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Stable isotope ratios in alpine rock ptarmigan and black grouse sampled along a precipitation gradient

Nina Dehnhard[a,*], Elizabeth Yohannes[b], Hannes Jenny[c], Gernot Segelbacher[d]

[a] *University of Antwerp, Department Biology – Behavioural Ecology & Ecophysiology Group, Campus Drie Eiken, Universiteitsplein 1, 2610 Antwerp (Wilrijk), Belgium*
[b] *University of Konstanz, Limnological Institute, Mainaustrasse 252, 78457 Konstanz, Germany*
[c] *Department of Wildlife and Fishery Service Grison, Loëstrasse 14, 7001 Chur, Switzerland*
[d] *Wildlife Ecology & Management, University of Freiburg, Tennenbacher Str. 4, 79106 Freiburg, Germany*

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Abstract

Rock ptarmigan (*Lagopus muta*) and black grouse (*Tetrao tetrix*) are two closely related alpine bird species that form relict populations in the European Alps. Besides manifold anthropogenic influences in this region, global climate change is forecast to lead to significant changes in temperatures and precipitation. We here analysed stable isotope ratios ($\delta^{13}C$ and $\delta^{15}N$) of feathers of both bird species and their potential dietary plants across a longitudinal precipitation gradient in south-east Switzerland.

Plant $\delta^{13}C$ was higher at higher altitudes and in drier areas (coinciding with higher longitudes) while plant $\delta^{15}N$ did not differ geographically. Black grouse $\delta^{13}C$ reflected the longitudinal pattern in precipitation and plant $\delta^{13}C$, and there was no indication for a change in dietary composition with precipitation (i.e. no significant changes in $\delta^{15}N$). In contrast, rock ptarmigan $\delta^{13}C$ was independent of precipitation and plant $\delta^{13}C$ values and showed a significant increase in $\delta^{15}N$ towards drier areas, suggesting a potential dietary shift.

In rock ptarmigan, we furthermore investigated intraspecific differences with age, between males and females and among years, and did not find any biologically meaningful intraspecific differences. Interspecifically, rock ptarmigan feathers had significantly higher $\delta^{13}C$ and lower $\delta^{15}N$ values than black grouse, reflecting a dietary segregation between both species. This may partly be due to the higher altitudinal distribution of rock ptarmigan in combination with an altitudinal gradient in plant $\delta^{13}C$. In addition, however, species also segregated in $\delta^{15}N$, most likely caused by a higher proportion of invertebrate diet in black grouse.

Zusammenfassung

Alpenschneehuhn (*Lagopus muta*) und Birkhuhn (*Tetrao tetrix*) sind zwei nahe verwandte Vogelarten, die Reliktpopulationen in den Europäischen Alpen bilden. Neben vielfältigen anthropogenen Einflüssen in dieser Region werden wegen des globalen Klimawandels signifikante Veränderungen in Temperatur und Niederschlag erwartet. Wir analysierten die stabile Isotopenzusammensetzung ($\delta^{13}C$ und $\delta^{15}N$) von Federn sowie potentiellen Nahrungspflanzen entlang eines Niederschlagsgradienten im Südosten der Schweiz.

*Corresponding author. Tel.: +32 03 265 23 47; fax: +32 03 820 22 71.
E-mail address: nina.dehnhard@uantwerpen.be (N. Dehnhard).

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Die δ^{13}C-Werte der Nahrungspflanzen nahmen mit Trockenheit (übereinstimmend mit zunehmenden Längengraden) und Höhe zu, während die Geographie keine Auswirkungen auf die δ^{15}N-Werte der Nahrungspflanzen hatte. δ^{13}C-Werte von Birkhuhnfedern reflektierten den longitudinalen Gradienten in Niederschlag und Pflanzen-δ^{13}C-Werten, und es gab keine Anzeichen für eine Änderung der Nahrungszusammensetzung entlang des Niederschlagsgradienten (d.h. keine signifikanten Veränderungen in δ^{15}N). In Alpenschneehuhnfedern hingegen waren die δ^{13}C-Werte unabhängig von Niederschlag und Pflanzen-δ^{13}C-Werten. Die δ^{15}N-Werte in Alpenschneehuhnfedern nahmen zudem signifikant mit Trockenheit zu, was potentiell auf eine Veränderung der Nahrungszusammensetzung entlang des Niederschlagsgradienten hinweist.

An Alpenschneehühnern untersuchten wir auch intraspezifische Unterschiede zwischen Altersklassen, Männchen und Weibchen sowie verschiedenen Jahren, fanden jedoch keine biologisch aussagekräftigen intraspezifischen Unterschiede. Interspezifisch wiesen Alpenschneehuhnfedern signifikant höhere δ^{13}C und niedrigere δ^{15}N-Werte auf als Birkhühner, was eine Abgrenzung der beiden Arten in ihrer Nahrung reflektiert. Dies kann zum Teil durch die unterschiedliche Nutzung des Lebensraums in Kombination mit dem Gradienten in Pflanzen-δ^{13}C mit ansteigender Höhe erklärt werden. Alpenschneehühner erschließen auch hochalpine Regionen, während Birkhühner nahe der Baumgrenze verbleiben. Zusätzlich unterschieden sich beide Arten jedoch auch in ihren δ^{15}N-Werten, was vermutlich durch einen höheren Anteil von Invertebraten in der Nahrung von Birkhühnern verursacht wird.

Keywords: European Alps; Global climate change; Plant isotope; Precipitation; Stable isotope analysis

Introduction

As typical for mountainous areas, the European Alps show a high diversity of different climate zones on a relatively small scale, mainly driven by the continuous temperature decrease with elevation (Frey & Lösch 2004). In addition, the European Alps form a barrier against weather fronts, which leads to higher precipitation at the edges and drier conditions in the central areas (Frey & Lösch 2004). As temperature and moisture are important determinants of the ecological niche of plants and animals (Begon, Townsend, & Harper, 2006), this diversity in Alpine climate habitats is also reflected in the diversity of habitats and species. This richness in Alpine wildlife is, however, severely affected by anthropogenic influences, such as the use of pastures and changes in grazing regimes (Meusburger & Alewell 2008; Patthey, Signorell, Rotelli, & Arlettaz, 2012; Paschetta et al., 2013), installation of hydroelectric power plants (Truffer, Markard, Bratrich, & Wehrli, 2001; Fette, Weber, Peter, & Wehrli, 2007), or recreational snow sport activities (Braunisch, Patthey, & Arlettaz, 2010; Negro, Isaia, Palestrini, Schoenhofer, & Rolando, 2010). In addition, the European Alps are one of the areas with the strongest observed warming trend worldwide, regionally showing increases of 1–2 °C of average annual air temperature during the 20th century (Begert, Schlegel, & Kirchhofer, 2005; Parolo & Rossi 2008). Along with further temperature increases, climate models for the European Alps predict changes in precipitation patterns, with generally drier summers and wetter winters (including rain), and an increase of extreme weather events including extreme rainfalls but also temporal droughts (Zimmermann, Gebetsroither, Züger, Schmatz, & Psomas, 2013; Gobiet et al., 2014). These climatological effects will lead to an elevation of the tree line, which is partly already visible (Dullinger, Dirnböck, & Grabherr, 2004). In addition to land use changes we will likely observe a reduction in size of high-alpine meadow habitats that goes along with an overall biodiversity loss (Dirnböck, Dullinger, & Grabherr, 2003; Engler et al., 2011).

Many of the now threatened high-altitude species are relict species that have survived in mountainous areas since the last glacial period, boosting local biodiversity (Ohlemüller et al., 2008; Dirnböck, Essl, & Rabitsch, 2011). Two prominent and closely related species that form relict populations in the European Alps are rock ptarmigan (*Lagopus muta*) and black grouse (*Lyrurus tetrix*). Rock ptarmigan are found in rocky areas above the tree line (from about 1800 m and up to more than 3000 m) (Glutz von Blotzheim, Bauer, & Bezzel, 1973; Pernollet, Korner-Nievergelt, & Jenni, 2015). In contrast, black grouse show a boreal distribution, with the main alpine habitat being the upper forest edge, i.e. the area of the tree line (Glutz von Blotzheim et al. 1973). Populations of both species in the European Alps were considered as stable until the mid-1990s (Schmid, Luder, Naef-Daenzer, Graf, & Zbinden, 1998; Peronace, Cecere, Gustin, & Rondinini, 2012). However, in the following decade rock ptarmigan declined by about 30% in both Switzerland (Keller, Gerber, Schmid, Volet, & Zbinden, 2010) and Italy (Peronace et al. 2012). In the same period, black grouse numbers declined by up to 20% in Italy (Peronace et al. 2012). Whether these declining trends that also persist on a global scale (Storch 2007) are already caused by the effects of climate change, or potentially other anthropogenic influences, is unknown and analyses are aggravated by the fact that population declines vary in size among regions (Furrer et al. 2016). However, with ongoing climate change effects, both rock ptarmigan and black grouse will have to track the shift of the tree line to higher elevations, a trend that is already visible in rock ptarmigan (Pernollet et al. 2015). Especially under warming