Critique #2: Tewksbury, J.J., D.J. Levey, N.M. Haddad, S. Sargent, J.L. Orrock, A. Weldon, B.J. Danielson, J. Brinkerhoff, E.I. Damschen, and P. Townsend. 2002. Corridors affect plants, animals, and their interaction in fragmented landscapes. Proceedings of the National Academy of Sciences **99**:12923-12926.

This paper examines issues relating to the role of corridors in connecting habitat patches. No objectives are stated in either the abstract or introduction. In the methods section, the authors state their intention to test two hypotheses, one that corridors serve as conduits for movement and the other that corridors act as drift fences. To test these hypotheses, they employed a complex experimental design. The intention of the design was to examine differential movements of butterflies, of pollen movement, and of seed dispersal with regard to connected and unconnected patches, and with regard to winged versus rectangular patches.

The strongest aspect of this research was the design and implementation of the data collection protocol. The methods employed for tracking the movements of animals, seeds, and pollen appeared to be creative and effective with appropriate controls and consideration for confounding factors. It could serve as an example for other researchers seeking a way to track the same relationships. Since the paper summarizes a complex project in just a few brief pages, it is difficult to assess the validity of the statistical analysis.

The research has fundamental weaknesses, however, which compromise the utility of the collected data. It is not clear that the hypothesis regarding corridors as conduits for movement addresses a research need. Extant research shows that corridors facilitate movement, that use of corridors is species specific, and that the dimensions of a given corridor determine the extent to which it is used (Beier and Noss 1998, Debinski and Holt 2000, Sieving et al. 2000). Research is lacking that shows how corridors affect the viability of a population (Beier and Noss, Debinski and Holt) or that clarifies "what makes a corridor good" (Perault and Lomolino 2000); although a species might make more use of a patch connected with a corridor, that does not demonstrate that lack of a corridor results in decreased population viability. Direct comparisons need to be made, whether through experiments or field observations, to address the effects of presence or absence of corridors on population viability. The finding that animals use corridors was statistically significant. The ecological significance lies in demonstrating a relationship between corridor use and population viability.

The experimental design resulted in the creation of 8 replicates called "landscapes". Each landscape had a peripheral patch connected to a central patch and three peripheral patches not connected to a central patch. The larger amount of movement to the connected patch was used to support the contention that corridors facilitate movement. There was no control, however, to analyze movement in the absence of corridors. As a result of the experimental design, one could reasonably conclude that, given 4 patches, one with a corridor and three without, the species preferentially move to the patch with the corridor. This does not demonstrate that species are less likely to move to a patch in the absence of corridors, a common fault in corridor research (Perault and Lomolino 2000), and therefore cannot be used to address "either/or" questions of reserve design, as suggested by the authors. An improved experimental design would contrast interpatch movement in landscapes with corridors to interpatch movement in landscapes without corridors. In designing the experiment as they did, the authors have also allowed an alternative explanation of the results. One could say that, given 4 peripheral patches, connecting one of them to a source patch with a corridor inhibits movement to the remaining unconnected patches, decreasing plant-animal interactions within the landscape. This finding would support the authors' hypothesis that corridors function as conduits, but without the inference of beneficial effects.

Another possible source of error is that the central patch, which served as a source, was the same size as the peripheral patches. Perault and Lomolino (2000) note that corridors can act as population sinks. Inglis and Underwood (1992) suggest that, in an experimental design, the source patch be an order of magnitude larger than the peripheral patches to provide a sufficient supply of individuals for each peripheral patch. Failure to do so can result in a confounding error since there could be a limited source available by the time the last patch is visited. Inglis and Underwood (1992) note that in experimental designs, a source patch of inadequate size invalidates the statistical analysis since the treatments lose their independence. Similarly, Beier and Noss (1998) note that short-term studies might prove only that connected patches are found more quickly and that longer-term studies of connected and unconnected patches could show no differences. This particular study was done over a much shorter time than many others (Debinski and Holt 2000) and is therefore susceptible to this error.

The project suffers from an additional confounding error which is quite important. One of the authors previously studied corridor use by *Junonia coenia*, one of the butterfly species under consideration (Haddad 2000). Haddad's (2000) study was conducted in the same geographic area. He found that the butterfly preferentially used corridors to colonize patches when the patches were within specific distances (128 - 384 m) of each other; the butterfly made greater use of the forest matrix when the patches were closer or farther apart than these distances . In his conclusions, Haddad stated that the presence or absence of corridors did not affect patch colonization by *Junonia coenia*; the critical factor was the distance between patches . This experiment was designed with the patches at distances of 150 m, within the range of distances at which it had already been determined that butterflies preferentially use corridors. Had the "landscapes" been designed with the patches closer together or farther apart, the results of this experiment would probably have been different. Failure to mention the results of the previous research, which was published prior to the commencement of field work on this project, is a critical flaw. Since the movement of the butterflies was related to the questions about pollen movement and drift fences, failure to reveal a pre-determined result throws much of the paper into question.

A secondary objective of the authors was to study whether or not corridors tend to funnel or direct animal movements, as a drift fence might. This is an interesting question but might have been inadequately addressed using patch "wings" of 75 meters. Since the wings were not connected to a patch at one end, it is unclear that they functioned as a corridor. The 75 meter wing is also shorter than the landscape-scale corridors often proposed and is therefore less likely to create a drift-fence effect; an animal can go around a short corridor more easily than a long corridor. The authors do not state how they chose the size of their patches and corridors. Size of patches, size of corridors, and the length/width ratios of corridors have all been shown to affect corridor use and significance; these findings have often been found to be species specific (Inglis and Underwood 1992, Beier and Noss 1998, Collinge 1998, Debinski and Holt 2000, Perault and Lomolino 2000). It is necessary to design and interpret research with an understanding of the implications of patch and corridor size for the species under consideration. As a correlate, it is difficult to extrapolate or generalize from research of this type.

The conclusions of the authors are difficult to assess in light of the flaws in the experimental design. Since the authors failed to isolate the effect of corridors, their conclusions regarding the benefits of connectivity on plant-animal interactions or plant population dynamics are not supported. Since the baseline levels of animal movement were unknown, it is not possible to know if connected patches benefited from corridors or if isolated patches suffered from the presence of corridors, i.e., if animals abandoned the isolated patches when given alternatives. It appears that relative findings of "more" were paired with assumptions of "increase" without knowledge of causality or norms.

The role of corridors needs to be understood, particularly given the need for information in making land management decisions. The difficulty of designing effective research to answer this question has promoted several reviews of the field. Additional research needs identified in these reviews are similar to those suggested by a reading of this paper. These would include understanding when habitat patches become so small or large that the existence of a corridor is no longer the determining issue in population viability (Collinge 1998); understanding the effects of matrix as well as the importance of corridors that connect to patches that differ in structure and function with regard to the species under consideration (Debinski and Holt 2000, Perault and Lomolino 2000); identifying critical corridors widths (Sieving et al. 2000); and demonstrating the effects of corridors on the viability of populations specifically in species that require connectivity (Beier and Noss 1998).

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