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Seasonal patterns of food use of wild boar (Sus scrofa L.) in a Central European floodplain forest

Wild boar populations are rising all over the world. This also counts for the Donau-Auen National Park. The aim of this study was to analyze seasonal and spatial changes in wild boars' diet, therefore we analyzed the stomach contents of 242 wild boars.

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Abstract

Wild boar populations are rising all over the world. This also counts for the Donau-Auen National Park (DANP). The aim of this study was to analyze seasonal and spatial changes in wild boars' diet in the DANP, the largest remaining floodplain forest in Central Europe.

We analyzed the stomach contents of 242 wild boars shot in the DANP. While in the western part (Lobau) of the DANP wild boars were shot from February 2015 until February 2016, from the Lower Austrian part of the park, we received wild boars' stomachs only from November 2015 until January 2016 due to different hunting measures. When stomach contents could not be determined by a visual inspection, the material was analyzed in a DNA-laboratory.

Like a lot of other studies we found plant matter as the most important and also most frequent food category in wild boars' stomachs. In more detail, grass and herbaceous plants and crops occurred most the frequently in our stomach samples and represented the food type with the biggest volume. Crops are used in the DANP for baiting, hence its recorded high importance as wild boar food could be overestimated, because wild boars more frequently utilizing baits will be shot with a higher likelihood. Animal diet was found in a negligible amount. We expected a bigger predation pressure of wild boars on herpetofauna, because in the national park different native amphibians and reptiles are found in high abundances. Contrary to our expectations just one frog was found. Differences in the diet composition between study areas could be interpreted as an effect of different management and/or the spatial variation human disturbance in the DANP.

Our data indicates that a more natural feeding behavior of wild boars in DANP could only be achieved when reducing baiting. However, this may reduce hunting success and subsequently may result in an increase of the wild boar population. Considering the potential negative impact of higher wild boar densities in the DANP (e.g. on the vegetation of the floodplain forest) and an increase of crop raiding individuals in agricultural areas adjacent to the park border, further studies evaluating different scenarios are urgently required before modifying the current management measures to control the park's wild boar population.

Key words

Diet, Donau-Auen National Park, Protected Areas, Wetlands, Austria

Zusammenfassung

Das Ansteigen von Wildschweinpopulationen ist ein globales Phänomen. Auch im Nationalpark Donau-Auen vermehren sich die Wildschweine zunehmend. In dieser Studie wird untersucht, wie sich die Nahrung der Wildschweine im Nationalpark Donau-Auen, dem größten noch bestehenden Auenwald Mitteleuropas, zusammensetzt und wie sie sich im Jahresverlauf und lokal verändert.

Hierfür wurden 242 Mägen von Wildschweinen aus dem Nationalpark ein Jahr lang untersucht. Dafür wurden Wildschweine in der Lobau von Februar 2015 bis Februar 2016 geschossen und deren Mägen entfernt. Im niederösterreichischen Teil des Nationalparks ist aufgrund eines anderen Managements eine Sammlung der Mägen von November 2015 bis Januar 2016 erfolgt. Die Analyse der Mageninhalte ist wurde optisch durchgeführt, jene Bestandteile, die nicht identifiziert werden konnten wurden in einem DNA-Labor analysiert.

Wie in vielen anderen Studien ernähren sich die Wildschweine auch im Nationalpark Donau-Auen vor allem von pflanzlicher Nahrung. Dabei spielen Gras und krautige Pflanzen sowie Körner die wichtigste Rolle. Körner, unter anderem Mais, wird im Nationalpark verwendet, um Wildschweine anzulocken um sie vom Hochstand aus schießen zu können, die sogenannte Kirrung. Die Bedeutung von Körnern könnte überschätzt werden, da Wildschweine, die an Kirrungen fressen, eine höhere Wahrscheinlichkeit haben, geschossen zu werden. Tierische Nahrung wurde in unserer Studie nur in sehr geringen Mengen festgestellt. Da der Nationalpark viele heimische Amphibien- und Reptilienarten in einem großen Ausmaß beheimatet, wurde von uns ein Prädationsdruck von Seiten der Wildschweine auf diese angenommen. Entgegen unserer Erwartung wurde jedoch nur ein Frosch gefunden. Lokale Unterschiede in der Nahrungszusammensetzung könnten auf unterschiedliches Management und/oder auf einer nicht gleich verteilten menschlichen Störung innerhalb des Nationalparks zurückgeführt werden.

Diese Studie weist darauf hin, dass ein natürlicheres Nahrungsverhalten der Wildschweine im Nationalpark nur durch eine Reduzierung der Kirrung erreicht werden

könnte. Jedoch könnte dies zu einer Reduzierung des Jagderfolgs führen und ein weiteres Ansteigen der Wildschweinpopulation bedeuten. Angesichts der potenziell negativen Effekte einer höheren Wildschweindichte im Nationalpark (u.a. auf die Vegetation im Auenwald) und einem Anstieg an Individuen, die landwirtschaftliche Schäden an den Nationalparkgrenzen verursachen könnten, werden weitere Studien, die unterschiedliche Szenarien untersuchen, dringend empfohlen, bevor die laufenden Management Maßnahmen zur Kontrolle der Wildschweinpopulation im Nationalpark überarbeitet werden.

Introduction

Wild boars were exterminated in the 17th century under Empress Maria Theresia, until 1945 wild boars in Austria were not found in the wild (Prossinagg and Haubenberger 2007). Since this time wild boars expanded their distribution range from Slovakia into Austria and continuously spread over the entire country (Briedermann 2009). Currently over 30,000 wild boars are hunted per year in Austria (Statistik Austria Jagdstatistik 2015). In the westernmost part of the floodplain forests of the Donau-Auen National Park (DANP), Eastern Austria almost 250 wild boars are shot annually within the city borders of Vienna, in the Lower Austrian part about 150 wild boars.

Many factors influence wild boars' population growth and support its recent range expansion. The reproduction rate is the highest rate among ungulates and the current litter size of about five is even higher than in the last decades (Bywater et al. 2010). The recently increasing high proportion of young females being fertile after already 8-9 months is facilitating the species' rapid population growth (Briedermann 2009). Formerly much lower reproductive rates were reported for wild boar populations in areas with a high density of large predators (Donarow and Templow 1938). Further, extreme winter conditions can lead to high mortality rates, especially in juvenile wild boars. However, the negative effect of cold temperatures in winter on population growth can be compensated by increased food availability in years of beech tree mast. Hence, the slightly increasing frequency of beech mast years in Austria combined with mild winters most likely both contributed to the species' positive population trend (Vetter et al. 2015). Additional factors like supplementary food, intensification of agriculture (resulting in higher crop availability) and declined hunting success

due to behavioral adaptations of wild boars might be associated with the increased population growth (Massei et al. 2014). Particularly, baiting used to hunt wild boars was reported as an important factor that can trigger the reproduction and increase the population growth by supporting and completing wild boars' diet (Ballari et al. 2014).

Wild boars are omnivorous generalists, but plant matter is more important than animal food. In all studies on wild boars' diet plants are more frequent and represent a higher volume percentage of the diet, while the contribution of animal matter to the total volume of food is mostly negligible (Asahi 1995, Ballari and Barrios-Garcia 2014, Ballari et al. 2014, Cellina 2008, Durio et al. 1995, Foutnier-Chambrillon et al. 1995, Genov 1981, Gimenez-Anaya et al. 2008, Herrero et al. 2006, Hohmann und Huckschlag 2015, Irizar et al. 2004, Schley and Roper 2003, Tucak 1996, Wishart et al. 2015, Wood and Roark 1980). This ratio of about 90% plant and 10% animal food remains the same also in different ecosystems like alpine valleys (Durio et al. 1995), coastal wetlands (Gimenez-Anaya et al. 2008), continental wetlands (Herrero et al. 2006) and pine forests (Irizar et al. 2004). In areas were wild boars are introduced, the consumption of animal food is slightly higher than in native areas (Ballari and Barrios-Garcia 2014). Wild boars are opportunistic and very flexible in their food selection. Hence, the food found in wild boars' stomachs often reflects the availability of food items. Consequently, there are seasonal differences in food use (Eriksson and Petrov 1995; Foutnier-Chambrillon et al. 1995; Genov 1981; Gimenez-Anaya et al. 2008; Herrero et al. 2006; Loggins et al. 2002; Schley and Roper 2003).

Wild boars can have a strong impact on animal species of high conservation relevance. In areas where the wild boar was introduced negative effects on native amphibians, reptiles and birds have been reported. In Australia, wild boars perform a strong predation pressure on northern snake-naked turtles (*Chelodina rugosa*) (Fordham et al. 2006) and three marine turtle species, the flatback (*Natator depressus*), olive ridley (*Lepidochelys olivacea*) and hawksbill (*Eretemochelys imbricata*) (Whytlaw et al. 2013). Further, introduced wild boars act as important predators of amphibian species like the endangered spadefoot toad (*Scaphiopus holbrookii*) in the USA (Jolley et al. 2010) or the green and golden bell frog (*Litoria aurea*) in New Zealand (Krull and Edger 2016). In birds particularly ground-nesting species are negatively affected by wild boars as documented for wading birds in Sweden (Carpio et al. 2016), the pheasant (*Phasianus colchicus*) in Italy (Senserini and Santilli 2016) and by a study from Estonia using artificial nests (Oja et al. 2015).

The aim of this study was to quantify seasonal changes in wild boars body condition and spatio-temporal differences in diet use in the largest remaining floodplain forest in Central Europe located in the DANP. Therefore, we analyzed stomach contents from wild boars shot in the DANP between February 2015 and February 2016.

Our hypotheses are:

(H1) Adult wild boars show seasonal changes in body condition due to seasonally changing food availability. In literature seasonal changes in body condition are already known (Cellina 2008) and also the connection of body condition ore food availability and reproduction effort have been analyzed (Cellina 2008; Massei 1996).

(H2) Diet composition and diet breadth of wild boars varies between the seasons. The diet used by wild boars strongly depends on the food availability (Fournier-Chambrillon et al. 1995). This leads to pronounced differences of food composition during the year. Former studies showed that grass and herbaceous plants are consumed mostly in spring, while cultivated plants and wheat are the major food component in summer, fruits, acorns, tubers and gains in autumn. The winter diet is dominated by roots and leafs but in snowless winters also grass is used (Eriksson and Petrov 1995; Genov 1981; Herrero et al. 2006; Loggins et al. 2002; Wood and Roark 1980).

(H3) Wild boars' food composition and diet breadth differs depending on different management measures and/or spatial differences of study sites. For instance, access to bait used to hunt wild boars can affect the species diet composition (Ballari et al. 2014).

(H4) The high density of wild boars in the DANP might represent a potential conversation problem due to negative effects on the native herpetofauna. The DANP harbors several threatened amphibian and reptile species, such as the Danube crest newt (*Triturus dobrogicus*), European fire-bellied toad (*Bombina bombina*), European green toad (*Bufo viridis*) or the European common spadefoot (*Pelopates fuscus fuscus*) and the European pond turtle (*Emys orbicularis*). A study on an introduced population of wild boars reported a huge predation pressure on the native herpetofauna (Jolley et al. 2010). Due to the high abundance of amphibians in floodplain forests they could represent a valuable food source for wild boars in the DANP, perhaps facilitating a preference for this prey during periods of high amphibian activity.

Methods

Study area and study sites

The Donau Auen National Park (DANP) is officially recognized as national park by the IUCN since 1996. It is located in eastern Austria and expands from the capital Vienna to the Slovakian Border. It is the largest connected floodplain area in Central Europe. The DANP has an area of over 9.300 hectares, covering three main ecosystems. Besides the most important area of floodplain forest (about 65% of the area) there are grasslands (15%) and waterbodies (20%). The DANP is overlapping two federal states, Vienna and Lower Austria. The Viennese part, also called “Lobau”, represents 24 percent of the DANP’s area, the remaining 76 percent area located in Lower Austria.

We split the national park into six study areas with almost the same size, two in the Viennese part and four in Lower Austria (Fig. 1). All harvested wild boars were shot north of the Danube River.

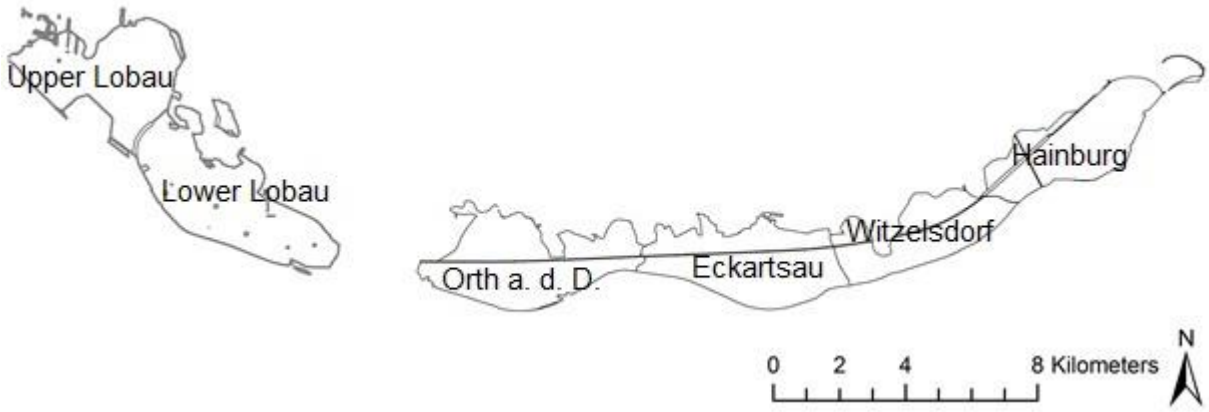

Fig. 1 Study areas of DANP, from which stomachs of shot wild boars were received and analyzed. The Viennese part, also called “Lobau”, was split into Upper and Lower Lobau. The area located in Lower Austria was separated into four site aresa, Orth a.d. D., Eckartsau, Witzelsdorf and Hainburg.

Stomach content analysis

We analyzed the contents of a total of 242 wild boars’ stomachs. A total of 144 wild boars were shot in Vienna and 98 in Lower Austria, in accordance with the management plan of the DANP. Considered wild boars were shot between February 2015 and February 2016 in the Lobau and during the Lower Austria hunting season from October 2015 until January 2016, respectively (Tab. 1). Males and females of all age classes were hunted (Tab. 2).

The hunters removed the wild boars' stomachs and froze them for later analysis. Information about weight, length, sex, age and information about the time and the location, where the wild boars were shot, were documented accurately by the hunters in a provided form for most of the animals (Appendix 1). The stomachs were thawed in the laboratory, after measuring the weight of the full stomach and the content a photo of the content was taken. The fullness of the stomachs and the percentage volume of the following food items were estimated: crops (including maize); grass and herbaceous plants; fruits, nuts and beechnut; root tuber (including sugar beet and carrot); acorn; mistletoe fruits; roots; birds; amphibians; carrion; snails; earthworms; terrestrial arthropods; soil and other matter. Animal matter was conserved in 96% alcohol and send to the Gen Laboratory of the University of Veterinary Medicine in Vienna for determination to identify the species.

Tab. 1. Number of wild boars shot from February 2015 until February 2016 in the six study areas in DANP over the yearly circle (spring = March-May; summer = June-August; autumn = September-November; winter = December-February). One wild boar could not assigned to a specific site, but it is clear that it was shot in the Lower Austrian part.

District	Vienna		Lower Austria					Total
Area	Upper Lobau	Lower Lobau	Orth a.d.D.	Eckartsau	Witzelsdorf	Hainburg	n.a.	
Spring	21	6	0	0	0	0	0	27
Summer	26	21	0	0	0	0	0	47
Autumn	5	32	1	15	4	2	0	59
Winter	21	12	26	10	25	14	1	109
Total	73	71	27	25	29	16	1	242

Tab. 2. Sex and Age of all shot wild boars considered in this study.

Sex/Age	Adult	Juvenile	n.a.	Total
Female	65	45	0	110
Male	78	45	3	126
n.a.	3	3	0	6
Total	146	93	3	242

Statistical analysis

To detect seasonal changes in food availability, we tested for differences in the fullness of wild boar stomachs between different months using a Kruskal-Wallis U test. We exclusively took

the data set form wild boars shot in the Lobau, because only in this part of the DANP we have data all over the year. A two-way crossed ANOVA was calculated to test for effects of months and weight classes on stomach fullness. The weight classes were categorized in the following way: up to 10 kg, 11 to 20 kg, 21 to 30 kg, 31 to 40 kg, 41 to 50 kg, 51 to 60 kg, 61 to 70 kg, 71 to 80 kg and 81 to 90 kg. Body condition was quantified for all adults by regressing body mass on body length, the latter used as a measure for body size. The residuals from this regression were used as an index of body condition. Individuals with positive residuals were considered being in better body condition than individuals with negative residuals (Jakob et al. 1996, Schulte-Hostedde et al. 2005). A crossed two-way ANOVA was calculated to test for effects of sex and season on body condition. To achieve a reliable sample size within groups, months were grouped into spring (March-May), summer (June-August), fall (September-November) and winter (December-February). Since body condition did not significantly vary between sexes (compare Results section), we pooled all body condition data and – due to the increased sample size – tested again for differences of body condition between months. A Pearson correlation was used to test for a relationship between fullness of stomachs and body condition.

Differences in food composition were quantified as Bray-Curtis similarities. To test for seasonal (winter, spring, summer and autumn) (considering only wild boars shot at Lobau) and spatial effects (only considering animals shot between November and January) on food composition respectively, we calculated one-way ANOSIMs and subsequent Pairwise Tests with Primer 7 (with 999 permutations). Additionally, similarity relationships were visualized by using non-metric multidimensional scaling (NMDS) ordinations. SIMPER analyses were calculated to detect which food components contribute most to similarities and dissimilarities respectively between different areas of the national park.

To evaluate changes in the utilized range of different food types between seasons and different areas of the national park, we calculated the Levin's Index of diet breadth ($B = \frac{1}{\sum {p_i}^2}$) and the standardized diet breadth ($B_a = \left(\frac{B-1}{n-1}\right)$). ρ_i represents the proportion each food occurred in the entire number of stomach samples in the respective season, n is the total number of all found food items. B_a is ranging between a minimum and maximum diet breadth of 0 and 1, respectively (Hurlbert, 1978).

To find out what the most important food items in wild boars diet are we further calculated the mean relative volume of each food item found in the wild boars stomach. The frequency of occurrence was calculated by the number of stomachs were the item was present divided by the total number of stomachs.

Only one juvenile male shot in the study area Upper Lobau was not considered in all statistical analysis because its stomach untypically contained only 100% soil matter.

Results

(1) Seasonal changes in stomach fullness and body condition

Stomach fullness differed significantly between months (Kruskal-Wallis U test: U = 28.174, df = 11, p = 0.003) in the Viennese part of DANP. In May the stomachs are the emptiest (56.4 ± 30.6%), the fullest stomachs were found in January (94.0% ± 7.0%) (Fig. 2). A two-way crossed ANOVA did only indicate an effect of month but not of weight class and the interaction term month X weight class (Tab. 3).

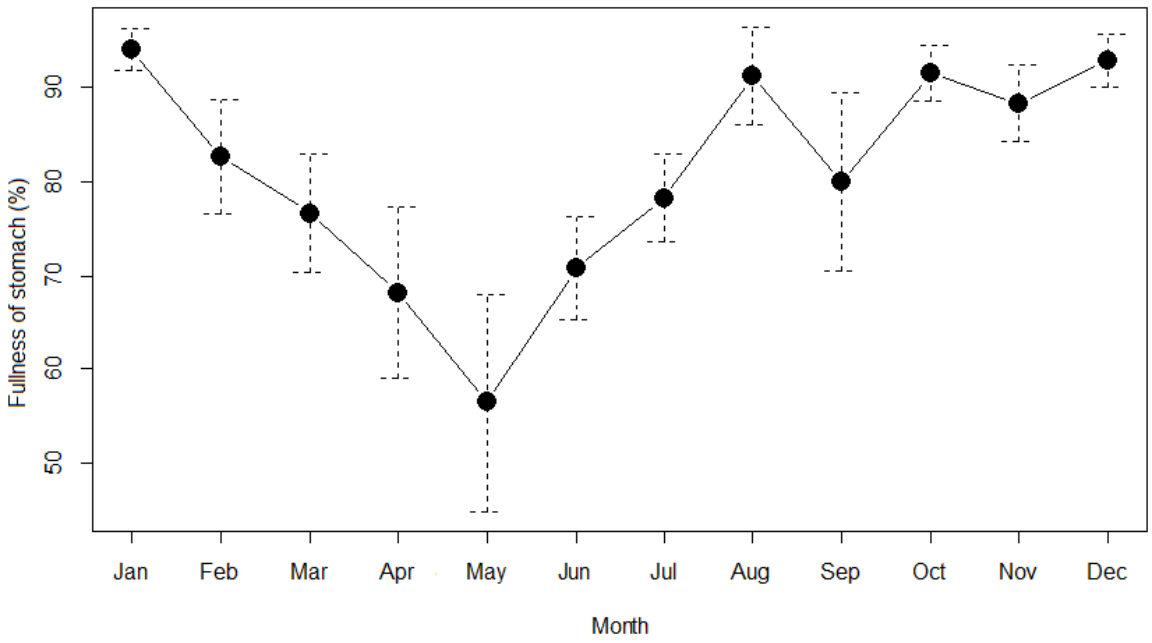

Fig. 2 Mean fullness of stomachs ± SE of wild boars shot in the Lobau in different months.

Tab.3 Results of a two-way crossed ANOVA testing for effects of month, weight class and the interaction term on fullness of stomach (%).

	Sum Sq	Df	*F*	*p*
Month	10292	1	2.3481	0.0143
Weight class	4169	7	1.5043	0.17679
Month X Weight class	15910	39	1.0238	0.45239
Residuals	33869	85		

Seasonal effects on body condition

Body condition (quantified as residuals resulting from a regression of body mass on body length) of wild boars shot at Lobau proved being significantly affected by between season (two-way crossed ANOVA: $F_3 = 12.61$, $p < 0.0001$) but not by sex ($F_1 = 0.43$, $p = 01550$) and the interaction term season X sex ($F_3 = 0.60$, $p = 0.6172$). Both sexes proved to be in a better body condition in autumn (Fig. 3). Due to an overall similar body condition of both sexes, data were pooled and tested for effects of month on body condition. Again seasonal effects proved to significantly affect body condition ($F_{11,78} = 9.03$, $p = 0.0001$). A distinct peak of higher body condition can be identified for the months October and November (Fig. 3).

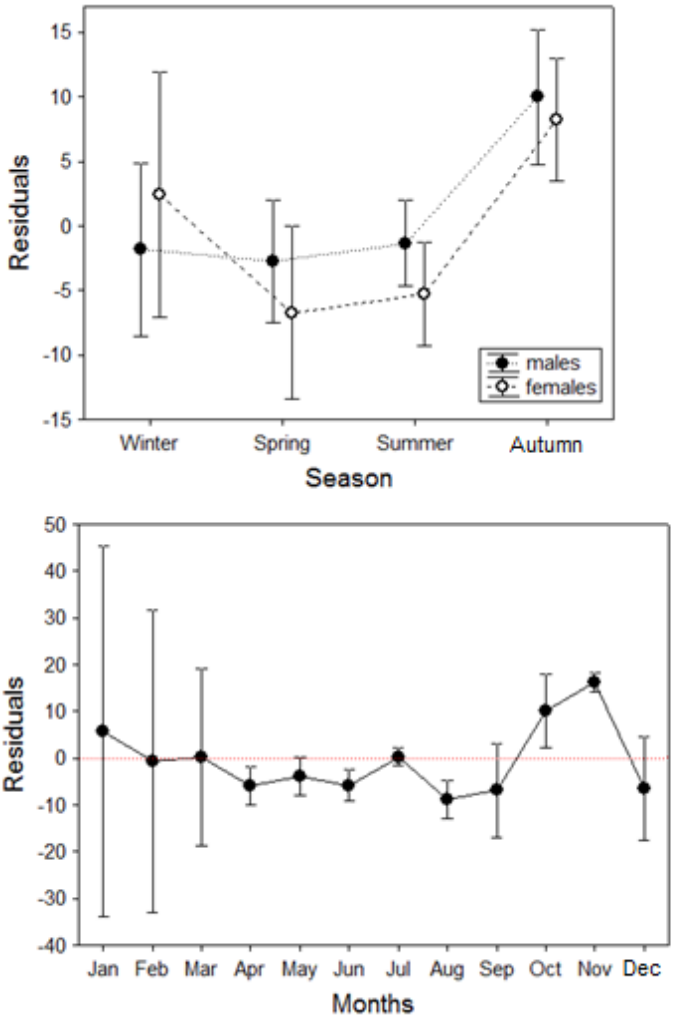

Fig. 3 Mean body condition (residuals resulting from a regression of body mass on body length) ± 95% CI of male and female wild boars in different seasons (graph on top) and of all wild boars in different months (bottom graph; 0 line indicated red), only considering individuals shot in Lobau.

There was no significant correlation between fullness of stomachs and body condition of adult wild boars shot at Lobau (Pearson correlation: $R^2 = 0.1889$, t = 1.7944, df = 87, p= 0.07623).

(2) Seasonal changes in diet composition and diet breadth

Although food composition was highly variable between individuals, independently of season, as indicated by the NMDS ordination (Fig. 4) a one-way ANOSIM indicated a significant effect of season on diet composition (Global $R = 0.126$, $p = 0.001$). In fact food composition differed between all seasons (Tab. 4).

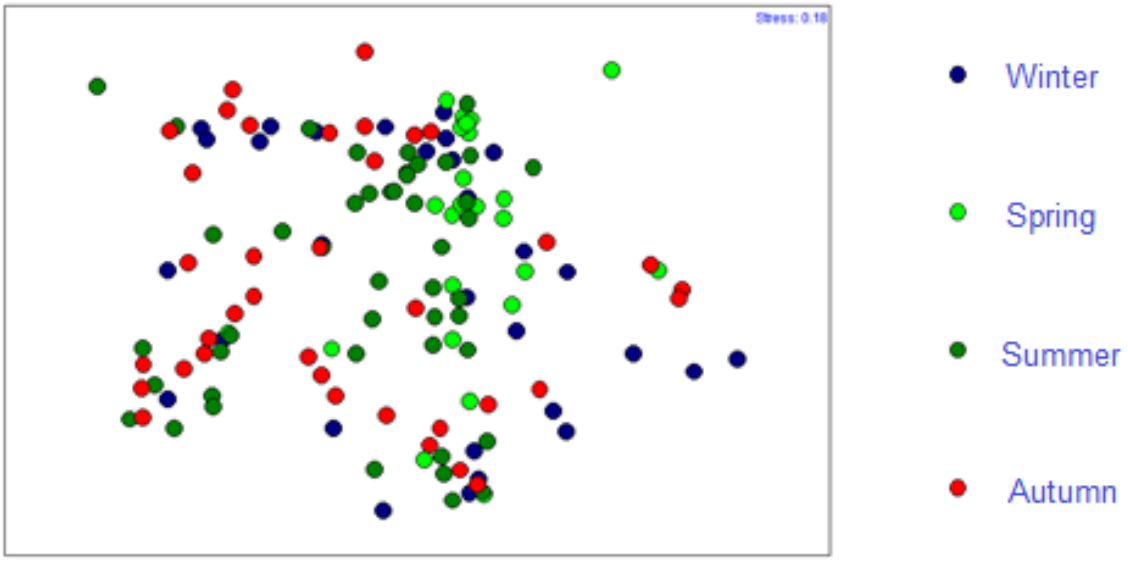

Fig 4. nMDS ordination visualizing similarity of stomach contents of individual wild boars shot in spring, summer, autumn and winter (seasons indicated by different color) in the Viennese part of the DANP.

Tab 4. Pairwise tests (one-way ANOSIMs) for seasonal differences in diet composition of wild boars shot at Lobau

Groups	R Statistic	*p*
Winter vs spring	0.056	0.04
Winter vs summer	0.162	0.001
Winter vs autumn	0.054	0.028
Spring vs summer	0.097	0.009
Spring vs. autumn	0.227	0.002
Summer vs autumn	0.125	0.002

The Levin's Index of diet breadth (B) and the standardized died breath (B_a) differed between seasons. In winter diet breath was highest (B = 4.440, B_a = 0.246), followed by autumn (B = 3.958, B_a = 0.211). Lowest values were reached in spring (B = 2.548, B_a = 0.111) and summer (B = 2.936, B_a = 0.138).

Plant material represented the most important food matter of wild boars' diet (Tab. 5). When considering all sampled stomachs the mean relative volume of plant matter was 94%. Crop seeds including maize are in total the most important food components by volume. Only grass and herbaceous plants are more important than crops in spring and winter. Fruit, nuts and beechnut also represent a food category that is found in big amounts particularly in

autumn and winter. Root tuber, especially sugar beet and in smaller parts carrots, are also present in stomachs all over the year with a relative volume of about 10%; only in spring the amount is smaller (Tab. 5).

Animal food components are found in much smaller amounts but they occur in 44% of the stomachs. The most important animal food matter are snails. Throughout the year invertebrates are consumed more often and in greater amounts than vertebrates (Tab. 5).

Tab. 5 Mean relative volume (%) of food types in different seasons in stomach contents of Viennese wild boars.

Food category	Spring	Summer	Autumn	Winter	Total	Frq
Plant matter	**94.2±±12.1**	**93.3±9.4**	**94.6±9.2**	**93.3±13.8**	**94.0±11.5**	**100.0**
Maize/Crop	36.1±33.8	40.9±33.9	38.3±33.9	27.4±31.8	36.8±34.1	81.1
Grass/ Herbaceous Pl.	38.3±34.1	31.8±31.2	25.8±28.8	29.9±31.0	33.3±31.3	88.8
Fruits/Nuts/Beechnut	6.7±18.0	9.2±21.2	12.0±20.8	14.3±26.6	10.7±21.6	37.8
Root Tuber	11.0±24.9	8.0±22.7	12.2±26.4	19.7±31.5	9.0±21.9	23.1
Acorn	0.6±4.1	2.1±7.2	3.8±10.5	–	2.3±8.4	11.2
Mistletoe	0.4±1.8	0.3±1.9	0.5±2.2	0.4±1.4	0.5±2.0	6.3
Root	1.0±4.1	0.9±4.0	2.1±5.9	1.6±3.0	1.5±4.7	16.8
Animal matter	**4.7±11.0**	**5.6±8.0**	**3.5±6.9**	**2.7±5.4**	**4.4±9.3**	**44.1**
Vertebrate	1.3±5.4	0.7±2.8	0.8±3.0	1.3±3.3	1.1±4.3	18.2
Bird	–	–	–	0.5±2.7	0.1±1.3	1.4
Amphibian	–	–	–	0.3±1.8	0.1±0.8	0.7
Carrion	1.3±5.4	0.7±2.8	0.8±3.0	0.6±1.5	0.9±4.1	16.1
Invertebrate	3.4±7.3	4.8±7.8	2.7±6.5	1.3±4.0	3.3±7.0	32.2
Snail	2.9±6.3	3.6±6.4	1.7±4.5	0.4±1.8	2.4±5.5	25.9
Earthworm	0.2±1.0	0.8±2.6	0.7±2.5	0.5±2.0	0.6±2.1	10.5
Terr. arthropod	0.3±1.1	0.4±1.9	0.3±1.8	0.3±1.8	0.3±1.7	8.4
Other matter	**0.8±4.4**	**0.8±4.4**	**1.6±5.7**	**4.0±10.9**	**1.5±6.1**	**8.4**
Soil	0.6±3.7	0.6±3.7	1.3±5.3	3.4±10.5	1.3±5.9	7.7
Other	0.3±2.4	0.3±2.4	0.3±2.3	0.6±3.5	0.1±1.7	0.7

Grass and herbaceous plants have the most relative volume of stomach content from December until May. In the other months from June until November crops have the biggest relative volume. The third important food category are fruits, nuts and beechnuts; however, this food type is completely missing from May until March. Root tubers are also important in the month of January until March and in November and December. All the other food categories are found in wild boars' stomach just in a small amount below 10% relative volume percent (Tab. 6). When evaluating the occurrence frequency of different food types in the stomach samples, plant matter can be found in all stomachs over the year, but the importance of animal food also visible. For example snails are present between May and July in more than half of the investigated stomachs (Tab. 7).

Tab. 6 Mean relative volume of Viennese wild boar's food items in different months.

	Grass/ Herbaceous Plants	Fruit/Nuts/ Beechnut	Maize/Crop	Acorn	Mistletoe	Root Tuber	Root	Bird	Amphibian	Carrion	Snail	Earthworm	Insect	Soil	Other
Jan	**33.5**	11.5	28.5	–	–	22.0	1.0	–	1.0	0.5	–	–	–	–	2.0
Feb	**29.9**	8.6	29.4	–	0.6	19.1	2.7	1.0	–	0.7	0.9	1.1	0.7	5.3	–
Mar	**52.2**	–	22.3	–	–	22.0	1.9	–	–	1.4	0.1	–	–	–	–
Apr	**69.4**	–	21.5	–	–	3.7	3.8	–	–	–	1.5	0.1	0.1	–	–
May	**41.4**	–	35.7	–	2.9	–	–	–	–	5.9	8.6	0.7	1.6	–	–
Jun	42.5	–	**46.3**	–	1.2	1.9	–	0.1	–	–	5.3	0.4	1.7	0.8	–
Jul	35.3	6.3	**44.4**	4.8	–	0.2	–	–	–	0.6	6.8	1.6	–	–	–
Aug	17.9	27.9	**50.9**	1.9	–	–	–	–	–	0.4	0.5	0.6	0.1	–	–
Sep	16.0	23.0	**52.6**	6.0	–	1.0	–	–	–	–	–	1.4	–	–	–
Oct	16.5	19.0	**37.4**	7.8	0.5	8.5	5.5	–	–	1.9	0.1	0.2	0.1	2.8	–
Nov	22.1	15.2	**43.5**	–	0.4	17.1	0.1	–	–	0.5	–	–	–	1.3	–
Dec	**24.7**	30.7	21.4	–	0.7	17.9	–	–	–	0.3	–	–	–	4.3	–

Tab. 7 Frequency of occurrence of food items in wild boars' stomach shot in Lobau in different months.

	Grass/ Herbaceous Plants	Fruit/Nuts/ Beechnut	Maize/Crop	Acorn	Mistletoe	Root Tuber	Root	Bird	Amphibian	Carrion	Snail	Earthworm	Insect	Soil	Other
Jan	80.0	30.0	80.0	–	–	40.0	10.0	–	10.0	10.0	–	–	–	–	10.0
Feb	100.0	26.7	86.7	–	13.3	46.7	46.7	6.7	–	20.0	20.0	20.0	13.3	20.0	–
Mar	100.0	–	88.9	–	–	55.6	33.3	–	–	44.4	11.1	–	–	–	–
Apr	100.0	–	72.7	–	–	36.4	27.3	–	–	–	18.2	9.1	9.1	–	–
May	100.0	–	57.1	–	28.6	–	–	–	–	28.6	**57.1**	14.3	28.6	–	–
Jun	84.6	–	92.3	–	15.4	15.4	–	7.7	–	–	**69.2**	7.7	30.8	7.7	–
Jul	80.8	34.6	88.5	23.1	–	3.8	–	–	–	15.4	**61.5**	19.2	3.8	–	–
Aug	75.0	75.0	87.5	25.0	–	–	–	–	–	25.0	12.5	12.5	12.5	–	–
Sep	100.0	80.0	100.0	40.0	–	20.0	–	–	–	–	–	40.0	–	–	–
Oct	90.0	75.0	75.0	30.0	5.0	20.0	45.0	–	–	20.0	5.0	5.0	5.0	25.0	–
Nov	83.3	75.0	75.0	–	8.3	25.0	8.3	–	–	16.7	–	–	–	8.3	–
Dec	85.7	57.1	57.1	–	14.3	28.6	–	–	–	14.3	–	–	–	14.3	–
Total	88.8	37.8	81.1	11.2	6.3	23.1	16.8	1.4	0.7	16.1	25.9	10.5	8.4	7.7	0.7

(3) Regional differences in food use and food composition

The NMDS ordination visualizing similarity relationships of diet composition of wild boars for the time period November-January indicates slight differences between animals shot in the Viennese and Lower Austrian part of the national park. (Fig. 5) These differences proved being significant (one-way-ANOSIM: Global $R = 0.164$, $p = 0.001$).

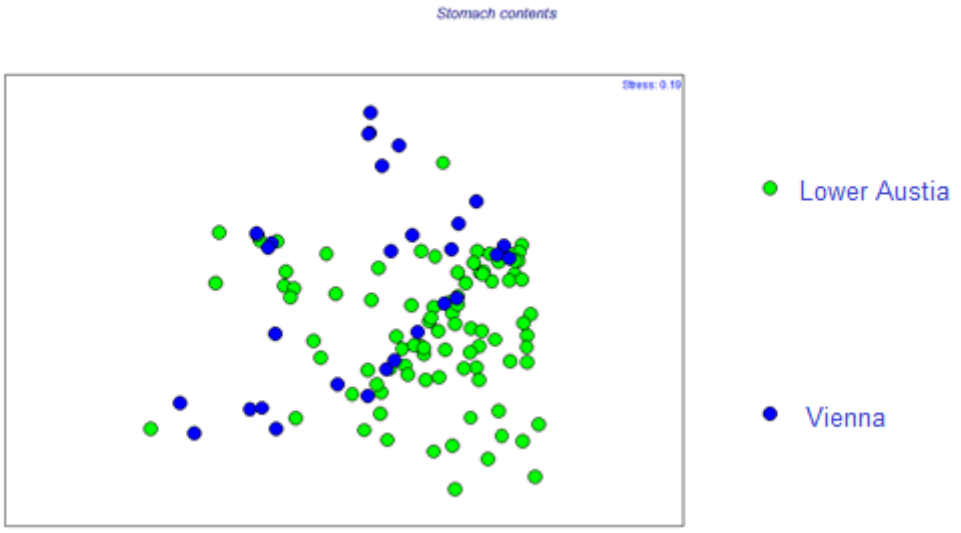

Fig. 5 nMDS plot visualizing similarity relationships of diet composition from Viennese and Lower Austrian wild boars

In Fig. 6 a difference of the food composition of wild boar between the study sites is lightly visible (one-way-ANOSIM Global Test Sample statisitc $R = 0.114$, $p = 0.001$).

In Lower Austria grass and herbaceous plants are explaining the most of the similarity between the stomachs from wild boars shot in November 2015 until January 2016. Combined with Fruit, Nuts and Beechnut these two food categories are explaining more than 80% of similarity of food composition (Tab. 8). During the same period in Vienna crops displace grass and herbaceous plants as the most responsible food item for similarity (Tab. 9). If we take a look at the whole DANP in these three month, we have four food items (in decreasing importance: maize/crop, grass/herbaceous plants, fruits/nuts/beechnut and root tuber) that are explaining over 80% of similarity in wild boars' diet (Tab. 10). Maize/crop and grass/herbaceous plants each of these two categories are almost as same important for the similarity of stomach content composition in our study.

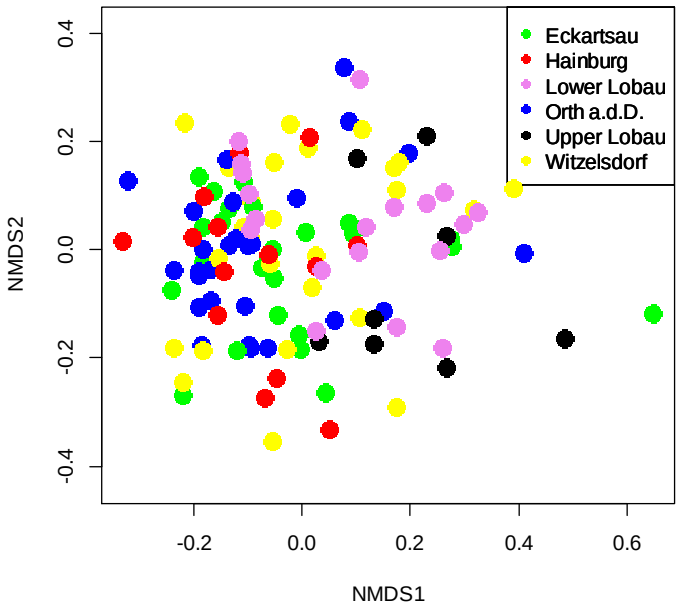

Fig. 6 nMDS plot visualizing the similarity of wild boars' stomach content composition in the six study sites in DANP (Eckartsau, Hainburg, Lower Lobau, Orth a.d.D., Upper Lobau and Witzelsdorf) in the months of November 2015 until January 2016.

Tab. 8 SIMPER of food items in Lower Austria from November 2015 until January 2016 with an average similarity of 37.11.

Lower Austria	Contrib%	Cum.%
Grass/ Herbaceous Plants	49.63	49.63
Fruit/Nuts/Beechnut	30.83	80.46
Root	8.11	88.57
Maize/Crop	5.90	94.47
Soil	4.19	98.66
Mistletoe	0.88	99.53
Root Tuber	0.38	99.92
Carrion	0.03	99.95
Acorn	0.03	99.97
Snail	0.02	99.99
Stone	0.01	100.00

Tab. 9 SIMPER of food items in Vienna from November 2015 until January 2016 with an average similarity of 31.94.

Vienna	Contrib%	Cum.%
Maize/Crop	40.10	40.10
Grass/ Herbaceous Plants	33.93	74.03
Fruit/Nuts/Beechnut	14.11	88.14
Root Tuber	11.61	99.75
Soil	0.12	99.86
Carrion	0.09	99.95
Mistletoe	0.04	99.99
Root	0.01	100.00

Tab. 10 SIMPER of food items in Lower Austria and Vienna from November 2015 until January 2016 with an average dissimilarity of 71.32.

Lower Austria & Vienna	Contrib%	Cum.%
Maize/Crop	24.45	24.45
Grass/ Herbaceous Plants	23.12	47.57
Fruit/Nuts/Beechnut	19.86	67.43
Root Tuber	14.47	81.90
Root	8.81	90.72
Soil	4.88	95.60
Mistletoe	1.50	97.09
Leguminous Plant	0.51	97.60
Carrion	0.50	98.11
Other	0.50	98.61
Snail	0.49	99.09
Stone	0.37	99.46
Acorn	0.29	99.75
Amphibian	0.24	99.99
Insect	0.01	100.00

The Levin's Index of wild boar diet breadth was higher in Lower Austria (B = 4.418, B_a = 0.244) than in Vienna (B = 4.041, B_a = 0.217) in the period November 2015 until January 2016. In detail comparing the six study sites Witzelsdorf has the highest value of diet breadth and Lower Lobau the lowest value (Tab. 11).

Tab. 11 Levin's Index of diet breadth calculated for wild boars shot in the different study areas between November 2015 and January 2016.

Study area	Number of stomachs	Number of 15 possible food categories	B	B_a
Upper Lobau	9.00	7.00	3.698	0.193
Lower Lobau	20.00	9.00	3.644	0.189
Orth a.d.D.	27.00	10.00	3.925	0.209
Eckartsau	25.00	12.00	4.136	0.224
Witzelsdorf	28.00	10.00	4.438	0.246
Hainburg	16.00	9.00	4.307	0.236

Discussion

Seasonal changes in body condition

Our study shows great seasonal variation in fullness of stomachs and body condition of wild boars in floodplain forests east of Vienna. That stomach fullness of Central European wild boars can change over the year was already documented before. However, the maximum and minimum stomach fullness in wild boars shot in Luxembourg occurred two months later (compare Cellina 2008). In detail in our study area stomach fullness stayed at a high level of around 90% (except in September: 80%) from August until February. The stomach fullness continuously decreased until May, when it reached a minimum of 56%, before it started increasing again. This suggests better food availability in the autumn and winter months compared to spring and early summer, hence perhaps reflecting the warm weather conditions and the snowless winter in during the study year. In other studies the mean stomach content was greatest in summer (e.g. Poland: Genov 1981). However, a relation between and stomach fullness and body weight and body condition respectively could neither be found by our study nor by other studies is not found (Asahi 1995; Cellina 2008). This clearly indicates that food quality cannot be compensated by a higher amount of ingested food.

Also the differences of wild boars' body condition in Vienna among the year are huge. As in other studies (Cellina 2008), the heaviest individuals for their body length are found for both sexes in autumn. Higher body weight triggers the reproduction, because of more births and a larger litter size (Massei et al. 1996). However, a better body condition doesn't always be associated with an increased reproduction of wild boars (Cellina 2008). That wild boars were capable of maintaining a relatively high body condition in our study area even during the winter months may have been caused by the warm and mild winter 2015/2016.

Seasonal changes of food composition

In stomachs of wild boars from DANP total plant matter was found in a much bigger amount than animal matter all over the year. In wild boars after 0.5 h typically 20% of the ingested cellulose has passed the stomach and after a second peak 7.5 h later half of the diet has passed the stomach (Zebrowska et al. 1978). The nearly negligible volume proportion of animal food but its high frequency of occurrence could be due to underestimation because of an easier

and faster digestion (Ballari and Barrios-Garcia 2014; Fournier-Chambrillon et al. 1995; Irizar et al. 2004).

In our study seasonal changes are visible especially in the consumption of fruits, acorns and root tubers and in the use of animal food. Fruits are mainly consumed in autumn and winter, acorns mostly in autumn and root tubers mostly in winter. This emphasizes the opportunistic feeding behavior of wild boars adapted to seasonal changes in food availability. Also in other studies the use of the food items mentioned above is confirmed for autumn (Eriksson and Petrov 1995; Loggins et al. 2002; Wood and Roark 1980). The only difference are root tubers, which are used mostly in winter in the Viennese part of DANP and not in autumn as documented by a study from Poland (Genov 1981). Beside root tuber wild boars' diet in winter is compiled of crops, grass and fruits. According to other studies, the winter diet mostly consists of roots, leafs and - in periods free of snow - of herbs, grass, fruits and insects (Eriksson and Petrov 1995; Wood and Roark 1980). So far, the occurrence of birds in the diet of wild boars is documented for all seasons except winter (Gimenez-Anaya et al. 2008; Herrero et al. 2006). In our study we found remains of birds in February and June. Furthermore, we found earthworms in wild boars' stomach mostly in summer and autumn. In contrast, in stomachs from Polish wild boars most earthworms were found in spring (Genov 1981).

The use of grass and herbaceous plants by wild boars in Vienna is just slightly higher in spring and lower in autumn compared to crops. Crops including maize are the most important food types found, occurring in 81 % of the analyzed wild boar stomachs in the Lobau with the highest amount in summer. For wild boars maize is a very attractive food source (Genov 1981), this is why it is used often for supplementary feeding. So maize and other crops are also used in the DANP for bait wild boars for hunt because of management reasons. Also in other studies the amount of maize is very high because of supplementary feeding (Fournier-Chambillon et al. 1995; Genov 1981). Cellina (2008) researched in her study the effect of supplemented feeding on wild boars on body condition and reproductive state. Crops and root tuber are used of supplementary food different reasons in most countries of Europa, especially to fend of the low natural food availability in winter months. She could not detect an effect of supplementary food on reproductive process and body condition. But she argued her results with the reason that supplementary food in her study area (Luxembourg) is available year around and that could have a ceiling effect.

Massei et al. (1996) found out that a high availability of acorns increase the body weight, more females are breeding and also the litter size increase. Furthermore they analyzed also the food and computed a Levins Index of diet breadth. They get a B_a between 0.4 and 0.6 exept of one year in spring they found a B_a<0.2. In our study we had year around a Ba around 0.2. According to them a very low Levins Index indicate a small diet breadth all over the year.

Regional differences in food use and food composition

Our study identified a difference between the food compositions in the two federal states during late autumn and winter. In Vienna crops including maize and wheat are used for baiting and are the most important food items. In Lower Austria grass and herbaceous plants are most important and maize and other crops play only a subordinate role in wild boars' diet. A possible explanation could be that in Lower Austria contrary to Vienna more than the half wild boars were not hunted with baiting. The diversity of the diet is also smaller in Vienna, here only four food categories explain 99% of the calculated similarity in diet composition, while in Lower Austria six food categories have to be considered to achieve this value.

Additional the results of the standardized Levins Index of the study sites in Vienna is under 0.2 and the study sites in Lower Austria reach a value of B_a<0.2, it also rise from west to east. This might be influenced by a stronger disturbance from visitors, because of the location of the capital city of Vienna. Ohashi et al. (2013) find a strong effect of wild boars when they are exposed to direct and indirect human disturbance. Wild boars diurnal activity increases by disturbance (Keuling et al. 2008). Hence to this also a changing in foraging habits and composition of wild boars' diet could be supposed.

Conservation relevance and conclusions

Wild boars can have negative effects on the native herpetofauna (Jolley et al. 2010; Krull and Egeter 2016, Whytlaw et al. 2013) and can represent important predators of bird nestlings and nests (Carpio et al. 2016; Oja et al. 2015; Senserini and Santilli 2016). Against results of other studies predation of protected animals could not be demonstrated with our study in the DANP. In 242 analyzed stomachs only one frog (*Pelophylax ridibundus*) (determined by photo by Johannes Hill, Österreichische Gesellschaft für Herpetologie ÖHG) and two times remains of birds were found. The genetic analysis of animal diet found in wild boar stomachs only identified remains of a roe deer (*Capreolus capreoulus*).

Beside predation also competition for food can have a big impact on the native fauna (Focardi et al. 2000; Kuiters et al. 2005; Loggins et al. 2002). The huge consumption of acorns not just influences the current food availability but also the regeneration of oaks and so also the future food resources (Loggins et al. 2002). Wild boars are also using hoards of acorns collected by small animals, this behavior influence the population growth of wild boars and small animals (Focardi et al. 2000).

Our study indicates that a high percentage of wild boars' diet consists of supplemental food from baiting, especially in the Lobau. Other hunting methods with reduced bait could reduce this food component in wild boars' diet, hence perhaps resulting in a more "natural" diet composition. Keuling et al. (2008) describe in their study that wild boars have a smaller home range with only single hunt. After battues wild boars are not changing significantly their use of space and neither their home ranges are changing or overlapping after battues. However, drive-hunting or battues like in Lower Austria could not be implemented that easy in the Lobau, an area used for recreational activities by a high number of visitors from Vienna during the entire course of the year.

Further, reducing of bait use could also have other negative impacts. First, the rooting of wild boars in the DANP could rise, which could finally result in a negative impact on the floodplain forest's natural vegetation. Second, conflicts with farmers could increase due to crop raiding by wild boars visiting agricultural areas adjacent to the border of the national park during periods of lower food availability. Wild boars show a seasonal variation of habitat selection that could not be predicted. Further studies evaluating different scenarios are urgently required before modifying the current management measures to control the park's wild boar population.

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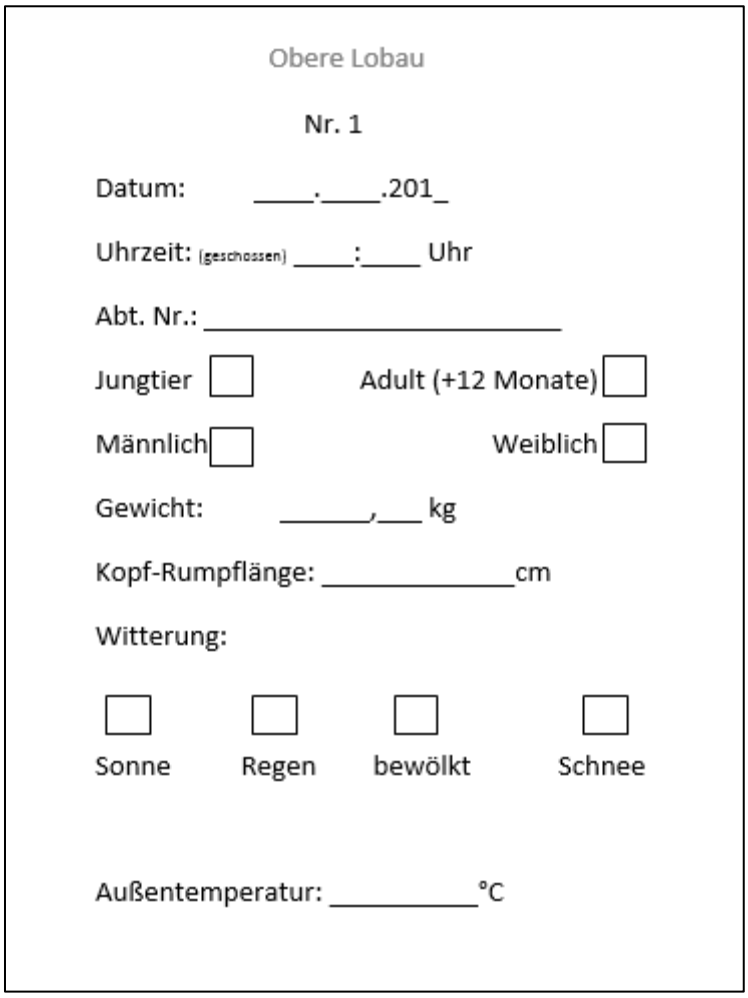
Appendix

Appendix 1. Form to fill out information about the shot wild boar for hunters with data of time, location, biological information of the wild boar and information about the weather and temperature.



Obere Lobau

Nr. 1

Datum: ____.____.201_

Uhrzeit: (geschossen) ____:____ Uhr

Abt. Nr.: _____

Jungtier ☐ Adult (+12 Monate) ☐

Männlich ☐ Weiblich ☐

Gewicht: _____,___ kg

Kopf-Rumpflänge: _____cm

Witterung:

☐ Sonne ☐ Regen ☐ bewölkt ☐ Schnee

Außentemperatur: _____°C

- Herausgeber: Nationalpark Donau-Auen GmbH
- Titelbild: Fink

- Als pdf-Datei direkt zu beziehen unter www.donauauen.at

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