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Zusatzmaterial zu:

Auswirkungen von Revitalisierungsmaßnahmen auf die Biodiversität von Mooren in der gemäßigten Klimazone – eine Metaanalyse

Supplement to:

The effects of restoration on peatland biodiversity in the temperate climate zone – A meta-analysis

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Zusammenfassung

In diesem Beitrag geben wir einen Überblick über die Auswirkungen von Moorrevitalisierungsmaßnahmen auf die Biodiversität von Mooren in der gemäßigten Klimazone. Dazu haben wir anhand einer systematischen Literatursuche und Metaanalyse die Diversität, Abundanz und Anzahl der vorkommenden Arten allgemein und die Abundanz und Anzahl generalistischer und moortypischer Arten aus 62 Studien zu Moorschutzmaßnahmen mit entwässerten oder naturnahen Vergleichsflächen ausgewertet. Im Vergleich zu degradierten Flächen weisen revitalisierte Moore eine durchschnittlich 49 % höhere allgemeine Biodiversität, eine 124 % höhere Abundanz moortypischer Arten und eine 65 % höhere Anzahl moortypischer Arten auf. Die allgemeine Biodiversität ist in revitalisierten im Vergleich zu naturnahen Mooren durchschnittlich 11 % niedriger, die Abundanz moortypischer Arten ist 37 % und die Anzahl moortypischer Arten 31 % geringer. Die Ergebnisse zeigen, dass Moorrevitalisierungsmaßnahmen messbare positive Auswirkungen auf die Biodiversität haben und unterstreichen die Dringlichkeit, bestehende naturnahe Moore zu schützen.

Naturnahe Moore – revitalisierte Moore – Revitalisierung – Renaturierung – Metaanalyse – moortypische Biodiversität – Hochmoor – Niedermoor

Abstract

We provide an overview of the effects of restoration measures on peatland biodiversity in the temperate climate zone. We conducted a systematic literature review and meta-analysis and analysed data for general species diversity, abundance and richness as well as abundance and richness of generalist and characteristic peatland species from 62 publications about peatland restoration measures with drained or near-natural control sites. Average values were higher in restored peatlands compared to degraded sites for general diversity (49 %), abundance of characteristic peatland species (124 %) and richness of characteristic peatland species (65 %). General diversity was 11 %, abundance of characteristic peatland species was 37 % and richness of characteristic peatland species 31 % lower in restored compared to near-natural peatlands. The results show that peatland restoration measures have a significantly positive impact on biodiversity and highlight the importance of protecting pristine and near-natural peatlands.

Near-natural peatlands – Restored peatlands – Restoration – Meta-analysis – Peatland biodiversity – Bog – Fen

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Tab. A: In der Analyse verwendete Datenquellen mit Informationen zu Herkunft, Moortyp und Vornutzung. Am Ende der Tabelle steht der für die Literaturrecherche verwendete Suchbegriff.

Table A: Data sources for the meta-analysis including information about origin, peat type and previous land use. Search string used in the literature search is shown at the bottom of the table.

Datenquelle	Herkunft	Moortyp	Vornutzung
Aggenbach C.J., Backx H. et al. (2013): Do high iron concentrations in rewetted rich fens hamper restoration? Preslia 85(3): 405 – 420.	NL/BE/PL	Niedermoor	Viele Gebiete mit unterschiedlicher Nutzung
Alsila T., Elo M. et al. (2021): Effects of habitat restoration on peatland bird communities. Restoration Ecology 29(1): 13304. DOI: 10.1111/rec.13304	FI	Verschiedene Gebiete, Hochmoor	Forst
Andras J.P., Rodriguez-Reillo W.G. et al. (2021): Rewilding the small stuff: The effect of ecological restoration on prokaryotic communities of peatland soils. FEMS Microbiology Ecology 96(10): FIAA144. DOI: 10.1093/FEMSEC/FIAA144	US	Hochmoor	Landwirtschaft
Basiliko N., Henry K. et al. (2013): Controls on bacterial and archaeal community structure and greenhouse gas production in natural, mined, and restored Canadian peatlands. Frontiers in Microbiology 4(7): 00215. DOI: 10.3389/fmicb.2013.00215	CA	Hochmoor/Niedermoor	Torfabbau
Bess J.A., Chimner R.A., Kangas L.C. (2014): Ditch restoration in a large Northern Michigan fen: Vegetation response and basic porewater chemistry. Ecological Restoration 32(3): 260 – 274. DOI: 10.3368/er.32.3.260	US	Niedermoor	Sonstige
Bobuľská L., Demková L. et al. (2020): Impact of peatland restoration on soil microbial activity and nematode communities. Wetlands 40(4): 865 – 875. DOI: 10.1007/s13157-019-01214-2	SK	Niedermoor	Sonstige (uneindeutig)
Brown L.E., Ramchunder S.J. et al. (2016): Macroinvertebrate community assembly in pools created during peatland restoration. Science of the Total Environment 569 – 570: 361 – 372. DOI: 10.1016/j.scitotenv.2016.06.169	UK	Hochmoor	Verschiedene (Landwirtschaft, Forst, Jagd)
Carroll M.J., Dennis P. et al. (2011): Maintaining northern peatland ecosystems in a changing climate: Effects of soil moisture, drainage and drain blocking on craneflies. Global Change Biology 17(9): 2.991 – 3.001. DOI: 10.1111/j.1365-2486.2011.02416.x	UK	Hochmoor	Landwirtschaft
D'Astous A. (2012): Approches par communautés et par traits pour l'évaluation du succès de restauration d'une tourbière. Dissertation. Université Laval. Québec: 100 S.	CA	Hochmoor	Torfabbau
Daza Secco E., Haapalehto T. et al. (2016): Do testate amoebae communities recover in concordance with vegetation after restoration of drained peatlands? Mires and Peat 18(12): 1 – 14. DOI: 10.19189/MaP.2016.OMB.231	FI	Verschiedene	Forst
Drapeau Picard A.P., Mazerolle M.J. et al. (2021): Impact of pool design on spider and dytiscid recolonization patterns in a restored fen. Restoration Ecology 29(5): 13384. DOI: 10.1111/rec.13384	CA	Niedermoor	Torfabbau
Elo M., Penttinen J., Kotiaho J.S. (2015): The effect of peatland drainage and restoration on Odonata species richness and abundance. BMC Ecology 15(1): s12898-015-0042-z. DOI: 10.1186/s12898-015-0042-z	FI	Hochmoor	Forst
Emsens W.-J., van Diggelen R. et al. (2020): Recovery of fen peatland microbiomes and predicted functional profiles after rewetting. The ISME Journal 14(7): 1.701 – 1.712. DOI: 10.1038/s41396-020-0639-x	UK/NL/BE/DE/PL	Niedermoor	Viele Untersuchungsflächen, genaue Nutzung unklar
Fontaine N., Poulin M., Rochefort L. (2007): Plant diversity associated with pools in natural and restored peatlands. Mires and Peat 2(6): 1 – 17.	CA	Hochmoor	Torfabbau
Frei S., Holderegger R., Bergamini A. (2021): Thirty years later: How successful was the restoration of a raised bog in the swiss plateau? Mires and Peat 27: 2193. DOI: 10.19189/MaP.2021.SNPG.StA.2193	CH	Hochmoor	Torfabbau
González E., Henstra S.W. et al. (2014): Is rewetting enough to recover *Sphagnum* and associated peat-accumulating species in traditionally exploited bogs? Wetlands Ecology and Management 22(1): 49 – 62. DOI: 10.1007/s11273-013-9322-6	CA	Hochmoor	Torfabbau
Görn S., Fischer K. (2015): Measuring the efficiency of fen restoration on carabid beetles and vascular plants: A case study from north-eastern Germany. Restoration Ecology 23(4): 413 – 420. DOI: 10.1111/rec.12203	DE	Niedermoor	Landwirtschaft
Görn S., Schulze F., Fischer K. (2015): Effects of fen management on bird communities in north-eastern Germany. Journal of Ornithology 156(1): 287 – 296. DOI: 10.1007/s10336-014-1125-x	DE	Niedermoor	Landwirtschaft
Green S.M., Baird A.J. et al. (2017): An experimental study on the response of blanket bog vegetation and water tables to ditch blocking. Wetlands Ecology and Management 25(6): 703 – 716. DOI: 10.1007/s11273-017-9545-z	UK	Hochmoor	Landwirtschaft
Grégoire Taillefer A., Wheeler T.A. (2013): Animal colonization of restored peatlands: Inoculation of plant material as a source of insects. Restoration Ecology 21(1): 140 – 144. DOI: 10.1111/j.1526-100X.2012.00867.x	CA	Hochmoor	Torfabbau
Haapalehto T., Juutinen R. et al. (2017): Recovery of plant communities after ecological restoration of forestry-drained peatlands. Ecology and Evolution 7(19): 7.848 – 7.858. DOI: 10.1002/ece3.3243	FI	Niedermoor	Forst
Hannigan E., Mangan R., Kelly-Quinn M. (2011): Evaluation of the success of mountain blanket bog pool restoration in terms of aquatic macroinvertebrates. Biology and Environment 111(2): 1 – 11. DOI: 10.3318/BIOE.2011.111.08	IE	Hochmoor	Torfabbau
Hedberg P., Kotowski W. et al. (2012): Vegetation recovery after multiple-site experimental fen restorations. Biological Conservation 147(1): 60 – 67. DOI: 10.1016/j.biocon.2012.01.039	SE	Niedermoor	Forst
Hoffmann H., Kleeberg A. et al. (2018): Riverine fen restoration provides secondary habitat for endangered and stenotopic rove beetles (Coleoptera: Staphylinidae). Insect Conservation and Diversity 11(2): 194 – 203. DOI: 10.1111/icad.12247	DE	Niedermoor	Landwirtschaft
Johansen A. (2021): A snapshot of restored bogs in Southeastern Norway: Short term vegetation change after rewetting of ombrotrophic mires. Masterarbeit. Norwegian University of Life Sciences. Ås, Norwegen: 39 S.	NO	Hochmoor	Forst

Tab. A: Fortsetzung.
Table A: Continued.

Datenquelle	Herkunft	Moortyp	Vornutzung
Karofeld E., Kaasik A., Vellak K. (2020): Growth characteristics of three *Sphagnum* species in restored extracted peatland. Restoration Ecology 28(6): 1.574 – 1.583. DOI: 10.1111/rec.13245	EE	Hochmoor	Torfabbau
Klimkowska A., van der Elst D.J., Grootjans A.P. (2015): Understanding long-term effects of topsoil removal in peatlands: Overcoming thresholds for fen meadows restoration. Applied Vegetation Science 18(1): 110 – 120. DOI: 10.1111/avsc.12127	NL	Niedermoor	Landwirtschaft
Klimkowska A., Van Diggelen R. et al. (2010): Prospects for fen meadow restoration on severely degraded fens. Perspectives in Plant Ecology, Evolution and Systematics 12(3): 245 – 255. DOI: 10.1016/j.ppees.2010.02.004	PL	Niedermoor	Landwirtschaft
Kotowski W., Dzierza P. et al. (2013): Shrub removal facilitates recovery of wetland species in a rewetted fen. Journal for Nature Conservation 21(5): 294 – 308. DOI: 10.1016/j.jnc.2013.03.002	PL	Niedermoor	Landwirtschaft
Kreyling J., Tanneberger F. et al. (2021): Rewetting does not return drained fen peatlands to their old selves. Nature Communications 12(1): s41467-021-25619-y. DOI: 10.1038/s41467-021-25619-y	UK/DE/NL/PL/CZ/DK/BY/UA	Niedermoor	Viele Flächen, 80 % Landwirtschaft
Krieger A., Fartmann T., Poniatowski D. (2019): Restoration of raised bogs – land-use history determines the composition of dragonfly assemblages. Biological Conservation 237: 291 – 298. DOI: 10.1016/j.biocon.2019.06.032	DE	Hochmoor	Landwirtschaft/Torfabbau
Laggoun-Défarge F., Mitchell E. et al. (2008): Cut-over peatland regeneration assessment using organic matter and microbial indicators (bacteria and testate amoebae). Journal of Applied Ecology 45(2): 716 – 727. DOI: 10.1111/j.1365-2664.2007.01436.x	CH	Hochmoor	Torfabbau
Laine A.M., Leppälä M. et al. (2011): Restoration of managed pine fens: Effect on hydrology and vegetation. Applied Vegetation Science 14(3): 340 – 349. DOI: 10.1111/j.1654-109X.2011.01123.x	FI	Niedermoor	Forst
Laine A.M., Tolvanen A. et al. (2016): Vegetation structure and photosynthesis respond rapidly to restoration in young coastal fens. Ecology and Evolution 6(19): 6.880 – 6.891. DOI: 10.1002/ece3.2348	FI	Niedermoor	Forst
Liu W., Fritz C. et al. (2021): Landscape-level vegetation conversion and biodiversity improvement after 33 years of restoration management in the Drentsche Aa brook valley. Restoration Ecology: 13601. DOI: 10.1111/rec.13601	NL	Verschiedene	Landwirtschaft
Maanavilja L., Aapala K. et al. (2014): Impact of drainage and hydrological restoration on vegetation structure in boreal spruce swamp forests. Forest Ecology and Management 330: 115 – 125. DOI: 10.1016/j.foreco.2014.07.004	FI	Sonstige	Forst
Mälson K., Sundberg S., Rydin H. (2010): Peat disturbance, mowing, and ditch blocking as tools in rich fen restoration. Restoration Ecology 18(2): 469 – 478. DOI: 10.1111/j.1526-100X.2009.00563.x	SE	Niedermoor	Forst
Mazerolle M.J., Poulin M. (2007): Persistence and colonisation as measures of success in bog restoration for aquatic invertebrates: A question of detection. Freshwater Biology 52(2): 383 – 385. DOI: 10.1111/j.1365-2427.2006.01700.x	CA	Hochmoor	Torfabbau
Mieczan T., Tarkowska-Kukuryk M. (2017): Microbial communities as environmental indicators of ecological disturbance in restored carbonate fen – Results of 10 years of studies. Microbial Ecology 74(2): 384 – 401. DOI: 10.1007/s00248-017-0957-3	PL	Niedermoor	Unklar
Muster C., Krebs M., Joosten H. (2020): Seven years of spider community succession in a *Sphagnum* farm. The Journal of Arachnology 48(2): 0161-8202-48.2.119. DOI: 10.1636/0161-8202-48.2.119	DE	Hochmoor	Landwirtschaft
Noreika N., Kotiaho J.S. et al. (2015): Rapid recovery of invertebrate communities after ecological restoration of boreal mires. Restoration Ecology 23(5): 566 – 579. DOI: 10.1111/rec.12237	FI	Sonstige	Forst
Noreika N., Kotze D.J. et al. (2016): Specialist butterflies benefit most from the ecological restoration of mires. Biological Conservation 196: 103 – 114. DOI: 10.1016/j.biocon.2016.02.014	FI	Sonstige	Forst
Paweł N., Romualda B. et al. (2018): Restoration of hydro-ecological conditions in Carpathian forested mountain fens. Wetlands Ecology and Management 26(4): 537 – 546. DOI: 10.1007/s11273-017-9590-7	PL	Niedermoor	Forst
Poulin M., Andersen R., Rochefort L. (2013): A new approach for tracking vegetation change after restoration: A case study with peatlands. Restoration Ecology 21(3): 363 – 371. DOI: 10.1111/j.1526-100X.2012.00889.x	CA	Hochmoor	Torfabbau
Pouliot K., Rochefort L. et al. (2021): The burial under peat technique: An innovative method to restore *Sphagnum* peatlands impacted by mineral linear disturbances. Frontiers in Earth Science 9: 658470. DOI: 10.3389/feart.2021.658470	CA	Hochmoor	Sonstige
Pravia A. (2018): The response of arthropod assemblages to peatland restoration in formerly afforested blanket bog. Dissertation. University of Aberdeen. Aberdeen: 324 S.	UK	Hochmoor	Forst
Purre A.-H., Ilomets M. (2021): Vegetation composition and carbon dioxide fluxes on rewetted milled peatlands – Comparison with undisturbed bogs. Wetlands 41(8): s13157-021-01518-2. DOI: 10.1007/s13157-021-01518-2	EE	Hochmoor	Torfabbau
Ramchunder S.J., Brown L.E., Holden J. (2012): Catchment-scale peatland restoration benefits stream ecosystem biodiversity. Journal of Applied Ecology 49(1): 182 – 191. DOI: 10.1111/j.1365-2664.2011.02075.x	UK	Hochmoor	Sonstige
Read H.J., Bealey C.E. (2021): The restoration of heathland and mire from secondary woodland: How realistic are target vegetation communities? Journal for Nature Conservation 62: 125943. DOI: 10.1016/j.jnc.2020.125943	UK	Hochmoor	Forst
Remm L., Sushko G. (2018): Dragonfly fauna in rewetted mires in Belarus: Diverse but different from natural sites. Wetlands Ecology and Management 26(6): 1.173 – 1.180. DOI: 10.1007/s11273-018-9625-8	BY	Hochmoor	Torfabbau

Tab. A: Fortsetzung.
Table A: Continued.

Datenquelle	Herkunft	Moortyp	Vornutzung
Rochefort L., LeBlanc M.-C. et al. (2016): Reintroduction of fen plant communities on a degraded minerotrophic peatland. Botany 94(11): 1.041 – 1.051. DOI: 10.1139/cjb-2016-0023	CA	Niedermoor	Torfabbau
Singh P., Ekrtová E. et al. (2021): Restoration of rare bryophytes in degraded rich fens: The effect of sod-and-moss removal. Journal for Nature Conservation 59: 125928. DOI: 10.1016/j.jnc.2020.125928	CZ	Niedermoor	Landwirtschaft
Soini P., Riutta T. et al. (2010): Comparison of vegetation and CO_2 dynamics between a restored cut-away peatland and a pristine fen: Evaluation of the restoration success. Restoration Ecology 18(6): 894 – 903. DOI: 10.1111/j.1526-100X.2009.00520.x	FI	Hochmoor	Torfabbau
Strobl K., Moning C., Kollmann J. (2020): Positive trends in plant, dragonfly, and butterfly diversity of rewetted montane peatlands. Restoration Ecology 28(4): 796 – 806. DOI: 10.1111/rec.12957	DE	Sonstige	Forst
Suren A., Lambert P. et al. (2011): The impact of hydrological restoration on benthic aquatic invertebrate communities in a New Zealand wetland. Restoration Ecology 19(6): 747 – 757. DOI: 10.1111/j.1526-100X.2010.00723.x	NZ	Sonstige	Landwirtschaft
Swindles G.T., Green S.M. et al. (2016): Evaluating the use of dominant microbial consumers (testate amoebae) as indicators of blanket peatland restoration. Ecological Indicators 69: 318 – 330. DOI: 10.1016/j.ecolind.2016.04.038	UK	Hochmoor	Sonstige
Van Dijk J., Stroetenga M. et al. (2007): The contribution of rewetting to vegetation restoration of degraded peat meadows. Applied Vegetation Science 10(3): 315 – 324. DOI: 10.1111/j.1654-109X.2007.tb00430.x	NL	Niedermoor	Landwirtschaft
Van Duinen G.A., Zhuge Y. et al. (2006): Effects of rewetting measures in Dutch raised bog remnants on assemblages of aquatic Rotifera and microcrustaceans. Hydrobiologia 565: 187 – 200. DOI: 10.1007/s10750-005-1913-7	NL	Hochmoor	Sonstige
Van Duinen G.-J.A., Brock A.M. et al. (2003): Do restoration measures rehabilitate fauna diversity in raised bogs? A comparative study on aquatic macroinvertebrates. Wetlands Ecology and Management 11(6): 447 – 459. DOI: 10.1023/B:WETL.0000007196.75248.a5	NL	Hochmoor	Sonstige
Watts C.H., Mason N.W. (2015): If we build – they mostly come: Partial functional recovery but persistent compositional differences in wetland beetle community restoration. Restoration Ecology 23(5): 555 – 565. DOI: 10.1111/rec.12227	NZ	Hochmoor	Torfabbau
Wentzell B.M., DeVito E.D., Shebitz D.J. (2021): Effects of restoration strategies on vegetation establishment in retired cranberry bogs. Plant Ecology 222(8): 897 – 913. DOI: 10.1007/s11258-021-01150-4	US	Sonstige	Landwirtschaft
Yamanaka S., Akasaka T. et al. (2017): Influence of farmland abandonment on the species composition of wetland ground beetles in Kushiro, Japan. Agriculture, Ecosystems and Environment 249: 31 – 37. DOI: 10.1016/j.agee.2017.07.027	JP	Niedermoor	Landwirtschaft

Suchbegriff (verwendet bei Scopus, 27.1.2022): (((biodivers* OR divers* OR "species richness" OR specialist* OR richness OR "indicator species" OR "community composition" OR composition OR abundance OR cover) AND (bog OR fen OR mire OR peat* OR peatland*) AND ("peatland restoration" OR restor* OR protect* OR rewet*) AND NOT (tropic*)))
BE = Belgien, BY = Belarus, CA = Kanada, CH = Schweiz, CZ = Tschechien, DE = Deutschland, DK = Dänemark, EE = Estland, FI = Finnland, IE = Irland, JP = Japan, NL = Niederlande, NO = Norwegen, NZ = Neuseeland, PL = Polen, SK = Slowakei, SE = Schweden, UA = Ukraine, UK = Vereinigtes Königreich, US = Vereinigte Staaten

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