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Influence of forest fragmentation on the game species population

Wpływ rozdrobnienia kompleksów leśnych na populacje zwierząt łownych

Summary. The survey aimed at evaluating the influence of forest fragmentation on game species population. Borders of forest areas in forest districts in the Lublin region were measured according to the cartographic method. The coefficient of forest fragmentation (km/km^2) was calculated as a total forest boundary length (km) to the total forest surface area (km^2) in a given forest inspectorate ratio. Based on the obtained data, the obtainment Pearson's correlation coefficients between forest boundaries length (km) and their fragmentation coefficient (km/km^2) vs. hunting obtainment size in the analyzed periods were calculated. The results showed that the European red deer occurrence is associated with the presence of compact forest complexes. Our results indicate the positive influence of forest fragmentation on the wild boar, brown hare and red fox populations size.

Key words: forest fragmentation, landscape structure, game density, harvesting

INTRODUCTION

The agriculture development initiated in The Neolithic caused a massive deforestation to make cultivated fields and pasture larger. It resulted in a sudden decrease of forest areas and fragmentation of forests. That process made a dramatic change in habitat conditions leading to formation of small and isolated forest spots distributed among agricultural ecosystems. A mosaic of phytocenoses with a surplus of secondary and anthropogenic communities was created [Olaczek 1976]. The habitat fragmentation had negative effects of wild animals species population. Fragmented forest complexes lost their specific microclimate resulting in a complete change of forest fauna living conditions, thus species attributed to a forest environment are particularly sensitive to forest fragmentation processes. A single compact forest makes better habitat conditions than large number of small and isolated "spots" with larger total surface area [Harris 1984].

The survey aimed at evaluating the influence of forest fragmentation on game species population (harvesting level).

MATERIAL AND METHODS

The survey consisted in measuring all the forest boundaries on topographic maps (1 : 50 000) using electronic opisometer "Plus" (SILVA) in all forest inspectorates (n = 25) belonging to Regional Directorate of National Forests in Lublin. All forests marked with a green color on topographic maps (national and private) the area of which exceeded 1 ha were taken into considerations. Measurable boundaries included all borders between a forest and a field as well as between a forest and a water reservoir. The coefficient of forest fragmentation (km/km^2) was calculated as a total forest boundary length (km) to total forest surface area (km^2) in a given forest inspectorate ratio.

Table 1. Correlation coefficient values between mean size of harvesting and mean numbers of game species in years 2001–2007 in forest districts in Lublin region
Tabela 1. Wartość współczynników korelacji pomiędzy wielkością pozyskania gatunków łownych a ich stanem liczebnym podawanym w Łowieckich Planach Hodowlanych w kolejnych sezonach łowieckich 2001/02–2006/07

Species Gatunki	Correlation coefficient values Współczynnik korelacji
Red deer Jeleń europejski	0.8792*
Fallow deer Daniel	0.9340*
Roe deer Sarna europejska	0.8575*
Wild boar Dzik	0.9571*
Brown hare Zając szarak	0.8763*
Red fox Lis pospolity	0.8429*

*significant at $p \leq 0.01$ – *istotne dla $p \leq 0{,}01$

Information on obtention of main game animal species in 2001/02–2006/07 were collected from Hunting-Breeding Plans made for particular forest inspectorates, and it was helpful in calculating of: red deer, fallow deer, and wild boar (n/1000 ha of forest area), roe deer and hare (n/100 ha of total hunting area), and fox (n/1000 ha of total hunting area). The amount of wild animal's obtention as a measure of population size was chosen in a survey, because such data is more credible. The obtention size does not fully represent the population size; however it is perfect to present the increasing or decreasing tendencies in a given species population and it is a key indicator of deer population

size [Brennan *et al*. 1993, Mysterud *et al.* 2007]. There is a strict positive correlation between forest density and hunting obtention of red deer and [Blanchong *et al.* 2006] and wild boar [Csányi 1995]. In order to confirm that thesis, the correlation coefficients between hunting animals number in Hunting-Breeding Plans and obtention size, were calculated. The obtention size of all discussed species was highly correlated with the number stated in Hunting-Breeding Plans (Tab. 1).

Based on achieved data, the Pearson's correlation coefficients between forest boundaries length (km) and their fragmentation coefficient (km/km^2) vs. hunting obtention size in analyzed periods, were calculated. The correlation coefficients were calculated for particular management periods and for average obtention size for all surveyed periods at significance level of $\alpha = 0.05$. Pearson's correlation coefficients were also calculated for dependence between game species obtention and the percentage of forest area.

RESULTS AND DISCUSSION

Mean level of red deer obtention (n/1000 ha) in 2001/02–2006/07 was positively correlated with the percentage of forest area; however, it was statistically insignificant dependence (Tab. 2). Instead, highly significant negative correlation between red deer hunting obtention size and forest boundaries length was found. The dependence referred

Table 2. Correlation coefficient values between mean size harvesting of game species (2001/02–2006/07) and percentage participation forest area
Tabela 2. Wartości współczynników korelacji pomiędzy średnią wielkością pozyskania łowieckiego gatunków łownych (2001/02–2006/07) a udziałem procentowym powierzchni leśnej

Species Gatunki	Participation of forest area (%) Udział powierzchni leśnej (%)
Jeleń Red deer	0.350
Daniel Fallow deer	0.346
Sarna Roe deer	0.223
Dzik Wild boar	-0.429*
Zając Brown hare	-0.544*
Lis Red fox	-0.157

*significant at $p \leq 0.05$ – * istotne dla $p \leq 0{,}05$

to average obtention for 6 management periods (2001/02–2006/07), as well as obtention levels in particular years (Tab. 3). Analysis of a dependence between forest fragmentation coefficient (km/km^2) and mean red deer hunting obtention within surveyed period revealed negative and significant correlation between those parameters (Fig. 1). The negative dependence referred to almost all particular management periods (Tab. 4). Re-

sults indicated that high percentage of forest area had positive influence on red deer presence in a hunting ground, while compact forest complexes presence was more important. Also other authors observed negative impact of forest fragmentation on red deer population due to agriculture development [Malin 1989]. According to Nyberg and Janz [1990], red deer population on open fields decreases along with the distance from a forest boundary. Own results confirm the opinion by Haber's *et al*. [1977] and Tomek's [2002] that red deer is typically forest species in Poland and it feeds on fields only periodically.

Table 3. Correlation coefficient values between forest edge lengths (km) and mean size harvesting of game species in each hunter season
Tabela 3. Wartości współczynników korelacji pomiędzy długością granic kompleksów leśnych (km) a wielkością pozyskania łowieckiego gatunków łownych w poszczególnych latach gospodarczych

Hunter season Sezon łowiecki	Red deer Jeleń	Fallow deer Daniel	Roe deer Sarna	Wild boar Dzik	Brown hare Zając	Red fox Lis
2001/02	-0.614*	-0.349	-0.286	0.256	0.474*	0.179
2002/03	-0.519*	-0.372	-0.310	0.053	0.391*	-0.101
2003/04	-0.596*	-0.385	-0.191	0.306	0.432*	-0.210
2004/05	-0.546*	-0.403*	-0.118	0.320	0.517*	-0.203
2005/06	-0.624*	-0.366*	-0.144	0.193	0.494*	-0.161
2006/07	-0.594*	-0.385	-0.218	0.120	0.374	-0.082
$\bar{x}$ harvesting $\bar{x}$ pozyskanie 01/02–06/07	-0.606*	-0.379	-0.275	0.224	0.459*	-0.232

*significant at $p \leq 0.05$ – * istotne dla $p \leq 0{,}05$

Fallow deer was characterized by similar relation towards compact forest areas (Tables 3 and 4), although according to other authors [Borkowski and Pudełko 2007], fallow deer rather chooses open areas such as meadows and middle-field bushes for living habitat.

The roe deer hunting obtention level was positively correlated – while also insignificantly – with the forest area percentage (Tab. 2). No dependence between roe deer obtention size and forest boundaries length (Tab. 3) or forest fragmentation coefficient (Tab. 4, Fig. 2) was recorded. Majority of correlation coefficients between these parameters was negative. Those results shows weaker associations of European roe deer with forest environment as compared to red deer or fallow deer. Among wild ungulates, roe

deer adapt its behavior the best way to environmental changes, which makes it well functions in fragmented forest complexes forming the field-forest mosaic. Roe deer associated with field ecosystems show apparent differences in behavior and herd size. Comparing to typical forest habitats, roe deer on open fields form larger herds, which is considered as a protective strategy against predators [Jepsen and Topping 2004]. Studies performed by Hewison *et al*. [2001] revealed that mean roe deer herd size increased along with the distance from the forest boundary. The more fragmented forests, the smaller individual area for roe deer females [Saïd and Servanty 2005]. Slight differences referring to weight and body length between field and forest roe deer were proven [Fruziński *et al*. 1982], while differences of morphological structure of internal organs [Hofmann *et al*. 1988] and no genetic distance between field and forest roe deer populations were confirmed [Hartl *et al*. 1993].

Table 4. Correlation coefficient values between fragmentation coefficient forest area (km/km^2) and mean size harvesting of game species in each hunter season
Tabela 4. Wartości współczynników korelacji pomiędzy współczynnikiem rozdrobnienia kompleksów leśnych (km/km^2) a wielkością pozyskania łowieckiego gatunków łownych w poszczególnych latach gospodarczych

Hunter season Sezon łowiecki	Red deer Jeleń	Fallow deer Daniel	Roe deer Sarna	Wild boar Dzik	Brown hare Zając	Red fox Lis
2001/02	-0.391*	-0.330	-0.012	0.423*	0.418*	0.136
2002/03	-0.193	-0.312	-0.103	0.189	0.232	0.012
2003/04	-0.342	-0.313	0.001	0.497*	0.356	-0.007
2004/05	-0.243	-0.331	-0.010	0.550*	0.400*	-0.013
2005/06	-0.313	-0.345	-0.071	0.525*	0.390*	-0.038
2006/07	0.322	-0.326	-0.081	0.451*	0.200	-0.090

*significant at $p \leq 0.05$ – * istotne dla $p \leq 0{,}05$

In a case of wild boar, a negative and significant dependence between their obtention amount and forest area percentage, was found (Tab. 2). Positive, although insignificant correlations were present between forest boundary length vs. wild boar hunting obtention size (Tab. 3) and significant dependencies between wild boar obtention vs. forest fragmentation coefficient both in particular years (Tab. 4) and for average obtention during the whole survey period (Fig. 3). It can indicate that wild boar – unlike European red deer – prefers small and fragmented forest spots, due to which it has easier access to fields abundant in attractive prey. Unfortunately, it is also associated with lar-

ger damages caused by wild boars on fields along with the distance from field-forest boundary [Drozd 1988]. Study made by Virgós [2002] revealed that wild boar population was higher on large forest areas rather than smaller ones, although the dependence was less apparent than in the case of roe deer.

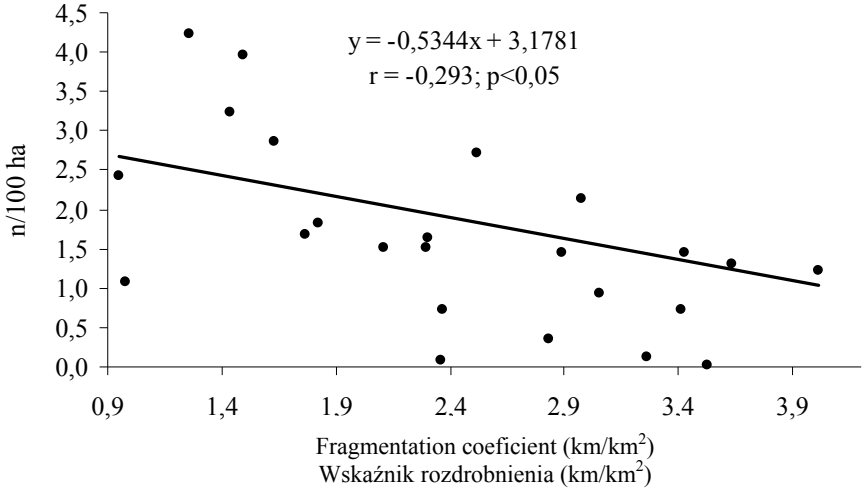

Fig 1. Correlation between fragmentation coefficient (km/km^2) and mean size harvesting of red deer (n/1000 ha) for time period

Ryc. 1. Zależność pomiędzy współczynnikiem rozdrobnienia kompleksów leśnych (km/km^2) a średnią wielkością pozyskania łowieckiego jeleni (n/1000 ha) za badany okres

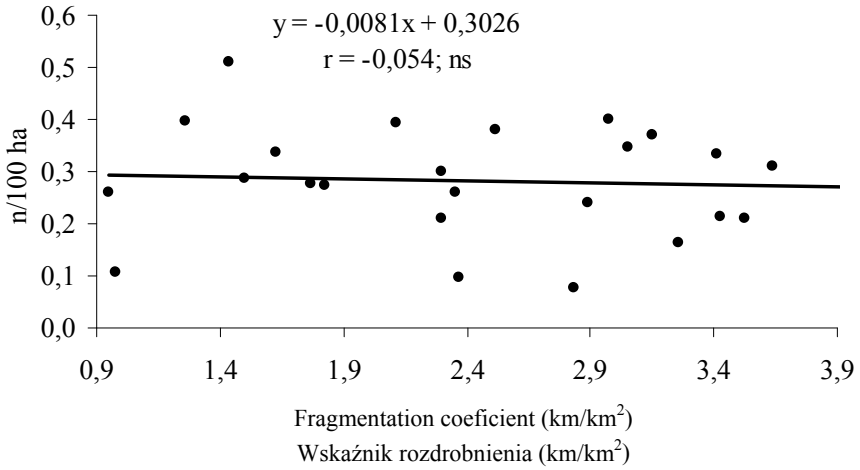

Fig. 2. Correlation between fragmentation coefficient (km/km^2) and mean size harvesting of roe deer (n/100 ha) for time period

Ryc. 2. Zależność pomiędzy współczynnikiem rozdrobnienia kompleksów leśnych (km/km^2) a średnią wielkością pozyskania łowieckiego saren (n/100 ha) za badany okres

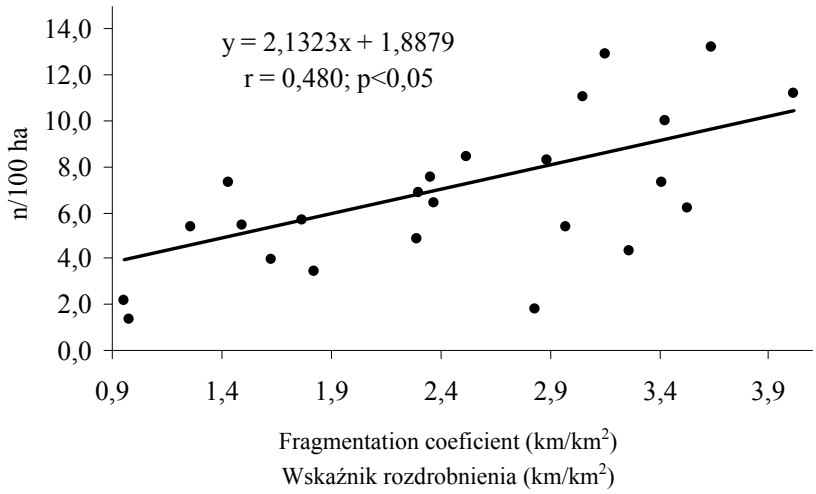

Fig. 3. Correlation between fragmentation coefficient (km/km^2) and mean size harvesting of wild boar (n/1000 ha) for time period
Ryc. 3. Zależność pomiędzy współczynnikiem rozdrobnienia kompleksów leśnych (km/km^2) a średnią wielkością pozyskania łowieckiego dzików (n/1000 ha) za badany okres

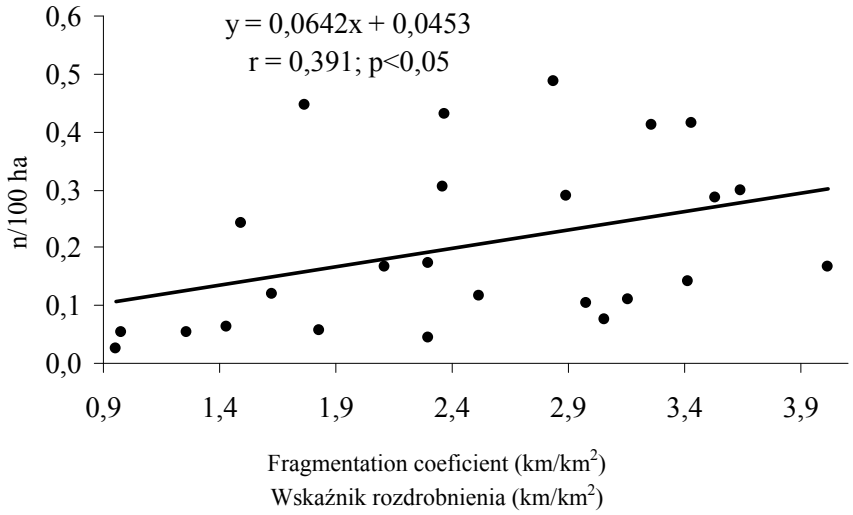

Fig. 4. Correlation between fragmentation coefficient (km/km^2) and mean size harvesting of brown hare (n/100 ha) for time period
Ryc. 4. Zależność pomiędzy współczynnikiem rozdrobnienia kompleksów leśnych (km/km^2) a średnią wielkością pozyskania łowieckiego zajęcy (n/100 ha) za badany okres

Own survey confirmed the association of hare with the field habitats: value of correlation coefficient between hare obtention size and forest area percentage amounted to -0.544, which was statistically significant at $p \leq 0.05$. Positive correlation between hare obtention level vs. forest boundary length (Tab. 3), as well as forest fragmentation coefficients (Tab. 4, Fig. 4) was recorded, which indicates the positive influence of forest habitats fragmentation on hare population. Panek and Kamieniarz [1999] discovered negative effects of large forest areas and agricultural monocultures on hare presence in a hunting ground.

Calculated correlation coefficients did not confirm any dependence between fox obtention size and forest area percentage. Dependence between fox obtention level vs. forest boundary length (Tab. 3) and forest fragmentation coefficient (Tab. 4) was neither observed. These results indicate that fox is not associated with particular habitat; instead, it is a species both of typically field and forest areas, regardless of their fragmentation level. Opinion of Goszczyński [1985] is different: according to the author, fox population density increases along with the length of field-forest boundary, hence foxes have an easy access to possibly many field habitats playing a role of hunting area for them.

CONCLUSIONS

1. European red deer occurrence is associated with the presence of compact forest complexes. Fragmentation of forest habitats negatively affects the species population.
2. No dependence between roe deer population size and forest fragmentation coefficient proves the species associations both with forest and field habitats, as well as it confirms the forest and field roe deer ecotypes presence.
3. Forest fragmentation favors the presence of wild boar in a hunting ground.
4. Hare occurrence is strongly associated with field habitats. Forest fragmentation has positive influence on the species population.
5. Fox presence is associated with both typically field and forest areas, regardless of their fragmentation level.

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Streszczenie. Celem pracy była ocena wpływu rozdrobnienia kompleksów leśnych na populacje gatunków łownych. W oparciu o prace kartograficzne wyliczono wskaźnik rozdrobnienia kompleksów leśnych (km/km^2) jako iloraz całkowitej długości granic leśnych (km) i całkowitej powierzchni kompleksów leśnych (km^2) w poszczególnych nadleśnictwach RDLP Lublin. Uzyskane dane pozwoliły na wyliczenie współczynników korelacji Pearsona pomiędzy wskaźnikiem rozdrobnienia (km/km^2) a wielkością pozyskania łowieckiego głównych gatunków łownych, dla wszystkich nadleśnictw, w analizowanych okresach gospodarczych. Wyliczono także współczynniki korelacji pomiędzy wielkością pozyskania łowieckiego gatunków łownych a udziałem procentowym powierzchni leśnej. Wyniki wykazały, że występowanie jelenia europejskiego na Lubelszczyźnie jest związane z obecnością zwartych kompleksów leśnych, natomiast rozdrobnienie kompleksów leśnych sprzyja populacjom dzików, zajęcy i lisów.

Słowa kluczowe: rozdrobnienie kompleksów leśnych, struktura krajobrazu, zagęszczenie zwierzyny, pozyskanie łowieckie