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Long-term changes in the quantity and quality of supplementary feeding of wildlife: are influenced by game managers?

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Abstract. The natural world is now receiving more and more food of anthropogenic origin, which is widely used by a large number of animal species. Among intentional supplementary feeding, one of the most common activities is the winter feeding of game animals, affecting the size, structure and behaviour of their populations. There is a lack of information, however, on long-term trends in supplementary feeding and changes in the type of feeders and feed provided, which can be crucial to understanding game animal dynamics. Our study is based on data collected in the years 1970-2015 in experimental hunting grounds in western Poland. Wildlife feed was provided in traditional feeders and along the ground (ground strips), the latter designed primarily to protect crops from damage by game animals. The first type of feeding activity decreased significantly, while the second increased significantly during the study period. The most frequent types of feed provided were root crops, cereals, hay and silage. Feed amounts between years had a strong auto-regressive temporal character, with a significant lag effect up to ten years. The total dry mass provided for game animals was also characterized by a significant lag effect, although it was weaker in comparison to individual feed types. The auto-correlation is probably a consequence of the availability and ability to store various types of feed over subsequent winters. We believe that the results presented here are the first to describe the problem of feeding animals over decadal timescales and indicate the modifications to feeding that have taken place, influenced by the animals, crop prices and social factors.

Key words: impact on agriculture, human-wildlife interactions, sociology, winter feeding, ground strips, wildlife management

Introduction

Food of anthropogenic origin, introduced intentionally or unintentionally, changes the living conditions of individual animals, populations and entire ecosystems (Oro et al. 2013). The most important feature of food of anthropogenic origin is its fairly high predictability; more reliable than intermittent natural food resources, e.g. mast years (Szemethy et al. 2003, Oro et al. 2013, Milner et al. 2014, Sorensen et al. 2014). One of the most widely used practices is supplementary feeding of game wildlife. This has a long tradition and since the last century has become common practice among game managers, mainly in Europe and North America (Putman & Staines 2004). The most intense feeding is performed during winter – in the critical period of food shortages (Szemethy et al. 2003, Katona et al. 2014, Milner et al. 2014). In recent times, however, to protect crops, or to decrease the number of collisions between large mammals and motor vehicles, supplementary feeding has also been extended to other seasons (Calenge et al. 2004, van Beest et al. 2010, Milner et al. 2014).

Humans provide, both intentionally and unintentionally, an increasing amount of feed, which is widely used by

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a large number of animal species (Oro et al. 2013). Feeding modifies the interaction between humans and wild game, and has an economic cost which can be a substantial part of the budget of those groups and organizations responsible for maintaining hunting grounds (Calenge et al. 2004). Therefore, at least in theory, preparing a feeding management plan based on harvest requirements should consist of measuring natural food availability (Milner et al. 2014, Ewen et al. 2015) and estimating the costs of game field cultivation and artificial feeding (Osborn & Jenks 1998). Ideally, however, the information needed to prepare feeding plans should be based on long-term data, because the management of wild game should have a long-term perspective (van Beest et al. 2010, Ballesteros et al. 2013, Ewen et al. 2015).

Despite the need for long-term data, the only published work compares just two time periods without taking into account dynamic annual differences (Tremblay et al. 2005). Yet we know that populations of game animals depend on the size of the harvest, available food sources, as well as natural factors such as climate and predation pressure. Therefore, it is necessary to have information about feeding programs and how to implement feeding over long periods of time, preferably under controlled conditions. In the current study, we use data from experimental hunting grounds in western Poland, used as a research hunting area since the second half of the 20th century (e.g. Pielowski & Bresiński 1982, Mysterud et al. 2007). Access to a series of unique data enabled us to look at different aspects of the feeding of game animals, from different perspectives useful for understanding socio-economic aspects of animal feeding, as well as to test effectiveness of wildlife practitioners, and finally to understand game animal populations over time (*cf.* Ewen et al. 2015).

As a result, we wanted to realize the following research objectives: (1) a description of long-term changes in the method of feeding game animals, with particular emphasis on changes in the number of feeding places; (2) an estimation of directional long-term changes in the provision of different types of additional feed for game animals; (3) calculation of temporal auto-correlation patterns in various types of feed and an attempt to explain their cause. Moreover, we will discuss the importance of the results and their importance when feeding is subject to limited resources of time and money. As far as we aware, this is the first work to investigate the phenomenon of feeding game animals over such a long (46 years) time period.

Material and Methods

Study area

The study was carried out in the ca. 100 km^2 experimental area of the Polish Hunting Association Research Station at Czempiń, western Poland (52°08′ N, 16°44′ E). This is in a typical farmland region, where agricultural land constitutes nearly 80 % of the area and cereals are the main crop. Small forests (40-270 ha) cover only 7 %, and clumps (< 1-15 ha) and strips of trees occupy 3 % of the area; the rest (10 %) is covered by human infrastructure. The mean annual temperature is ca. 8 °C (sub-zero mean monthly temperatures occur in December-February) with mean annual precipitation ca. 550 mm.

Game animals

The main game animals regularly using feeding stations locally are: roe deer *Capreolus capreolus* (the most abundant ungulate species living in both forests and open agricultural land), red deer *Cervus elaphus*, fallow deer *Dama dama* and wild boar *Sus scrofa*. Using methods explained in detail in specially dedicated publications (Bresiński & Jędryczkowski 1999, Mysterud et al. 2007, Panek & Budny 2017) we may assume that the density of game animals per 100 km^2 in late autumn before the regular start of winter feeding were (mean ± SD): roe deer 764 ± 227, red deer 16 ± 12, fallow deer 27 ± 30 and wild boar 29 ± 31. The population size of all the above mentioned species has significantly increased in the study area since the 1970s.

Supplementary feeding

All necessary information used in analyses were obtained from diaries deposited in the Field Station of the Polish Hunting Association in Czempiń, Poland, that were obliged to quote the type and quantity of the food being provided. At the end of each hunting season (March/April) the local rangers prepared mandatory reports on the hunting economy to the national government. The reports included documents (bills) of all bought feed, including price and source (factory or local farmers), as well as all feeding activities, including building and use of the feeding stations. This particular aspect was under very detailed control, not only by researchers working in the Field Station of the Polish Hunting Association, but also by state officers. This situation was very similar in all Polish hunting areas, but most do not retain information for longer than 10 years. However, in the study area, copies of these field reports are available from the archives since the 1960s. This makes the situation in the local hunting area practically unique across the world.

Supplementary feeding in the study area started no later than the 1960s and has continued till now. Feed was partially provided randomly or near hunting platforms as bait, but mainly at special feeding stations. In the earlier years, classic wooden feeders were constructed for game animals, mainly cervids, in winter (for details see results section). These feeders were constructed both in forests and in small clumps of trees among arable fields. Distances between feeders were at least 1.5 km. Feeders were mostly stocked with hay, but also with cereals and roots.

Ground-level feeding places (ground strips), created mainly to protect crops from wild boar, incorporated ploughed strips of land (e.g. unused forest roads) located near forest edges (mean distance from the forest edge ± SD = 152 ± 54 m, range 90-250 m, n = 25). These ground strips had a width of about 5 m and their length, dependent on local conditions, ranged from 100 to 260 m (mean ± SD = 185 ± 51 m, n = 16). Feed (mainly cereals, but also roots) was scattered along the strips and often mixed with the soil.

Data handling and statistical analyses

Supplementary feed was divided into the following categories: (1) dry vegetation – mainly meadow hay,

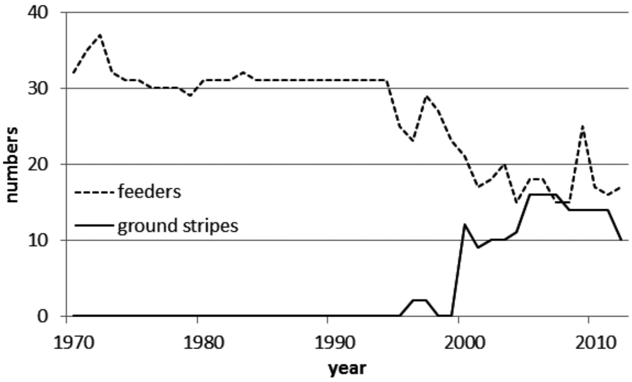

Fig. 1. Temporal change in the number of feeding stations (dashed line) and ground strips (continuous line) in 1970-2015.

(2) root crops (roots) – potato and beet, (3) cereals – mainly maize, (4) silage, (5) other – bread, sugar beet pulp, chestnuts and acorns. The last category comprises only 2 % by dry matter of all delivered feed.

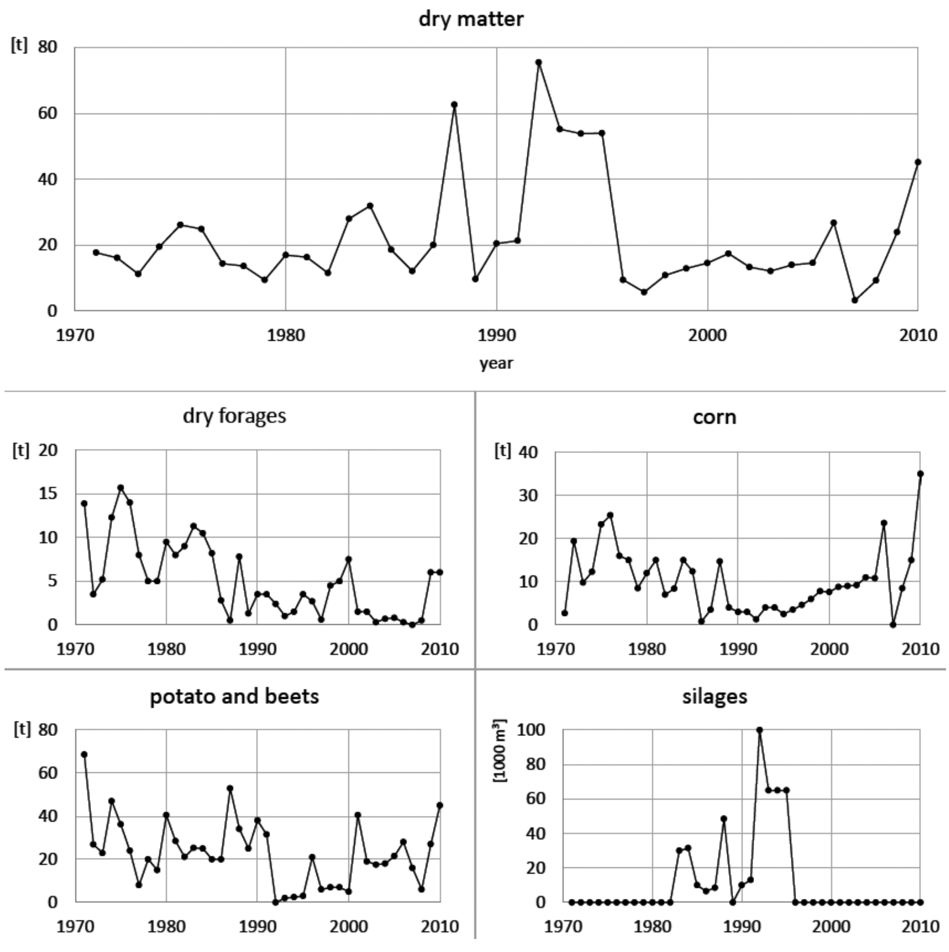

Fig. 2. Temporal changes in nutritional provision (dry mass in kg) in the study area by supplementary feeding (main panel), and in the amount of particular feed types (smaller upper panels; expressed in 1000 kg or m³ per winter season).

Table 1. Spearman correlation matrix of total dry mass of feed and particular feed types between 1970 and 2015 (defined in the Methods section). Sample size = 46 for each correlation. Key to statistical significance: $^{*}P < 0.05$ and $^{**}P < 0.01$.

	Total dry mass	Hay	Roots	Cereals	Silage	Other
Year	–0.054	–0.583**	–0.320*	–0.093	–0.073	–0.030
Total dry mass		0.116	–0.049	0.140	0.876**	0.640**
Hay			0.416**	0.412**	–0.087	–0.169
Roots				0.314*	–0.331*	–0.249
Cereals					0.067	0.149
Silage						0.690**

Table 2. Results of auto-correlation analysis with time lag up to 10 years for particular feed types provided to game animals in the Czempiń study area during 1970-2015 (defined in the Methods section).

	Total dry mass			Hay			Roots		
Lag	Auto-correlation	Box-Ljung Statistic		Auto-correlation	Box-Ljung Statistic		Auto-correlation	Box-Ljung Statistic	
		Value	*P*		Value	*P*		Value	*P*
1	0.426	8.743	0.003	0.568	15.510	0.000	0.322	4.987	0.026
2	0.147	9.807	0.007	0.340	21.180	0.000	0.046	5.094	0.078
3	–0.055	9.960	0.019	0.238	24.035	0.000	0.103	5.623	0.131
4	0.049	10.085	0.039	0.242	27.054	0.000	0.053	5.769	0.217
5	–0.015	10.097	0.073	0.253	30.432	0.000	0.058	5.950	0.311
6	–0.041	10.189	0.117	0.205	32.708	0.000	–0.008	5.953	0.428
7	0.039	10.275	0.174	0.228	35.603	0.000	–0.036	6.025	0.537
8	–0.068	10.543	0.229	0.245	39.041	0.000	–0.088	6.463	0.595
9	–0.097	11.094	0.269	0.229	42.129	0.000	0.078	6.824	0.655
10	–0.109	11.809	0.298	0.166	43.788	0.000	–0.015	6.837	0.741
	Cereals			**Silage**			**Others**		
Lag	Auto-correlation	Box-Ljung Statistic		Auto-correlation	Box-Ljung Statistic		Auto-correlation	Box-Ljung Statistic	
		Value	*P*		Value	*P*		Value	*P*
1	0.403	7.801	0.005	0.591	16.816	0.000	0.431	8.922	0.003
2	0.132	8.657	0.013	0.403	24.790	0.000	0.287	12.965	0.002
3	0.070	8.905	0.031	0.210	27.008	0.000	0.014	12.976	0.005
4	0.232	11.685	0.020	0.146	28.109	0.000	–0.006	12.978	0.011
5	0.164	13.105	0.022	0.054	28.261	0.000	0.244	16.125	0.006
6	0.122	13.915	0.031	–0.016	28.275	0.000	0.082	16.486	0.011
7	0.038	13.995	0.051	0.025	28.310	0.000	0.086	16.901	0.018
8	0.018	14.014	0.081	–0.009	28.314	0.000	–0.084	17.306	0.027
9	0.010	14.019	0.122	0.028	28.362	0.001	–0.106	17.970	0.036
10	–0.095	14.564	0.149	–0.041	28.461	0.002	–0.144	19.219	0.038

Total supplementary feed provided annually was calculated from dry matter content based on animal nutrition standards (Ruszczyc 1985): meadow hay – 886 g/kg, roots – 150 (potato) and 220 (beet) g/kg, silage – 335 g/kg, oats – 875 g/kg, acorns – 910 g/kg, chestnuts – 855 g/kg, fresh sugar beet pulp – 100 g/kg, maize – 900 g/kg.

We used data from the winters 1970/1-2015/6. The index 1970 is used to refer to the period November 1970-March 1971. However, the introduction of ground strips has extended feed provision to the spring when farmers are sowing their spring crops.

Because the area operated by the local hunting association has changed over the study period (93-149 km^2), we recalculated the number of feeding stations, ground strips and supplementary feed per 100 km^2. Analysis of the temporal auto-correlation of the provided feed types, as well as the total dry mass of provided feed was done with a maximum time-lag of 10 years (Clark & Bjørnstad 2004).

Means are presented ± SD, and $P = 0.05$ used as a threshold for significance. All analyses were done in SPSS 21.

Results

Temporal changes in the method of supplementary feeding

During the study period the method of supplementary feeding changed dramatically; the number of feeder stations (15-37 per year) significantly decreased ($r_s = -0.856$, $P < 0.0001$) while the number of ground strips (0-16 per year) increased ($r_s = 0.824$, $P < 0.0001$) (Fig. 1).

Temporal changes in supplementary feed types

The feed provided varied between years; there was a negative trend in the provision of hay and roots, and silage was negatively correlated with roots (Table 1), since they were used alternatively (Fig. 2).

Temporal auto-correlations in provided feed types

The provision of supplementary feed was temporally auto-correlated, but there were differences between particular feed types in the strength, lag time, and sign of auto-correlation (Table 2). Generally, auto-correlation between provided feed types was very strong, except for roots.

Discussion

Using the long-term data collected on supplementary feeding we show that in the period 1970-2015 there were distinct changes in the provision of game feed. The traditional support of mainly deer populations during winter (Groot Bruinderink et al. 2000, Putman & Staines 2004, Katona et al. 2014) changed dramatically to prevent crop damage, mainly by wild boar (Calenge et al. 2004). This is probably linked to two features. Firstly, increasing local roe, red and fallow deer populations became better able to survive the winter, even without significant feeding (Kaluzinski 1982, Pielowski & Bresiński 1982, Mysterud et al. 2007). Secondly, an even stronger visible effect of increasing wild boar population and changing habitat selection by this species across Europe, as well as locally, was observed (Calenge et al. 2004, Mysterud et al. 2007, Keuling et al. 2009, Frackowiak et al. 2013). Since wild boar have recently started to forage in the open and to damage crops, one of the most popular methods to reduce losses to farmers is to create ground strips, and use them to provide additional feed for animals (Calenge et al. 2004, Frackowiak et al. 2013).

Probably these changes are part of a broader problem of how to support sustainable populations of game animals in the critical period and reduce the damage caused to crops (Putman & Staines 2004, Milner et al. 2014). The damage prevention methods are common practice among wildlife managers and will presumably become a major component of supplementary feeding in the future. This streamlined approach is also becoming more common in nature conservation (Martinez-Abrain & Oro 2013, Ewen et al. 2015).

The change of feeding practice also extends to the amount and type of feed used, since different feed is used in feeders compared to ground strips. This factor is associated with a reduced supply of feed at feeding stations (Urbanska et al. 2012, Katona et al. 2014). However, the trend from feeding stations to ground strips, linked to an extended feeding season, does not explain the annual variability in feed provided. The periodic nature of the prices of different feed types and their availability are probably also influential. This view is supported by a strong temporal auto-correlation in particular feed types; such a phenomenon has also been described in other areas of feeding (Marzec 2012, Urbanska et al. 2012, Katona et al. 2014, Milner et al. 2014).

An interesting result, however, is the discovery of temporal auto-correlation for different types of feed with strong, statistically significant time lags from one year (roots) to 10 years (hay). Most likely this is associated with the storage of unused feed for a few subsequent years. In addition, different kinds of feed can be strongly affected by economics, availability for purchase (especially before 1989 in the communist economy), and recommendations by hunting authorities (Marzec 2012, Urbanska et al. 2012, Milner et al. 2014). Temporal auto-correlation is the consequence of the lack of a rigorous plan or a scientific basis for supplementary feeding. It could be concluded that current economics rather than a long-term management plan dictate the supplementary feeding policy.

We agree with previous opinions that supplementary feeding programs are not always best adapted to the specific goals of local management, the size of game populations, and not even to cost-efficiency strategies (Katona et al. 2014, Milner et al. 2014). The results of our analysis indicate that the long term approach to feeding animals has been strongly determined by social and economic factors.

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