

An update on the status of habitat corridors

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Ecology of Fragmented Landscapes

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Every paper that I encounter regarding habitat corridors begins by discussing their popularity in use for conservation and management planning and shortly after questions their success. Corridors have been a hot topic and popular trend in fragmented landscapes and connectivity since the 1980's. I would like to discuss here the recent works involving habitat corridors and how the science has developed over the years. I will begin by addressing some of the strengths and weaknesses that have been presented in a recent review of their use for conservation by Chetkiewicz et al. (2006). Then I will discuss experimental evidence in favor of or against their implementation in planning and conservation. Finally I will conclude by summarizing what I have learned through reading recent literature presenting corridors and habitat fragmentation.

Chetkiewicz et al. (2006) have provided a complete overview of corridor implementation in conservation efforts. Some of the main shortcomings that were discussed included a focus around the separation between pattern and processes of the species being targeted for management, sometimes leading to the ineffective creation of corridors. Damschen et al. (2006, 2008) examine the phenomena of plant dispersal through a habitat matrix and the effectiveness of corridors in facilitating increased biodiversity in connected habitat patches. This research at the Savannah River Site in South Carolina, as well as modeling work done by Earn et al. (2000) is strengthening the knowledge of processes and integrating patterns of plant communities in fragmented landscapes. The work by Damschen et al (2006) first documented the importance of corridors and habitat connectivity in general for plant community biodiversity and in 2008 expanded this knowledge by integrating a modeling approach and examining specific dispersal characteristics of plants and their use of corridors.

Fragmented landscapes, caused in part by deforestation and urbanization, created a massive concern for biodiversity conservation at a global scale. Ferraz et al. (2003) show that tropical deforestation in Amazonia has immediate and negative impacts on tropical bird diversity, and that the longer the habitat remains fragmented the less likely species will be able to recover and more extinctions will occur. Landscapes are being destroyed and broken up at alarming rates. Biologists and conservationists are looking to implement immediate strategies to buffer the losses due to fragmentation and rescues organisms from extinction. This hasty implementation at a global scale has caused alarm for some scientists.

Simberloff and Cox (1987) wrote an article addressing the need for more research and evidence, using applicable controls in experiments, evaluating the effectiveness and true benefits of habitat corridors. Simberloff et al. (1992) wrote another popular article questioning the effectiveness of corridors as an investment for conservationists that should be implemented on such large scales without being able to say if they are working or not. At the time these articles were written, the evidence for the effectiveness of many corridors was lacking and they were being integrated into management plans without targeting specific species, therefore leading to ineffective or poorly placed corridors within the landscape. Some of the main concerns Simberloff and others addressed were the lack of scientific evidence supporting the successful use of organisms through existing corridors, the increased risks of disease spread and invasive species through such strips of land, and the waste of large sums of money that may be used for other, more effective management strategies. Many of their arguments were centered on the theory of island biogeography.

These articles caught the attention of many scientists, including Noss (1987) who questioned the validity of many of their arguments and emphasized the urgency of the issue. Noss (1987) points out that many of the current preserves are too small to sustain viable populations and something must be done to enhance their effectiveness, suggesting corridors as a realistic approach. One of the most prominent concerns with corridors is the enhancement of disease transmission. McCallum and Dobson (2002) presented research examining this 'naïve' view by discussing the weaknesses of previously implemented models used for examining host-pathogen interactions. They have developed an adaptation to these models and have concluded that the overall benefits outweigh the risks of increased disease transmission. Another concern is the enhancement of invasive plants and organisms through such corridors, promoting their spread across the landscape. Damschen et al. (2006) were able to test for this occurrence in their experiment examining the role of corridors in maintaining biodiversity of plant communities. While they witnessed increases in population sizes of many rare/endangered species within their study habitat, there was no positive association with exotic plants and corridors. Increasing the synchrony of subpopulations within a metapopulation, thereby enhancing the allee effect, abiotically harsh bad years, and demographic stochasticity is another concern of enhancing population connectivity (Earn et al. 2000). Through the use of population models, Earn et al. (2000) have been able to create a valued model with parameters that may be difficult to measure but estimatable in some cases, that can be used to evaluate the risks imposed on populations with varying dispersal abilities, and can also be used to control/eradicate introduced species and identify immunization strategies in the face of infectious human diseases. This will allow managers to better adapt their corridor planning to help and not hinder fragmented populations.

Another obstacle to tackle in the implementation of habitat corridors is the applicability to a broader spectrum of organisms rather than specific species. In the review of corridors for conservation (Chetkiewicz et al. 2006) there was a large discussion about the Canmore corridor created to support grizzly bear populations in Canada. This is an example of a corridor that, in my opinion, was poorly planned for conservation purposes and focused on its human use, with walking paths and trails throughout leading to increased interaction between humans and bears, sometimes resulting in death. Other investigations into specific species have shown benefits to seed dispersing birds (Levey et al. 2005), a variety of plant species (Damschen et al. 2006) and other larger organisms such as the Florida Panther and Spotted Owl. Other organisms are not as consistently benefiting from such designs, which can be seen with work done by Öckinger and Smith (2008). While the quality and appropriateness of this study is questionable in my view, there is ample support for the need to streamline corridor applicability to organisms and planning. The main point here is that taking a species-specific approach is very time consuming and requires a lot of resources. A more broad application is desired by scientists and conservationists.

Many researchers have been developing models and identifying key life-history traits that can be identified across taxon and used to assess the effectiveness of corridors on population enhancement and preservation. Haddad (1999) attempted to predict corridor use of species by investigating their behavior and movement at the boundaries of the habitat. While trying to broaden the approach of habitat corridors, his final conclusions still emphasized the need for species-level investigations. This was in part because the three butterfly species

that he followed throughout habitat patches at the Savannah River site all utilized the habitat in different ways. However, other key findings that Haddad (1999) concluded were that as patches became farther apart, the importance of corridors in facilitating species movements increased, and that large patches that currently exist in managed areas may be enhanced more by adding stepping-stones rather than full corridors connecting these areas to other habitat patches. Hudgens and Haddad (2003) implemented a modeling approach to generate guidelines at a broader taxonomic scale using broad life-history traits. The most important traits in the model parameters included growth rates, reproductive rates and contributions to the metapopulation, migration behaviors and the minimal number of individuals necessary to sustain a population (mvp). This model was very effective and supported by many species-specific investigations. However, the parameters required are numerous and may need investigating for many species that are targeted for management.

Habitat corridors as a mechanism against fragmentation has been given a lot of attention and taken some time to grow into a mature discipline. There are wide applications of corridors in management and restoration practices but even recent publications still question their effectiveness. For particular species, such as birds, plants dispersed by seed-eaters, large mammals, and insects, there is a lot of research and support. The development of large-scale research areas, such as those in the Amazonia and the Savannah River site, have contributed greatly to our understanding of corridors in the preservation of biodiversity, and continue to be areas where active research is happening. Scientists are still working towards an effective broad approach to evaluate corridor effectiveness across genera.

ANNOTATED BIBLIOGRAPHY

Chetkiewicz, C-L.B., C. C. St. Clair, and M.S. Boyce. 2006. Corridors for Conservation: Integrating Pattern and Process. *The Annual Review of Ecology, Evolution, and Systematics* 37:317-342

This review discusses the current practice of corridors and how this implementation causes them to fall short of their conservation promise. The authors offer that this is the result of poor planning and hodge-podge placement of corridors within the landscape, as well as a lack of accountability through publications and peer review of such programs. Chetkiewicz et al. clarify that theoretically the purpose of corridors are to increase movement of individuals, preventing local extinctions by increasing gene flow, retaining ecological processes of the ecosystem, and promoting movement in response to climate change. The disconnect in conservation occurs between the pattern and process of systems, leading to ineffective implementation of corridors. In order to implement corridors in an effective way, a species or groups of species must be identified and the natural history of those species must be well understood in order to know how organisms move within a landscape and how the land is used. This is very species specific and must be altered to fit the system targeted for conservation. Many new tools are offered to combine pattern and process in order to more effectively evaluate and implement corridors in management strategies.

Damschen, E.I., Brudvig, L.A., Haddad, N.M., Levey, D.J., Orrock, J.L., and J.J. Tewksbury. 2008. The movement ecology and dynamics of plant communities in fragmented landscapes. *PNAS* 105(49):19078-19083.

This paper tested a question centered in the new theory of movement ecology. Movement ecology is a unified framework that was recently created, linking basic life history and behavior with environmental variables in order to study the movement of species across the landscape. Damschen et al. used this theory to generate hypotheses about the community assemblages and dispersal of plants in fragmented landscapes at the Savannah River Site. They extrapolated two aspect of the theory of movement ecology to test these communities: inclusion of the effects of competition on plant establishment in communities which is not in the current framework and they extrapolated from the individual level to plant communities. The plants examined exhibited three modes of dispersal: bird, wind and no dispersal mechanism. The main goal of this research was trying to understand the degree to which connectivity effects can be predicted by plant dispersal traits. Bird dispersed plants exhibited a rapid increase in connected areas and then became saturated, following the pattern of bird movements in this fragmented landscape. The wind dispersed plants showed a linear trend increasing in connected areas over time. This was strongly determined by the prevailing wind direction at the site. The no dispersal structure plants also exhibited a linear increase similar to wind plants, suggesting that they may in fact have some type of assistance mechanism dispersing them throughout the landscape. The researches have adapted a new theory in a creative way to examine connectivity and plant dispersal, which has not been done nearly as much as animals. The conclusion is that research must be done to learn more about the

specific traits in wind species that affect movement patterns and no dispersal plants, as well as an evaluation of the necessity of movement ecology as a discipline. Is it really necessary or does it just provide more conflict and confusion? Furthermore, research is also needed to better understand the motion capacity and external forces establishing plant communities.

Damschen, E.I., Haddad, N.H., Orrock, J.L., Tewksbury, J.J., and D.J. Levey. 2006. Corridors increase plant species richness at large scales. *Science* 313:1284-1286.

The aim of this research was to supply evidence for the support of corridors in maintaining biodiversity at a plant community level, expanding beyond single species responses. The study was conducted on a large landscape within 50ha plots at the Savannah River Site in South Carolina. There was one central 100m by 100m patch surrounded by four patches of the same size 150m away. One of the patches was connected to the central patch with a corridor and the other three patches varied in shape and orientation. All patches not connected to the central patch had an equal edge-area ratio and the sizes for habitats in this study were based on USFS management activities. There was a sharp contrast between the more open patch habitat and the closed canopy pine forest matrix habitat. The experiment began with equal plant community richness in 2000 and was monitored through 2005, resulting in a 20% increase in species richness in the connected patch compared to all other unconnected patches. They were able to reject four other hypotheses that have been associated with plant community composition based on the design of the experiment: the increase in richness was not caused by an increase in area or elongation of the patch, it was not generated by patch shape independent of connectivity, the soil seed bank could not account for the differences in plant community richness among the patches and soil moisture differences could not explain plant community differences between the patches. Connectivity consistently remained the driver for species richness within the habitat patches. Another criticism of corridors is that they may increase the movement of exotic and invasive species. This study showed no support for this argument, and supported the movement of rare/endangered plant species within the core and connected patch. The final conclusions about habitat corridors and plant community dynamics are that corridors promote colonization by increasing seed deposition in connected habitats, they increase pollen movement promoting within-patch recruitment and they increase the abundance of otherwise competitively excluded seedlings by altering seed predator presence and behavior.

Earn, D.J.D., Levin, S.A. and P. Rohani. 2000. Coherence and conservation. *Science* 290:1360-1364.

This paper addresses the concern of increased synchrony of population dynamics due to corridor connectivity in the context of mathematical modeling. Current literature suggests that corridors increase the rescue effect of populations but also may synchronize the population as a whole in bad years, demographic stochasticity and allee effects. Earn et al. created a model that allows one to determine the likelihood of synchronous fluctuations based on dispersal behaviors of the species of interest. The model is based on two trends in dispersal, equal coupling (randomly dispersed in patches throughout the landscape) and nearest neighbor (dispersal occurs more often in connected patches). The dispersal pattern of the species was

the most important factor in the model but typically the risk of coherence (synchrony) is larger for smaller r (maximum fecundity measure) and larger m (fraction of individuals migrating before reproduction) species. Earns et al. found no special trend between chaos and population persistence, a trend that theoretical population ecologists have been seeking to find. The most novel and applicable finding in this model development was the criteria of populations dynamics that suggests when $r|\lambda| < 1$ coherence is inevitable and a substantial extinction risk to the population is unavoidable. λ is a statistic that characterizes the influence of dispersal pattern on the susceptibility of coherent oscillations. The numbers that are required for the parameters of the model are difficult to determine from field data, but estimation is possible to a degree, making it more applicable. Furthermore the model developed here can be used to control/eradicate introduced species and identify immunization strategies in the face of infectious human diseases.

Ferraz, G., Russell, G. J., Stouffer, P.C., Bierregaard, R.O.Jr, Pimm, S.L. and T.E. Lovejoy. 2003. Rates of species loss from Amazonian forest fragments. PNAS 100(4):14069-14073.

The goal of this research was to determine the minimum fragment size of forest in order to retain understory bird species that will be sensible for conservationists. They used mist-netting to survey forest understory birds in habitat fragments of varying size in Amazonia over 13 years of observations. The researchers conducted over 21,600 captures during the 13 year period, and were able to identify both resident and transient species in fragments following deforestation events. Their results follow the theories of island biogeography. Four of the main conclusions from their data are: 1. smaller fragments start with fewer species than larger fragments, 2. number of species drops quickly following fragmentation, 3. species differ in their probabilities of extinction, and 4. smaller fragments lose a given proportion of the species present more quickly than larger ones. The information provided in this article for conservationists is extremely helpful and should be incorporated in tropical forest areas. First they conclude that the minimum size of fragmented forest necessary to maintain species until regeneration occurs in the surrounding area is 1,000 ha (10 km²). Furthermore, if the surrounding areas are not going to regenerate, then the size of forest fragment necessary to maintain understory bird species diversity increases to 10,000 ha (100km²) which is greater than most forest fragments and out of reach to many conservation organizations.

Haddad, Nick M. 1999. Corridor use predicted from behaviors of habitat boundaries. The American Naturalist 153(2):215-227.

This article calls for a rapid need for methods which assess positive and negative effects of corridors on species with varying behavior and life-history characteristics. It outlines the usefulness of behavior approaches, which characterize an organisms movement within and between habitat patches in order to better understand how organism are predicted to use corridors in the landscape matrix. Haddad states that most of the current evidence for corridor effectiveness is confounded by many other factors due to experimental design issues. Two important hypotheses were outlined in order to distinguish the effectiveness of corridors: 1. animals must be more likely to leave a patch through corridors than is expected at random 2. the proportion of animals dispersing successfully through corridors must be greater than other

alternatives. The experiment was done at the Savannah River Site, the distance between patches and corridors was altered and Haddad examined the movement of three species of butterflies among this landscape. The movement paths were recorded on maps of each patch. Furthermore a model was developed, similar to random walk models and this data along with other previously published work by Haddad and others was used in the model to evaluate its effectiveness. One of the more important findings, important for conservationists, was that as patches became farther apart corridors had a greater effect on movement. Haddad also suggests that in current conservation areas that are large it would be more effective to create stepping stones between large patches, rather than corridors, because species living in large patches don't move throughout the landscape and require as much guidance as those in small patches requiring more frequent trips outside of the patch. A final emphasis was placed on the importance of species specific investigations, because the three species observed in this study, and other published reports, show that species behave differently in their use of corridors and movement within a habitat.

Hudgens, B.R. and N.M. Haddad. 2003. Predicting which species will benefit from corridors in fragmented landscapes from population growth models. *The American Naturalist* 161(5):808-820.

This paper used a mathematical modeling approach to generate guidelines for corridor effectiveness at a broad taxonomic scale. They report on the need of a unified theory of corridors and highlight the current literatures focus on individual species rather than trends. The major factors in species life-histories that played a deterministic role in the effectiveness of corridors and was a major focus of their models included species growth rates, reproductive rates, contributions to the metapopulation, migration rates and their tendency to migrate, even minimal numbers of individuals, within the matrix of the habitat. Their model results were supported by many species specific publications, including the organisms study at the Savannah River Site, validating their parameters and calculations. The need for more information regarding the migration of the individual species of interest was emphasized, as well as the time scale goals of the corridor. There are three main questions identified at the conclusion of the paper that are suggested as main focuses for conservationists to determine when contemplating the use of corridors in their management plans. The questions are: 1. what is the time scale of the conservation goal? 2. is the major threat of local extinction due to sustained population decline or boom-bust cycles? and 3. What is the migration rate through the matrix? I think that the authors attempt to lessen the investigation into species-specifics for corridor planning was not achieved because the parameters required in the model and the additional migration information needed is still a lot of details that will need to be known for the individual species at which the corridor is directed. Some general conclusions include the effectiveness of corridors on smaller patches compared to larger patches, their importance in more heterogeneous landscape matrices when movement through the matrix is restricted, and the greater benefit attained by smaller-bodied organisms in relation to larger-bodied ones are noteworthy.

Levey, D.J., B.M. Bolker, J.J. Tewksbury, S. Sargent, and N.M. Haddad. 2005. Effect of Landscape Corridors on Seed Dispersal by Birds. *Science* 309:146-148.

This is a very effective research article providing evidence for the use of corridors for a certain species that combines small scale observations, landscape modeling, and landscape application/observation that the Simberloff et al. paper was emphasizing is lacking. The authors are examining the link between birds, plants, and corridors by documenting the feeding and seed dispersal of Eastern Bluebirds (*Sialia sialis*) and their major food source wax myrtle (*Myrica cerifera*). The experiment examined the effectiveness of various corridor sizes, shapes, and connectedness testing two different corridor hypotheses: (1) traditional corridor hypothesis and (2) drift-fence hypothesis. Their results and observations supported the traditional corridor hypothesis (corridors act as dispersal conduits, channeling organisms between connected patches). More importantly, experimenters learned that the birds actually use the corridor edge as a road map, but not the interior of the corridor. The corridor in this situation is facilitating the mutualism between seed-dispersing herbivores. This article highlights the importance of corridors and their edges and encourages land owners and conservation groups to purchase connected land whenever possible.

McCallum, H. and Dobson, A. 2002. Disease, habitat fragmentation and conservation. Proc. R. Soc. Lond. B 269:2041-2049.

There are currently a lot of naïve views in the literature that fragmentation is good for disease transmission and the use of corridors enhances the threat of disease transmission and resulting extinctions. A major flaw in the current host-pathogen models is the βSI factor, undistinguishing the reference of S and I to density or abundance. If it refers to abundance, then fragmentation is good. If it refers to density, then fragmentation is bad because it packs more organisms into a smaller space, increasing the density at which individuals within a population occur. Also, they point out that current models ignore the ability of localized patches to recover from extinctions and that pathogens may persist in reservoir hosts and create a constant feedback to surviving individuals of the endangered population. McCallum and Dobson alter current models to include these two phenomena and conclude that the ability of a species to recolonize a patch that had gone extinct may provide more opportunities for a species to recover. When including the dynamic of a reservoir population, the results are much more stochastic and in some cases may lead to more extinctions of the endangered species. The overall conclusions emphasize that the risks are outweighed by the benefits and corridors have more helpful attributes to endangered species than increased threats of disease transmission.

Noss, Reed F. 1987. Corridors in real landscapes: a reply to Simberloff and Cox. Conservation Biology 1(2):159-164.

Noss refers to corridors as a fad in conservation planning, which I thought was a bold and cunning start to this reply. Corridors are incorporated into planning and design with only a vague awareness of the underlying biological issues and strategy. Noss, however, urges that active strategies to combat fragmentation must proceed quickly because species threats and dangers occur immediately following fragmenting events. A major criticism of Simberloff and Cox presented was their argument against biogeographic analogies in support of corridors, but used these analogies when arguing against their use in conservation. Noss suggests that

researchers should refrain from theory and use real-world problems and analogies to form their support for against the use of corridors in conservation strategies in order to eliminate theoretical disagreements. One of the largest debates about corridors is their role in genetic maintenance of the target species, which Simerloff and Cox discuss. The solution they offer is to move individuals artificially, which Noss emphasizes deserves a philosophical discussion about such an endorsement and the applicability of such a method to preserve populations. Furthermore, Noss simply states that the financial argument, which was a large portion of the Simberloff and Cox paper, was weak and mentions it no more. Instead, Noss points out that planners and architects already incorporate 'greenspace' into their plans and it would be advantageous for all if they would team up fir biologists to create such spaces that serve as double-duty to preserve species and enhance the aesthetic appeal of urban areas. Finally, Noss points out that almost all existing preserves are far too small to sustain viable populations and the corridor strategy is one way to enhance their effectiveness.

Öckinger, Erick and Henrik G. Smith. 2008. Do corridors promote dispersal in grassland butterflies and other insects? *Landscape Ecology* 23:27-40.

Öckinger and Smith evaluated grassy habitats, patch characteristics and open linear strips on three species of butterflies and their movement across the landscape in southern Sweden. In addition, they investigated the literature to examine insect use of corridors. This paper is unique in the sense that it focuses on insects and corridors, which are commonly overlooked in the literature in the United States, with the exception of particular pollinators. They used mark-recapture methods to assess the movement of butterflies within the matrix of habitats in the agricultural region of Sweden. Habitat quality proved to be the most important dispersal factor, emphasizing that the location of the corridor as well as the quality of vegetation within that area is very important to consider in management planning. The authors admit that they were unable to identify the types of movements they observed, which was emphasized as lacking in the Chetkiewicz et al. article. Another interesting conversation in this article is the differentiation of habitat types in the landscape matrix. The matrix in this study consisted of open habitats. Other habitats targeted for corridor management are forests and riparian zones, in which cases corridors may be used more heavily than seen here because of the heterogeneity of the environments. Overall conclusions are that patch quality is important but more work needs to be done and the holes in behavior need to be filled.

Simberloff, D.J. and J. Cox. 1987. Consequences and costs of conservation corridors. *Conservation Biology* 1(1):64-71.

The subject of this article is based on the suggestion that corridors should be maintained between refuges whenever possible, posed by Wilson and Willis in 1975. The arguments and theoretical background used for this article's discussion of corridor effectiveness is based on the theory of island biogeography. The paper outlines arguments that are typically presented in the literature that support habitat corridors includes the rescue effect, increased immigration rates, large mammal range requirements, and the idea that small isolated populations lead to extinctions. The authors point out that much of this support is based on the assumption of inbreeding pressures on smaller populations, which they say are variable by species and

difficult to determine. Much of the experimental evidence supporting corridors lack controlled data or even a mention for the need of such comparisons, which Simberloff and Cox argue as a weakness of this field of science. Furthermore, the authors state that the rescue effect has not been measured and documented as an actual benefit of corridors, but instead is always assumed to be true. Simberloff and Cox highlight the ambiguity in current cases showing benefits of corridors. The disadvantages of corridors, which were warranted much more attention, included the benefits received by introduces predators, contagious diseases, fire, increased exposure to humans, domestic animals, and other predators, weedy noxious species, poisoning from local roadways and the outrageous and persistent economic costs that are associated with such designs. Simberloff and Cox discussed in detail the proposed corridor plans for the Florida panther, which we now know have been pursued. They conclude by emphasizing the need for cost analysis and the fact that corridor implementation, which has become a hasty response to habitat fragmentation, may be taking away from other, more effective, management strategies. Finally, theoretical generalizations do not apply and the effectiveness of corridors must be evaluated for each species being targeted for conservation/management.

Simberloff, D., J.A. Farr, J. Cox, and D.W. Mehlman. 1992. Movement Corridors: Conservation Bargains or Poor Investments? *Conservation Biology* 6(4): 493-504.

Simberloff et al. have addressed the effectiveness and overall acceptance of the use of corridors in conservation biology. Corridors have become a popular investment in the field of conservation and this essay emphasizes the lack of proof. The establishment of corridors has been designated the savior of diversity within the scientific community and this essay emphasizes the lack of scientific proof for such a designation. There is a very strong argument for the inability to direct the movement of animals. Animals are moving to attain resources that are spread throughout the landscape, but do these resources need to be present in the space they are moving through? The role of a corridor is to protect these resources that they are searching for, but only in small strips to get from one larger area to another. The experimental evidence that has been presented in scientific literature, they argue, lack control, balance, and do not discuss the movement of organisms in the absence of current corridors. The importance of corridors for facilitation of species shifts resulting from climate change may have been overlooked, and in order to be useful the corridor must function beyond a movement path and be suitable for breeding which requires a different set of habitat qualities. Simberloff et al. also discuss the negative effects, such as spread of disease, invasive species, increased edge habitats and metapopulation sinks, and the lack of scientific investigation with conclusive evidence in this area. The criticisms presented are thought provoking; regardless of the nature of being able to answer the questions they pose. The overall conclusion of the paper is very solid and requires attention among the conservation community: when spending at the level of corridor land purchases, all options for conservation/management should be considered.