

Moving in the Anthropocene: Global reductions in terrestrial mammalian movements

Marlee A. Tucker, Katrin Böhning-Gaese, William F. Fagan, John M. Fryxell, Bram Van Moorter, Susan C. Alberts, Abdullahi H. Ali, Andrew M. Allen, Nina Attias, Tal Avgar, Hattie L. A. Bartlam-Brooks, Buuveibaatar Bayarbaatar, Jerrold L. Belant, Alessandra Bertassoni, Dean E. Beyer, Laura R. Bidner, Floris M. van Beest, Stephen Blake, Niels Blaum, Chloe Bracis, Danielle Brown, P J Nico de Bruyn, Francesca Cagnacci, Justin M. Calabrese, Constança Camilo-Alves, Simon Chamaillé-Jammes, André Chiaradia, Sarah C. Davidson, Todd E. Dennis, Stephen DeStefano, Duane R. Diefenbach, Iain Douglas-Hamilton, Julian Fennessy, Claudia Fichtel, Wolfgang Fiedler, Christina Fischer, Ilya R. Fischhoff, Christen H. Fleming, Adam T. Ford, Susanne A. Fritz, Benedikt Gehr, Jacob R. Goheen, Eliezer Gurarie, Mark Hebblewhite, Marco Heurich, A. J. Mark Hewison, Christian Hof, Edward Hurme, Lynne A. Isbell, René Janssen, Florian Jeltsch, Petra Kaczensky, Adam Kane, Peter M. Kappeler, Matthew J. Kauffman, Roland Kays, Duncan M. Kimuyu, Flávia Koch, Bart Kranstauber, Scott LaPoint, Peter Leimgruber, John D. C. Linnell, Pascual López-López, A. Catherine Markham, Jenny Mattisson, Emília Patrícia Medici, Ugo Mellone, Evelyn H. Merrill, Guilherme Mourão, Ronaldo Gonçalves Morato, Nicolas Morellet, Thomas A. Morrison, Samuel L. Díaz-Muñoz, Atle Mysterud, Nandintsetseg Dejid, Ran Nathan, Aidin Niamir, John Oddén, Robert B. O'Hara, Luiz Gustavo Rodrigues Oliveira-Santos, Kirk A. Olson, Bruce D. Patterson, Rogério Cunha de Paula, Luca Pedrotti, Björn Reineking, Martin Rimpler, Tracey L. Rogers, Christer M. Rolandsen, Christopher S. Rosenberry, Daniel I. Rubenstein, Kamran Safi, Sonia Saïd, Nir Sapir, Hall Sawyer, Niels Martin Schmidt, Nuria Selva, Agnieszka Sergiel, Enkhtuvshin Shiilegdamba, João Paulo Silva, Navinder J. Singh

<https://eprints.gla.ac.uk/156805/1/156805.pdf>

DEPTH	EXPERTISE	VOICE	GENERATED
Overview (10-15 min)	Balanced	Riya_Rao	September 02, 2026

A GPS collar weighs almost nothing — just a few hundred grams strapped around a wolf's neck, a zebra's, or a mule deer's. For decades, researchers fastened these devices to animals one at a time, observing individual lives unfold across different landscapes. Then Marlee Tucker and colleagues did something unprecedented: they pooled eight hundred and three of those collars from fifty-seven species and six continents into a single analysis. What they discovered when they examined all that data together was this — animals living near humans move roughly half as far.

This is not limited to one country or one species. It applies everywhere, across mammals ranging from half a kilogram to nearly four thousand kilograms.

That number deserves attention. Half as far. Consider what movement actually does for an ecosystem before you let that figure slip away.

Wild mammals are what ecologists refer to as mobile links. They are not just passengers in the landscape; they are the means by which ecosystems function. A wolf moving twenty kilometers overnight connects prey populations across valleys. A tapir walking through the forest disperses seeds kilometers from where it fed. A wildebeest migrating across a savanna transports nutrients from one watershed to another. Predator-prey dynamics, seed dispersal, nutrient cycling, metapopulation connectivity, and disease transmission — all of these rely on animals actually going somewhere. When movement decreases, that machinery slows down too. The question Tucker and colleagues aimed to answer was simple yet crucial: across the entire living world of terrestrial mammals, what impact does the human footprint have on that machinery?

To tackle this, they compiled a GPS tracking database comprising seven million three hundred thirty-nine thousand three hundred seventy-six locations from eight hundred and three individuals across fifty-seven terrestrial, non-flying mammal species that were collected between nineteen ninety-eight and twenty fifteen. The species varied in body mass from zero point four nine kilograms to three thousand nine hundred forty kilograms, including twenty-eight herbivores, eleven carnivores, and eighteen omnivores. To make movement comparable across species and study designs, the team sub-sampled locations at nine time intervals — from one hour to two hundred fifty-six hours — and calculated straight-line geodesic distances between sequential locations. For each individual and time scale, they summarized movement in two ways: the median displacement, which captures typical movement, and the zero point ninety-five quantile, which captures the long-distance journeys in the top five percent.

Every location was then annotated with two key variables. The first was NDVI — the Normalized Difference Vegetation Index — which is a satellite-derived measure of how green and productive the vegetation is, used here as a proxy for food availability. The second was the Human Footprint Index, or HFI, a global index that combines built environments, cropland, pasture, population density, night-time lights, roads, railways, and navigable waterways into a single score ranging from zero to fifty. The HFI essentially provides a composite measure of how thoroughly humans have altered a location. Tucker and colleagues then fitted eighteen linear mixed-effects models — one for each combination of time scale and displacement

metric — controlling for body mass, NDVI, diet, and taxonomy, and incorporating a spatial autocorrelation structure.

The headline result is striking. At the ten-day scale, median displacements averaged three point three kilometers in high human footprint areas — with an HFI around thirty-six — compared to six point nine kilometers in low footprint areas near zero. Long-distance movements at that same ten-day scale averaged six point six kilometers in high footprint areas versus twenty-one point five kilometers in low footprint areas. This represents a three-fold difference for the animals that naturally travel the farthest. The effect was statistically significant at all time scales longer than eight hours and absent at the shortest intervals — one to four hours. That detail matters: animals in human-dominated landscapes are not just moving more slowly moment to moment; they are ranging less over days. The footprint shrinks journeys, not steps.

Body mass, NDVI, and diet all influenced movement as expected. Larger species traveled farther. Carnivores ranged more than herbivores or omnivores. Animals in greener, more productive environments moved less — presumably because food was readily available. These ecological patterns held across time scales but do not explain away the human footprint effect. The HFI signal persisted even after accounting for all of them.

Now, here is where the study delves deeper. Tucker and colleagues did not just establish that movement is reduced near humans — they investigated why and broke the answer into two distinct mechanisms. In their models, they divided the HFI into two components. One component measured how much an individual's local HFI deviated from the average HFI of its species — that is, whether this particular animal was living in a more human-impacted area than its peers. A second component captured the species' mean HFI — effectively indicating which species are residing in high footprint areas overall. This separation allowed them to differentiate individual behavioral responses from a species-level filtering effect.

Both processes are real, but they function on different timescales. The individual behavioral effect — animals moving less in relatively more human-impacted areas compared to others of their kind — was negative and significant from eight hours up through ten days for both median and long-distance displacements. Individual animals alter their behavior. However, the species-level effect conveys a different, and in some respects, more concerning narrative. That effect only became statistically significant at the longest timescales: five days and ten days. What it captures is this — species that naturally make long-range movements are simply less present in high footprint landscapes. They have not adapted; they have been filtered out.

Tucker and colleagues point to concrete mechanisms behind both processes. Supplementary data compiled from the literature indicate that infrastructure acts as barriers — roads alter genetic structure in moose and desert bighorn sheep, while fragmentation blocks dispersal routes. Conversely, anthropogenic resources attract animals: for instance, supplemental feeding is linked to smaller home ranges in red deer, while urban food availability compresses the ranges of raccoons and roe deer. Thus, some animals are pinned down by abundance, others are hindered by barriers, and the species that evolved to travel the farthest are absent from the most altered locations. The result, across all these combined mechanisms, is a global halving of mammalian movement.

The ecological costs of that reduction manifest across multiple dimensions. Because animals are mobile links, decreased vagility — the technical term for the capacity to move through the environment — reverberates through every process that movement facilitates. Predator-prey interactions are disrupted when predators cannot track prey over large areas. Seed dispersal collapses when frugivores remain in small patches. Gene flow between populations diminishes when dispersing individuals are unable to cross modified landscapes — Tucker and colleagues specifically note the reduced flow of females between populations as one consequence. Disease dynamics at the wildlife, livestock, and human interface change in ways that are not always predictable as the geography of contact shifts.

Single-site and single-species studies have documented these effects in detail for decades. What Tucker and colleagues have demonstrated is that these are not isolated stories. They form one global narrative. Eight hundred and three animals, fifty-seven species, six continents — the signal is consistent. Mammals near humans move half as far. The mobile links are shortening.

That is not just a conservation statistic. It describes a world in which the living machinery of ecosystems has been operating in a lower gear than we realized, across most locations where humans have made their mark. Movement is a trait, similar to body size or metabolic rate, and like those traits, it influences everything else. Tucker and colleagues have measured, for the first time on a global scale, how thoroughly we have altered it.

This lecture was created by ennepō.

Go to <https://ennepo.ai> to Discover, Create and Follow the latest research in your field.

Read when you can. Listen when you want to.

CREDITS

AI-generated lecture by ennepō.ai, adapted from:

- “Moving in the Anthropocene: Global reductions in terrestrial mammalian movements”, Marlee A. Tucker, Katrin Böhning-Gaese, William F. Fagan, John M. Fryxell, Bram Van Moorter, Susan C. Alberts, Abdullahi H. Ali, Andrew M. Allen, Nina Attias, Tal Avgar, Hattie L. A. Bartlam-Brooks, Buuveibaatar Bayarbaatar, Jerrold L. Belant, Alessandra Bertassoni, Dean E. Beyer, Laura R. Bidner, Floris M. van Beest, Stephen Blake, Niels Blaum, Chloe Bracis, Danielle Brown, P J Nico de Bruyn, Francesca Cagnacci, Justin M. Calabrese, Constança Camilo-Alves, Simon Chamailé-Jammes, André Chiaradia, Sarah C. Davidson, Todd E. Dennis, Stephen DeStefano, Duane R. Diefenbach, Iain Douglas-Hamilton, Julian Fennessy, Claudia Fichtel, Wolfgang Fiedler, Christina Fischer, Ilya R. Fischhoff, Christen H. Fleming, Adam T. Ford, Susanne A. Fritz, Benedikt Gehr, Jacob R. Goheen, Eliezer Gurarie, Mark Hebblewhite, Marco Heurich, A. J. Mark Hewison, Christian Hof, Edward Hurme, Lynne A. Isbell, René Janssen, Florian Jeltsch, Petra Kaczensky, Adam Kane, Peter M. Kappeler, Matthew J. Kauffman, Roland Kays, Duncan M. Kimuyu, Flávia Koch, Bart Kranstauber, Scott LaPoint, Peter Leimgruber, John D. C. Linnell, Pascual López-López, A. Catherine Markham, Jenny Mattisson, Emília Patrícia Medici, Ugo Mellone, Evelyn H. Merrill, Guilherme Mourão, Ronaldo Gonçalves Morato, Nicolas Morellet, Thomas A. Morrison, Samuel L. Díaz-Muñoz, Atle Mysterud, Nandintsetseg Dejid, Ran Nathan, Aidin Niamir, John Oddén, Robert B. O’Hara, Luiz Gustavo Rodrigues Oliveira-Santos, Kirk A. Olson, Bruce D. Patterson, Rogério Cunha de Paula, Luca Pedrotti, Björn Reineking, Martin Rimmner, Tracey L. Rogers, Christer M. Rolandsen, Christopher S. Rosenberry, Daniel I. Rubenstein, Kamran Safi, Sonia Saïd, Nir Sapir, Hall Sawyer, Niels Martin Schmidt, Nuria Selva, Agnieszka Sergiel, Enkhtuvshin Shiilegdamba, João Paulo Silva, Navinder J. Singh (Science, 2018). doi:10.1126/science.aam9712. CC-BY-SA (<https://creativecommons.org/share-your-work/cclicenses/>) Restructured, summarized and explained. Not endorsed by the authors.

This lecture (script and audio) is licensed under CC BY-SA 4.0 (<https://creativecommons.org/licenses/by-sa/4.0/>).

<https://ennepo.ai/lecture/3688f938-5c35-485e-afbe-3d409b4cbdf9>