EKOLOGIA POLSKA (Ekol. pol.)	37	1–2	157–178	1989

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ENERGY FLOW THROUGH BREEDING BIRD COMMUNITIES OF SELECTED HABITATS OF THE AGRICULTURAL LANDSCAPE *

ABSTRACT: Quantitative studies of breeding avifauna have been conducted in eight sample areas delimited in different habitats of the agricultural landscape of the region of Toruń (crop fields, tree-lined field roads, village area, forest-adjoining fields). The results show great variation in the breeding bird communities of the habitats under study. The number of species ranged from 2 to 32, and the density from 5.3 to 215.6 pairs $\cdot$ 10 ha^{-1}. On the basis of the results of quantitative studies estimates have been made of the energy flow through the bird communities (assimilation), as well as of the remaining elements of their energy balance: respiration, production, consumption and excreta.

KEY WORDS: Agrocenosis, breeding bird communities, density, energy balance.

1. INTRODUCTION

The commonest land ecosystems are agroecosystems. They cover 33.6% of the land surface, exceeding slightly the percentage of forest environments (R o c z n i k Statystyczny 1983). In spite of this, there is insufficient information on agroecosystems. Particularly scarce, compared with the state of information on forest ecosystems, is the knowledge of biocenotic processes. One of the causes of this state of affairs is the insufficient amount of data from basic research. This refers also to the studies of ornithofauna. In Poland, the biology of some bird species inhabiting the agricultural landscape has been studied in some detail. Examples of this are publications concerning *Passer domesticus* (L.) and *P. montanus* (L.) (Ł ą c k i 1959, 1962, P i n o w s k i 1966, 1967a, 1967b, 1968, G r a c z y k et al. 1968, P i n o w s k i and W ó j c i k 1969, W i e l o c h and F r y s k a 1975), *Sturnus vulgaris* L. (M i c h o c k i 1965, G r o m a d z k i 1969, 1979, 1980, B o g u c k i 1977),

* This study was financially supported under projects MR II/23 and CPBP 01.10.03.

Corvus frugilegus L. (P i n o w s k i 1956, 1959, D y r c z 1966) and *Perdix perdix* (L.) (O k o and W ó j t o w s k i 1960, O k o 1963). Much less work has been done on breeding bird communities and their groupings outside the breeding season. Breeding birds of field groves have been studied among others by C z a r n e c k i (1956, 1959), F o k s o w i c z and S o k o ł o w s k i (1956), R i a b i n i n (1957) and G r o m a d z k i (1970). In a small number of publications there can be found some data on birds of village buildings (e.g. S i k o r a 1966, T o m i a ł o j ć 1970, K u ź n i a k 1978). The smallest number of papers, however, have been devoted to the avifauna of crop fields (e.g. J a b ł o ń s k i 1964, K u ź n i a k 1978). Also there is only very perfunctory knowledge of the groupings of birds inhabiting these habitats outside the breeding season (J a b ł o ń s k i 1972, G ó r s k i 1976). In Polish literature there are no data whatsoever on the bioenergetics of whole bird communities inhabiting agroecosystems.

The objective of the studies whose results have been presented in this paper was to establish the species composition, dominance structure and density of the breeding bird communities of selected environments of the agricultural landscape of the environs of Toruń. Another objective was to determine the amount of energy flowing through these communities, and to work out an energy balance for them.

2. STUDY AREA

The studies were conducted in a farming area in the territorial division Łysomice, adjoining Toruń. Eight sample areas were delimited (a total of 113.0 ha) concentrated round two villages lying about 9 km apart, Papowo Toruńskie and Piwnice (Fig. 1). Three areas located near Papowo Toruńskie lay in a vast area under crop, and the five other ones were situated along the border line between crop fields and a large forest area (environs of Piwnice). All of them were at 4 – 5 km distance from the northern administrative boundary of Toruń.

The sample areas represented different elements of the agricultural landscape: crop fields, tree-lined field roads, villages and a forest adjoining the crop fields. Area A included a field of the Experimental Agricultural Station of Copernicus University at Koniczynka (35.2 ha) lying east of Papowo Toruńskie. The field was planted with wheat "Grana" (spring variety). The area represented a habitat characteristic of the large field farming style of state farms (PGR).

Area B was a complex of small crop fields belonging to individual farmers (28.0 ha) and was situated south of Kolonia Papowska. It consisted of 20 small fields from 0.26 to 3.25 ha in area. The predominant crops growing in them were barley and rye (9 fields slightly exceeding 50% of the total area). The remaining fields were under wheat, sugar beats, peas, alfalfa, oats, clover, flax and poppy. This area represented a mosaic of many crops, characteristic of individual farms.

Area C was delimited in a field of the Experimental Agricultural Station at Piwnice planted with barley (26.6 ha). The southern part of this area bordered on the forest, and

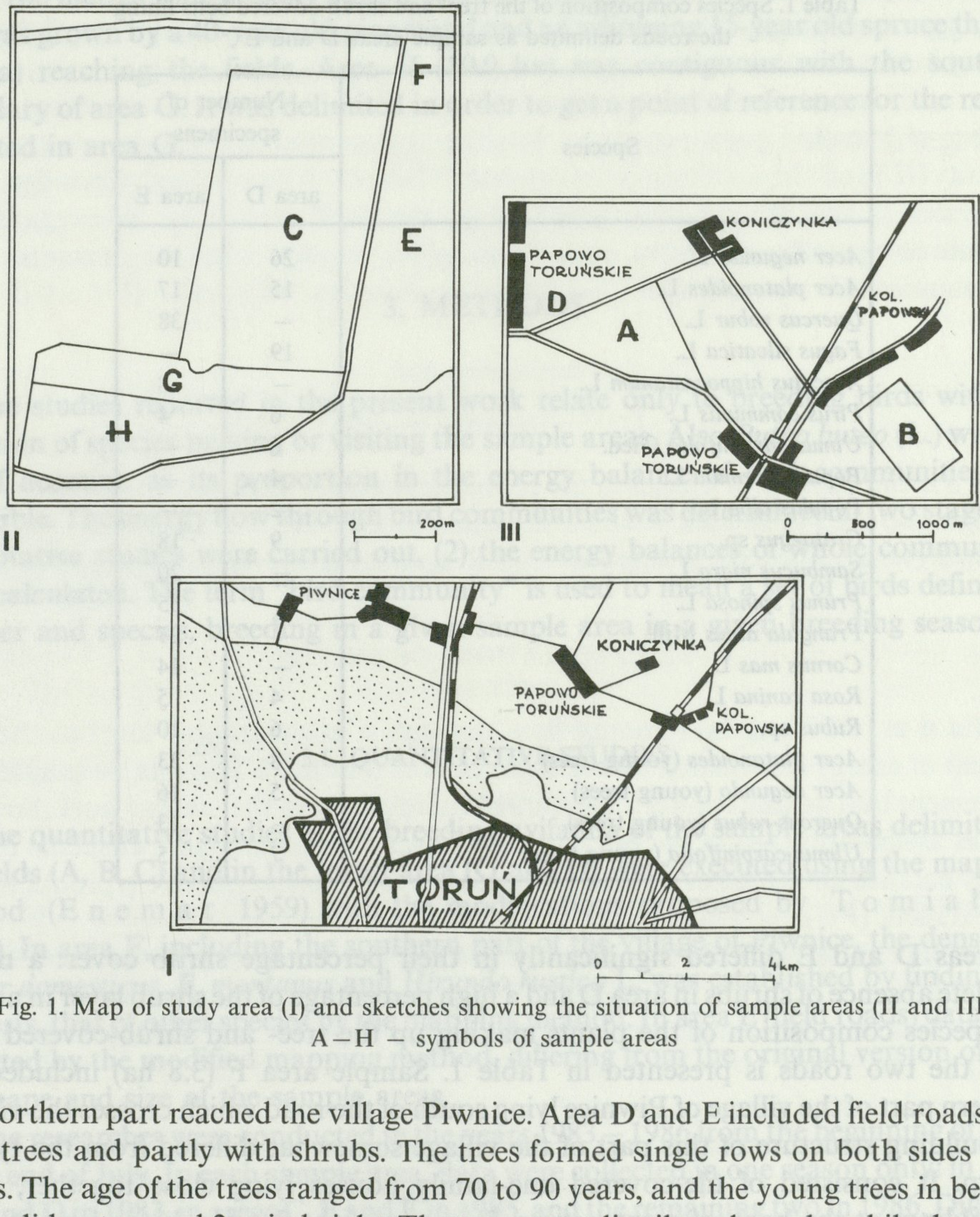

Fig. 1. Map of study area (I) and sketches showing the situation of sample areas (II and III)
A – H – symbols of sample areas

the northern part reached the village Piwnice. Area D and E included field roads lined with trees and partly with shrubs. The trees formed single rows on both sides of the roads. The age of the trees ranged from 70 to 90 years, and the young trees in between them did not exceed 2 m in height. The trees were distributed evenly, while the shrubs formed large clumps.

Area D was a 870-m long section of the road connecting Papowo Toruńskie with Koniczynka. It adjoined the northern part of area A. The road together with the two tree-covered belts was 15 m in width and 1.3 ha in area. The road was lined with trees over its whole length, while shrubs grew only along its western 50-m long end. The tree lines consisted mainly of *Acer negundo* L., *Fagus silvatica* L. and *Acer platanoides* L.

Area E (1.36 ha) was a field road 680 m long and 15 m wide. It connected the village Piwnice with a nearby forest. Trees grew on both sides of the road, and along its southern (350 m long) section there were also dense shrubs. The predominant tree species were *Quercus robur* L., *Acer platanoides* and *Acer negundo*. The road constituted the eastern boundary of area C.

Table 1. Species composition of the tree- and shrub-covered belts lining the roads delimited as sample areas D and E

Species	Number of specimens	
	area D	area E
Acer negundo L.	26	10
Acer platanoides L.	15	17
Quercus robur L.	–	38
Fagus silvatica L.	19	–
Aesculus hippocastanum L.	–	8
Pirus communis L.	6	4
Ulmus carpinifolia Gled.	6	–
Populus tremula L.	4	–
Populus alba L.	2	–
Crataegus sp.	9	18
Sambucus nigra L.	–	20
Prunus spinosa L.	–	35
Frangula alnus Mill.	–	27
Cornus mas L.	–	14
Rosa canina L.	4	5
Rubus sp.	6	10
Acer platanoides (young trees)	8	33
Acer negundo (young trees)	5	16
Quercus robur (young trees)	–	13
Ulmus carpinifolia (young trees)	7	5

Areas D and E differed significantly in their percentage shrub cover: a nearly complete absence of shrubs in area D and a high percentage of the shrub layer in area E. The species composition of the plants making up the tree- and shrub-covered belts along the two roads is presented in Table 1. Sample area F (3.8 ha) included the southern part of the village of Piwnice lying south of the road which crosses the village. The building structure of this part of the village somewhat differed from the typical pattern. It consisted of tile-covered one-family houses lying close together, small outbuildings at the back of most houses, four new eight-flat blocks and one typical farmstead (farmhouse, cow-shed and barn). Next to the outbuildings were vegetable gardens with some fruit bushes and a small number of fruit trees. Areas G and H were delimited in the northern part of the already mentioned forest area adjoining crop fields. It was grown by 87 and 90-year old Pino-Quercetum. The moderately close treestand consisted of *Pinus silvestris* L. (80 – 85%) and *Quercus robur* (15 – 20%). They were accompanied by *Carpinus betulus* L., *Betula verrucosa* Ehrh., *Ulmus carpinifolia* Gled., and in places also by *Alnus glutinosa* Gaertn. A comparatively large number of trees had hollows in the trunks, mostly chopped out by woodpeckers. The well developed undergrowth layer was made up mainly of *Corylus avellana* L., *Frangula alnus* Mill., *Sambucus nigra* L., to a lesser extent of young trees of *Carpinus betulus* and *Quercus robur*, as well as *Evonymus europaea* L. and *Rubus* sp. Area G (6.2 ha) was a belt about 100 metres wide directly adjoining crop fields (it bordered on area C). Its eastern part was grown by a 40-year old pine stand and an adjoining 15-year old spruce thicket (0.5 ha) reaching the fields. Area H (10.9 ha) was contiguous with the southern boundary of area G. It was delimited in order to get a point of reference for the results collected in area G.

3. METHODS

The studies reported in the present work relate only to breeding birds with the exclusion of species passing or visiting the sample areas. Also *Buteo buteo* (L.) was left out of account, as its proportion in the energy balance of bird communities was negligible. The energy flow through bird communities was determined in two stages: (1) quantitative studies were carried out, (2) the energy balances of whole communities were calculated. The term "bird community" is used to mean a set of birds defined in number and species, breeding in a given sample area in a given breeding season.

3.1. QUANTITATIVE STUDIES

The quantitative studies of the breeding avifauna of the sample areas delimited in the fields (A, B, C) and in the forest area (G and H) were executed using the mapping method (E n e m a r 1959) with the modifications proposed by T o m i a ł o j ć (1968). In area F, including the southern part of the village of Piwnice, the density of *Passer domesticus*, *P. montanus* and *Hirundo rustica* L. was established by finding out the nests, that of other species by the mapping method. In area E (field roads) data were collected by the modified mapping method, differing from the original version only in the shape and size of the sample areas.

The researches were conducted in the years 1983 – 1986 from the beginning of April to the end of July. In each sample area, data were collected in one season only: in areas A, B and D in 1983, in areas C, E and F in 1985, and the remaining two in 1986. Different numbers of censuses were executed in the particular areas: in areas A, B and D – 8, in C and E – 10, in F – 7. In area F the nests of *Passer domesticus*, *P. montanus* and *Hirundo rustica* were counted (25 V 1985). Areas G and H were treated as a whole, and one common count was made for them; in analysing the results, however, they were presented separately for each area. The species with large breeding territories distributed in both sample areas (*Cuculus canorus* L., *Garrulus glandarius* L.) were included in the bird communities of either area. Their densities were estimated taking into account the joint area of G and H. A total of 11 censuses (including two evening ones) were carried out, as well as three additional ones along the border between field and forest. The density of *Sturnus vulgaris* was established by searching out nests (1 VI 1986).

As a criterion of breeding in all the sample areas was adopted the finding of a nest with eggs or nestlings, traces of feeding the young and three recordings of the male singing in the same place.

In analysing the results of field counts, the birds density was expressed by the number of breeding pairs per 10 ha. For the bird communities under study species diversity (H') and the coefficient of evenness (J') have been determined. Considering the differences in size among the sample areas, the coefficients were not regarded as absolute comparative measures, but only as values characterizing the structures of the communities. H' was calculated according to Schanon's formula (Lloyd et al. 1968):

$$H' = \sum_{i=1}^{S} p_i \log_2 p_i$$

where S is the number of species in the community and p_i – the fraction of individuals belonging to the i-th species. J' was established using the formula given by Pielou (1966): $J' = H' \cdot (\log_2 S)^{-1}$, where H' and S denote the above parameters.

3.2. CALCULATIONS OF ENERGY

Odum (1977) defines energy flow through a given trophic level as the total amount of energy assimilated by the organisms of that level. This can be simplified to a statement that assimilation is a measure of energy flow. In the present work, however, besides assimilation (A) of the bird communities also the remaining elements of their energy balance have been established: respiration (R), consumption (C), production (P) and excrecta (FU).

The energy balances of whole multispecies bird communities have been obtained by summing up A, R, P, C and FU of the populations of individual species. The calculations of these elements have been based on formulae adopted by Alatalo (1978).

Assimilation of the population of each species was calculated as the total of four sections (separate formulae for passerine and non-passerine birds):

1. EMR – energy necessary to support metabolism (so-called existence energy) (in $\mathrm{kJ \cdot ha^{-1} \cdot season^{-1}}$)

passerines

$$EMR = \left[\sum_{i=1}^{L} (4.3372 \cdot W^{0.5300} - (0.14457 \cdot W^{0.5300} - 0.05240 \cdot W^{0.6210}) \cdot t_i) \right] \cdot 2 \cdot D \cdot \mathrm{q}$$

non-passerines

$$EMR = \left[\sum_{i=1}^{L} (4.3372 \cdot W^{0.5300} - (0.14457 \cdot W^{0.5300} - 0.01801 \cdot W^{0.7545}) \cdot t_i) \right] \cdot 2 \cdot D \cdot \mathrm{q}$$

where W – body weight of bird (for species in which the body weights of the male and the female are different, separate calculations were made for males and for females using the above formulae (without using multiplier 2), and the results were added together, D – coefficient of density (breeding pairs $\cdot$ ha^{-1}), t_i – mean daily temperature of the i-th day of the birds' stay in a given area (°C), L – number of days the birds stayed in the sample area, q – coefficient converting calories to joules (q = 4.1868).

2. $EACT$ – energy used for activities other than existence metabolism (e.g. flight) (in kJ $\cdot$ ha^{-1} $\cdot$ season^{-1})

passerines

$$EACT = \left[0.40 \cdot (1.5720 \cdot W^{0.6210})\right] \cdot 2 \cdot D \cdot L \cdot \mathrm{q}$$

non-passerines

$$EACT = \left[0.40 \cdot (0.5404 \cdot W^{0.7545})\right] \cdot 2 \cdot D \cdot L \cdot \mathrm{q}$$

where notation of variables as in section 1.

3. EBR – energy used by adult birds to supply increased activity connected with breeding (e.g. egg laying and hatching, territorial behaviour, feeding the young) (in kJ $\cdot$ ha^{-1} $\cdot$ season^{-1})

passerines

$$EBR = \left[0.20 \cdot (1.5720 \cdot W^{0.6210})\right] \cdot 2 \cdot D \cdot F \cdot M \cdot \mathrm{q}$$

non-passerines

$$EBR = \left[0.20 \cdot (0.5404 \cdot W^{0.7545})\right] \cdot 2 \cdot D \cdot F \cdot M \cdot \mathrm{q}$$

where M – number of days during which the birds were preoccupied with breeding (beginning of laying – termination of breeding, i.e. 5–15 days after the young have left the nest), F – mean number of broods reared by a pair of birds in the period studied. The remaining variables as in section 1.

4. $EJUV$ – energy assimilated by the nestlings (in kJ $\cdot$ ha^{-1} $\cdot$ season^{-1})

$$EJUV = (5.2 \cdot P) \cdot \mathrm{d}$$

P is production; it was calculated according to the formula:

$$P = (1.8 \cdot W - 1.05 \cdot Z) \cdot D \cdot K \cdot F \cdot S \cdot \mathrm{q} \quad (\mathrm{kJ} \cdot \mathrm{ha}^{-1} \cdot \mathrm{season}^{-1})$$

where: Z – mean weight of eggs, K – mean number of eggs in the brood, S – breeding success (75% in hole-nesters and 60% in others), d – coefficient of digestive efficiency, whose value was accepted generally to be 0.75 (Weiner and Głowaciński 1975). The remaining variables as in section 1 and 3.

The results of the calculations executed according to the above formulae were added up to obtain the values of assimilation (A) for the populations of the particular species: $A = EMR + EACT + EBR + EJUV$. Respiration ($R$) was determined as the difference of assimilation (A) and production (P): $R = A - P$. Consumption (C) was determined as the quotient of assimilation and the coefficient of digestive efficiency (d = 0.75): $C = A \cdot \mathrm{d}^{-1}$. In the balance excreta (FU) were also taken into account, their energy value being determined as the difference of consumption and assimilation: $FU = C - A$.

The totals of A, R, P, C and FU calculated for the particular species populations are the energy balances of the whole communities. The calculations of energy balances of the bird communities from all the sample areas covered the period from April 1st to July 31st. In calculating the standard metabolism the author used data on mean daily temperatures supplied by the Institute of Meteorology and Water Management in Toruń (the distance between the sample areas and the point where the measurements were taken did not exceed 7 km). The data, necessary for calculations, on the birds body weight, the number of broods, the number of eggs in a brood, the weight of eggs and the duration of egg hatching and feeding the young have been taken from literature (Szczepski and Kozłowski 1953, Ferens 1967, 1971, Bogucki 1977). The calculations have been made on a microcomputer ZX SPECTRUM.

4. RESULTS AND DISCUSSION

The results of quantitative studies of the breeding avifauna of selected habitats of the agricultural landscape have been listed in Tables 2–6. There were considerable differences among the bird communities of the particular sample areas. They showed different species compositions, different numbers of species (from 2 to 32) and a high dispersion of density coefficients (from 5.3 to 215.6 pairs $\cdot$ 10 ha^{-1}).

Table 2. Structure of bird communities of the sample areas S — number of species, D — density of breeding pairs, SC — standing crop

Symbol of sample area	Size of area ha	Year of study	S	D pairs $\cdot$ 10 ha^{-1}	SC g $\cdot$ ha^{-1}	SC kJ $\cdot$ ha^{-1}	H'	J'
A	35.2	1983	5	8.9	71.7	570	1.6	0.69
B	28.0	1983	5	11.2	96.5	767	1.5	0.65
C	26.6	1985	2	5.3	34.2	272	0.4	0.37
D	1.3	1983	8	92.4	555.8	4421	2.9	0.97
E	1.0	1985	11	215.6	1007.9	8019	3.4	0.97
F	3.8	1985	7	165.9	673.7	5359	1.9	0.69
G	6.2	1986	32	126.5	1225.1	9747	4.7	0.93
H	10.9	1986	28	87.4	848.9	6751	4.0	0.83

By far the smallest number of species and the lowest density were recorded for the communities inhabiting the areas in crop fields. In area A (field under wheat) and B (a mosaic of many different crops) the communities were made up of five species, the dominants being *Alauda arvensis* L., *Motacilla flava* L. and *Saxicola rubetra* (L.) (Table 3). In area C only two nesting species were found, *A. arvensis* and *S. rubetra*. It is difficult to determine explicitly what factors contributed to such a low number of breeding species. Area C differed from the other two in the first place in directly

Table 3. Breeding bird communities of sample areas delimited in crop fields — coefficient of density, dominance and energy parameters of particular species
D — density of breeding pairs, $D\%$ — dominance, SD — standing crop, A — assimilation, R — respiration, P — production, C — consumption, FU — excreta

Study area	Species	D	$D\%$	SC		A	R	P	C	FU
		pairs per 10 ha	%	$g \cdot ha^{-1}$	$kJ \cdot ha^{-1}$	$MJ \cdot ha^{-1} \cdot season^{-1}$				
A	*Alauda arvensis* L.	4.3	48.4	28.8	229	14.50	14.01	0.49	19.33	4.83
	Motacilla flava L.	3.4	38.7	11.9	95	6.54	6.42	0.12	8.72	2.18
	Saxicola rubetra (L.)	0.6	6.5	2.1	17	1.12	1.09	0.03	1.49	0.37
	Perdix perdix (L.)	0.3	3.2	25.7	204	6.71	5.85	0.86	8.95	2.24
	Emberiza calandra L.	0.3	3.2	3.2	25	1.35	1.30	0.05	1.80	0.45
	Total 5 species	8.9	100.0	71.7	570	30.22	28.67	1.55	40.29	10.07
B	*Alauda arvensis*	6.8	61.3	45.5	362	22.95	22.18	0.77	30.60	7.65
	Motacilla flava	2.9	25.8	10.1	80	5.57	5.46	0.11	7.43	1.86
	Saxicola rubetra	0.7	6.5	2.4	19	1.31	1.28	0.03	1.75	0.44
	Perdix perdix	0.4	3.2	34.3	273	8.97	7.83	1.14	11.96	2.99
	Emberiza calandra	0.4	3.2	4.2	33	1.79	1.72	0.07	2.39	0.60
	Total 5 species	11.2	100.0	96.5	767	40.59	38.47	2.12	54.13	13.54
C	*Alauda arvensis*	4.9	92.9	32.8	261	16.48	15.92	0.56	21.97	5.49
	Saxicola rubetra	0.4	7.1	1.4	11	0.74	0.72	0.02	0.99	0.25
	Total 2 species	5.3	100.0	34.2	272	17.22	16.64	0.58	22.96	5.74

Table 4. Breeding bird communities of sample areas including tree-lined field roads – coefficients of density, dominance and energy parameters of particular species. Explanations as in the Table 3

Study area	Species	D	D%	SC		A	R	P	C	FU
		pairs/ /10 ha	%	g · ha^{-1}	kJ · ha^{-1}	MJ · ha^{-1} · season^{-1}				
D	*Strunus vulgaris* L.	15.4	16.7	245.8	1955	65.65	63.01	2.64	87.53	21.88
	Passer montanus (L.)	15.4	16.7	69.3	551	45.50	43.28	2.22	60.67	15.17
	Fringilla coelebs L.	15.4	16.7	63.8	508	36.88	36.07	0.81	49.17	12.29
	Emberiza hortulana L.	15.4	16.7	77.0	613	31.84	31.18	0.66	42.45	10.61
	Motacilla alba L.	7.7	8.3	33.1	263	20.31	19.62	0.69	27.08	6.77
	Sylvia communis Lath.	7.7	8.3	25.4	202	12.83	12.51	0.32	17.11	4.28
	Parus caeruleus L.	7.7	8.3	16.9	134	14.29	13.67	0.62	19.05	4.76
	Carduelis carduelis (L.)	7.7	8.3	24.5	195	15.35	15.12	0.23	20.47	5.12
	Total 8 species	92.4	100.0	555.8	4421	242.65	234.46	8.19	323.53	80.88
E	*Passer montanus*	29.4	13.6	132.3	1052	86.66	82.42	4.24	115.55	28.89
	Fringilla coelebs	29.4	13.6	121.7	968	70.22	68.67	1.55	93.63	23.41
	Emberiza citrinella L.	29.4	13.6	169.3	1347	94.89	90.91	3.98	126.52	31.63
	Parus caeruleus	19.6	9.1	43.1	343	36.28	34.96	1.59	48.37	12.09
	Serinus serinus (L.)	19.6	9.1	48.6	387	32.52	31.90	0.62	43.36	10.84
	Carduelis chloris (L.)	19.6	9.1	103.8	826	60.13	57.67	2.46	80.17	20.04
	Carduelis carduelis	19.6	9.1	62.3	496	38.94	38.34	0.60	51.92	12.98
	Emberiza hortulana	19.6	9.1	98.0	780	40.01	39.17	0.84	53.35	13.34
	Sturnus vulgaris	9.8	4.5	156.4	1244	41.36	39.68	1.68	55.15	13.79
	Sylvia borin (Bodd.)	9.8	4.5	40.1	319	17.45	17.02	0.43	23.27	5.82
	Sylvia communis	9.8	4.5	32.3	257	16.12	15.71	0.41	21.49	5.37
	Total 11 species	215.6	99.8	1007.9	8019	534.58	516.18	18.40	712.78	178.20

adjoining a large forest area and in the kind of crop (barley). Out of the three field habitats the highest density was found in area B (11.2 pairs $\cdot$ 10 ha^{-1}). In area A it was more than 20% lower (8.9 pairs $\cdot$ 10 ha^{-1}), and the lowest density was found in area C (5.2 pairs $\cdot$ 10 ha^{-1}). It follows from the above data that a diversified structure of crops (like that in area B) favours the settlement in such habitats of a larger number of breeding pairs. This conclusion is also supported by the differences in density of *Alauda arvensis* (Table 3). This is in line with the conclusions of Wasilewski (1967), who conducted studies in forest environments. He also demonstrated that the whole bird community grows in numbers proportionately to the increase in the diversity of the habitat. The very low density of avifauna in area C is due to the vicinity of the forest. A 150 to 200 m wide zone along the forest edge was completely uninhabited by birds, which of course affected the total density of the community. The fact that species of open spaces avoid areas bordering on forests has already been pointed out by Pinowski (1954). This phenomenon is probably due to two factors: strong pressure of predators and high competition for food. Parts of fields directly adjoining forests are intensively penetrated by forest predatory mammals, which for birds may constitute a barrier to colonizing these areas. The small chance of rearing the brood may have led in species nesting in open spaces to the development of a mechanism of avoiding forest-adjoing areas in selecting their breeding territories. The other factor, competition for food, may also be of considerable importance. During the breeding season, birds inhabiting the forest edge forage rather intensively in the field belt about 70 m wide adjoining the forest. The following species were observed to forage in the belt in question: *Emberiza citrinella* L., *Carduelis carduelis* (L.), *Fringilla coelebs* L., *Parus major* L., *P. coeruleus* L., *Anthus trivialis* (L.) and *Turdus philomelos* C. L. Brehm. The very low values of coefficients of species diversity (*H'*) and evenness (*J'*) of the communities discussed (Table 2) follow from the small number of species that make them up and the great differences in their percentages.

The bird communities of sample areas D and E situated on field roads lined with trees and a varying number of shrubs, showed high values of bird density coefficients. In area D 8 species were found to nest (Table 4), and the density of the whole community was 92.4 pairs $\cdot$ 10 ha^{-1}. A much higher density (215.6 pairs $\cdot$ 10 ha^{-1}) and a greater number of species (11) were found in area E (Table 4). Such high values of density coefficients are characteristic of bird communities inhabiting tree-covered belts along field roads. A much higher density (369.5 pairs $\cdot$ 10 ha^{-1}) was found by Gromadzki (1970) while studying communities of breeding birds in mid-field groves in the environs of Turew. The factor responsible for the differences in the number of breeding species and in bird density between areas D and E, was in the first place, the difference in structure of the vegetation making up the tree belts. In area E the percentage of the shrub layer was high, while in area D it was negligible (Table 1). It follows from Gromadzki's paper (1970) that the number of birds inhabiting mid-field groves increases as the shrub layer increases in density. The presence of a shrub layer also influences the number of bird species, as for many of them it is an indispensable attribute of the habitat (e.g. for species of the genus *Sylvia*). The greater number of species and at the same time the greater density of the bird community of

Table 5. Breeding bird community of the sample area (F) delimited in the village of Piwnice — coefficients of density, dominance and energy parameters of particular species.
Explanations as in the Table 3.

Species	D	D%	SC		A	R	P	C	FU
	pairs/ /10 ha	%	g · ha⁻¹	kJ · ha⁻¹	MJ · ha⁻¹ · season⁻¹				
Passer domestivus (L.)	84.2	50.8	357.0	2840	240.29	228.40	11.89	320.39	80.10
Hirundo rustica L.	42.1	25.4	159.9	1272	87.16	82.90	4.26	116.21	39.05
Passer montanus	21.1	12.7	94.9	755	62.19	59.14	3.05	82.92	20.73
Sylvia communis	5.3	3.2	17.4	138	8.71	8.49	0.22	11.61	2.90
Phoenicurus ochruros (Gmel.)	5.3	3.2	16.1	128	10.39	9.93	0.46	13.85	3.46
Fringilla coelebs	5.3	3.2	21.9	174	12.65	12.37	0.28	16.87	4.22
Hippolais icterina (Vieill.)	2.6	1.6	6.5	52	3.41	3.34	0.07	4.55	1.14
Total 7 species	165.9	100.1	673.7	5359	424.80	404.57	20.23	566.40	141.60

area E may have been due to the close vicinity of the forest. This is indicated by the presence of species characteristic of the forest and forest edge (not occurring in area D) such as: *Sylvia borin* (Bodd.), *Carduelis chloris* (L.) and *Emberiza citrinella.* A characteristic feature of both communities was a fairly even percentage of species (Table 4), which is reflected by a very high coefficient of evenness (0.97) and a relatively high H' (2.9 and 3.4).

The bird community inhabiting area F, delimited in the southern part of the village of Piwnice, showed a small number of species (7) and high density (165.9 pairs $\cdot$ 10 ha^{-1}). Similar densities were obtained by Tomiałojć (1970) and Kuźniak (1978) while studying birds in different villages. The core of the community were two species (*Passer domesticus* and *Hirundo rustica*), whose joint percentage was 76.2% (Table 5). A similarly large percentage of these species was noted by the authors quoted above (around 80%). The four most numerous species were associated with the farm buildings of the village, while the three remaining ones (a total of only 5 pairs) with the environment of the gardens adjoining the farm buildings. Kuźniak (1978), in the five villages he studied, found from 14 to 32 species, but the total numbers of the communities depended on only three species (*Passer domesticus*, *Hirundo rustica* and *P. montanus*), while the contribution of the remaining ones was negligible. The small number of species nesting in area F was due, in the first place, to the structure of the village of Piwnice (the part of it that was studied), where the buildings stand close together and lack diversity (no such elements as a church, barns, etc.), only small areas are occupied by gardens, there are no orchards or any other sites grown with trees, such as a park. The comparatively small size of area F may also have had an effect on the result. The bird community of the area in question had low values of H' and J', the main cause of which was the great differences in the abundance of the particular species.

The results obtained from areas G and H reflect the effect of the close vicinity of crop fields on the avifauna of forest areas. Both areas were grown by the same type of treestand, viz. Pino-Quercetum. Area H represented a mid-forest habitat and was separated from the crop fields by a belt, about 100 m wide, which constituted sample area G. In area H 28 species were found to nest (Table 6), and the total density was 87.4 pairs $\cdot$ 10 ha^{-1}. The density coefficient of area G was by more than 30% higher (126.5 pairs $\cdot$ 10 ha^{-1}) and the number of species was higher too (32). Eight of them were characteristic of forest-edge habitats and did not occur in area H. Their contribution to the community amounted to 27%. The presence of these species in area G was the direct cause of the difference in density between the communities in question. In both areas *Sturnus vulgaris* is a decided dominant. Its high density is due to a comparatively large number of hollow trees and the vicinity of open spaces. Birds of this species were linked with the forest by their nesting place, but they foraged in agriculturally managed environments (crop fields, meadows, orchards, villages, etc.). In area G the dominant group consisted of 5 species, in area H – of 4 (Table 6). The feebly marked dominance in the bird community of area G (J' = 0.93) and the considerable number of species were responsible for the very high value of H' (4.7). The community inhabiting area H showed a similarly high species diversity coefficient (4.0).

Table 6. Breeding bird communities of sample areas delimited in a forest complex bordering on crop fields — coefficients of density, dominance and energy parameters of particular species

Explanations as in the Table 3

Study area	Species	D	D%	SC		A	R	P	C	FU
		pairs per 10 ha	%	$g \cdot ha^{-1}$	$kJ \cdot ha^{-1}$	$MJ \cdot ha^{-1} \cdot season^{-1}$				
	Strunus vulgaris	16.1	12.7	256.9	2044	68.17	65.41	2.76	90.89	22.72
	Fringilla coelebs	9.7	7.6	40.1	319	22.94	22.43	0.51	30.59	7.65
	Sylvia atricapilla (L.)	6.5	5.1	27.9	222	13.16	12.70	0.46	17.55	4.39
	Emberiza citrinella	6.5	5.1	37.4	298	20.81	19.93	0.88	27.75	6.94
	Carduelis carduelis	6.5	5.1	20.6	164	12.78	12.58	0.20	17.04	4.26
	Lanius callurio L.	4.8	3.8	32.1	255	12.46	12.12	0.34	16.61	4.15
	Hippolais icterina	4.8	3.8	12.0	95	6.28	6.16	0.12	8.37	2.09
	Sylvia borin	4.8	3.8	19.6	156	8.50	8.29	0.21	11.33	2.83
	Sylvia communis	4.8	3.8	15.8	126	7.82	7.62	0.20	10.43	2.61
	Sylvia curruca L.	4.8	3.8	11.7	93	7.01	6.89	0.12	9.35	2.34
	Turdus philomelos C.L. Brehm.	4.8	3.8	71.3	567	26.48	25.31	1.17	35.31	8.83
	Parus major L.	4.8	3.8	18.7	149	13.16	12.41	0.75	17.55	4.39
	Serinus serinus	4.8	3.8	11.9	95	7.89	7.74	0.15	10.52	2.63
	Carduelis chloris (L.)	4.8	3.8	25.4	202	14.60	14.00	0.60	19.47	4.87
	Dendrocopos major (L.)	3.2	2.5	53.1	422	18.75	17.88	0.87	25.00	6.25
G	*Phylloscopus trochilus* (L.)	3.2	2.5	5.8	46	3.85	3.78	0.07	5.13	1.28
	Phylloscopus collybita (Vieill.)	3.2	2.5	4.9	39	4.04	3.96	0.08	5.39	1.35
	Phylloscopus sibilatrix (Bechst.)	3.2	2.5	6.4	51	4.24	4.16	0.08	5.65	1.41
	Erithacus rubecula (L.)	3.2	2.5	10.4	83	7.09	6.85	0.24	9.45	2.36
	Parus caeruleus	3.2	2.5	7.0	56	5.86	5.60	0.26	7.81	1.95
	Certhia familiaris L.	3.2	2.5	5.9	47	5.00	4.87	0.13	6.67	1.67
	Anthus trivialis (L.)	1.6	1.3	7.2	57	3.61	3.52	0.09	4.81	1.20
	Phasianus colchicus L.	1.6	1.3	388.8	3093	71.56	62.03	9.53	95.41	23.85
	Oriolus oriolus (L.)	1.6	1.3	23.3	185	5.78	5.58	0.20	7.71	1.93
	Troglodytes troglodytes (L.)	1.6	1.3	2.9	23	2.47	2.41	0.06	3.29	0.82
	Muscicapa striata (Pall.)	1.6	1.3	5.9	47	2.75	2.69	0.06	3.67	0.92
	Turdus merula L.	1.6	1.3	30.9	246	10.88	10.28	0.60	14.51	3.63

	Certhia brachydactyla C.L. Brehm	1.6	1.3	3.0	24	2.54	2.47	0.07	3.39	0.85
	Coccothraustes coccothraustes (L.)	1.6	1.3	17.1	136	6.50	6.35	0.15	8.67	2.17
	Emberiza calandra	1.6	1.3	17.0	135	6.55	6.38	0.17	8.73	2.18
	Cuculus canorus L.	0.6	0.5	13.4	107	4.45	3.89	0.56	5.93	1.48
	Garrulus glandarius (L.)	0.6	0.5	20.7	165	5.46	5.19	0.27	7.28	1.82
	Total 38 species	126.5	100.0	1225.1	9747	413.44	391.48	21.96	551.26	137.22
	Sturnus vulgaris	24.8	28.3	395.8	3149	104.14	99.89	4.25	138.85	34.71
	Fringilla coelebs	8.3	9.4	34.3	273	19.63	19.19	0.44	26.17	6.54
	Phylloscopus sibilatrix	5.5	6.3	11.1	88	7.28	7.14	0.14	9.71	2.43
	Parus major	4.6	5.2	17.9	142	12.61	11.89	0.72	16.81	4.20
	Dendrocopos major	3.7	4.2	61.4	488	21.68	20.68	1.00	28.91	7.23
	Parus caeruleus	3.7	4.2	8.1	64	6.78	6.48	0.30	9.04	2.26
	Phylloscopus collybita	2.8	3.1	4.3	34	3.53	3.46	0.07	4.71	1.18
	Erithacus rubecula	2.8	3.1	9.1	72	6.21	6.00	0.21	8.28	2.07
	Muscicapa striata	2.8	3.1	10.3	82	4.82	4.71	0.11	6.43	1.61
	Sitta europaea L.	2.8	3.1	11.6	92	6.79	6.60	0.19	9.05	2.26
	Certhia familiaris	2.8	3.1	5.2	41	4.36	4.24	0.12	5.81	1.45
	Anthus trivialis	1.8	2.1	8.2	65	4.07	3.97	0.10	5.43	1.36
H	*Troglodytes troglodyks*	1.8	2.1	3.3	26	2.78	2.71	0.07	3.71	0.93
	Hippolais icterina	1.8	2.1	4.5	36	2.35	2.30	0.05	3.13	0.78
	Sylvia borin	1.8	2.1	7.3	5.8	3.18	3.10	0.08	4.24	1.06
	Sylvia atricapilla	1.8	2.1	7.7	61	3.63	3.50	0.13	4.84	1.21
	Turdus merula	1.8	2.1	34.8	277	12.24	11.56	0.68	16.32	4.08
	Turdus philomelos	1.8	2.1	26.7	212	9.92	9.48	0.44	13.23	3.31
	Certhia brachydactyla	1.8	2.1	3.4	27	2.85	2.77	0.08	3.80	0.95
	Coccothraustes coccothraustes	1.8	2.1	19.2	153	7.30	7.13	0.17	9.73	2.43
	Columba palumbus L.	0.9	1.0	85.6	681	14.04	13.28	0.76	18.72	4.68
	Streptopelia turtur (L.)	0.9	1.0	26.4	210	5.02	4.91	0.11	6.69	1.67
	Dendrocopos medius (L.)	0.9	1.0	10.7	85	4.18	4.02	0.16	5.57	1.39
	Parus palustris L.	0.9	1.0	1.9	15	1.46	1.43	0.03	1.95	0.49
	Regulus regulus (L.)	0.9	1.0	0.9	7	1.08	1.04	0.04	1.44	0.36
	Emberiza citrinella	0.9	1.0	5.1	41	2.87	2.75	0.12	3.83	0.96
	Cuculus canorus	0.6	0.7	13.4	107	4.45	3.89	0.56	5.93	1.48
	Garrulus glandarius	0.6	0.7	20.7	165	4.81	4.54	0.27	6.41	1.60
	Total 28 species	87.4	99.4	848.9	6751	284.06	272.66	11.40	378.74	94.68

Table 7. Energy balance and ecological efficiencies of the bird communities
A — assimilation, *R* — respiration, *P* — production, *C* — consumption, *FU* — excreta, *P/SC* — coefficient of biomass turnover, *P/A* — production/assimilation = ecological efficiency

Symbol of sample area	*A*	*R*	*P*	*C*	*FU*	*P/SC*	*P/A* %
	MJ · ha^{-1} · season^{-1}						
A	30.22	28.67	1.55	40.29	10.07	2.72	5.13
B	40.59	38.47	2.12	54.13	13.54	2.76	5.22
C	17.22	16.64	0.58	22.96	5.74	2.13	3.37
D	242.65	234.46	8.19	323.53	80.88	3.45	3.38
E	534.58	516.18	18.40	712.78	178.20	2.29	3.44
F	424.80	404.57	20.23	566.40	141.60	3.77	4.76
G	413.44	391.48	21.96	551.26	137.82	2.26	5.31
H	284.06	272.66	11.40	378.74	94.68	1.69	4.01

The energy budgets of the bird communities inhabiting the sample areas under study were highly differentiated (Table 7), which obviously was the consequence of the differences in species composition and in the numbers of birds making up these communities. They include only the breeding season, i.e. four months, from April to July. In that period, in the temperate zone, the birds entire production is concentrated, which is effected by the increase in body weight of the developing nestlings. The bird communities under study were characterized by a very high dispersion of production values. The lowest values (from 0.58 to 2.12 MJ · ha^{-1} · season^{-1}) were noted in field areas, much higher values (from 8.19 to 21.96 MJ · ha^{-1} · season^{-1}) were found in the remaining areas. The bird communities of areas G and F were characterized by the highest production. The production of the bird communities consituted from 3.37 to 5.31% of the assimilation value (*P/A*), and its ratio to the birds' biomass (*P/SC*) was from 1.69 to 3.77.

It is difficult, however, to estimate the percentage of the remaining energy parameters in the annual balance because of the complete lack in literature of any data on this subject for environments of the agricultural landscape. It follows from Weiner and Głowaciński's (1975) paper that in the months from April to July in a mixed forest the birds assimilation reaches 63.9% of the annual assimilation. The rate of energy flow (assimilation) in our bird communities also varied considerably: from 17.22 to 534.58 MJ · ha^{-1} · season^{-1}. The lowest assimilation values (from 17.22 to 40.59 MJ · ha^{-1} · season^{-1}) were found in bird communities inhabiting areas delimited in crop fields (A, B, C). On the basis of data for wheat (Pasternak 1974) and rye (Kukielska 1973, Wilkoń-Michalska 1987), it can be assumed that the primary production of cereal crops in Poland is around 265 000 MJ · ha^{-1} · growing season^{-1}. Since the growing season of cereal crops approximately coincides with the period covered by the present studies of avifauna, it is possible to estimate the ratio of the amount of energy flowing through the communities of breeding birds to the primary production of the habitats inhabited by them. Through the bird community of area A (wheat crop), during the period under study, flowed about 0.011% of the energy constituting the primary production of that habitat, and through the bird community of area C (barley) – only 0.006%. In areas D, H, G and F the rate of energy flow was much higher than in the field areas (from 242.65 to 424.80 $MJ \cdot ha^{-1} \cdot season^{-1}$). But definitely the highest assimilation value (534.58 $MJ \cdot ha^{-1} \cdot season^{-1}$) was recorded in area E. The percentages of the particular species in the energy flow through the bird communities are presented in Tables 3–6.

The birds' consumption in the sample areas was from 23.96 to 712.78 $MJ \cdot ha^{-1} \cdot season^{-1}$ (Table 7), and the differences in its value among the particular areas were similar to those of assimilation.

The results presented above show that the breeding bird communities of different habitats of the agricultural landscape vary widely, and the dispersion of the values of such coefficients as density, standing crop, production, assimilation and consumption (Tables 2, 7) is much greater than in forest ecosystems (G ł o w a c i ń s k i 1975, G ł o w a c i ń s k i and W e i n e r 1977, 1983). The basic factor determining the species composition and density of the avifauna in the sample areas under study was no doubt the structure of the environment, which determined its potential suitability for birds nesting. The poorest bird communities inhabited sample areas A and C (wheat crop and barley crop), which differed from the remaining areas by greater homogeneity. A somewhat richer community inhabited area B, which included a mosaic of many different crops, and so presented a diversified horizontal structure. Even more species and a much higher density of birds were found in the tree belts lining field roads (areas D and E), which had a more diversified vertical structure, compared with the crop fields. In crop fields only one plant layer can be distinguished, while in the tree belts there are three: the herb layer, the shrub layer and the tree crown layer. In areas D and E the effect of the shrub layer on the avifauna of the mid-field tree belts was particularly conspicuous. The number of species, and particularly the bird density, in area D with a small number of shrubs were much lower than those in area E, where the shrub layer was very well developed. An even more diversified environment structure, offering good nesting opportunities for such species as *Passer domesticus*, *P. montanus* and *Hirundo rustica*, was found in area F, which included the southern part of the village of Piwnice. But by far the richest structure of environment was characteristic of the areas delimited in the forest, and this was reflected in the very large number of breeding species and the considerable density of birds.

The results of quantitative studies, as well as observations of the birds foraging, suggest that the avifauna of the agricultural landscape is also significantly affected by the birds different strategies of getting food. These differences depend mainly on the diversity of habitats in the agricultural landscape (crop fields, orchards, groves, villages and other habitats). In birds inhabiting this landscape it is possible to distinguish three strategies of getting food:

1. Foraging within the occupied and defended territories. This way of getting was peculiar to all bird species inhabiting the field areas, forest area H (in it *Sturnus vulgaris* was an exception) and to some other species in the other areas.

2. Foraging within the defended territories and in undefended areas adjoining the

former. It was this way that the birds inhabiting the tree belts along field roads foraged. They searched for food both in the occupied territory, i.e. in the tree belts, and in the adjoining crop field. The birds were observed to fly away over distances not exceeding 50 m. This way of foraging was also exhibited by some species inhabiting the border zone between forest and field (*Emberiza citrinella*, *Carduelis carduelis*) and birds belonging to typically forest species (*Fringilla coelebs, Parus major*, *P. coeruleus*, *Anthus trivialis* and *Turdus philomelos*), whose territories were in direct vicinity of crop fields. They flew up to 70 m away from the forest. It is the birds foraging in adjoining crop fields that accounts for the very high values of assimilation and consumption of the bird communities of sample areas D, E and G (Table 7).

3. Foraging at considerable distances from the breeding areas. This way of foraging was practised by species nesting in comparatively large aggregations: *Sturnus vulgaris*, *Passer domesticus*, *P. montanus* and *Hirundo rustica.* They showed very high densities and constituted the cores of the communities in areas F, G and H. The birds were associated with the sample areas in the first place by their nesting sites, but they foraged mainly in the nearby agriculturally managed areas (e.g. in crop fields, orchards, gardens).

The materials presented in this paper suggest that in working out the energy balance of the breeding avifauna of an agricultural landscape, investigations should be conducted over relatively wide areas including various environments. In this way the energy flow through populations of species foraging outside the breeding areas will also be comprised in the study.

5. SUMMARY

Quantitative studies of the breeding avifauna of the agricultural landscape were conducted in the years 1983–1986 in 8 sample areas (A–H) including various habitats: a spring-wheat field – A, an area with a mosaic of different crops – B, a barley field – C, a field road lined with trees and a small number of shrubs (Table 1) – D, a field road lined with trees and a large number of shrubs (Table 1) – E, the southern part of the village of Piwnice – F, a Pino-Quercetum bordering on crop fields (100 m wide belt) – G, a mid-forest part of the Pino-Quercetum – H. The sample areas were situated 4–5 km away from the northern administrative boundary of Toruń (Fig. 1). The investigations concerned only breeding birds, i.e. those nesting in the sample areas. The energy calculations were based on the formulae adopted by Alatalo (1978). The energy balances have been worked out for the period in which the studies were conducted, i.e. from April 1st to July 31st.

The results of quantitative studies are listed in Tables 2–6, the energy balances of the bird communities in Table 7, the percentages of the particular species in the balances of whole communities in Tables 3–6.

The results have revealed very wide differences among the bird communities of the particular environments of the rural landscape. The number of breeding species in the sample areas under study was from 2 to 32, and the communities density was from 5.3 to 215.6 pairs · 10 ha^{-1}. The smallest numbers of species (2–5) and the lowest densities (5.3–11.2 pairs · 10 ha^{-1}) were noted in areas delimited in crop fields. The communities inhabiting the tree-lined field roads and the village of Piwnice exhibited a very high density (92.4–215.6 pairs · 10 ha^{-1}) and a small number of species (7–11). Areas G and H have been used to demonstrate the effect of the vicinity of crop fields on the avifauna of forest areas, which was reflected in great differences in the species composition (Table 6) and density (126.5 and 87.4 pairs · 10 ha^{-1}) between the communities of the two areas (grown by the same kind of treestand).

Accepting after O d u m (1977) that a measure of energy flow is assimilation, the rate of energy flow through the breeding bird communities of the sample areas has been estimated. It was highly differentiated: from 17.22 to 534.58 MJ · ha^{-1} · $season^{-1}$. The production ranged from 0.58 to 21.96 MJ · ha^{-1} · $season^{-1}$.

It has been found that the source of so much variation in the breeding avifauna of the agricultural landscape was to be found, in the first place, in the great differences in structure among the habitats making it up and, consequently, in the nesting possibilities they offer. The other cause is believed to be the diversity of foraging strategies of the birds inhabiting the agricultural landscape due to its high habitat diversity. Three types of foraging strategies have been distinguished: (1) Foraging within the occupied and defended territories. This way of getting food is specific to all species inhabiting crop fields and to some species of the other habitats. (2) Foraging within defended territories and in adjoining undefended areas. This way of foraging is found in birds inhabiting mid-field narrow belts grown with trees and edges of larger groves and forests. (3) Foraging at considerable distances from the breeding areas. It is in this way that species nesting in comparatively large agglomerations forage, e.g. *Sturnus vulgaris*, *Passer domesticus*, *P. montanus*, *Hirundo rustica*.

6. POLISH SUMMARY

Badania ilościowe awifauny lęgowej krajobrazu rolniczego prowadzono w latach 1983–1986 na 8 powierzchniach próbnych (A–H) obejmujących różne siedliska: pole obsiane pszenicą jarą — A, obszar z mozaiką wielu różnych upraw — B, uprawę jęczmienia — C, zadrzewioną i w małym stopniu zakrzaczoną (tab. 1) śródpolną drogę — D, zadrzewioną i silnie zakrzaczoną (tab. 1) śródpolną drogę — E, południową część wsi Piwnice — F, Pino-Quercetum graniczący z polami uprawnymi (pas o szerokości 100 m) — G, śródleśną część Pino-Quercetum — H. Powierzchnie usytuowane były w odległości 4–5 km od północnej granicy administracyjnej Torunia (rys. 1). Badaniami objęto wyłącznie ptaki lęgowe, a więc gniazdujące na powierzchniach próbnych. Wykonując obliczenia energetyczne stosowano wzory przyjęte przez A l a t a l o (1978). Bilanse energetyczne opracowano dla okresu, w którym prowadzono badania, tzn. 1 kwietnia — 31 lipca.

Wyniki badań ilościowych zestawiono w tabelach 2–6, bilans energetyczny badanych zespołów w tabeli 7, a udział poszczególnych gatunków w bilansie całych zespołów w tabelach 3–6.

Na podstawie uzyskanych wyników stwierdzono, że zróżnicowanie zespołów ptaków poszczególnych siedlisk krajobrazu rolniczego jest bardzo duże. Liczba gatunków lęgowych na badanych powierzchniach próbnych wynosiła od 2 do 32, a zagęszczenie zespołów od 5,3 do 215,6 par · 10 ha^{-1}. Najmniejszą liczbę gatunków (2–5) i najniższe zagęszczenie (5,3–11,2 par · 10 ha^{-1}) odnotowano na powierzchniach wytyczonych na polach uprawnych. Zespoły zasiedlające zadrzewione śródpolne drogi i wieś Piwnice charakteryzowały się bardzo dużym zagęszczeniem (92,4–215,6 par · 10 ha^{-1}) i niewielką liczbą gatunków (7–11). Na przykładzie powierzchni G i H przedstawiono efekt wpływu sąsiedztwa pól na awifaunę terenów leśnych, który ujawnił się dużymi różnicami w składzie gatunkowym (tab. 6) i zagęszczeniu (126,5 i 87,4 par · 10 ha^{-1}) zespołów ptaków obu powierzchni (porastał je ten sam typ drzewostanu).

Przyjmując wg O d u m a (1977), że miarą przepływu energii jest asymilacja, określono dla badanych powierzchni próbnych tempo przepływu energii przez zespoły ptaków lęgowych. Było ono bardzo zróżnicowane i wynosiło od 17,22 do 534,58 MJ · ha^{-1} · $sezon^{-1}$. Produkcja kształtowała się w granicach od 0,58 do 21,96 MJ · ha^{-1} · $sezon^{-1}$.

Stwierdzono, że źródłem tak dużego zróżnicowania awifauny lęgowej krajobrazu rolniczego jest przede wszystkim duże zróżnicowanie struktury tworzących go środowisk i związanych z nią potencjalnych możliwości gniazdowania ptaków. Jako drugą przyczynę wysunięto różnorodność strategii żerowania ptaków zasiedlających krajobraz rolniczy związaną z jego mozaikowatością. Wyróżniono trzy typy strategii zdobywania pokarmu: (1) Żerowanie w obrębie zajętych i bronionych terytoriów. Ten sposób zdobywania pokarmu jest właściwy dla wszystkich gatunków zasiedlających pola uprawne oraz dla części gatunków pozostałych środowisk. (2) Żerowanie w obrębie bronionych terytoriów oraz na nie bronionych terenach do nich przylegających. W ten sposób żerują ptaki zasiedlające wąskie pasy zadrzewień śródpolnych oraz obrzeża większych zadrzewień i dużych kompleksów leśnych. (3) Żerowanie w znacznych odległościach od terenów lęgowych. W ten sposób żerują gatunki gniazdujące w stosunkowo dużych skupieniach, np. *Sturnus vulgaris, Passer domesticus, P. montanus, Hirundo rustica.*

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(*Received 15 December 1987*)