The Role of Corridors in Conservation: Solution or Bandwagon?

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Corridors are currently a major buzzword in conservation biology and landscape ecology. These linear landscape features may perform numerous functions, but it is their role in facilitating movement of fauna that has attracted much recent debate. The database supporting the idea of corridors acting as faunal conduits is remarkably small, and few studies have actually demonstrated that movement along corridors is important for any given species. Such data are very difficult to obtain, and conservation biologists are thus faced with the problem of whether to recommend the allocation of resources to corridors on the assumption that they may be important.

The potential importance of corridors (strips of native vegetation or habitat connecting otherwise isolated remnants), previously hinted at in the wildlife management literature[1], was formalized for the first time in terms of nature reserve design in the mid-1970s[2,3]. The following statements appeared: 'If the preserve must be divided, extinction will be lower when the fragments can be connected by corridors of natural habitat, no matter how thin the corridors'[2] and 'If there are several disjunct reserves, connecting them by strips of the protected habitat may significantly improve their conservation function at little further cost in land withdrawn from development ... especially in the case of sedentary species with restricted habitat preferences ... corridors between reserves may dramatically increase dispersal rates over what would otherwise be negligible values'[3].

These statements, together with other principles of reserve design, have been quoted in policy documents and textbooks, despite being supported by few empirical data at the time, and being subject to considerable debate since[1]. The issue of corridors, in particular, has received considerable recent attention[4]. The question I address here is whether the value of corridors in fostering faunal movement and reducing extinction probabilities is now better supported by available data, and whether the current emphasis on conservation corridors is justified.

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What are corridors?

First, it is necessary to examine exactly what is meant by 'corridor'. It has been used to describe a suite of different structures, with different modes of origin and different functions[4–7]. A corridor can generally be considered to be a linear feature of vegetation that differs from the surrounding vegetation and connects at least two patches that were connected in historical time[7]. Other definitions can be used, and indeed almost any strip of vegetation could be viewed as a corridor in some contexts. When considering faunal movement, however, the important component of the corridor is that it allows movement *from* somewhere *to* somewhere else. Corridors can occur as natural environmental features, such as riparian strips, or can be created by human activities such as clearing of adjacent vegetation (in which case a remnant corridor results) or modification of the vegetation in a linear strip (as in powerline corridors). Corridors can also be constructed by humans, as in the case of hedgerows and windbreaks[8,9]. Corridors may have different properties, depending on their characteristics. Width is especially important: a distinction can be drawn between strip corridors, which are wide enough to have an interior that is not dominated by edge effects, and line corridors, in which edge effects permeate the entire structure[5]. Other structures, such as highway underpasses and greenways, have also been called corridors[4].

In terms of function, corridors may act as important components of a regional conservation system, by retaining important species or providing representative examples of native vegetation types that complement those in reserves[10]. They may also serve as faunal habitat, alter landscape fluxes[11], provide shelter and reduce wind and water erosion, and enhance the aesthetic appeal of a landscape[6]. However, the main area of debate on corridors has been their function in facilitating movement of fauna.

Movement of fauna

It is generally accepted that fauna need to move across the landscape for a variety of reasons, including dispersal and resource acquisition, and that movement is required to counter the potential effects of fragmenting faunal populations into small, isolated units. Movement can be thought of as minimizing the impacts of demographic stochasticity and inbreeding depression[12–14]. Some argue, however, that the requirement for faunal movement may have been overstated, and that corridors may not be required to foster it when it is necessary[4].

While movement along corridors is frequently assumed to occur, there have been relatively few studies that have shown that corridors are actually required for movement. Studies that have been frequently cited as illustrating corridor use for faunal movement[15,16], do not, in fact, provide clear evidence[4,17]. The types of study required to establish unequivocally that corridors are important for faunal movement are difficult and costly to design and implement and require intensive, long-term observations[7,17]. It has been pointed out that only five out of 36 contributions in a recent conference proceedings on the topic of corridors[18] presented new data on animal movement, and three of these concluded that corridors may be relatively unimportant[4]. However, recent studies of marked or radiotagged animals have indicated that some species do use corridors for movement, in preference to moving across open ground[19–22] (Box 1), although some of these data can still be criticized as not providing unequivocal evidence of the need for corridors[4]. The question becomes one of how much evidence is required (Box 2).

Corridors: good or bad?

Faced with this degree of uncertainty concerning the value of corridors for animal movement, what is the scientific community to

Box 1. Animals that move in corridors

Studies that have indicated that corridors are used for movement have used observations, mark–recapture and telemetry techniques[18–22]. A series of studies on woodland mice (*Peromyscus leucopus*) and chipmunks (*Tamais striatus*) in fragmented habitats in Canada have indicated that most movements of these species were in wooded fencerows[19]. Radio telemetry of *P. leucopus* confirmed that these animals preferred to move along fencerows, and that fencerows are also major pathways for movement by *T. striatus* through farmland[19,22].

In another fragmented landscape in the Western Australian wheatbelt, marked individuals of the Western yellow robin *Eopsaltria grieogularis*, a species dependent on remnant vegetation, were observed and captured moving along well-vegetated corridors but not along poorly-vegetated strips[20,22]. In contrast, in the same study, the singing honeyeater *Lichenostomus virescens*, which is more widespread and can tolerate more disturbed conditions, was observed to fly over open ground. Nevertheless, well vegetated linkages were also used by this species.

A further study of bird movements (using a capture–recapture technique) between a forest and a littoral zone in Poland found that more birds of many passerine species moved where a strip of shrubs connected the two, compared with where there was no connection. A selection of other studies report observational evidence that mammal and bird species move along corridors between remnant areas[18,25,37].

recommend concerning corridors? There are two main approaches to this problem. One is to point out the lack of evidence for the utility of corridors, while indicating their potential negative effects and the possibility that putting resources into corridors may mean that they are not available for other, potentially more beneficial, conservation activities[4,23]. The other is to accept the uncertainties involved but to assume a null hypothesis that corridors are valuable and hence should be maintained, acquired or created as part of a regional conservation network[7,24–28].

The question is whether it is better to retain corridors now with the possibility that they may be found to be ineffective as more data accumulate, or to de-emphasize corridors with the possibility that they may be found to have been important once they have disappeared. There are clear reasons for both viewpoints, and the problem of how to reconcile them centres around the lack of empirical data. This problem is central to much of conservation biology, and presents the biologist with a dilemma. Advice to management and planning bodies is urgently required now, but the level of information available is not sufficient to make recommendations based on adequate knowledge. Does the biologist then refuse to comment until adequate data are collected, or make a best-bet judgement now? The second course of action seems to be the only one available, given the urgency of most conservation management decisions. The task then should be to maximize the likelihood that the decisions made achieve the desired result (e.g. regional biota conservation).

The disadvantages of corridors include the possibility that they will act as conduits for invasive species, predators, pests and diseases that would otherwise not have been able to spread[4,23]. There is the possibility that corridors will allow the movement of species that are relatively mobile anyway, and will do nothing to enhance movement of more sedentary species that may be at greater risk of extinction[26]. The possibility has also been raised that corridors may actually act as population sinks, drawing organisms away from habitat patches into edge-dominated corridors where the risk of predation and mortality is high[29,30]. The problem with all these arguments is again that there are few empirical data to show whether the presence of corridors would actually have a greater adverse impact than their absence. A further argument is that the cost of maintaining or creating corridors is such that opting for corridors forecloses other options[4], although in some cases there may be few other options available.

It seems likely that corridors will neither be a panacea nor a complete disaster, will benefit some species but not others[28], and with careful planning can form part of a regional conservation network. Often, corridors are planned as last resorts ('bandages for a wounded natural landscape'[30]), in anticipation of increased isolation of habitat patches. Lack of concrete evidence of their utility should not exclude them from conservation plans unless better solutions can be found. Paucity of data is not a case against corridors, but a case for collecting more (and better) data.

Corridor objectives and design

In this context it becomes important to specify the objectives of a given corridor. Many corridors may be present for reasons other than to facilitate faunal movement, and their design and management will vary accordingly[6]. Where corridors are being considered as part of a strategy to maintain viable populations of particular species, the requirements of the species in question need to be examined and the corridor designed accordingly[31]. Corridor design may need to be species-specific, despite a desire by managers to provide corridors to suit a wide range of species. Any given corridor is likely to function as a conduit for only one or a few species; hence, target species have to be selected[31]. Target species are often those that are vulnerable to extinction in isolated patches, but this need not always be the case. Corridor design will vary according to whether movement is required for periodic migrations, for foraging requirements or for immigration into isolated patches. Correct design will require information on the autecology of the target species, their habitat and foraging requirements, behavioural attributes (territoriality, etc.) and interactions with other species[31].

It is also important to consider edge effects and corridor width. Since they are essentially linear remnants, corridors have a high edge:area ratio. Impingement of corridor vegetation by factors arising in the matrix through which it passes will modify many aspects of the corridor environment, e.g. microclimate, nutrient and water regime, degree of invasion, predation levels[6,30,32]. For edge-aversive species, corridor width needs to be such that some portion of the corridor represents 'interior' habitat, unaffected by the particular edge effects of importance to that species.

These aspects of corridor design indicate that a fairly detailed knowledge of the ecology of target species is required, and assume that it is then possible to translate this knowledge into practical guidelines for corridor design and

implementation. Unfortunately, for many species the required level of knowledge is not available, and it is certainly by no means clear that, even with this knowledge, adequate corridors can be developed. One can, however, differentiate between landscapes that have already been fragmented and those that are still moderately intact. In the first case, 'retro-fitting' of corridors is required, whereas in the second, maintenance of existing linkages is possible. The second option is much easier than the first[31]. Hence it can be argued that maintenance of existing linkages should be an important component of any conservation plan, on the basis that it is easier to retain them now than to replace them in the future.

Future developments

Currently, no one knows whether corridors will be effective in mitigating the impacts of landscape fragmentation[31]. The potential role of corridors in mitigating the effects of rapid climate change (by allowing migration of the biota, including plants) is even less well known[26,33]. However, the concept of corridors has become an important one in conservation management, and it is important that some answers are obtained so that a scientific rationale for corridor planning and design can be developed. Although modelling can help focus on conceptual issues[29,30], and model systems can provide indicative results[34], answers to practical conservation questions can come only from studies of real populations in real landscapes. We need to know whether target species use corridors already in existence, whether they will use corridors that are established between isolates, and whether there are less costly alternatives to corridor establishment and maintenance. We also need to know whether corridors established primarily for other functions (e.g. windbreaks) can also serve a conservation function, and hence whether conservation management can be integrated into the overall management of the landscape[35,36].

It is unlikely that the current interest in corridors will abate without hard evidence to show that they are definitively ineffective. Thus, conservation biologists must ensure that corridor planning is integrated into a broader conservation strategy that considers all options[4]. Researchers can make use of the current level of activity to test and refine ideas on corridor function; the interplay between research and management can be highly fruitful. Conservation biology has been plagued by debate on issues which have little bearing on practical conservation management[32]. It is important that conservation biologists recognize that there is considerable management activity concentrating on corridors now, on the assumption that corridors are useful. In order to test whether this assumption is correct, conservation biologists need to obtain hard data on corridor function and develop practical guidelines for corridor planning and design.

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Box 2. Can we prove that corridors are important?

Most evidence for the use of corridors for movement comes from studies involving relatively few observations of relatively small numbers of individuals of relatively few species (Box 1). When can the level of evidence be taken as adequate that corridors do have a function in faunal movement? The number of observations of animals using corridors is increasing[16,24,25], while a few studies indicate that some species prefer to use corridors if they are available[19–22]. However, it is unlikely that any studies will ever be able to prove unequivocally that faunal species actually require corridors and cannot move without them. It is likely that the role of corridors is to increase the probability of movement from one place to another, and hence to increase the probability of the species' survival. Accumulation of anecdotal and observational evidence of individuals or small numbers of animals moving in corridors adds weight to the argument that corridors play a role in movement, and if this can be supported by more detailed studies, experimentation and modelling, the evidence gains more credence. A little weak (observational) evidence is weak, but is still evidence; a lot of independent weak evidence is slightly stronger, but still cannot take the place of strong experimental or manipulative evidence. At present, a lot of independent, mostly weak, evidence has accumulated that corridors are important for movement. Decisions have to be made using this evidence, in anticipation of the accumulation of stronger evidence as detailed studies mature.

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Letters to the Editor

Scientific Communication: The Burden of Responsibility

A recent perspective by Grosberg and Levitan[1] in *TREE* criticized an earlier historical review by C. Young[2], which observed that the recently popularized 'supply-side ecology'[3] has often ignored more than a century's legacy of literature on larval biology and recruitment. Young also documented several cases of research duplication in this field and asked why the modern supply-side papers are suddenly so successful when so many older, available and prescient papers are seldom cited.

The issue at hand may be viewed as a dramatic example of scientific prematurity[4], in which the significance of a paper (e.g. Mendel's) is not recognized in its time; in the case of supply-side ecology, an entire literature has been undercited while the field was being rediscovered. Grosberg and Levitan look to the philosopher D. Hull[5] for justification. Hull argues that intellectual progress is made only when an idea is presented in a context that the appropriate audience can understand and relate to. That is, the responsibility for both dissemination and assimilation of an idea resides with its advocate. Grosberg and Levitan suggest that a number of the older publications have been justifiably ignored because they were published in specialized, hard-to-obtain journals, contained little quantitative data and failed to provide novel theoretical constructs. The implication is that modern ecologists such as Gaines and Roughgarden[3] commit no marketing errors while many of the older authors failed in their responsibility to communicate properly.

In reading the older literature, however, it is clear that many authors addressed general scientific audiences, used the best available quantitative techniques (ANOVA could not be used until it was invented!) and cast their conclusions in general population and community contexts. Some, such as Hjort[6,7], offered theories with broad implications that have seldom been acknowledged outside fishery science. I would add my opinion that many classical papers that are commonly cited remain largely unread; many citations result from the snowball effects of gossip or by citing without comprehension papers cited by others.

Only a decade ago, these same issues were highlighted by Jackson[8], who demonstrated that excellent work in plant ecology spanning nearly a third of a century had been largely ignored by American ecologists. Similar points have been made recently by Oksanen[9] in the context of community ecology. Not only is it a tremendous waste of time to reinvent important ideas[9], it is grossly unfair to ignore the priority and hard work of the earlier scientists. Grosberg and Levitan's argument is not adequate justification for abandoning our intellectual heritage.

I agree that authors have the responsibility to present their work to a broad audience and in a manner which is of general interest, but I disagree with the extreme position attributed to Hull. This is contrary to the entire concept of priority, basic to the rules of nomenclature, which has been the foundation of scientific reporting. Catchy titles and slick salesmanship should not be required of scientific communicators, but sound scholarship should be. The take-home message of Jackson's, Young's, and Oksanen's reviews is that many very worthy papers are either ignored or cited without indication that they were assimilated. I am concerned that we are seeing a justification for releasing authors from the responsibility of understanding the history of their discipline, and a trend that encourages the mounting of publicity campaigns to sell one's papers.

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Reply from Grosberg and Levitan

Dayton's assertion that we are critical of Young's review[2] baffled us. On the contrary, we praised Young's scholarship and stated, 'The paper makes it absolutely clear that "supply-side" ecology has century-old roots. As such, the paper constitutes an invaluable resource for those interested in reconstructing the history of a now highly influential set of ideas in population and community ecology'[1]. Dayton also suggests that our article encourages ecologists to be sloppy scholars and 'to ignore the priority and hard work of the earlier scientists.' In fact, we