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The effect of oilseed rape occurrence on main prey abundance and breeding success of the Common Buzzard *Buteo buteo*

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Summary

Capsule The occurrence of oilseed rape increased main prey abundance and breeding success of Common Buzzards.

Aims We tested whether the occurrence of oilseed rape influences the abundance of Common Voles, i.e. the main prey of Common Buzzards and so also nesting activity and breeding success of Common Buzzards.

Methods The study was carried out in 2005–2012 in a 38 km^2 area in western Poland, where oilseed rape plantations (12–106 ha) covered 18% of the agricultural land. The number of active burrow entrances was used as an index of vole abundance in various crops, and Buzzard breeding performance, i.e. the occurrence of annual nesting attempts in individual long-term nesting sites as well as the presence and number of fledglings, was estimated by observations of their nests.

Results The index of vole abundance was highest in oilseed rape, and judging by the proportion of active burrow entrances (33–77%), the plantations of this plant typically supported larger portion of the local vole population than other crops. The acreage of oilseed rape fields around the individual nesting sites of Buzzards did not affect the probability of nesting attempts in these sites. However, the probability of successful nesting and the number of fledglings per successful nest increased with the area of oilseed rape around the Buzzard nesting sites.

Conclusion The occurrence of oilseed rape may positively affect prey availability and in turn the breeding success of Buzzards. The spread of oilseed rape may be also beneficial for other vole eating raptors hunting in the agricultural landscapes.

Introduction

In the recent decades a considerable decline in the abundance of many birds living in rural areas has been observed in Europe, and this phenomenon is linked to the intensification of agriculture and land use changes, including enlarging the size of arable fields and modifying the composition of crop species (Stoate *et al.* 2001, Green *et al.* 2005, Kleijn *et al.* 2009, Stoate *et al.* 2009). One of the observed changes in the crop structure is a clear increase in the popularity of oilseed rape *Brassica napus* (FAO statistics, http://faostat.fao.org). For example in Poland the area of this plant nearly doubled during the period 2000–2011, and its share recently reached 8% of the sown area (GUS 2012).

The spread of oilseed rape could have various effects on birds inhabiting agricultural landscapes. The increase in acreage of this plant was estimated as unfavourable for birds that prefer spring crops during the nesting period and that avoid winter crops which quickly become too high in the spring, e.g. for the Skylark *Alauda arvensis* (Newton 2004). In addition, the oilseed rape fields frequently replaced set-aside plots which constituted the favourable habitat of Skylarks (Gillings *et al.* 2010). On the other hand, for certain birds, such as the Reed Bunting *Emberiza schoeniclus*, oilseed rape fields may create additional breeding habitat (Newton 2004). Moreover, oilseed rape is an important food source for some birds. For example, its leaves are included in the autumn - winter diet of Grey Partridges *Perdix perdix* (Orłowski *et al.* 2011) and constitute the most important winter food resource of Great Bustards *Otis tarda* in Central Europe, where this species is on the edge of extinction (Streich *et al.* 2006). The increase in acreage of oilseed rape improved the availability of foliar food and the status of Woodpigeons *Columba palumbus* in Britain (Newton 2004). Oilseed rape may also provide additional food for several species of birds feeding on seeds, especially the Common Linnet *Carduelis cannabina* (Newton 2004).

In this paper we test the hypothesis that the increase in acreage of oilseed rape may also indirectly affect food resources of raptors. The Common Vole *Microtus arvalis* is the primary or important prey of many raptor species hunting in the agricultural landscape (Newton 1979). This small rodent is particularly numerous among the perennial vegetation, for example alfalfa and grasses (e.g. Ryszkowski 1982). Hence, the change in land use involving the elimination of grassland can lead to significant reduction of food resources for some raptors and contribute to a decline in their numbers, as indicated, for example, in the UK (Newton 2004). However, high densities of Common Voles have also been reported in plantations of oilseed rape (Ryszkowski 1982).

The most common and widespread raptor species in Europe is the Common Buzzard *Buteo buteo* (Newton 1979, Cramp & Simmons 1980). Its food varies regionally, for example in some areas of Britain the Common Rabbit *Oryctolagus cuniculus* is the main prey (Graham *et al.* 1995, Sim et al. 2001). However, on the European continent, including Poland, a major component of the Common Buzzard diet in the areas dominated by agriculture is usually the Common Vole (Mebs 1964, Goszczyński & Piłatowski 1986, Spidsø & Selås 1988, Jędrzejewska & Jędrzejewski 1998, Skwierzyński 2006, Jankowiak & Tryjanowski 2013).

The aim of this study was to estimate the impact of oilseed rape occurrence on the abundance of the Common Vole and in turn on the breeding performance of the Common Buzzard. We predicted that nesting attempts, breeding success and high number of fledglings in Buzzard nests will be more frequently observed in nesting sites surrounded by larger acreage of oilseed rape plantations.

Materials and methods

Study area

The study was carried out in 2005–2012 in a 38 km^2 area located near Czempiń, south of Poznań, in western Poland. The study area consisted mainly of arable land with relatively large areas of individual fields, varying in size from 10 to 100 hectares. The main crops were cereals, but oilseed rape, maize, sugar beets, potatoes and alfalfa were also cultivated. Among crop fields there were scattered clumps of forest formed by both deciduous and coniferous trees. They had a surface area of <1 to 100 ha and covered a total of only 8% of the study area. The Common Buzzard was the most abundant raptor species in western Poland, and its regional density increased from an average of 20 pairs per 100 km^2 in the early 1980s (Pielowski 1991), to about 37 pairs per 100 km^2 in 2005–2012 (M. Panek, unpubl. data). During the study a few pairs of regularly nesting Goshawks *Accipiter gentilis*, Sparrowhawks *Accipiter nisus*, Marsh Harriers *Circus aeruginosus* and isolated cases of breeding by other raptor species were found (M. Panek, unpubl. data).

Field methods

Every year all oilseed rape plantations situated in the study area were recorded on maps (scale 1:10,000; Head Office of Geodesy and Cartography, Warsaw), on which roads, ditches and hedgerows, i.e. field borders, were marked. The size of individuals crop fields was then estimated from these maps (to the nearest 1 ha).

The abundance of Common Voles was estimated by counting their burrow entrances. It has been found in agricultural areas in Poland that the number of burrows used by Common Voles was positively correlated with the numbers of these animals (Mackin-Rogalska *et al.* 1986). Similar methods for assessing relative vole abundance have been successfully applied in some previous Buzzard studies (Krüger 2002, Schindler et al. 2012). Five transect routes were established, with a total length of 35 km, covering the study area evenly. Burrow counts were carried out every year in March. Only active burrow entrances with clear signs of use (fresh digging, droppings, pieces of food), located up to 3 m on both sides of the transect routes, were recorded. Moreover, the type of vegetation in which the burrows were placed was categorized as winter cereals, oilseed rape, alfalfa and other (stubbles, mustard and other green cover crops, wild plants; no active entrances were found on ploughed fields). During the vole counts, the type of crop (or the presence of ploughed land) on each crossed arable field was noted on the above mentioned maps. Next, the total length of sections running through the selected vegetation types on each transect route was measured from these maps (to the nearest 10 m). Finally, the annual and long-term average numbers of burrow entrances per transect length unit for each vegetation type were calculated (burrow index hereafter). The obtained index primarily reflected relative vole abundance at the beginning of Buzzard breeding season, i.e. during the pre-laying and laying period. However, the index seems to be less representative for the period of young rearing in May and July, as the rate of spring changes in vole numbers could vary between years and crop types (e.g. Ryszkowski 1982).

The occurrence of occupied nests of Common Buzzards and their reproductive success in the study area was estimated every year using the methodology commonly utilized in research on birds of prey (e.g. Newton 1979, Jędrzejewska & Jędrzejewski 1998). Namely, the area was visited from the second half of March to mid-July, once every two weeks. In March and April, clumps of forest were searched to find Buzzard nests. A low forest cover in the study area allowed the unambiguous designation of individual long-term nesting sites of Buzzards. A nesting site was defined as an isolated clump of forest or a group of neighbouring clumps, surrounding by treeless agricultural land, in which in at least one study year a nesting attempt was observed. So, if in a given forest clump Buzzard nesting attempts were found only in some years, this part of the study area was also regarded as the same nesting site in the remaining years. It was assumed that within a given nesting site a nesting attempt occurred in a given year, if during the incubation period, i.e. in April or May, a Buzzard sitting on the nest was observed at least once. The locations of active nests were marked on the above mentioned maps and nest coordinates were calculated based on the kilometre grid of the map (accuracy 50 m). Further visits to occupied nests were aimed at evaluating reproductive success. A breeding attempt was considered as successful when at least one fully feathered offspring (i.e. without white down feathers on the head) was observed on the nest before the anticipated fledging time. At this stage of their development, the number of offspring was also counted. Observations were carried out from the ground, from a distance of several dozen meters from the nests using binoculars.

Based on the above mentioned maps showing the distribution of oilseed rape fields in the study area, we measured the acreage of this crop around all Buzzard nesting sites, both in the years with nesting attempts and without occupied nest. The measurements (to the nearest 1 ha) took place within a radius of 1 km from the nest location, i.e. in a circle of about 3 km^2, which approximately corresponded to the area obtained by dividing the area of the study by the average number of Buzzard pairs found there (see results). In the case of some nesting sites, breeding attempts found in successive years occurred in the same nest, and in other nesting sites breeding attempts took place in different nests from year to year (typically spaced apart by several dozen meters within a given clump of forest, and only rarely up to 300 m). Therefore, the average nest locations were estimated from the nest coordinates and used to plot the circles in which the annual area of oilseed rape was measured.

In the study area 19 Buzzard nesting sites were found; 15 of these were located in small forest patches from <1 to 15 ha and 4 in larger forests of 45 and 100 ha. In all these cases the mean nest locations were up to 150 m from the edges of the forest.

Statistical analysis

Differences in the burrow index between the four crop categories and between the years were tested using two-factor analysis of variance implanted in the Statistica Software. Next, we fitted a mixed effect model to the measures of the Buzzard breeding performance where oilseed rape area was considered as a fixed explanatory variable and year nested within the nesting site were considered as random effects. First, we fitted a mixed model on the nest occupancy (nesting attempt vs no active nest) as a response variable where we assumed binomial error structure. Only year was considered as a random effect in this particular model to ensure model convergence. Next, we fitted a model on the nesting success (at least one fledgling produced vs nest failure) with binomial error structure and a model on the number of fledglings where we assumed a Poisson error structure. These last two models were fitted to the data from only active nesting sites and from nests with successful nesting, respectively. The mixed models were fitted using library lme4 in R (Bates *et al.* 2014).

Results

The size of individual oilseed rape fields ranged from 12 to 106 ha, with a mean of 37 ha (n = 104, se = 2). In individual years the oilseed rape plantations covered from 5.6 to 23.9% (mean = 17.8%, n = 8, se = 2.4) of the agricultural land. The data on the occurrence of all selected crop types in the study area came from the transect routes, which covered mainly winter cereals (24.5–55.5% of total transect length in individual years, mean = 36.8%, n = 8, se = 3.6), and successive crops were oilseed rape (6.5–22.4%, mean = 17.6%, n = 8, se = 2.6), alfalfa (3.7-12.6%, mean = 8.2%, n = 8, se = 1.3) and other vegetation (mainly stubbles and cover crops; 2.0–20.9%, mean = 11.5%, n = 8, se = 2.4), while the remaining parts constituted ploughed land.

The burrow index differed between years ($F_{7,93}$ = 14.4, P < 0.001) and crop types ($F_{3,93}$ = 35.3, P < 0.001), with a significant interaction between these variables ($F_{21,93}$ = 6.3, P < 0.001). During five of the eight study years, the highest values of this index were found in oilseed rape (long-term mean = 64.2 burrow entrances per km, n = 33, se = 13.1); another crop with abundant voles was alfalfa (mean = 46.4, n = 18, se = 16.5), while in other crops (mean = 15.6, n = 37, se = 4.0) and especially in winter cereals (mean = 3.0, n = 37, se = 0.6) the burrow index was low (Fig. 1). Based on the numbers of burrow entrances per km of transects in various crop types and on the share of crop types in the study area, the distribution of voles between these crops was evaluated. Despite the dominance of winter cereals in the study area, they apparently contained only a small portion of the local Common Vole population because the contribution of burrow entrances found in these crops varied in different years only from 0 to 13.9% of the total number found on the transects. In some years, a high percentage of these entrances was reported in alfalfa fields (up to 49.1%). During seven out of the eight study years, however, most vole burrow entrances occurred in oilseed rape, where their contribution ranged from 32.9 to 77.2% (Fig. 2).

In the 19 Buzzard nesting sites found in the study area, 11-16 nesting attempts were recorded in individual years (mean 14.2, n = 8, se = 0.6). It gives a density of 28.9 to 42.1 pairs per 100 km^2 (mean 37.4 pairs per 100 km^2, n = 8, se = 1.7). In total, 114 nesting attempts were observed on 152 occasions (nesting sites × years), 84 of the nesting attempts were successful (74%), and the mean number of fledglings per successful nest amounted to 1.5 (range 1–3, se = 0.1).

The probability of nesting attempt in a given nesting site was not related to the area of oilseed rape around the nest (b ± se = 0.006 ± 0.006, z = 0.99, P =0.32). The probability of nesting success was positively related to the area of oilseed rape around the nest (b ± se = 0.029 ± 0.010, z = 2.78, P = 0.005, Fig. 3a), as was the number of fledglings in successful nests (b ± se = 0.008 ± 0.002, z = 2.94, P = 0.003, Fig. 3b).

Discussion

During most spring seasons, the highest index of Common Vole density occurred in the oilseed rape fields. Moreover, judging by the number of active burrow entrances (Mackin-Rogalska *et al.* 1986), plantations of this plant contained the majority of the population of this prey living in the study area compared to other crops. The high densities of Common Voles in oilseed rape fields were probably connected with relatively large green biomass in this crop, because plant production is known as a factor influencing small rodent populations (e.g. Laine & Henttonen 1983, Tkadlec *et al.* 2006). Therefore, the occurrence of oilseed rape positively affected the local abundance of Buzzard food resources.

According to Newton (1979), most raptor populations are limited by the availability of their prey. For example, in England, it was found that the local density of breeding Common Buzzards was dependent on the abundance of their main prey (Graham *et al.* 1995, Sim et al. 2001). In our study, however, the occurrence of oilseed rape plantations with numerous voles apparently had little effect on the probability of nesting attempts by Buzzards. On the other hand, territory occupation and nesting attempts by Buzzards could be locally affected also by vole resources in other vegetation. Alfalfa was less common than oilseed rape in the study area, but in some years a considerable part of agricultural land was covered in winter and early spring with stubbles and cover crops (mainly mustard) where the burrow index was sometimes high. Moreover, Newton (1979) emphasized that the abundance of prey may be the most important factor affecting the breeding populations of raptors mainly in areas where there are no limits in the availability of nesting sites. Wooded patches covered only a small part of the study area. It is therefore possible that the choice of nesting sites for these birds may have been limited there. Thus, they probably bred in places which primarily provided sufficient nesting conditions (e.g. trees with good nest base, safety), so to a large extent regardless of the distribution of crops rich in food in a given year.

Reproductive success of Buzzards, i.e. both the probability of successful nesting and the number of fledglings, was higher in nests surrounded by a considerable area of oilseed rape fields. In our study area Buzzards nested mainly in small forest patches and only a few nests were located near the edges of larger forests. It is therefore unlikely that the higher proportion of forested area (and so potentially a smaller area of oilseed rape) in the diameter of 1 km around some nesting sites introduced any significant bias in the above conclusion. Thus, the relationship between the occurrence of oilseed rape and the breeding parameters of Buzzards may be linked with the abundance of Common Voles. The influence of food resources, changing in time or space, on the breeding success of Common Buzzards has been observed in a number of studies (e.g. Newton 1979, Swann & Etheridge 1995, Austin & Houston 1997, Selås 2001, Sim *et al.* 2001; although see Krüger 2004). According to Goszczyński & Piłatowski (1986), Common Buzzards are generalist predators switching to other prey, mostly birds, when the availability of small rodents is low. On the other hand, they are not then able to achieve an equivalent hunting efficiency which would enable them to maintain high breeding success.

Oilseed rape fields were characterized by higher vole density index in early spring than other crops. However, during the feeding of young by Buzzards in May and June, oilseed rape becomes high and dense, which may limit the location and capture of voles by these predators. On the other hand, high densities of voles in oilseed rape plantations may result in their subsequent dispersal to adjacent crops, especially to some spring crops (Ryszkowski 1982), and therefore higher availability of this prey in the territories of Buzzards containing oilseed rape fields. In addition, the abundance of food may affect the course and results of breeding in raptors to a large extent by the effects on the condition of females at the beginning of the breeding season and on the clutch size (Newton 1979). It was found that the territorial pairs of the Common Buzzard often stayed in their territories throughout the winter and during this time they preferred vegetation patches rich in voles (Weir & Picozzi 1975, Schindler *et al.* 2012). Furthermore, it seems unlikely that the capture of voles in oilseed rape by Buzzards is limited (in comparison to other vegetation) during the winter and at the beginning of spring when this plants are not fully grown.

Although the occurrence of oilseed rape did not affect the breeding activity of Buzzards in their individual territories, it was positively related to the reproductive success, and thus potentially positively influenced the abundance of this species. Thus, changes in agriculture, consisting of increased planting of oilseed rape should be beneficial for the species. It might therefore be one of the reasons for the increase of Common Buzzard numbers observed in Europe in the last decades (BirdLife International 2014). The population of Common Buzzards also increased in Poland in the second half of the 20th century (Tomiałojć & Stawarczyk 2003); however, in the years 2000–2013 a slight decline was observed (Chodkiewicz *el al.* 2013). Therefore, even if the relatively high reproductive success of Buzzards nesting near oilseed rape plantations in our study area would not be important for the viability of the local population, the higher young production my still support emigration to other locations, including regions with decreasing populations.

The importance of oilseed rape occurrence may also apply to other birds of prey hunting small rodents in the agricultural landscape. For example, the European Kestrel *Falco tinnunculus* is a raptor species feeding mainly on voles, and the density of this prey correlated positively with its reproductive output (e.g. Village 1982, Korpimäki 1986). Moreover, the availability of voles in crop fields determined the size of clutches and breeding success in Montagu's Harriers *Circus pygargus* in France (Salamolard *et al.* 2000). For Marsh Harriers *Circus aeruginosus* in Spain, the beneficial factor was the presence of areas with intensive agriculture, especially where crops such as alfalfa probably contained high densities of small rodents (Cardador *et al.* 2011). Thus, similarly the observed increase in oilseed rape acreage may be beneficial for the conservation of raptor species hunting in the agricultural landscape. In other words, the presence of this crop can potentially compensate for adverse effects that some changes of agricultural land use have on the birds of prey, as it was described by Newton (2004).

On the other hand, some birds of prey feeding primarily on small rodents hunt at least occasionally other animals, such as game birds, and thus could potentially limit these populations (Valkama *et al.* 2005). For example in France, the decrease of Grey Partridge numbers was caused mainly by an increase of female losses (Bro *et al.* 2001). The female mortality rate was correlated with the abundance of harriers, mainly the Hen Harrier *Circus cyaneus*, suggesting that these predators could have some influence on the populations of this galliform bird (Bro *et al.* 2001, Bro *et al.* 2006). Moreover, the occurrence of harriers increased with the larger crop fields (Bro *et al.* 2001), so it was dependent on habitat, probably through its impact on food availability. Therefore, in a similar way, if the increase in oilseed rape acreage favours some birds of prey, it may also cause higher losses in their secondary prey. Similar relationships may also apply to certain predatory mammals. For example, in Polish farmland, Common Voles constitute a major part of the diet of Red Foxes *Vulpes vulpes*, which hunt also hares and partridges (Goszczyński 1995). High vole numbers typically limit predation of vole-eating predators on alternative prey species, because the predators switch between food sources with changes in their relative abundance, but such response may be too weak to affect prey species which constitute only a small part of predator diet, i.e. secondary prey (Norrdahl & Korpimäki 2000). Increased abundance of main prey may cause higher predator pressure on accidentally predated secondary prey especially when these two types of prey coexist in a space (Vickery *et al.* 1992). This condition is fulfilled in the case of Common Voles and some wild birds or small game animals. However, it was also suggested that the increase of predation pressure on farmland birds may not be related to increased predator abundance but rather to unfavourable habitat changes resulted in higher vulnerability of prey species (Evans 2004).

Thus, this study showed that the development of oilseed rape plantations may affect animals living in agricultural landscapes not only by modifying habitat features and plant food resources. The increase in acreage of this crop may improve prey availability for vole eating predators and, in this way, positively influence their populations. It may, however, also potentially increase the pressure of such predators on some of their secondary prey, although this remains to be tested.

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Figure 1. The index of common vole abundance (average number of burrow entrances per km of transects ±se) in individual crop types near Czempiń, western Poland, in the years 2005–2012.

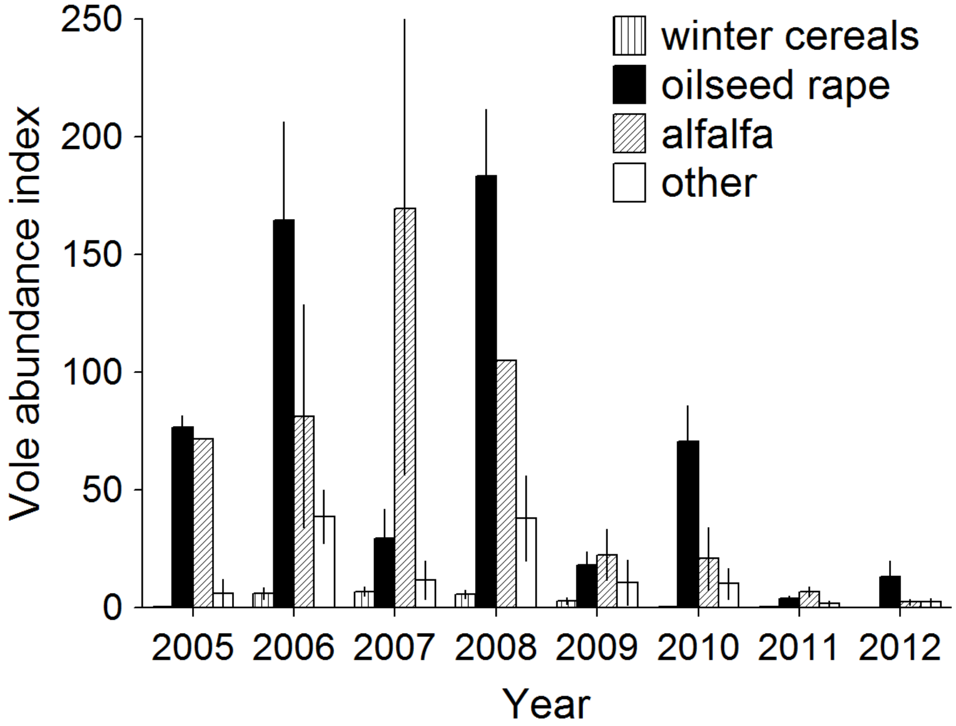

Figure 2. The distribution of common vole burrow entrances in individual crops (the ratio of entrance number in a given crop type to the total number of entrances found in a given year) near Czempiń, western Poland, in the years 2005–2012.

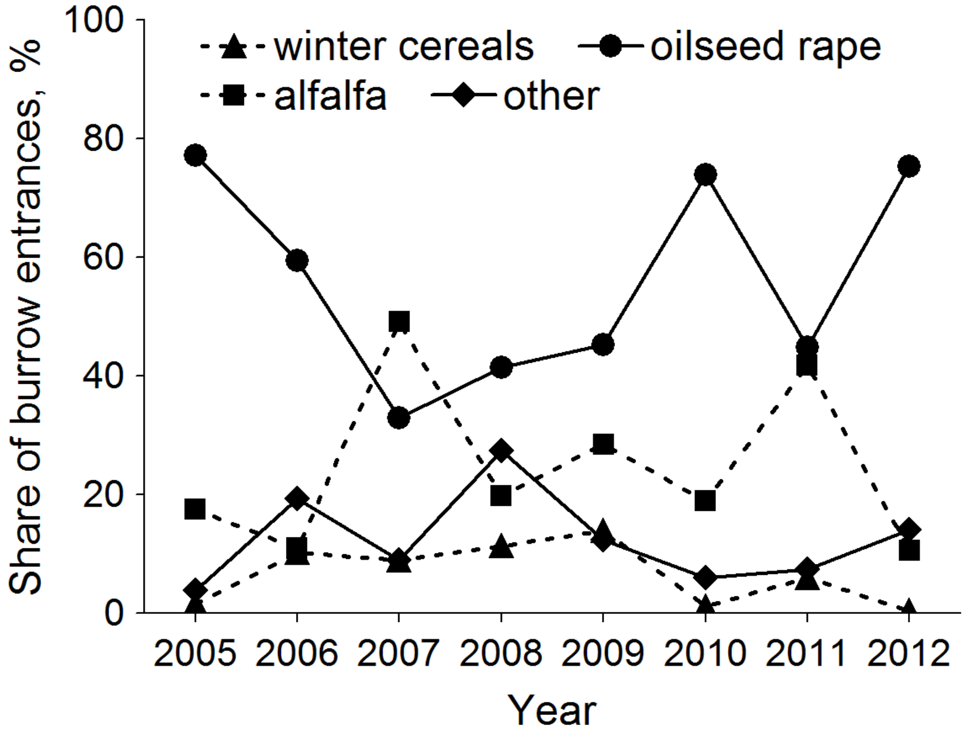

Figure 3. The relationship between area of oilseed rape in a diameter of 1 km around the nest and a) the probability of nesting success, and b) the number of fledglings in the Common Buzzard, western Poland. Shown is the fit on the original scale from the mixed effect model with 95% confidence intervals.