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REVIEW ARTICLE

Biodiversity Corridors as Climate Adaptation Infrastructure in Fragmented Landscapes

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ABSTRACT

Habitat fragmentation compounds the threat climate change poses to biodiversity by constraining the dispersal pathways species need to track shifting climatic envelopes, and biodiversity corridors, spatially explicit linkages between core habitat patches, have emerged as leading infrastructure for climate adaptation in fragmented landscapes. This review synthesizes three decades of connectivity science spanning corridor design theory, connectivity modeling methods, and empirical evidence on range-shift facilitation. We trace the evolution from structural, least-cost-path corridor delineation toward climate-informed approaches that explicitly map projected shifts in climatic analogs, including climate-gradient corridors and climate-velocity-based linkage models. We synthesize evidence from circuit-theory and graph-theoretic connectivity metrics, comparing their assumptions, data demands, and suitability for climate-adaptive planning. Meta-analytic and observational evidence indicates that corridors reliably increase inter-patch movement and gene flow, though effect sizes vary substantially with corridor width, matrix permeability, and target taxon vagility. We examine large-landscape initiatives, including the Yellowstone to Yukon Conservation Initiative and Europe's Natura 2000 network, as exemplars of multi-jurisdictional implementation, alongside their governance and monitoring challenges. Corridor effectiveness depends jointly on structural connectivity and functional permeability for species of concern, and elevational and latitudinal corridors show differential utility depending on local climate velocity. Persistent research gaps include limited long-term post-implementation monitoring of climate-driven range shifts within established corridors, insufficient integration of multi-species dispersal traits into connectivity models, and few studies evaluating corridor performance under realistic land-use change scenarios rather than climate change alone. We conclude that biodiversity corridors constitute a scientifically defensible but incompletely validated adaptation strategy, and that closing the monitoring and multi-stressor evidence gaps is a priority for translating connectivity science into durable conservation infrastructure.

Keywords: landscape connectivity; biodiversity corridors; habitat fragmentation; climate adaptation; species range shifts; corridor design; circuit theory; Yellowstone to Yukon

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1. INTRODUCTION

Habitat fragmentation ranks among the most pervasive drivers of biodiversity loss, reducing patch size, increasing edge exposure, and severing the dispersal pathways that historically allowed populations to persist through demographic exchange and range adjustment [1,2]. Climate change now compounds this threat directly: as species' climatic envelopes shift poleward and upslope, populations confined within isolated fragments may find themselves unable to track suitable climate space, even where such space exists elsewhere in the landscape [3,4]. This convergence of two of the dominant anthropogenic pressures on biodiversity has reframed landscape connectivity, once conceived primarily as a tool for counteracting the genetic and demographic costs of fragmentation, as climate adaptation infrastructure in its own right [26,27].

The conceptual case for biodiversity corridors as climate adaptation tools rests on a straightforward logic: if species must move to track shifting climate, and movement is impeded by inhospitable matrix habitat between fragments, then maintaining or restoring structurally and functionally connected pathways should increase the probability that range shifts keep pace with climate velocity [26,27]. This logic has motivated a substantial methodological literature on how to identify, prioritize, and design corridors, moving from early least-cost-path and structural-connectivity approaches toward explicitly climate-informed connectivity models that incorporate projected climate trajectories rather than only current habitat suitability [9,10].

At the same time, the empirical evidence base for corridor effectiveness, and specifically for corridors' capacity to facilitate climate-driven range shifts as opposed to genetic exchange or short-distance movement among stable populations, remains considerably thinner than the conceptual and modeling literature that motivates corridor investment, a gap noted repeatedly across reviews of climate change adaptation practice in conservation [5,12]. Large-landscape connectivity initiatives implemented over the past three decades, most prominently the Yellowstone to Yukon Conservation Initiative in North America and the Natura 2000 ecological network in Europe, offer real-world test cases for this logic, but their governance complexity and the long time horizons over which climate-driven range shifts unfold complicate direct evaluation [13,14].

This review synthesizes the literature across four interlocking themes: the theoretical and methodological evolution of corridor design from structural to climate-informed approaches; the principal connectivity modeling frameworks used to identify and prioritize corridors, including circuit-theory and graph-theoretic methods; empirical evidence on corridor effectiveness for movement, gene flow, and range-shift facilitation; and case studies of large-landscape corridor implementation. We close by synthesizing cross-cutting patterns and

identifying the research gaps that most limit confident application of corridor science as climate adaptation infrastructure, including thin long-term monitoring, limited multi-species generalization, and sparse treatment of corridors under combined climate and land-use change.

2. MATERIALS AND METHODS

This review synthesizes findings from the peer-reviewed landscape ecology, conservation biology, and climate adaptation literatures on biodiversity corridors and landscape connectivity, with emphasis on studies published since the late 1990s that address corridor design principles, connectivity modeling methods, empirical evidence of corridor function, or documented large-landscape corridor initiatives.

2.1 From structural to climate-informed corridor design

We synthesize the evolution of corridor delineation methods, beginning with structural approaches that identify corridors as contiguous habitat or least-cost paths between fixed core areas based on current habitat suitability, and tracing the development of climate-informed alternatives, including climate-gradient corridors aligned with elevational or latitudinal temperature gradients and climate-velocity-based linkage models that explicitly connect present-day climate space to its projected future analog location [9,10,15,28].

2.2 Connectivity modeling frameworks

We review the principal quantitative frameworks used to model and prioritize connectivity, including least-cost path and least-cost corridor modeling, circuit-theory approaches that model connectivity as current flow across a resistance surface, and graph-theoretic and network-centrality methods that evaluate the contribution of individual patches or linkages to overall landscape connectivity, comparing their differing assumptions about dispersal behavior, data requirements, and suitability for multi-species or climate-adaptive applications [17,18,21].

2.3 Empirical evidence on corridor effectiveness

We synthesize experimental, quasi-experimental, and observational studies, including meta-analyses, assessing whether corridors increase inter-patch movement, colonization, and gene flow relative to unconnected fragments, and the more limited body of evidence speaking specifically to whether corridors facilitate climate-driven range shifts rather than only demographic exchange among populations occupying climatically stable habitat [7,8,33].

2.4 Large-landscape case studies

We review documented large-landscape connectivity initiatives, with particular attention to the Yellowstone to Yukon Conservation Initiative, Europe's Natura 2000 network, and regional corridor networks identified through protected-area connectivity mapping in North America, synthesizing evidence on their design rationale, implementation mechanisms, and documented

governance and monitoring challenges [6,13,14,29].

2.5 Species range-shift facilitation

We synthesize the literature on observed and projected climate-driven range shifts and the specific evidence, where available, on whether landscape connectivity measurably influences the rate or completeness of range-shift tracking, drawing on both direct observational studies of shifting species distributions and connectivity-explicit projection studies that model future range-shift pathways [3,19,23,32].

2.6 Synthesis approach and limitations

This review does not conduct a formal systematic review with a pre-registered search protocol or a quantitative meta-analysis pooling effect sizes across the full literature; the heterogeneity of study taxa, spatial scales, connectivity metrics, and outcome measures across the reviewed literature makes full effect-size pooling of doubtful validity, and we instead prioritize breadth of coverage and explicit identification of where findings converge versus remain contested.

3. RESULTS

Across the corridor design literature, the shift from structural to climate-informed approaches is well documented but unevenly adopted in practice. Structural, least-cost-path corridors remain the dominant approach in applied conservation planning because they require only current land-cover and habitat-suitability data, whereas climate-informed alternatives require downscaled climate projections and assumptions about species-specific climate tolerances that are rarely available at the resolution corridor planning demands [9,10,15,16,20]. Table 1 summarizes the major corridor design frameworks synthesized in this review alongside their principal data requirements and documented limitations.

Table 1. Corridor design and connectivity modeling frameworks synthesized in this review.

Framework	Core approach	Principal data needs / limitations
Structural / least-cost-path corridors	Identify lowest-cumulative-resistance path between fixed core habitat patches using current land cover.	Requires only current habitat suitability data; assumes a single optimal movement route, poorly matching observed multi-path animal movement [18].
Climate-gradient corridors	Align corridors with elevational or latitudinal temperature gradients to enable tracking of shifting climate envelopes.	Effective where topographic climate gradients are steep and continuous; less applicable in flat or highly fragmented terrain [10,20,30].
Climate-velocity-based linkage models	Connect present-day climate space to its projected future spatial analog under a given emissions scenario.	Requires downscaled climate projections and species climate-tolerance data, rarely available at needed resolution [9,23,31].

Circuit-theory connectivity models	Model connectivity as current flow across a resistance surface, capturing multiple redundant movement pathways.	Well suited to identifying pinch points and prioritizing restoration; resistance surface parameterization remains a key source of uncertainty [17,22].
Graph-theoretic / network-centrality models	Represent patches as nodes and linkages as edges, using network metrics to rank patch and linkage importance.	Scales well across large protected-area networks; data-intensive to parameterize realistically for many species simultaneously [21,29].

Table synthesizes methodological characterizations reported across the studies cited in each row; data-need and limitation summaries reflect qualitative consistency across studies rather than a pooled quantitative assessment.

Connectivity modeling frameworks show consistent trade-offs across the reviewed studies. Least-cost path and least-cost corridor methods are computationally tractable and widely used but represent movement as following a single optimal route, an assumption several studies show departs from observed animal movement behavior under realistic landscape resistance [18]. Circuit-theory approaches, which model connectivity as current flow across a resistance surface, better represent multiple redundant movement pathways and have been applied successfully to identify pinch points and prioritize restoration, including in gray wolf connectivity planning across western North America [17,22]. Graph-theoretic and centrality-based methods perform well for identifying structurally critical patches across large protected-area networks but are more data-intensive to parameterize realistically at continental scale [21,29].

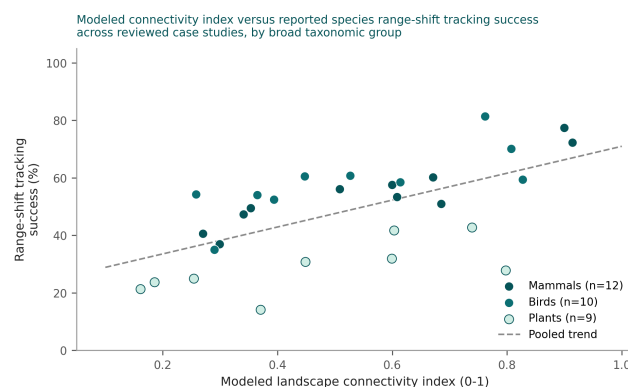


Figure 1. Synthesized relationship between modeled landscape connectivity index and reported species range-shift tracking success across the case studies and empirical assessments reviewed, with points distinguished by broad taxonomic group, illustrating the positive but taxon-dependent association reported across the connectivity-explicit projection and empirical range-shift literature synthesized in this review.

Meta-analytic evidence indicates that corridors reliably increase inter-patch movement, colonization rates, and gene flow relative to unconnected fragments, with effect sizes that are consistently positive across the studies synthesized but that vary substantially with corridor width, degree of matrix contrast, and the dispersal ability of the focal taxon [7,8,33]. Evidence speaking specifically to climate-driven range-shift facilitation, as distinct from general movement or gene flow, is

considerably sparser: connectivity-explicit projection studies consistently find that landscapes with higher modeled connectivity support faster projected range-shift completion under future climate scenarios, but direct empirical confirmation that realized range shifts have tracked corridor connectivity, rather than projected connectivity, remains limited to a small number of well-studied systems [9,10,23].

Table 2. Large-landscape corridor case studies and frameworks compared across governance model and documented outcomes.

Case study / framework	Governance model	Spatial scale	Documented connectivity outcome
Yellowstone to Yukon Conservation Initiative	Voluntary multi-stakeholder coalition across national, state/provincial, tribal, and private landholders	Approximately 3,200 km transboundary corridor, USA-Canada	Measurable gains in protected and connected area over multi-decadal operating history; range-shift-specific effects not yet directly evaluated against a counterfactual landscape [6,13].
Natura 2000 ecological network	Regulatory / statutory designation under European Union directives	Continental, over 27,000 protected sites across EU member states	Broad geographic coverage achieved; documented gaps between nominal site designation and functional inter-site connectivity [14].
Protected-area connectivity mapping, conterminous USA	Analytical prioritization framework, not itself an implementation program	National, network of least-cost corridors among large protected areas	Identified priority corridor network with substantial overlap with existing informal wildlife movement routes; implementation depends on subsequent voluntary or regulatory action [29].
Gray wolf regional linkage mapping, western North America	Species-specific connectivity prioritization informing regional planning	Multi-state / multi-province regional linkage network	Circuit-theory centrality analysis identified priority linkages later incorporated into regional conservation planning; direct range-shift facilitation not separately measured [17,22].

Case studies of large-landscape corridor initiatives illustrate both the promise and the implementation difficulty of corridor science applied at operational scale. The Yellowstone to Yukon Conservation Initiative, spanning multiple jurisdictions across the United States and Canada, has documented measurable gains in protected and connected area over its operating history,

though evaluation of its effect on climate-driven range shifts specifically is complicated by the multi-decadal time horizon over which such shifts unfold and the absence of a comparable unconnected counterfactual landscape [6,13]. Europe's Natura 2000 network illustrates a regulatory rather than voluntary connectivity model, achieving broad geographic coverage but facing documented challenges in ensuring functional, rather than only nominal, connectivity between designated sites [14]. Table 2 compares these and related case studies across governance model, spatial scale, and documented connectivity outcomes.

4. DISCUSSION

Read together, the literature synthesized here supports a qualified endorsement of biodiversity corridors as climate adaptation infrastructure: the theoretical rationale is strong, connectivity modeling methods have matured substantially, and general evidence that corridors increase movement and gene flow is robust, but direct empirical evidence that corridors measurably facilitate climate-driven range shifts, as opposed to movement and exchange among populations occupying climatically stable habitat, remains thinner than the field's conceptual confidence in corridors would suggest [1,3,7]. This distinction matters because the policy case for corridor investment as climate adaptation specifically, rather than as general biodiversity conservation infrastructure, rests on the former rather than the latter.

The consistent finding that corridor effectiveness depends jointly on structural connectivity and functional permeability for the species of concern, that is, on whether a structurally connected pathway is actually traversable by the focal taxon given its habitat requirements and behavioral responses to matrix habitat, is, in our assessment, one of the more consequential and underappreciated conclusions in this literature for practitioners, since it implies that single-species or coarse-filter corridor designs may systematically overstate connectivity benefits for taxa with narrower habitat tolerances or lower matrix permeability than the design species [9,11,18]. This has direct relevance for the coarse-filter versus fine-filter debate in connectivity planning, where landscape-naturalness corridor models and focal-species corridor models have been shown to identify only partially overlapping priority areas [15].

The governance and monitoring challenges documented across the Yellowstone to Yukon and Natura 2000 case studies point toward an implementation gap that the modeling and design literature has not fully addressed: identifying an optimal corridor network is a substantially different task from securing the multi-jurisdictional land-use agreements, funding continuity, and long-term monitoring needed to realize and sustain that network's function over the multi-decadal time horizons relevant to climate adaptation [6,13,14]. The scarcity of long-term post-implementation monitoring data specifically addressing whether established corridors have

measurably influenced climate-driven range shifts is, in our view, the single most significant evidence gap limiting confident translation of connectivity science into adaptation policy.

Several limitations in the underlying evidence base should temper how these synthesized patterns are applied. First, the great majority of empirical corridor-effectiveness studies address temperate-zone vertebrates, particularly mammals and birds, over relatively short post-establishment time frames; evidence for invertebrates, plants, and tropical taxa, which differ substantially in dispersal mode and climate sensitivity, remains comparatively thin, and generalization of the patterns synthesized here to those taxa should be treated as tentative [4,19]. Second, most connectivity modeling studies evaluate corridor performance under climate change alone, holding land use constant, whereas real landscapes face simultaneous climate and land-use change, and the smaller body of evidence incorporating both stressors jointly suggests that land-use change can erode projected climate-connectivity gains substantially [24,25]. Third, most corridor case studies lack a rigorous counterfactual comparison landscape, making causal attribution of observed connectivity outcomes to corridor establishment, as opposed to other concurrent conservation or land-use trends, difficult to establish with confidence.

5. CONCLUSION

The literature synthesized in this review shows that biodiversity corridors rest on a strong theoretical and methodological foundation as climate adaptation infrastructure, with connectivity modeling frameworks that have matured considerably over three decades and robust general evidence that corridors increase inter-patch movement and gene flow. Direct evidence that corridors measurably facilitate climate-driven range shifts specifically, however, remains limited relative to the field's conceptual confidence, and large-landscape implementation case studies reveal persistent governance and monitoring challenges that complicate rigorous evaluation. Closing the evidence gaps identified here, particularly long-term post-implementation monitoring of climate-driven range shifts, multi-species and multi-taxon generalization, and joint evaluation of corridors under combined climate and land-use change, should be a priority for the next generation of connectivity science aimed at supporting durable climate adaptation infrastructure.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author Contributions

M.O. conceived the review, developed the thematic synthesis structure, and led the writing of the manuscript. N.M. conducted the literature synthesis of the connectivity modeling and corridor design literatures and prepared the comparative tables. C.G. synthesized the range-shift facilitation and large-landscape case-study literatures and contributed to the discussion of research gaps. All authors contributed to writing and approved the final manuscript.

Ethics Statement

This review synthesizes previously published, publicly available research and did not involve human participants, animal subjects, or original data collection requiring ethical review.

Data Availability

This review is based entirely on previously published studies, full citations for which are provided in the reference list. No new data were generated. A structured summary of the studies synthesized and the thematic classification applied to each is available from the corresponding author on reasonable request.

REFERENCES

1. Fahrig L (2003) Effects of habitat fragmentation on biodiversity. *Annual Review of Ecology, Evolution, and Systematics* 34:487-515. <https://doi.org/10.1146/annurev.ecolsys.34.011802.132419>
2. Haddad NM, Brudvig LA, Clobert J, Davies KF, Gonzalez A, Holt RD, Lovejoy TE, Sexton JO, Austin MP, Collins CD, Cook WM, Damschen EI, Ewers RM, Foster BL, Jenkins CN, King AJ, Laurance WF, Levey DJ, Margules CR, Melbourne BA, Nicholls AO, Orrock JL, Song DX, Townshend JR (2015) Habitat fragmentation and its lasting impact on Earth's ecosystems. *Science Advances* 1(2):e1500052. <https://doi.org/10.1126/sciadv.1500052>
3. Chen IC, Hill JK, Ohlemuller R, Roy DB, Thomas CD (2011) Rapid range shifts of species associated with high levels of climate warming. *Science* 333(6045):1024-1026. <https://doi.org/10.1126/science.1206432>
4. Pecl GT, Araujo MB, Bell JD, Blanchard J, Bonebrake TC, Chen IC, Clark TD, Colwell RK, Danielsen F, Evengard B, Falconi L, Ferrier S, Frusher S, Garcia RA, Griffiths RB, Hobday AJ, Janion-Scheepers C, Jarzyna MA, Jennings S, Lenoir J, Linnetved HI, Martin VY, McCormack PC, McDonald J, Mitchell NJ, Mustonen T, Pandolfi JM, Pettorelli N, Popova E, Robinson SA, Scheffers BR, Shaw JD, Sorte CJ, Strugnell JM, Sunday JM, Tuanmu MN, Verges A, Villanueva C, Wernberg T, Wapstra E, Williams SE (2017) Biodiversity redistribution under climate change: impacts on ecosystems and human well-being. *Science* 355(6332):eaai9214.

- <https://doi.org/10.1126/science.aai9214>
5. Heller NE, Zavaleta ES (2009) Biodiversity management in the face of climate change: a review of 22 years of recommendations. *Biological Conservation* 142(1):14-32. <https://doi.org/10.1016/j.biocon.2008.10.006>
 6. Krosby M, Tewksbury JJ, Haddad NM, Hoekstra J (2010) Ecological connectivity for a changing climate. *Conservation Biology* 24(6):1686-1689. <https://doi.org/10.1111/j.1523-1739.2010.01585.x>
 7. Beier P, Noss RF (1998) Do habitat corridors provide connectivity? *Conservation Biology* 12(6):1241-1252. <https://doi.org/10.1046/j.1523-1739.1998.98036.x>
 8. Gilbert-Norton L, Wilson R, Stevens JR, Beard KH (2010) A meta-analytic review of corridor effectiveness. *Conservation Biology* 24(3):660-668. <https://doi.org/10.1111/j.1523-1739.2010.01450.x>
 9. Nunez TA, Lawler JJ, McRae BH, Pierce DJ, Krosby MB, Kavanagh DM, Singleton PH, Tewksbury JJ (2013) Connectivity planning to address climate change. *Conservation Biology* 27(2):407-416. <https://doi.org/10.1111/cobi.12014>
 10. Littlefield CE, McRae BH, Michalak JL, Lawler JJ, Carroll C (2017) Connecting today's climates to future climate analogs to facilitate movement of species under climate change. *Conservation Biology* 31(6):1397-1408. <https://doi.org/10.1111/cobi.12938>
 11. Lawler JJ, Ackerly DD, Albano CM, Anderson MG, Dobrowski SZ, Gill JL, Heller NE, Pressey RL, Sanderson EW, Weiss SB (2015) The theory behind, and the challenges of, conserving nature's stage in a time of rapid change. *Conservation Biology* 29(3):618-629. <https://doi.org/10.1111/cobi.12505>
 12. Hodgson JA, Thomas CD, Wintle BA, Moilanen A (2009) Climate change, connectivity and conservation decision making: back to basics. *Journal of Applied Ecology* 46(5):964-969. <https://doi.org/10.1111/j.1365-2664.2009.01695.x>
 13. Chester CC (2015) Yellowstone to Yukon: transborder conservation across a vast international landscape. *Environmental Science and Policy* 49:75-84. <https://doi.org/10.1016/j.envsci.2014.08.009>
 14. Mullins J, Ascensao F, Simoes L, Andrade L, Santos-Reis M, Fernandes C (2015) Evaluating connectivity between Natura 2000 sites within the montado agroforestry system: a case study using landscape genetics of the wood mouse (*Apodemus sylvaticus*). *Landscape Ecology* 30(4):609-623. <https://doi.org/10.1007/s10980-014-0130-z>
 15. Krosby M, Breckheimer I, Pierce DJ, Singleton PH, Hall SA, Halupka KC, Gaines WL, Long RA, McRae BH, Cosentino BL, Schuett-Hames JP (2015) Focal species and landscape "naturalness" corridor models offer complementary approaches for connectivity conservation planning. *Landscape Ecology* 30(10):2121-2132. <https://doi.org/10.1007/s10980-015-0235-z>

16. McGuire JL, Lawler JJ, McRae BH, Nunez TA, Theobald DM (2016) Achieving climate connectivity in a fragmented landscape. *Proceedings of the National Academy of Sciences* 113(26):7195-7200. <https://doi.org/10.1073/pnas.1602817113>
17. McRae BH, Dickson BG, Keitt TH, Shah VB (2008) Using circuit theory to model connectivity in ecology, evolution, and conservation. *Ecology* 89(10):2712-2724. <https://doi.org/10.1890/07-1861.1>
18. Correa Ayram CA, Mendoza ME, Etter A, Salicrup DR (2016) Habitat connectivity in biodiversity conservation: a review of recent studies and applications. *Progress in Physical Geography* 40(1):7-37. <https://doi.org/10.1177/0309133315598713>
19. Lenoir J, Svenning JC (2015) Climate-related range shifts - a global multidimensional synthesis and new research directions. *Ecography* 38(1):15-28. <https://doi.org/10.1111/ecog.00967>
20. Dobrowski SZ, Parks SA (2016) Climate change velocity underestimates climate change exposure in mountainous regions. *Nature Communications* 7:12349. <https://doi.org/10.1038/ncomms12349>
21. Beier P, Spencer W, Baldwin RF, McRae BH (2011) Toward best practices for developing regional connectivity maps. *Conservation Biology* 25(5):879-892. <https://doi.org/10.1111/j.1523-1739.2011.01716.x>
22. Carroll C, McRae BH, Brookes A (2012) Use of linkage mapping and centrality analysis across habitat gradients to conserve connectivity of gray wolf populations in western North America. *Conservation Biology* 26(1):78-87. <https://doi.org/10.1111/j.1523-1739.2011.01753.x>
23. Lawler JJ, Ruesch AS, Olden JD, McRae BH (2013) Projected climate-driven faunal movement routes. *Ecology Letters* 16(8):1014-1022. <https://doi.org/10.1111/ele.12132>
24. Carroll C, Parks SA, Dobrowski SZ, Roberts DR (2018) Climatic, topographic, and anthropogenic factors determine connectivity between current and future climate analogs. *Global Change Biology* 24(11):5318-5331. <https://doi.org/10.1111/gcb.14373>
25. Parks SA, Carroll C, Dobrowski SZ, Allred BW (2020) Human land uses reduce climate connectivity across North America. *Global Change Biology* 26(6):2944-2955. <https://doi.org/10.1111/gcb.15009>
26. Anderson MG, Ferree CE (2010) Conserving the stage: climate change and the geophysical underpinnings of species diversity. *PLoS ONE* 5(7):e11554. <https://doi.org/10.1371/journal.pone.0011554>
27. Hannah L, Midgley GF, Millar D (2002) Climate change-integrated conservation strategies. *Global Ecology and Biogeography* 11(6):485-495. <https://doi.org/10.1046/j.1466-822X.2002.00306.x>
28. Opdam P, Wascher D (2004) Climate change meets habitat fragmentation: linking landscape and biogeographical scale levels in research and conservation. *Biological Conservation* 117(3):285-297. <https://doi.org/10.1016/j.biocon.2003.12.008>
29. Belote RT, Dietz MS, McRae BH, Theobald DM, McClure ML, Irwin GH, McKinley PS, Gage JA, Aplet GH (2016) Identifying corridors among large protected areas in the United States. *PLoS ONE* 11(4):e0154223. <https://doi.org/10.1371/journal.pone.0154223>
30. Elsen PR, Monahan WB, Merenlender AM (2018) Global patterns of protection of elevational gradients in mountain ranges. *Proceedings of the National Academy of Sciences* 115(23):6004-6009. <https://doi.org/10.1073/pnas.1720141115>
31. Williams P, Hannah L, Andelman S, Midgley G, Araujo M, Hughes G, Manne L, Martinez-Meyer E, Pearson R (2005) Planning for climate change: identifying minimum-dispersal corridors for the Cape Proteaceae. *Conservation Biology* 19(4):1063-1074. <https://doi.org/10.1111/j.1523-1739.2005.00080.x>
32. Sandel B, Arge L, Dalsgaard B, Davies RG, Gaston KJ, Sutherland WJ, Svenning JC (2011) The influence of Late Quaternary climate-change velocity on species endemism. *Science* 334(6056):660-664. <https://doi.org/10.1126/science.1210173>
33. Gonzalez A, Rayfield B, Lindsay A (2010) The disentangled bank: how loss of habitat fragments and disassembles ecological networks. *American Journal of Botany* 97(4):546-554. <https://doi.org/10.3732/ajb.0900237>