results Dussault et al. (2005) observed; and 2) if we kept patch size constant and still observed perplexing results from ED, there may be a fundamental problem with the algorithm. Based on outcomes from our initial exploratory analyses of the ED method, along with our extensive past work on the behavior of CA under variable circumstances, we hypothesized that 1) ED had potential to produce results that might be difficult to interpret; and 2) CA would produce results that were consistent with known parameters of simulated data, regardless of spatial context or shape of habitat types, so long as no habitats contained 0% use (Bingham and Brennan 2004, Bingham et al. 2007).

METHODS

The CA method uses multivariate analysis of variance (MANOVA) models to analyze log-ratios for comparison of

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utilization and availability of habitats using animals as experimental units (Aebischer et al. 1993). When a test statistic such as Wilks' lambda is significant, this indicates that nonrandom habitat use has occurred. After we observed nonrandom habitat use, our next step was to find which habitat was used more (or less) than expected relative to another habitat. Additional details about how CA works are provided by Aebischer et al. (1993) and Manly et al. (2002).

The ED method also uses MANOVA models to detect nonrandom habitat utilization using animals as experimental units. We calculated mean observed Euclidean minimum distances to each habitat type for each animal using observed locations. We also simulated 20,000 random points within the hypothetical study area for each utilization configuration using the pseudorandom number function RANUNI in the Statistical Analysis System (SAS release 8.1, SAS Institute, Cary, NC) to model a uniform random distribution. We then obtained a randomized Euclidean mean minimum distance to each habitat type for each animal. Following techniques of Conner et al. (2003), we calculated a matrix of ratios by dividing the simulated observed mean minimum distance for each animal–habitat combination by the corresponding randomized mean minimum distance for each habitat type (rows of matrix were individual animals and columns were habitat types). We used a MANOVA test (Wilks' lambda) to detect a significant deviation from a vector of 1s, which represented the null hypothesis that the observed mean minimum distance equals the randomized mean minimum distance. We interpreted a significant Wilks' lambda as an indication of nonrandom resource selection. If we determined nonrandom use, the next step, as for CA, was to find where use deviated from random and which habitat was used more than expected relative to another habitat. We then used pair-wise t-tests to determine preference of any habitat type over any other habitat type (Conner et al. 2003).

We used the same data sets as for the simulation study areas and the same available habitat data we produced with known parameters for both the CA and ED analyses. We simulated 2 study areas, one with adjacent rectangles of equal area and the other with concentric rings and an inner circle of equal area. We selected geometric shapes to create hypothetical study areas for 2 reasons: 1) for ease of programming; and 2) because these shapes approximated, albeit simply, basic landscape habitat patterns. For example, adjacent rectangles can be considered an approximation of the types of landscape habitat patterns that occur on relatively level or flat landscapes such as prairies or agricultural fields. Concentric rings, with an inner circle, can be considered as representing elevational gradients in montane systems, a playa lake, or prairie pothole surrounded by adjacent native vegetation or crops, or an island in an archipelago subject to consistent rising and falling tides or water levels. In the simulated study areas for both the adjacent rectangles and concentric rings, we modeled what we considered the simplest arrangements possible of differing habitats. We used these simple simulation designs because we hypothesized that if our results were difficult to
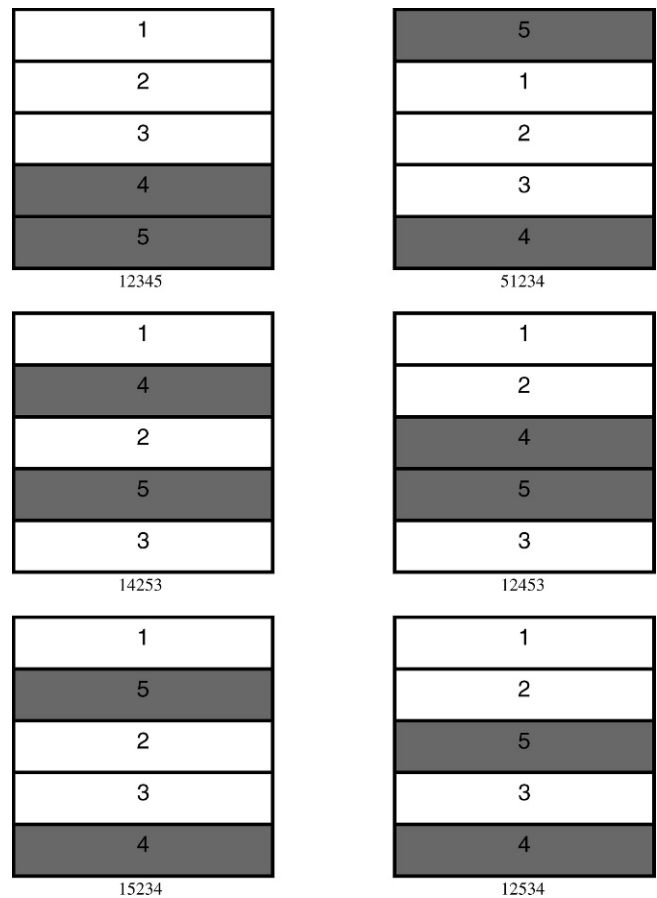
Figure 1. Six utilization permutations of 5 habitat types for simulated study area 1 consisting of 5 parallel, contiguous rectangular strips, each consisting of 20% of the study area (i.e., equal availability). To model utilization, we simulated 100 observations per animal for 30 animals by randomly assigning 30% of observations for each animal to habitats 1–3 (unshaded rectangles) and 70% to habitats 4 and 5 (shaded rectangles).

interpret in this context, they would only be more difficult to interpret in more complex scenarios.

Our first simulated study area was a 10- × 10-unit square with each of the resulting 100 units labeled as a particular habitat category 1–5. We used number of squares assigned to each habitat category as the availability percentage. We assigned 20 squares to each of the habitat categories 1–5 in parallel contiguous rectangular strips, thus modeling each of the habitats 1–5 as equally available with rectangles of the same size and shape (Fig. 1). We then modeled the 5 equally available habitats with 10% average utilization for each of habitats 1–3 and 35% average utilization for each of the 2 habitats 4 and 5 by randomly assigning 30% of observations for each animal to habitats 1–3 and 70% to habitat types 4 and 5. We modeled the resulting 6 possible utilization permutations for the 5 adjacent rectangles 12345, 51234, 14253, 12453, 15234, and 12534, where, for example, the permutation 12345 represents the utilization scheme where habitats 1 (with 10% utilization) and 5 (with 35% utilization) are the outside rectangles and habitats 2–4 are the inside rectangles in the given order (Fig. 1). Only 6 utilization permutations are possible because of the way we modeled the habitat utilizations. For example, the utiliza-
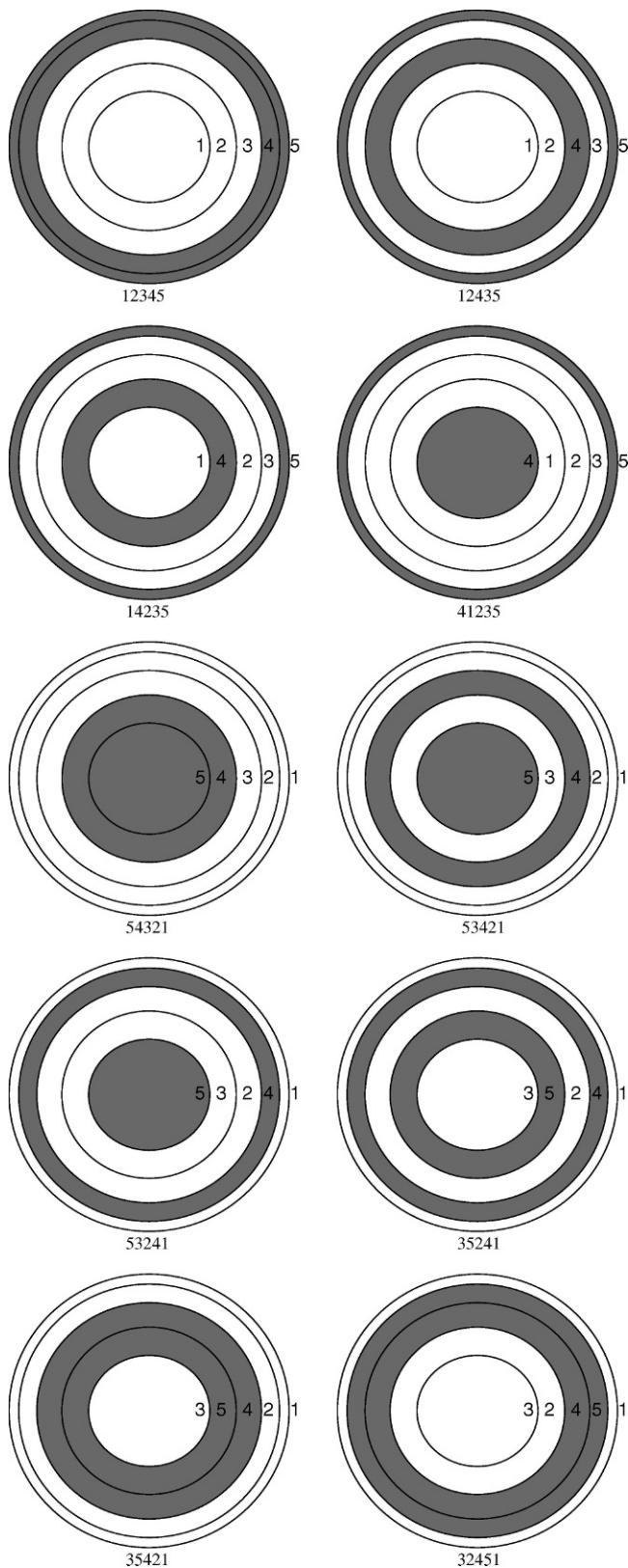
Figure 2. Ten utilization permutations of 5 habitat types for simulated study area 2 consisting of a circular region consisting of 20% of the study area and 4 concentric circles forming 4 circular bands (rings), each consisting of 20% of the study area (i.e., equal availability). To model utilization, we simulated 100 observations per animal for 30 animals by randomly assigning 30% of observations for each animal to habitats 1–3 (unshaded rings) and 70% to habitats 4 and 5 (shaded rings).

tion permutation 12345 is one of the 12 equivalent utilization permutations such as 32154 because of the 6 possible utilization permutations of 1–3 and 2 permutations of 4 and 5. Thus, the 6 possible utilization permutations we considered to constitute all those that represent different patterns of utilization where we modeled habitats 1–3 each with 10% average utilization and habitats 4 and 5 each with 35% average utilization.

Our second simulated study area consisted of a circular region with 20 square units of area, and 4 concentric circular rings, each with 20 square units of area (Fig. 2). As with our first simulated study area, we modeled the 5 equally available habitat types with 10% utilization for each of the 3 habitat types 1–3 and 35% for each of the 2 habitat types 4 and 5. For this simulated study area, there were 10 possible utilization permutations (12345, 12435, 14235, 41235, 54321, 53421, 53241, 35241, 35421, and 32451), where, for example, the permutation 12345 represents an inner circular region labeled habitat type 1, habitat 2 is the first circular ring about habitat 1, et cetera, with the outermost ring labeled habitat type 5 (Fig. 2.) As before, for study area 1 any of the 12 possible permutations such as 32154, because of the 6 possible combinations of 1–3 and 2 combinations of 4 and 5, form utilization permutations equivalent to that represented by 12345. An additional 4 possible utilization permutations exist here because, for example, of 12345 (with habitat 1 as the center circular region and habitat 5 as the outermost ring) and 54321 (with habitat 5 as the center circular region and habitat 1 as the outer most ring) representing different utilization permutations, whereas they do not represent different permutations for study area 1.

We simulated 100 observations/animal for 30 animals (resulting in no 0% observations for any animal in any habitat category) by randomly assigning 30% of observations for each animal to habitats 1, 2, and 3 and 70% to habitats 4 and 5, for each of 1,000 simulations of each utilization permutation. The reason for this restricted randomization was to model habitats 1–3 as equally avoided, habitats 4 and 5 as equally preferred, and each of habitats 4 and 5 as preferred over each of habitats 1–3, using Neu et al. (1974) terminology. We tested for nonrandom utilization using 1,000 simulations for each of the 16 permutations of 5 habitats (i.e., 6 for study area 1 and 10 for study area 2), for a total of 16,000 simulations. We determined nonrandom utilization using Wilks' lambda for both ED and CA methods. We performed all statistical analyses with SAS release 8.1 (SAS Institute).

RESULTS

We did not observe inflated misclassification error rates for CA. Of the 1,000 simulations for each of the 16 utilization permutations of the 5 habitats, <1.2% indicated a misclassification ($P < 0.01$) of a particular habitat category preferred over another for either study area (Tables 1, 2). Conversely, the ED method produced widely varying classifications depending on the particular pattern of habitat utilization. For all 16 habitat utilization permutations, CA found each of habitats 4 and 5 (each with 35% utilization)

Table 1. Percentage of 1,000 simulations where we found a habitat to be preferred ($P < 0.01$) over another habitat using Euclidean distance analysis for simulated study area 1 consisting of 5 parallel, contiguous congruent rectangular areas, each consisting of 20% of the total study area (equal availability). To model utilization, we simulated 100 observations per animal for 30 animals by randomly assigning 30% of observations for each animal to habitats 1–3 and 70% to habitats 4 and 5. We also report results from compositional analysis (CA). Expected values for simulations are presented in the far right column based on relative frequencies, using Neu et al. (1974) terminology.

Preference of	Juxtaposition combination[a]						All CA results	Expected values
	12345	51234	14253	12453	15234	12534		
1 over 2	100	100	0	0	9.9	0	≤0.3	0
2 over 1	0	0	100	100	16.1	100	≤0.4	0
1 over 3	0	10.4	8.1	0	0	0	≤0.4	0
3 over 1	100	15.5	19.4	100	99.9	100	≤1.0	0
1 over 4	0	0	0	0	0	0	0	0
4 over 1	100	100	100	100	100	100	100	100
1 over 5	0	0	0	0	9.9	0	0	0
5 over 1	100	100	99.1	100	16.0	100	100	100
2 over 3	0	0	100	0	0	0	0	0
3 over 2	100	100	0	100	100	100	≤0.7	0
2 over 4	0	0	99.8	0	0	0	0	0
4 over 2	100	100	0	100	100	100	100	100
2 over 5	0	0	99.7	0	14.3	0	0	0
5 over 2	100	100	0	100	10.5	100	100	100
3 over 4	0	0	0	0	0	0	0	0
4 over 3	100	100	98.4	100	100	81.0	100	100
3 over 5	0	0	0	0	99.7	100	0	0
5 over 3	100	100	100	100	0	0	100	100
4 over 5	0	16.5	10.2	0	100	100	≤0.4	0
5 over 4	100	9.5	15.7	89.7	0	0	≤0.8	0

[a] Juxtaposition combinations of 5 equally available habitats (1–5) with 10% average utilization of habitats 1, 2, and 3, respectively, and 35% average utilization of habitats 4 and 5, respectively.

preferred ($P < 0.01$) over each of the habitats 1–3 (each with 10% utilization) for all 1,000 simulations (Tables 1, 2). We expected this result because we modeled each of habitats 4 and 5 with 35% use and 20% availability to be preferred and each of habitats 1–3 with 10% use and 20% availability to be avoided.

Whereas CA did not indicate a preference of any of the avoided habitats 1–3 over any of the preferred habitats 4 and

Table 2. Percentage of 1,000 simulations where we found a habitat to be preferred ($P < 0.01$) over another habitat using Euclidean distance analysis for simulated study area 2 consisting of a circular region consisting of 20% of the study area and 4 concentric circles forming 4 circular bands (rings), each consisting of 20% of the study area (i.e., equal availability). To model utilization, we simulated 100 observations per animal for 30 animals by randomly assigning 30% of the observations for each animal to habitats 1–3 and 70% to habitats 4 and 5. We also report results from compositional analysis (CA). Expected values for simulations are presented in the far right column based on relative frequencies, using Neu et al. (1974) terminology.

Preference of	Juxtaposition combination[a]										All CA results	Expected values
	12345	12435	14235	41235	54321	53421	53241	35241	35421	32451		
1 over 2	0.2	0	0	100	100	19.7	100	0	0	100	≤0.9	0
2 over 1	61.7	100	100	0	0	7.2	0	100	100	0	≤0.9	0
1 over 3	0	0	0	55.6	0	0	0	66.5	0	100	≤1.2	0
3 over 1	100	100	100	1.1	100	100	100	0.1	100	0	≤0.9	0
1 over 4	0	0	0	0	0	0	100	0	0	0	0	0
4 over 1	100	100	100	100	100	100	0	100	100	100	100	100
1 over 5	0	0	0	0	0	0	0	0	0	0	0	0
5 over 1	100	100	100	100	100	100	100	99.7	100	100	100	100
2 over 3	0	0	0	0	0	0	0	100	0	100	≤0.8	0
3 over 2	100	100	100	100	100	100	100	0	99.9	0	≤0.9	0
2 over 4	0	0	64.2	0	0	0	0	100	0	0	0	0
4 over 2	100	100	0.6	100	100	100	93.9	0	100	100	100	100
2 over 5	0	0	0	0	0	0	0	96.0	0	0	0	0
5 over 2	100	100	100	100	100	100	100	0	100	100	100	100
3 over 4	0	100	97.0	0	0	100	100	0	0	0	0	0
4 over 3	100	0	0	100	100	0	0	100	100	100	100	100
3 over 5	0	75.9	0	0	0	0	0	0	0	0	0	0
5 over 3	100	0	100	100	100	100	100	100	100	100	100	100
4 over 5	0	0	0	99.7	0	0	0	4.0	0	2.7	≤0.5	0
5 over 4	98.6	100	100	0	100	100	100	33.8	98.7	38.5	≤0.8	0

[a] Juxtaposition combinations of 5 equally available habitats (1–5) with 10% average utilization of habitats 1, 2, and 3, respectively, and 35% average utilization of habitats 4 and 5, respectively.

5 for all 16,000 simulations, ED found ≥ 1 of the avoided habitats 1–3 preferred over ≥ 1 of the preferred habitats 4 and 5 in nearly all (≥ 997) 1,000 simulations of 3 of the 6 utilization permutations for study area 1 and nearly all (≥ 970) 1,000 simulations of 5 of the 10 utilization permutations for study area 2 (all $P < 0.01$), illustrating what would be Type II errors if obtained with CA (Tables 1, 2). Also, in some cases, >1 of habitat types 1–3 were found by ED to be preferred over habitat type 4 or 5 for all 1,000 simulations; for example, using the utilization permutation "53241" for study area 2, we found both habitat types 1 and 3 to be preferred ($P < 0.01$) over habitat type 4 for all 1,000 simulations (Table 2).

Whereas CA only indicated preference between a pair of habitats 1–3 in ≤ 21 of the 1,000 simulations for any utilization permutation, ED indicated a preference between each pair of habitats 1–3 for all 1,000 simulations of half of the 16 possible utilization permutations, and in ≥ 259 of the 1,000 simulations for each of the other 8 utilization permutations (all $P < 0.01$), illustrating what would be Type I errors if obtained with CA (Tables 1, 2). Likewise, whereas CA indicated no preference ($P > 0.01$) between habitats 4 and 5 for almost all (>987) of the 1,000 simulations of each of the 16 utilization permutations, ED indicated a preference ($P < 0.01$) between habitats 4 and 5 for all 1,000 simulations of half of the possible utilization permutations and in ≥ 259 of the 1,000 simulations for each of the other 8 utilization permutations (Tables 1, 2).

DISCUSSION

In general, for each of the 16 possible utilization permutations modeled, the results for CA and ED differed in some way when determining pairwise preferences for 10 possible pairs of habitats. These differences were apparently dependent on the juxtaposition of habitats; they did not emerge in a clear or predictable pattern but rather seemed to be systematic errors from ED.

Our results indicated that there was a fundamental problem with the ED algorithm proposed by Conner et al. (2001, 2003) for assessing nonrandom use of resources by wildlife. Such results call into question the use of ED for future studies of resource selection. In contrast, CA provided results that were consistent and reliable based on the same sets of simulated data with known parameters that were also subjected to ED analysis. The conclusion that use of ED could result in habitat preference rankings different from those obtained using CA, "… unless habitat types are randomly distributed and occur in similar sizes and shapes" (Dussault et al. 2005:3123) was not supported by our results. Instead, our simulations, which used all possible juxtapositions of habitat types and controlled for size and shape, indicated that ED could result in habitat preference rankings that were far different from those obtained using CA. Because all results from CA were easily interpretable, whereas those from ED were not, we believe there is a fundamental problem with how ED assesses resource use.

Our simulations using CA and ED represented 2 approaches to analyses of the same data sets with known

parameters of resource selection. These 2 approaches are often used to analyze similar kinds of empirical data. How then can these 2 methods result in such widely differing conclusions and interpretations? Compositional analysis is a classification method that uses a deterministic approach based on point locations of an animal in particular habitat patches. The properties of CA are well known and documented (Aitchison 1986), whereas the properties of ED, despite numerical roots in classic geometry, are not well documented in the resource selection literature analyses.

Euclidean distance analysis incorporates use of distances between point locations of an animal in relation to the perimeter of a certain habitat patch (Conner et al. 2001, 2003). Conner et al. (2003, fig. 1) illustrated this point by showing how increasing patch size can dramatically influence whether points of an animal located in patch A can indicate that those animals might also have an affinity for patch B (even if few or no locations of the study animal were observed in patch B) because locations of the animal in patch A were close to the edge of patch B. Although this point may seem deceptively simple, we believe that this is the fundamental basis of the inconsistency of results and difficulty of interpretation from our ED analyses. Analyses that use ED are, therefore, based on the concepts of Conner et al. (2003), highly context dependent. However, dependency on context of patch size and distance of the animal to the edge of an unused or avoided habitat patch, among other factors, apparently causes nonsensical results from ED.

Inconsistency of results and difficulty of interpretation raise concerns about inferences obtained from ED, whereas the reasons for consistent results from CA are fairly well known. For example, we constrained all habitat patches to contain ≥ 1 location of an animal in each hypothetical study area. In situations where all habitat patches contain ≥ 1 location of an animal, CA has been documented as a consistent, reliable, and efficient estimator (Aitchison 1986). In cases where habitats are not used by an animal, and some small non-zero value is used to replace zero, inflated Type I and Type II errors can occur in CA (Bingham and Brennan 2004, Bingham et al. 2007). Despite this shortcoming with CA, which is known to statisticians (Aitchison 1986), our CA results were consistent, reliable, and interpretable when based on analyses of simulated data with known parameters and no 0% utilization. Our ED results, in contrast, were neither consistent, reliable, nor interpretable.

Our results also indicate that juxtaposition of adjacent habitats can influence the outcome of ED analyses, unfortunately in an inconsistent manner that belies interpretation. As such, comparisons among studies of resource selection of the same species but in different areas would seem to be virtually impossible when analyses are based on ED.

A different aspect of ED (compared with other approaches such as Neu et al. [1974] or CA) is that for a habitat to be considered preferred, proportional use of that habitat does not have to be greater than its proportional availability.

Furthermore, whereas CA always indicates no preference between 2 habitats with the same proportional use and proportional availability (e.g., habitat types 1–3, regardless of their relative use or availability) regardless of location, ED does not. With ED a preference between 2 habitats with the same relative use and availability can result depending only on relative location. Also, in perhaps an even worse situation, ED indicated habitats with relative availability more than their relative use were preferred over another habitat with relative use more than its relative availability. Such an outcome is not possible with CA.

Although the ecological context was not resource selection, Ludwig and Reynolds (1988:175) showed that potential systematic bias also emerged when ED was applied to similarity distance measures of ecological data and noted, "… we do not recommend their use. It is clear from our results … that spurious results can occur." Our results confirm and support those of Dussault et al. (2005) who called into question interpretation of results from ED. The problem, however, as shown by our simulations, goes beyond basic issues of interpretation and indicates that ED methods of determining resource selection can have an untenable bias that should give any objective ecologist cause for concern.

Management Implications

If analyses of resource selection data are systematically biased, then the possibility of incorrect management decisions is likely. Such a potential for systematic bias certainly seems to be the case if ED is used for such analyses, and we therefore recommend not using this algorithm for assessments of resource selection. As an alternative to ED, CA provides consistent, reliable, and interpretable results based on data with known parameters, so long as all habitat patches have a level of occupancy >0 for each animal.

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