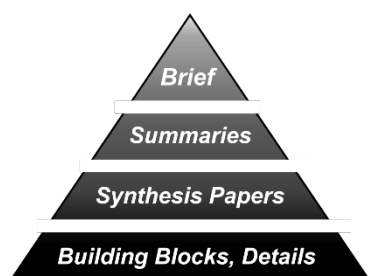


## Arctic Answers Knowledge Pyramid

“Can animal grazing help to reduce permafrost thaw?”

By T. Windirsch, B. C. Forbes, and J. Strauss



**Arctic Answers Briefs** answer questions about Arctic environmental change that are framed for policy makers. Each Brief concisely conveys the state of the science. For supporting information and further reading, the **Knowledge Pyramid** of the state of the science and knowledge is presented below with the references from the Brief at the apex, built upon layers of references of increasingly more technical information: summaries, synthesis papers, and the building blocks of detailed basic research and technical academic studies.

**Key References:** *Selected references that provide recent, accessible information needed to answer policy-relevant questions about rapid Arctic change (also cited in the Brief).*

Beer, C., Zimov, N., Olofsson, J., Porada, P., and Zimov, S. 2020. Protection of Permafrost Soils from Thawing by Increasing Herbivore Density. *Scientific Reports* 10 (4170).

<https://doi.org/10.1038/s41598-020-60938-y>

Olofsson, J., and Post, E. 2018. Effects of large herbivores on tundra vegetation in a changing climate, and implications for rewilding. *Phil. Trans. R. Soc. B: Biological Sciences* 373 (20170437).

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Pennisi, E. 2018. ‘Rewilding’ landscapes with rhinos and reindeer could prevent fires and keep Arctic cool. *Science* 363 (6423).

<https://doi.org/10.1126/science.aav8264>

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<https://doi.org/10.3389/fenvs.2022.893478>

Zimov, S. A., Zimov, N. S., Tikhonov, A. N., and Chapin III, F. S. 2012. Mammoth steppe: a high-productivity phenomenon. *Quart. Sci. Rev.* 57, 26-45.

<https://doi.org/10.1016/j.quascirev.2012.10.005>

**Summaries:** *State-of-the-art information on main findings, critical questions, and societal importance written for non-technical audiences.*

Jepson, P. 2020. Arctic rewilding could mitigate climate change. *Rewilding Europe – blog*.

<https://rewildingeurope.com/blog/arctic-rewilding-could-significantly-mitigate-climate-change/>

Lamm, B. 2021. Untamed: Rewilding the Arctic to Curb Climate Change. *Colossal*. <https://colossal.com/untamed-rewilding-the-arctic-to-curb-climate-change/>

**Syntheses:** *Resources for a comprehensive and often more technical understanding of the issue and how different concepts interrelate.*

Christie, K. S., Bryant, J. P., Gough, L., Ravolainen, V. T., Ruess, R. W., and Tape, K. D. 2015. The Role of Vertebrate Herbivores in Regulating Shrub Expansion in the Arctic: A Synthesis. *BioScience* 65 (12),

<https://doi.org/10.1093/biosci/biv137>

Macias-Fauria, M., Jepson, P., Zimov, N., and Malhi, Y. 2020. Pleistocene Arctic megafaunal ecological engineering as a natural climate solution?. *Phil. Trans. R. Soc. B: Biological Sciences* 375 (1794).

<https://doi.org/10.1098/rstb.2019.0122>

- Loranty, M. M., Abbott, B. W., Blok, D., Douglas, T. A., Epstein, H. E., Forbes, B. C., Jones, B. M., Kholodov, A. L., Kropp, H., Malhotra, A., Mamet, S. D., Myers-Smith, I. H., Natali, S. M., O'Donnell, J. A., Phoenix, G. K., Rocha, A. V., Sonnentag, O., Tape, K. D., and Walker, D. A. 2018. Reviews and syntheses: Changing ecosystem influences on soil thermal regimes in northern high-latitude permafrost regions. *Biogeosciences* 15 (17). <https://doi.org/10.5194/bg-15-5287-2018>
- Tuomi, M., Väisänen, M., Ylännä, H., Brearley, F. O., Barrio, I C., Bråthen, K. A., Eischeid, I., Forbes, B. C., Jónsdóttir, I. S., Kolstad, A. L., Macek, P., Petit Bon, M., Speed, J. D. M., Stark, S., Svavarsdóttir, K., Thórsson, J., and Bueno, C. G. 2021. Stomping in silence: Conceptualizing trampling effects on soils in polar tundra. *Functional Ecology* 35 (2). <https://doi.org/10.1111/1365-2435.13719>

**Building Blocks: Technical studies with details and foundational information about individual concepts.**

- Fischer, W., Thomas, C. K., Zimov, N., and Göckede, M. 2022. Grazing enhances carbon cycling but reduces methane emissions during peak growing season in the Siberian Pleistocene Park tundra site. *Biogeosciences* 19, 1611-1633. <https://doi.org/10.5194/bg-19-1611-2022>
- Holmgren, M., Groten, F., Carracedo, M. R., Vink, S., and Limpens, J. 2023. Rewilding Risks for Peatland Permafrost. *Ecosystems* 26, 1806-1818. <https://doi.org/10.1007/s10021-023-00865-x>
- Köster, K., Berninger, F., Köster, E., and Pumpanen, J. 2015. Influence of Reindeer Grazing on Above- and Belowground Biomass and Soil Carbon Dynamics. *Arctic, Antarctic, and Alpine Research* 47 (3). <https://doi.org/10.1657/AAAR0014-062>
- Kristensen, J. A., Svenning, J.-C., Georgiou, K., and Malhi, Y. 2022. Can large herbivores enhance ecosystem carbon persistence? *Trends in Ecology & Evolution* 37 (2). <https://doi.org/10.1016/j.tree.2021.09.006>