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# EFFECT OF LANDSCAPE STRUCTURE ON NEST SITE SELECTION AND NESTING SUCCESS OF GREY PARTRIDGE *PERDIX PERDIX* IN WESTERN POLAND

ABSTRACT: The effect of agricultural landscape structure (size of crop fields, occurrence of permanent cover areas) on grey partridge *Perdix perdix* nest site selection and nesting success was studied in an area with high variation of crop field size, using radiotelemery (21 located nests, 31 nesting attempts observed) and dummy nests (n = 240). Partridges preferred permanent cover as nesting site, but in areas with smaller crop fields and lower proportion of permanent cover areas a tendency to nest in crops, mostly in cereals, was observed. In partridge home ranges, where nesting attempts were successful, average length of permanent cover areas without trees was higher than in ones with lost nests. Predation of dummy nests was higher in permanent cover than in cereals, but survival index of dummy nests situated in permanent cover increased with increasing length of permanent cover areas in study plots.

KEY WORDS: grey partridge, *Perdix perdix*, nesting, nesting success, agricultural landscape

## 1. INTRODUCTION

Nesting success may be negatively affected by habitat fragmentation as a consequence of edge-related increase in predation level (Gates and Gysel 1978, Andrén *et al.* 1985, Andrén and Angelstam 1988, Møller 1989, Chamberlain *et al.* 1995). Since relative amount of edge increases as patch size decreases, especially high predation rates may occur in small habitat patches (Wilcove 1985, Small and Hunter 1988, Møller 1988, 1991, Andrén 1992). Habitat fragmentation increases with intensification of human land use. Hence, it seems important to study the effect of landscape structure on nest predation rate of birds which have a tendency to nest in small habitat patches.

Grey partridge *Perdix perdix* prefers to nest in areas covered with permanent spontaneous vegetation, such as hedgerows, ditches, fencelines and roadsides, that is in small habitat patches among crop fields (Potts 1986). Nesting success is an important parameter of grey partridge population dynamics. It has been found that the parameter's variation in space and time is one of key mechanisms determining the population level and, due to its density dependence, also regulating the species' density (Potts 1980, 1986, Panek 1992). Extensive research conducted in England showed that nesting success of partridges depended on density of predators feeding on eggs and hunting for incubating females as well as on availability of permanent cover areas (Potts 1980, 1986, Tapper *et al.* 1982, Rands 1988, Tapper *et al.* 1996). An increase in partridge nesting success with increasing amount of permament cover areas among crop fields has also been reported in other European countries, including Poland (Petrjanos 1990, Birkan *et al.* 1994, Panek 1994, 1997). Moreover, nesting success of partridges in Poland turned out positively correlated with crop field segmentation degree (Panek and Kamieniarz 1998). Reasons for the phenomenon were not known, but it was suspected that in areas with small fields partridges often place their nests in crops, where eggs and incubating females are safer from predators than in permanent cover.

The objective of this study was to estimate the effect of agricultural landscape structure, i.e. the occurrence of permanent cover areas and the size of crop fields, on nest site selection, predation pressure and nesting success of partridges in western Poland.

## 2. STUDY AREA

The study was carried out from 1994 to 1997 in an area of 97 km$^2$, located around Czempiń (south of Poznań) in western Poland. The region contained mostly agricultural landscape, in which small woodlands covered 7% of the area. The crop fields were characterized by high variation of size: from < 1 ha to 50 ha. The main crops were cereals (58%), but beets and potatoes (19%), oilseed rape (6%), maize (6%), alfalfa and grasses (5%) were also cultivated. Small, extensively utilized orchards located usually in vicinity of villages, made up 1% of the area. There were also narrow linear stretches of vegetation providing permanent cover (ditches, roadsides, balks). Occasionally the vegetation was distributed in clumps. The permanent cover areas contained variety of plants, from herbaceous vegetation to dense shrubs and trees, and occupied 1.9% of the study area with the density of linear elements and borders of non-linear elements averaging 2.4 km/km$^2$ (including 56% without trees and 44% with trees). No correlation was found between the size of crop fields and the occurrence of permanent cover in the study area (R. Kamieniarz and M. Panek – unpublished).

Potential predators of partridge eggs and incubating females included magpie *Pica pica* and hooded crow *Corvus corone* (their density – 4.7 and 0.7 pairs per 10 km$^2$, respectively; M. Panek – unpublished), raven *Corvus corax*, red fox *Vulpes vulpes* (whose density probably increased during the study period and was estimated to 1 individuals per km$^2$ in spring 1997; W. Bresiński and M. Panek – unpublished) as well as mustelids – badger *Meles meles*, stone marten *Martes foina*, pine marten *Martes martes*, polecat *Mustela putorius* and stoat *Mustela erminea*.

## 3. METHODS

Nest site selection and nesting success of partridge pairs living in crop fields of different structure were studied using radiotelemetry. From 1995 to 1997 paired males and females caught in April or at the beginning of May were equipped with necklace radiotelemetry tags. The capture area covered 24 km$^2$ of the total study area. The tagged individuals were located at different day time, possibly every day, from the end of April to the end of July, in order to identify their home range and nesting process course. Whenever a male was banded, i.e. the nest was not known, nesting process course was estimated by the following criteria: incubation in progress was reflected by observations of the male without the female and the male's limited movements, loss of clutch was reflected in the male's and female's renewed, every-day observations together, and the male's movements alone, usually outside the current area, was interpreted as the female's death while incubation. Nesting success was considered to have taken place whenever at least one chick was hatched.

Observation places of partridges with telemetry tags were plotted on maps scaled 1:5000. The maps were used for describing agricultural landscape structure in home ranges of individual pairs and around their nests. Due to a different number of locations obtained for individual pairs, an average home range size found in Czempiń was utilized. Pairs located every day for one month prior to incubation occupied home ranges of the size of 10 ha on average (calculated with minimum convex polygon method; R. Kamieniarz and M. Panek – unpublished). Variables describing landscape structure were calculated for a circle-shaped area of 10 ha (radius 178 m) with the nest situated centrally. When comparing landscape structure for successful or unsuccessful nesting attempts, the center of the circle was situated in the mean location of a given pair from the period prior to incubation (n from 9 to 38 locations). In the cases of located nests, the nests were actually within a 140 m range from the calculated home range centers (mean 70 m, n = 21, SD = 42).

Variables describing landscape structure included cereal crops area, number of crop fields and length of permanent cover areas (divided into areas with trees and those without trees). It has been assumed for calculating the number of crop fields that a single field was an area with homogenous crop separated from similar areas with other crops or linear permanent cover area ≥ 1 m wide. Length of all linear permanent cover areas ≥ 1 m wide, i.e. balks, strips, ditches and roadsides was also measured. In case of few nonlinear permanent cover areas, their perimeter was measured. The use of different vegetation for nesting places in relation to its availability in the area was tested according to statistical methods given by Neu *et al.* (1974) and Byers *et al.* (1984).

In order to estimate differences in predator pressure on ground nests depending on vegetation type and agricultural landscape structure dummy nests were used. From 1994 to 1996 round plots covering 1 km$^2$ each were determined throughout the whole study area. The plots were selected randomly, but with overlap degree < 50%. For each of the plots the landscape structure was described (number of crop fields and the total length of permanent cover areas) by taking measurements both on the map and in the field, as described above. Dummy nests were placed in the plots in May and June. Each of the nests consisted of three pheasant eggs, the clutch size suggesting incomplete partridge clutch. In each of the plots 4 dummy nests were placed: two in permanent cover areas, one in alfalfa or grass field (or in permanent cover, should there be none of the former), and one in cereals. They were placed randomly 0.5 m from the border of vegetation. The dummy nests were then checked every 5 days for a month. Whenever destruction of the eggs was recorded, on the grounds of the traces left the reason was determined, i.e. predation or agrotechnical measures. Should the eggs have disappeared and no clear traces be left, the destruction was attributed to predators. If the vegetation around the dummy nest had been mowed, it was assumed that the nest had been destroyed during mowing, irrespectively of the eggs' condition. During 3 years 240 dummy nests were placed in 60 different plots.

## 4. RESULTS

Out of 21 located partridge nests, 9 were situated in permanent cover, 3 in spontaneous vegetation in small orchards between the fields, and 9 in crops (including 6 in cereals, 1 in grass field, and 2 in other crops). For the purpose of statistical analysis data for permanent cover and orchards have been combined due to the small sample size. When comparing nest site distribution with the expected nest location frequency, calculated according to vegetation composition in the study area (0.5 nests for permanent cover/orchards and 20.5 for crops), the actual numbers proved that partridges preferred permanent cover/orchards and used crops to an extent lesser than their availability ($\chi^2 = 270.9$, $P < 0.001$ for both habitats). No significant difference was found between expected and observed frequency of nests in cereals and in other crops (expected 5.2 and 3.8 nests, respectively, $\chi^2 = 0.291$, $P = 0.6$). Out of 9 nests built in permanent cover, 8 were in areas without trees and 1 in an area with trees. When compared to the expected frequency of nest placement in the two types of permanent cover (5.0 for areas without trees and 4.0 for areas with trees), the difference turns out close to significance ($\chi^2 = 3.133$, $P = 0.08$). Thus, partridges seem to avoid vicinity of trees.

Landscape structure around partridge nests differed for clutches situated in permanent cover and in crops. The average number of crop fields was higher for nests located in crops and the average values of cereal area and total length of permanent cover areas did not differ significantly. However, after dividing the permanent cover areas into areas with trees and those without trees, it was observed that the average length of permanent cover areas without trees around nests located in permanent cover areas was higher than around nests in crops (Table 1).

Out of 21 known nests 3 were evidently abandoned in result of human interference (those were excluded from the analysis), 12 were destroyed, in all the cases by predators, and in 6 nests chicks were hatched. Out of 10 nests situated in permanent cover/orchards, 2 were successful, and out of 6 nests in cereals, 4 were successful, the difference turns out close to significance ($\chi^2 = 3.484$, $P = 0.07$). Moreover, information about outcome of 10 other nests of unknown location was collected, giving altogether 28 nesting attempts, out of which 9 (32%) were successful. In the home ranges, where nesting attempts were successful, average length of permanent cover areas without trees was higher than in ones with lost nests. Average numbers of crop fields, total length of permanent cover areas and length of permanent cover areas with trees did not differ significantly (Table 2).

Out of 240 placed dummy nests, 13% was destroyed by predators and 15% by agrotechnical measures. Agrotechnical measures, mostly mowing, caused higher number of dummy nest losses in alfalfa and grass fields than in permanent cover and in cereals. Predators destroyed more nests located in permanent cover, alfalfa and grass fields than in cereals (Table 3). No differences were re-

Table 1. Average values (±SD) of variables describing agricultural landscape structure on an area of 10 ha around partridge nests located in permanent cover and in crops, western Poland

| Location of nests | Area of cereals (ha) | Number of crop fields | Length of permanent cover areas ($km/km^2$) | | |
|---|---|---|---|---|---|
| | | | total | without trees | with trees |
| Permanent cover (n = 9) | 5.0 (±3.0) | 5.1 (±4.0) | 5.0 (±1.5) | 3.8 (±1.2) | 1.2 (±1.4) |
| Crops (n = 9) | 6.5 (±1.5) | 9.9 (±2.6) | 4.4 (±3.3) | 1.8 (±1.7) | 2.6 (±3.2) |
| Significance of differences df = 16 | t = 1.371 $P = 0.2$ | t = 3.041 $P = 0.008$ | t = 0.497 $P = 0.6$ | t = 2.938 $P = 0.01$ | t = 1.229 $P = 0.2$ |

Table 2. Average values (±SD) of variables describing agricultural landscape structure in partridge home ranges, where nesting attempts resulted in success or loss of nest, in western Poland

| Nesting effect | Number of crop fields | Length of permanent cover areas ($km/km^2$) | | |
|---|---|---|---|---|
| | | total | without trees | with trees |
| Success (n = 9) | 8.0 (±3.6) | 6.1 (±1.4) | 4.6 (±2.1) | 1.5 (±1.9) |
| Loss (n = 19) | 6.8 (±4.3) | 4.5 (±2.5) | 2.5 (±1.7) | 2.0 (±2.0) |
| Significance of differences df = 26 | t = 0.728 $P = 0.5$ | t = 1.738 $P = 0.09$ | t = 2.760 $P = 0.01$ | t = 0.666 $P = 0.5$ |

Table 3. Losses in dummy nests located in different places and controlled for a month in western Poland (ns – not significant)

| Location of dummy nests | Reason of losses | |
|---|---|---|
| | predators | agrotechnical measures |
| 1. Permanent cover (n = 139) | 17% | 6% |
| 2. Alfalfa and grass fields (n = 41) | 15% | 61% |
| 3. Cereals (n = 60) | 3% | 3% |
| Significance of differences | 1–2: $\chi^2$ = 0.086, ns | 1–2: $\chi^2$ = 64.482, $P$ < 0.001 |
| | 1–3: $\chi^2$ = 9.684, $P$ < 0.01 | 1–3: $\chi^2$ = 0.515, ns |
| | 2–3: $\chi^2$ = 3.832, $P$ = 0.05 | 2–3: $\chi^2$ = 41.318, $P$ < 0.001 |

corded in losses caused by predators in dummy nests located in permanent cover areas without trees and with trees (16%, n = 71 and 17%, n = 68, respectively; $\chi^2 = 0.013$, $P = 0.9$).

Analysis of predator pressure on dummy nests situated in permanent cover in relation to agricultural landscape structure was carried out using their relative survival time. The survival index was calculated for individual ranges of variables describing the landscape structure. It was derived by dividing the total number of days until destruction of dummy nests by predators (or until the end of the control period for the nests that were intact), by the total number of exposure days (that is until the end of the assumed control period or until they were destroyed during agrotechnical measures). Survival index increased with increasing length of permanent cover areas in study plots, with a tendency to stabilize when permanent cover areas were more abundant,

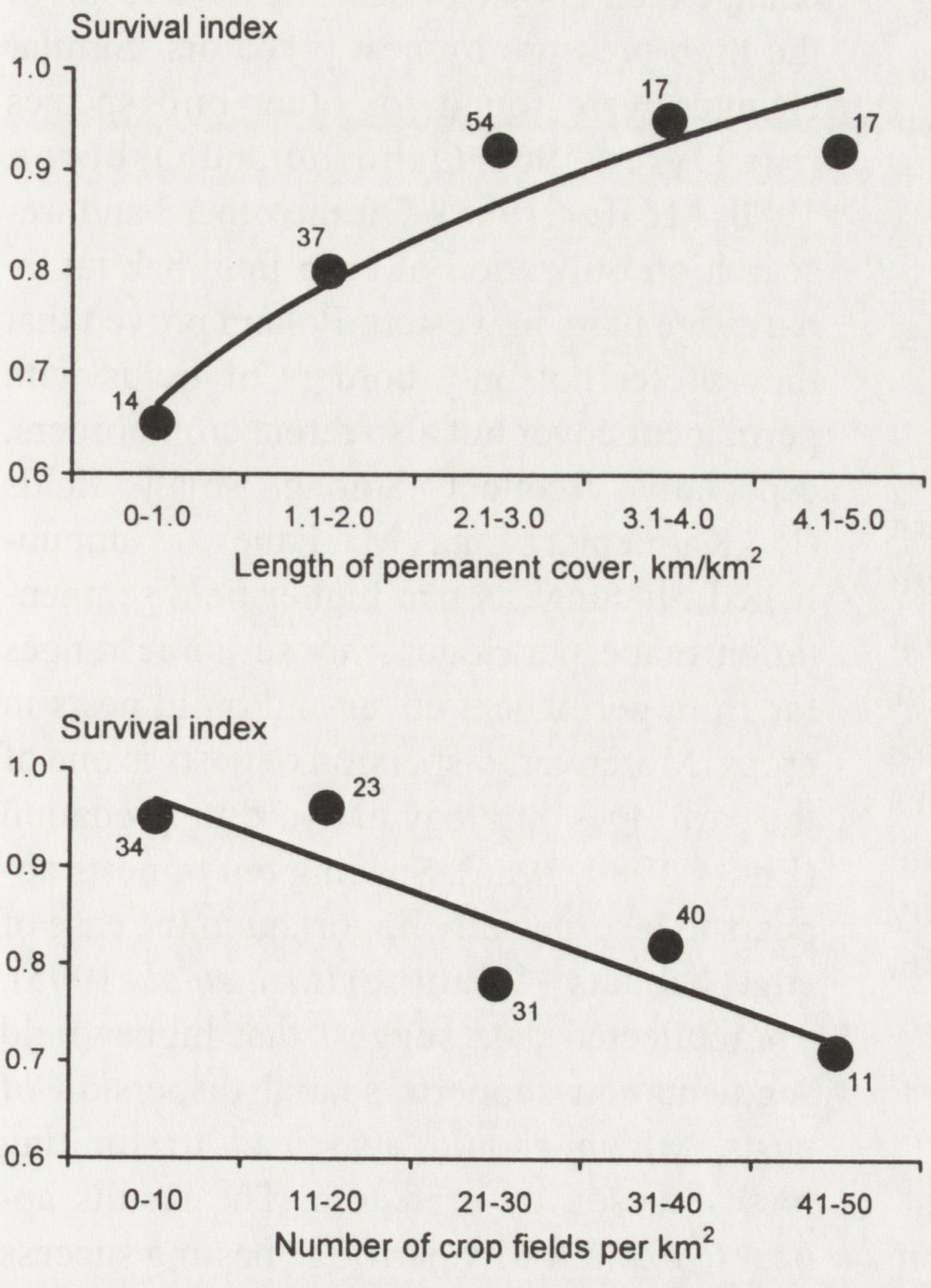


Fig. 1. Survival index of dummy nests placed in permanent cover related to length of permanent cover areas and number of crop fields on 1 km$^2$ study plots in western Poland (sample sizes are given). The survival index is a quotient of total number of days until destruction by predators and total number of exposure days. For length of permanent cover areas: $R^2_3 = 0.939$, $P = 0.006$, $y = 0.75x^{0.18}$; for number of crop fields: $r^2_3 = 0.812$, $P = 0.04$, $y = -0.0062x + 1.00$

and decreased with increasing number of crop fields, i.e. segmentation degree (Fig. 1).

## 5. DISCUSSION

The high predation on grey partridge nests located in permanent cover areas results from the fact that such areas are also preferred by hunting predators (Potts 1980, 1986). However, predator pressure on nests in permanent cover can decrease with increasing amount of the cover, as proved in the experiments with dummy nests. Such an effect resulted probably from lower penetration by predators per unit of permanent cover areas in plots with their higher availability. The lower predation on partridge nests in areas with abundant permanent cover should also be supported by vaster opportunities of selecting a safe place for a nest in such areas (Rands 1988). However, the survival time for dummy nests stabilized for higher amount of permanent cover. It could have resulted from increasing density of predators in plots with abundant permanent cover, which neutralized the penetration dispersion effect. Potts (1986) proved that in areas with high predator density the effect of decreasing losses of partridge nests with increasing proportion of permanent cover areas could be irrelevant or not take place at all.

The chance of nesting success of partridges tagged radiotelemetrically in western Poland was higher only in home ranges with higher amount of permanent cover without trees, whereas the effect was not observed for permanent cover with trees. It was proved repeatedly that predator pressure on partridges was higher nearby treestands than far from them and places with trees were avoided by the birds (Döring and Helfrich 1986, Potts 1986, Rands 1987a, Carroll *et al.* 1990, Meriggi *et al.* 1990, Meriggi *et al.* 1992).

Crops were used by partridges for nesting places less often than their availability in the study area. Simultaneously, predation on dummy nests located in cereals turned out substantially lower than in permanent cover, and partridge nests in cereals were probably more frequently successful than nests in permanent cover. However, nest site selection may be genetically determined (Cody 1985). The grey partridge probably evolved in a steppe environment where grass would have formed much of the potential nesting habitat (Potts 1986, Rands 1988). According to Rands (1986), female partridges use last year's dead grass to cover their eggs during laying period, and the quantity of dead grass is the most important variable in predicting where the birds choose to nest. At the same time, dead grass occur mainly on permanent cover areas. Home ranges of pairs nesting in crops were characterized by relative low proportion of permanent cover areas and high field segmentation degree. In such plots, the highest predation pressure on dummy nests located in permanent cover was found. Therefore, partridges probably partially change their choice of nest sites as a result of the high pressure by nest predators. Similar changes were found for other bird species (e.g. Dyrcz 1969, Osborne and Osborne 1980, Møller 1988). On the other hand, research on utilization of crop field habitat by partridge pairs in western Poland proved that they prefer not only borders of fields with permanent cover but also direct crop borders, especially frequent among small fields (R. Kamieniarz and M. Panek – unpublished). It suggests that higher field segmentation made partridges choose home ranges far from permanent cover and build nests in crops. Moreover, dispersion of nests is one of the partridges' strategy of avoiding predation (Potts 1980, 1986). Spacing out of nests appears to be especially important in the case of edge habitats (Chamberlain *et al.* 1995). The collected data suggest that higher field segmentation supports spatial dispersion of nests, which should also lead to limiting losses caused by predators. The results appear to explain why partridge nesting success in Poland has been higher in areas with higher field segmentation (Panek and Kamieniarz 1998).

Predator pressure on dummy nests located in permanent cover increased with increasing segmentation degree of crop fields surrounding them. Moreover, the increase in nesting success with increasing field segmentation degree found in Poland between areas (Panek and Kamieniarz 1998) has not been observed inside the area, for the average number of crop fields in partridge home ranges with and without nesting success do not significantly differ. It may be connected with higher local predator density in plots with higher segmented fields. Also Angelstam (1986) suggested that the edge-related increase of predation rate in habitat patches depends on their surrounding matrix, because areas which contain more food for generalist predators allow higher density of the predators.

Mowing was mentioned as important reason of partridge nest losses in regions with low permanent cover availability, where many nests were located in crops (Potts 1980). In Poland it regards rather nesting in perennial crops, such as alfalfa, clover and grasses, mowed usually at the end of May and in June, but to a lesser extent – cereals, whose intense harvesting starts usually in the second half of July, i.e. after the main nesting season of partridges. Dummy nests situated in alfalfa or grass fields were characterized by very high losses connected to agricultural practices, especially mowing. About 60% of the nests was destroyed during the works within a month, and the actual losses of partridge nests might have been even higher due to the total period of laying and incubation exceeding one month. However, alfalfa and grasses covered in the study area only 5% of the total area and their use by partridges for nesting purposes was rather scarce. Partridge nesting losses caused by mowing may be high in regions with high proportion of the crops and simultaneous low availability of permanent cover.

Substantial losses in partridge nests, especially located in crops, may sometimes be caused by floods during heavy rains (Potts 1986). It can take place more often in regions with soil of poor permeability. However, this negative effect of partridge nesting in crops probably rarely occurs in Poland on a large scale, for the field segmentation supporting nesting in crops proved positively correlated with nesting success here (Panek and Kamieniarz 1998).

Increasing intensity of agriculture in Poland leads to gradual increase in crop field acreage and liquidation of permanent cover areas among fields. The process causes reduction of nesting success and results in density decrease of partridges (Pielowski *et al.* 1993, Panek and Kamieniarz 1998, Panek 1999). Undoubtedly expansion of field acreage is rather inevitable due to economic reasons. It appears to regard liquidation of permanent cover areas to a lesser extent, for those can take up a lesser share of agricultural landscape. Protection of the current and creation of new strip structures with spontaneous vegetation on the borders of crop fields is one of methods of preserving partridges and other species in agricultural landscape (Rands 1987b).

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## 6. SUMMARY

The aim of this study was to estimate the effect of agricultural landscape structure, i.e. the size of crop fields and the occurrence of areas covered with permanent spontaneous vegetation, on nest site selection, predation pressure and nesting success of grey partridges *Perdix perdix* in western Poland.

The study was carried out in an area contained mostly agricultural landscape, with crop fields characterized by high variation of size and various permanent cover areas between fields (ditches, roadsides, balks, clumps). Nest site selection and nesting success were studied using radiotelemetry (21 located nests and 31 nesting attempts observed). Agricultural lands-

cape structure (cereal crops area, number of crop fields, length of permanent cover areas with and without trees) was described in home ranges of individual pairs and around their nests (average home range size of 10 ha was used). In order to estimate differences in predator pressure on ground nests depending on vegetation type and landscape structure dummy nests were used (n = 240). Dummy nests were placed in various vegetation in study plots covering 1 $km^2$, for which the landscape structure was described.

Partridges preferred permanent spontaneous vegetation as nesting site (12 nests) and used crops to an extent lesser than their availability in the study area (9 nests, including 6 in cereals). Around nests located in crops, the average number of crop fields was higher and the average length of permanent cover areas without trees was lower than around nests located in permanent cover (Table 1). In the home ranges, where nesting attempts were successful, the average length of permanent cover areas without trees was higher than in ones with lost nests (Table 2).

Agrotechnical measures, mostly mowing, causes higher number of dummy nests losses in alfalfa and grass fields than in permanent cover and in cereals, and predators destroyed more nests located in permanent cover, alfalfa and grass fields than in cereals (Table 3). Relative survival time of dummy nests located in permanent cover increased with increasing lenght of permanent cover areas in study plots, with a tendency to stabilize when these areas were more abundant, and decreased with increasing number of crop fields (Fig. 1).

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