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Regular research paper

Michał CIACH*, Małgorzata BYLICKA

Department of Forest Zoology and Wildlife Management, Faculty of Forestry,
University of Agriculture, al. 29 Listopada 46, 31-425 Kraków, Poland,
*e-mail: mciach@ar.krakow.pl (corresponding author)

RELATIVE ABUNDANCE AND FLOCK SIZE OF WINTERING COMMON CROSSBILLS *LOXIA CURVIROSTRA* L. IN WESTERN CARPATHIANS: A HABITAT INFLUENCE

ABSTRACT: A study of wintering Common Crossbills (*Loxia curvirostra* L.) was conducted in the winter periods 2002/2003–2006/2007 in the Western Carpathians. Birds were surveyed on transects in natural mountain European beech (*Fagus sylvatica* L.)-Silver fir (*Abies alba* Mill.)-Norway spruce (*Picea abies* (L.) Karst.) forests of the Tatra Mts, Pieniny Mts, Babia Góra Mt. and Gorce Mts (total length 41.4 km) as well as in a habitat mosaic with Scots pine (*Pinus sylvestris* L.) and Mountain pine (*Pinus mugo* Mill.) stands in the Kotlina Orawsko-Nowotarska valley (total length 31.5 km). Birds mean density underwent annual changes from 1.9 to 15.5 ind. 10 km⁻¹ in the natural mountain forests and from 0.9 to 12.1 ind. 10 km⁻¹ in the habitat mosaic. The median flock size in the natural mountain forests was 2, and it varied from 1 to 4 in subsequent seasons. They were smaller than flocks recorded in the habitat mosaic in the valley – median 2.5 (from 2 to 7 in subsequent seasons). The size of foraging and flying flocks did not differ significantly in natural mountain forest nor in the valley habitat mosaic. In the natural mountain forests, birds preferred habitats dominated by Norway spruce, and avoided European beech-Silver fir forests. The median flock size was 2 in habitats with Norway spruce, and 8 in stands where Norway spruce was absent. The variation in bird density presumably reflected the changes in quantity and location of food resources. Birds moved within stands with varying proportions of Norway spruce in the

mountains as well as between the mountains and the valley, where habitat with mosaics of Scots pine and Mountain pine dominated.

KEY WORDS: Common Crossbill, *Loxia curvirostra*, wintering, flocking, habitat structure

1. INTRODUCTION

Habitat selection is a hierarchical process of behavioral responses that may result in the disproportionate use of habitats to influence survival and fitness of individuals (Jones 2001). Organisms choice of habitat and its use depend upon many factors – from which both inter- and intra-specific interactions and food resources availability are the basics (Sapir *et al.* 2004, Whittingham and Evans 2004). However, habitat quality change, and local populations respond either by shift the habitats they occupy or adapt to by changing their behaviour (Bylicka *et al.* 2007).

Crossbills *Loxia* sp. are bird species specialized in utilizing conifer seeds as a food source (Newton 1967, 1972). Their bill morphology is adapted to extracting seeds from cones (Benkman 1987a, 1988a). This high specialization impedes extracting seeds from anything other than conifer species

(Benkman 1988b). Depending on which part of the range they are found and the season of the year, the diet of Common Crossbills (*Loxia curvirostra* L.) varies between the seeds of various species of spruces, pines and larches (Newton 1967, Pfennig 1986, Benkman 1987a, b, Cramp and Perrins 1994). However, a major part of their diet in Europe is the seeds of Norway spruce *Picea abies* (Newton 1972). This seed crop varies annually, with years of peak production known as mast years (Białobok 1977). The mast crops are spatially diverse as well, thereby affecting bird movements (Senar *et al.* 1993, Summers 1999, Newton 2006b).

The breeding biology of the Common Crossbill is strongly influenced by the mast crop of Norway spruce. In these favourable trophic conditions birds might breed in early winter (Griscom 1937, Tordoff, Dawson 1965, Cramp and Perrins 1994, Hahn 1997). Furthermore, young birds achieve sexual maturity in their first year of life, sometimes while still in juvenile plumage (Berthold and Gwinner 1972, Jenni and Wrinkler 1994). Presumably, spruce additionally affects local density changes during mast years.

The winter ecology of Common Crossbills in the Western Carpathians, where Norway spruce occurs commonly is poorly known. The area still holds natural ecosystems, including mountain ranges covered by natural European beech *Fagus sylvatica* Silver fir *Abies alba*-Norway spruce forests as well as the neighbouring Kotlina Orawsko-Nowotarska valley with Scots pine *Pinus sylvestris* and Mountain pine *Pinus mugo* forests.

The aim of this paper is to describe Common Crossbill density changes and flock sizes in relation to the habitats used. We expected that decrease of birds density in optimal habitats (Norway spruce forests) will involve an increase of birds number in neighbouring sub-optimal habitats. Moreover, clustering of food sources within sub-optimal habitats will led to increase of flock size.

2. STUDY AREA

Natural forests of Tatra Mts, Pieniny Mts, Babia Góra Mt. and Gorce Mts are protected as national parks (Fig. 1). Each mountain range is characterized by an altitudinal pattern of vegetation communities. The lower mountain zone is covered by European beech-Silver fir forest with an admixture of

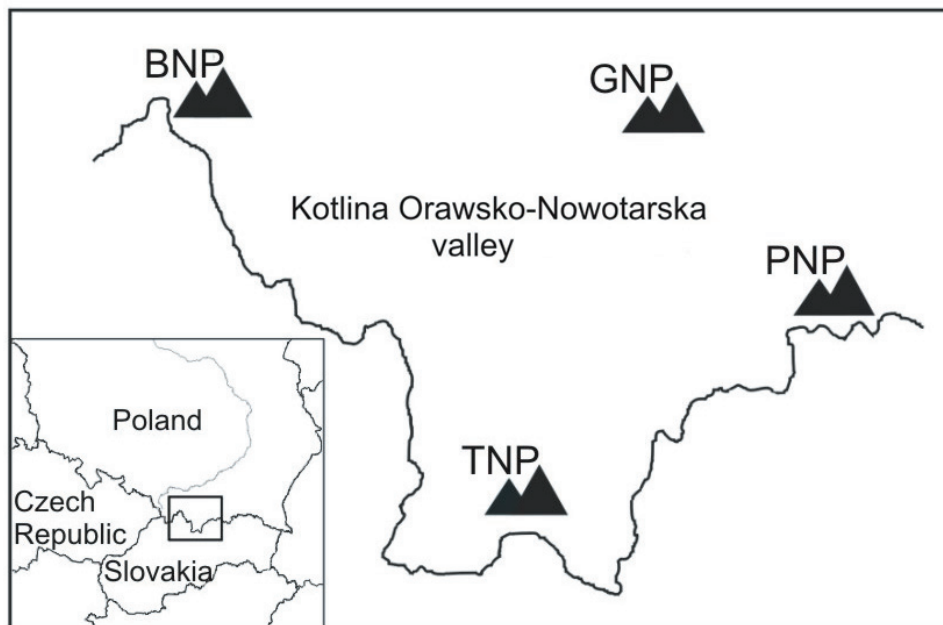


Fig. 1. Study area (BNP – Babia Góra National Park, GNP – Gorce National Park, PNP – Pieniny National Park, TNP – Tatra National Park).

other deciduous species, whereas the upper mountain zone has homogeneous Norway spruce. At higher altitudes, above tree line, non-forest communities and Mountain pine shrub occur (Pawłowski 1977). However, during winter the latter are inaccessible for birds due to thick snow cover.

The individual mountain ranges are separated by valleys, of which the Kotlina Orawsko-Nowotarska valley is centrally located (Fig. 1). Within Poland it has a surface area of approximately 370 km². The valley's floor is about 500–600 m a.s.l. and borders the above mentioned mountain ranges, which exceed 1000 m a.s.l. (Kondracki 1998). The climate of the valley is continental and differs from the neighbouring mountain ranges (Konček 1974). Under severe climatic conditions the pine forests *Calamagrostio villosae Pinetum*, as well as extensive high peat bogs overgrown with Scots pine, Mountain pine and their natural hybrid *Pinus × rhaetica* have been shaped (Pawłowski 1977). Peat bogs and pine forests, along with built-up areas and farmlands create a varied habitat mosaic, in which small forests, afforestation and clumps of trees occur.

3. METHODS

Surveys were carried out in the Western Carpathians during five winter seasons in 2002/2003 – 2006/2007 using the line transect method (Hildén *et al.* 1991). Surveys were conducted on marked transects (total length 41.4 km) in the middle of December, January and February. Transects were located in natural forests in the Gorce National Park, Babia Góra NP, Pieniny NP and Tatra NP (Fig. 1). Transects ran over different types of European beech-Silver fir-Norway spruce forests so as to reflect individual mountain range forest communities. Birds were counted within a belt 50 meters wide on each side of the transect. The observer walked at a speed of 1–3 km h⁻¹ and noted the number of birds and their flock size. The forest type where birds were first observed was classified into a habitat type, depending on the Norway spruce component of the stand. The following habitat types were distinguished: (a) mono-specific Norway spruce forests, (b) mixed forests with not less than 70% of Nor-

way spruce, (c) mixed forests with 60–40% of Norway spruce, (d) mixed forests with equal Norway spruce, Silver fir and European beech, and (e) European beech-Silver fir forests. An additional category was (f) natural deforestation – terrain where due to natural processes old Norway spruce forests were wind-damaged and some early forest successions along with single mature trees were present. The behaviour of observed birds was classified into one of the following categories: (a) foraging – birds looking for and exploiting food within the canopy or (b) flying – towards movements above the canopy.

Surveys in the Kotlina Orawsko-Nowotarska valley were carried out during October to March from 2002/2003–2004/2005. In the present paper, results of surveys conducted only in the middle of December, January and February were used. Surveys were conducted regularly on marked transects with total length 31.5 km. They were located in habitat mosaic of open areas, peat bogs and forests of Scots pine and Mountain pine between the towns of Czarny Dunajec, Piekelnik and Ludźmierz. The observer walked at a speed of 2–3 km h⁻¹ and noted flock sizes and bird behaviour (foraging or flying). A detailed description of transects is given elsewhere (Ciach *et al.* 2006).

Bird density was calculated as individuals per 10 km of transect for each month (December, January and February), and for each season as a whole. Median flock size for each month and each season was also calculated. To analyse habitat use, foraging and flying flock size in natural mountain and valleys forests, data from all months and seasons were pooled. Habitat selection was calculated using Jacobs' *D* index (Jacobs 1974):

$$D = U - A/U + A - 2U \times A \quad (1)$$

where *U* is proportion of use and *A* is proportion of availability. Values of the index range from -1, indicative of strong avoidance, to +1, indicative of strong preference, whereas values around 0 are regarded as neutral. Statistical procedures were performed using the Statistica 7.1 software (StatSoft 2005) according to Zar (1999).

4. RESULTS

4.1. Density changes

The mean density of Common Crossbills in natural mountain forests of the Western Carpathians varied from 1.9 ind. 10 km⁻¹ (2004/2005) to 15.5 ind. 10 km⁻¹ (2006/2007).

The highest intra-seasonal variation was in 2005/2006, when the density decreased from 19.9 ind. 10 km⁻¹ in January to 0.5 ind. 10 km⁻¹ in February (Fig. 2). The mean density recorded in the habitat mosaic of Kotlina Orawsko-Nowotarska valley varied from 0.9 ind. 10 km⁻¹ (2003/2004) to 12.1 ind. 10 km⁻¹ (2004/2005). The highest intra-seasonal

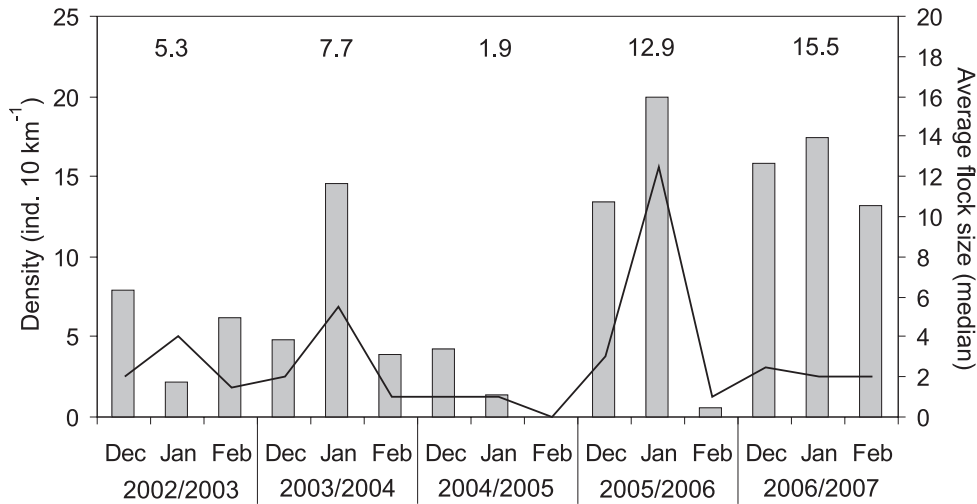


Fig. 2. Winter density (bars) and median flock size (line) of Common Crossbill *Loxia curvirostra* in natural mountain European beech *Fagus sylvatica*-Silver fir *Abies alba*-Norway spruce *Picea abies* forests of Western Carpathians (number of flocks $N_f = 114$, number of individuals $N_i = 402$, top numbers present mean density value in a given season).

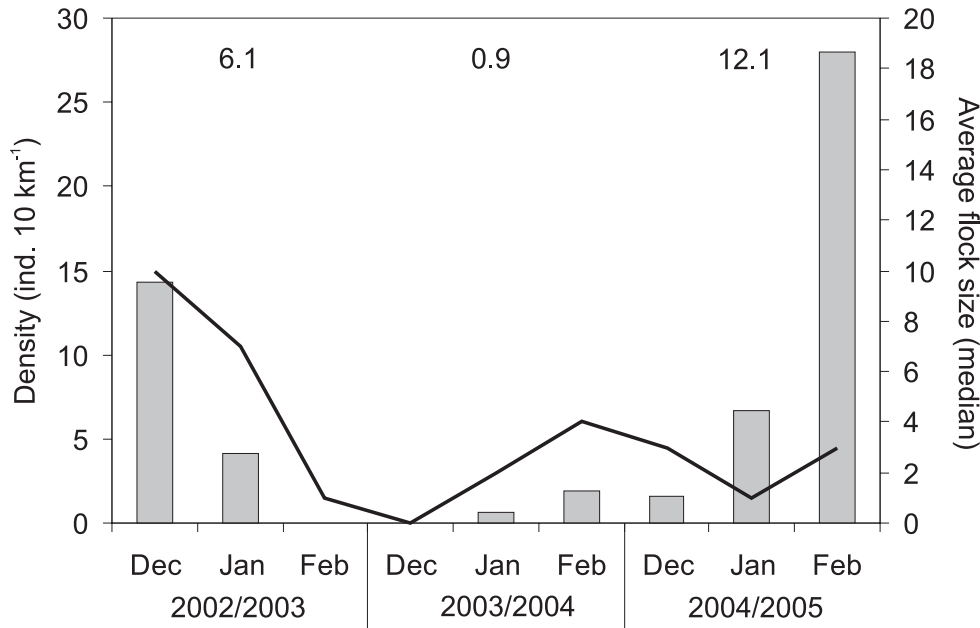


Fig. 3. Winter density (bars) and median flock size (line) of Common Crossbills *Loxia curvirostra* in habitat mosaics with Scots pine *Pinus sylvestris* and Mountain pine *Pinus mugo* in the Kotlina Orawsko-Nowotarska valley (number of flocks $N_f = 50$, number of individuals $N_i = 347$, top numbers present mean density value in a given season).

variation was recorded in 2004/2005, when the density increased from 1.6 ind. 10 km⁻¹ in December to 27.9 ind. 10 km⁻¹ in February (Fig. 3).

4.2. Flock size

The median flock size in the natural mountain forests of the Western Carpathians was 2, and in different seasons varied from 1 to 4 (Table 1). The highest intra-seasonal difference in median flock size was recorded in 2005/2006 between January (12.5) and February (1) (Fig. 2). The median flock size in the habitat mosaic of Kotlina Orawsko-Nowotarska valley was 2.5 and in different seasons varied from 2 to 7 (Table 2).

The highest intra-seasonal differences in median flock size were recorded in 2002/2003 (Fig. 3). The differences in flocks size in natural mountain forests and in the habitat mosaic of Kotlina Orawsko-Nowotarska valley were close to being statistically significant (Mann-Whitney U Test: $Z_c = -1.72$, $P = 0.086$).

In the natural mountain forests foraging flock sizes did not differ significantly from flying flock sizes (Mann-Whitney U Test: $Z_c = -0.15$, $P = 0.88$) with medians of 2 (Table 1). The same held for the habitat mosaics of the Kotlina Orawsko-Nowotarska valley (Mann-Whitney U Test: $Z_c = -0.91$, $P = 0.36$), where medians were 5 and 2.5 in foraging and flying flocks, respectively (Table 2).

Table 1. Flock sizes of foraging and flying Common Crossbills *Loxia curvirostra* recorded in natural mountain European beech *Fagus sylvatica*-Silver fir *Abies alba*-Norway spruce *Picea abies* forests of the Western Carpathians (N_r – number of flocks, N_i – number of individuals).

Season	All flocks				Foraging flocks				Moving flocks			
	Nr	Ni	Median (quartiles)	Range	Nr	Ni	Median (quartiles)	Range	Nr	Ni	Median (quartiles)	Range
2002/2003	23	64	2 (1; 3.5)	1–13	4	22	4 (2.5; 7)	1–13	12	31	2 (1.75; 3.25)	1–5
2003/2004	20	62	2 (1; 3)	1–15	6	17	1.5 (1; 2.75)	1–9	11	42	2 (1.5; 3.5)	1–15
2004/2005	10	17	1 (1; 1.75)	1–6	1	1	1	1	8	15	1 (1; 2)	1–6
2005/2006	13	107	4 (1; 14)	1–35	6	72	7.5 (4.25; 14.5)	2–35	5	19	1 (1; 2)	1–14
2006/2007	48	152	2 (1; 4)	1–13	22	61	2 (1; 2.75)	1–13	20	80	3.5 (2; 5.25)	1–12
Total	114	402	2 (1; 4)	1–35	39	173	2 (1; 4.5)	1–35	56	187	2 (1; 4)	1–15

Table 2. Flock sizes of foraging and flying Common Crossbills *Loxia curvirostra* recorded in habitat mosaic with Scots pine *Pinus sylvestris* and Mountain pine *Pinus mugo* in the Kotlina Orawsko-Nowotarska valley (symbols as in Table 1)

Season	All flocks				Foraging flocks				Moving flocks			
	Nr	Ni	Median (quartiles)	Range	Nr	Ni	Median (quartiles)	Range	Nr	Ni	Median (quartiles)	Range
2002/2003	9	74	7 (1; 8)	1–34	3	13	5 (3; 6)	1–7	5	60	8 (7; 10)	1–34
2003/2004	7	19	2 (1.5; 4)	1–5	3	10	3 (2.5; 4)	2–5	2	3	1.5 (1.25; 1.75)	1–2
2004/2005	34	254	2 (1; 6)	1–62	5	115	7 (3; 42)	1–62	23	131	2 (1; 6)	1–50
Total	50	347	2.5 (1; 6.75)	1–62	11	138	5 (2.5; 7)	1–62	30	194	2.5 (1; 7)	1–50

4.3. Relationship between flock size and density

The median flock size in the natural mountain forests changed significantly along with density (Pearson's correlation coefficient: $r = 0.64$, $P = 0.011$) (Fig. 4). An exception occurred in 2006/2007 season, when the high density of $15.5 \text{ ind. } 10 \text{ km}^{-1}$ was associated with an average flock size of 2. The median flock size in the valley habitat mosaic did not change significantly along with birds density (Pearson's correlation coefficient: $r = 0.26$, ns), except for February 2004/2005, when the high density of $27.9 \text{ ind. } 10 \text{ km}^{-1}$ was associated with a median flock size of 2. After excluding the data from this month, the relationship between median flock size and bird density was significant (Pearson's correlation coefficient: $r = 0.82$, $P = 0.013$) (Fig. 4). In addition, with equal density, regression lines indicate that flocks recorded in habitat mosaic of the Kotlina Orawsko-Nowotarska valley were distinctly bigger than those recorded in natural mountain forests.

4.4. Forest habitats use

In the natural mountain forests, 55% of Common Crossbill flocks ($N = 100$) were recorded in mono-specific Norway spruce forests. In mixed forests, with a varying proportion of Norway spruce, the percentage of flocks was *ca.* 10%. However, only 5% of flocks occurred in European beech-Silver fir forests without Norway spruce (Table 3). Common Crossbill preferred habitats dominated by Norway spruce as well as natural deforestations, where single mature Norway spruces were still present. Moreover, birds selected mixed forests with equal Norway spruce, Silver fir and European beech, but avoided European beech-Silver fir forests without Norway spruce (Table 3). The median flock size in habitat types with Norway spruce was 2, and in European beech-Silver fir forests it was 8. The differences in flocks size in habitat types with and without Norway spruce were close to being statistically significant (Mann-Whitney U Test: $Z_c = 1.94$, $P = 0.052$).

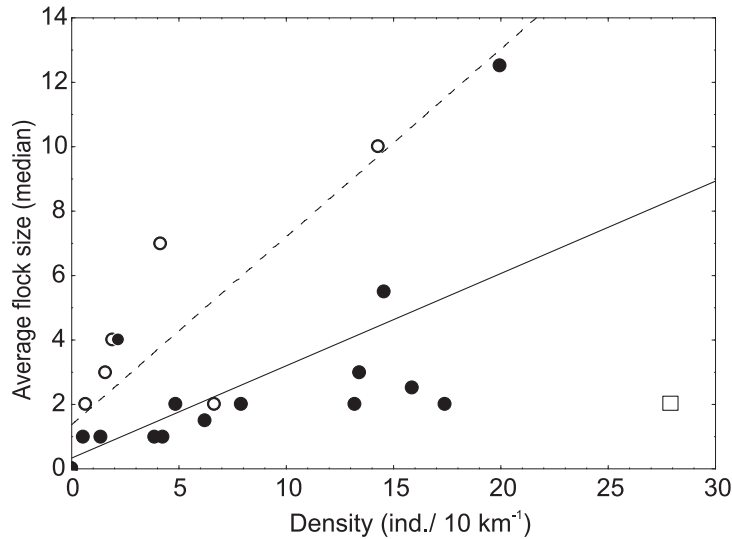


Fig. 4. Relations between median flock size and density of Common Crossbill *Loxia curvirostra* recorded in natural mountain European beech *Fagus sylvatica*-Silver fir *Abies alba*-Norway spruce *Picea abies* forests of the Western Carpathians (fill circles and solid line; $r = 0.64$, $P = 0.011$, $y = 0.34 + 0.29x$) and in habitat mosaic with Scots pine *Pinus sylvestris* and Mountain pine *Pinus mugo* stands of Kotlina Orawsko-Nowotarska valley (open circles and dashed line; $r = 0.82$, $P = 0.013$, $y = 1.37 + 0.58x$, square – excluded data from February 2004/2005).

Table 3. Habitat use and selection by Common Crossbills *Loxia curvirostra* in natural mountain European beech *Fagus sylvatica*-Silver fir *Abies alba*-Norway spruce *Picea abies* forests of Western Carpathians (symbols as in Table 1). Jacobs' *D* index of habitat selection see formula (1).

Forest type	Nr	%	Ni	%	Median flock size (quartiles)	Range	Jacobs' <i>D</i> index
Mono-specific Norway spruce forests	55	55	201	53.6	2 (1; 3.5)	1–35	0.23
Mixed forests with not less than 70% Norway spruce	12	12	37	9.9	2 (1; 4.25)	1–10	–0.08
Mixed forests with 60–40% Norway spruce	10	10	42	11.2	2 (2; 4.75)	1–15	–0.02
Mixed forests with equal Norway spruce, Silver fir and European beech	11	11	33	8.8	2 (1; 3)	1–13	0.28
European beech–Silver fir forests	5	5	36	9.6	8 (2; 9)	2–15	–0.70
Natural deforested areas	7	7	26	6.9	1 (1; 4.5)	1–13	0.43
Total	100	100	375	100		1–35	

5. DISCUSSION

Failure in the seed crop of Norway spruce coupled with high numbers of birds is the main cause of large-scale nomadic movements of Common Crossbills (Reinikainen 1937, Summers 1999, Newton 2006a, b). Their movements occur in summer, when birds leave areas with exhausted food resources, in search of other Norway spruce or other conifer seed crops. In other periods only short movements occur, in relation to local changes in food accessibility (Newton 2006b). Common Crossbills searching for local Norway spruce seeds perform in the Western Carpathians only short-distance movements, although they probably occurred between different mountain ranges. When the Norway spruce crop fails Scots pine and Mountain pine seeds are used and birds move between mountain ranges and Kotlina Orawsko-Nowotarska valley, which offered a rich source of pines seeds. Crossbills looking for favourable food resources move along regular migration routes leading

to significant changes in bird density (Newton 2006a). In the 2004/2005 season, crossbills left natural mountain forests at the end of winter, moving towards Kotlina Orawsko-Nowotarska valley.

Food sources in natural mountain forests and in the habitat mosaics of valleys are ephemeral in character. Common Crossbill using relatively stable food sources – like pine seeds – are considered to be resident (Senar *et al.* 1993). However, abundance changes in Kotlina Orawsko-Nowotarska valley show that Scots pine and Mountain pine occurred there do not provide a stable and preferred food base. Newton (2006b) pointed that only some of the birds stayed temporarily in pine forests while searching for other food sources. However, in years with Norway spruce seeds crop failure, birds use Scots pine and Mountain pine seeds (2004/2005 season), with probable breeding attempts in pine stands.

Common Crossbill density increased at the beginning of winter due to an influx of migrants and decreased as winter pro-

gressed (Marquiss and Rae 1994). High density recorded in natural mountain forests in the entire 2006/2007 season suggested that 2006 was a mast year for Norway spruce. In other years, at the beginning of the breeding season (February) bird abundance decreased as few birds remained in years of spruce crop failure.

Common Crossbills flock sizes are mainly determined by seed accessibility and distribution (Benkman 1987b, 1990). Decrease of food accessibility leads to flocking behaviour, which facilitates food finding and reduces predation risk (Benkman 1997). Differences in the spatial distribution of food sources within forests and habitat mosaics, which are the direct result of landscape structure and tree species composition in the Western Carpathians underlie flocking strategies. Bigger flock sizes in the habitat mosaics of the Kotlina Orawsko-Nowotarska valley than in natural mountain forests resulted from clustering of food sources within the valley. Differences in flock size were also recorded within natural mountain forests, where birds using stands without Norway spruce formed bigger flocks than those with. However, flocking into large groups leads to intra-specific competition – increase of aggression and decrease of foraging rate (Benkman 1997). In natural mountain forests, flocking into large groups is unprofitable in stands with Norway spruce, where food sources are evenly spread. The same may apply during mast years, when food searching does not require much time. Then groups of two birds become the optimal foraging flock size (Benkman 1988c), as recorded in 2006/2007 in natural mountain forests.

Large-scale modification of the environment is known to have the impact on life-history traits of European birds species (Martin and Clobert 1996). Extensive environmental transformations – deforestation and changes in tree species communities – might change Common Crossbills flocking and migration behaviour. Simple, mono-specific coniferous forests, which are remotely located over highly deforested Europe might lead to massive Crossbills departures in specific species crop failure years (Newton 2006b). On the other hand, a mosaic of diverse forest

habitats might eliminate the need for mass departures. The natural character of mountain forests, and the existence of habitat mosaics with high peat bogs covered by Scots pine and Mountain pine in neighbouring valleys, still present in the Western Carpathians, allow the local population of Common Crossbills to persist there year after year. Birds in natural mountain forests of the temperate zone might not show such strong tendency to long-distance eruptive movements when different coniferous forests are present within a relatively small area.

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