Aufsatz • Original manuscript

Dieses Zusatzmaterial ist nicht im Hauptartikel enthalten und online abrufbar unter
https://online.natur-und-landschaft.de/zusatz/3_2023_A_Beckert

# 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

Marvin Beckert und Ana Carolina Rodríguez

Natur und Landschaft — 98. Jahrgang (2023) — Ausgabe 3: 141 – 148

## 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

Manuskripteinreichung: 16.8.2022, Annahme: 12.12.2022

DOI: 10.19217/NuL2023-03-06

**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

**Dr. Marvin Beckert**
**Korrespondierender Autor**
**Bundesamt für Naturschutz**
**Fachgebiet II 2.3 „Nationales Naturerbe, dynamische Systeme und Klimawandel"**
**Konstantinstraße 110**
**53179 Bonn**
**E-Mail: marvin.beckert@bfn.de**

Studium der Umweltwissenschaften mit ökologischem Schwerpunkt in Aberdeen, Schottland. Im Anschluss einige Monate Forschungsassistenz in der Renaturierungsökologie in Perth, Australien. Promotion in Bodenkunde in Aberdeen und Sydney zum Thema „Kohlenstofffraktionen in organischen Böden in Schottland und Tasmanien". Seit 2021 Tätigkeit im Themenfeld Moorschutz mit Schwerpunkt Revitalisierung und Klimaschutz im Fachgebiet II 2.3 „Nationales Naturerbe, dynamische Systeme und Klimawandel" am Bundesamt für Naturschutz.

**Dr. Ana Carolina Rodríguez**
**Fundación Centro de los Bosques Nativos FORECOS**
**Los Robles 510 interior**
**Isla Teja, Valdivia**
**CHILE**
**E-Mail: carolina.rodriguez@miresofchile.cl**