POLISH ACADEMY OF SCIENCES • INSTITUTE OF ZOOLOGY

MEMORABILIA ZOOLOGICA

MEMORABILIA ZOOL.	41	11—69	1986

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STRUCTURE OF THE FAUNA OF WARSAW. THE STUDY AREA

ABSTRACT

The paper describes in detail 30 study plots located in urban green habitats of Warsaw, where the structure of invertebrate fauna was investigated in 1974—1978. The following characteristics are included: soil structure, pH, calcium carbonate and organic matter content, C:N ratio, content of heavy metals, activity of soil enzymes, daily and seasonal dynamics of mean and extreme temperatures, mean relative air humidity, content of dust, carbon oxides, and nitrogen oxides in the air, floristic composition, plant cover, biomass, ratio of mono- to dicotyledonous plant in the herb layer of lawns and general description of the woody vegetation.

GENERAL DESCRIPTION OF THE STUDY AREA

Warsaw, like all the other large towns, has specific habitat conditions largely differing from those in the entire region where Warsaw is located. This is related to a decrease in the effect of natural habitat conditions, which is masked by the activity of human population more of less deliberately shaping the environment.

The soil of urban habitats is largely changed as compared with natural ones. The changes in morphological soil properties and bio-physico-chemical soil formation processes caused by human activity are so large that a separate category of anthropogenic soils has been distinguished (Konecka-Betley et al., in print), machanically, hydrologically, and chemically transformed. Admixtures of limestone rubble from buildings destroyed during the war accounted for changes in the mechanical composition of soil, its alkalization, and accumulation of calcium carbonate in the surface layers of the soil profile. Soils of the lawns located near streets with much traffic are polluted with compounds of heavy metals (zinc, copper, lead, and cadmium), and seasonally they are enriched with sodium chloride and calcium chloride, which are applied against ice in winter (Dobrzański et al. 1971, Czarnowska et al. 1976, Czarnowska, Konecka-Betley 1977, Czarnowska 1980). Soils changed in this way are not suitable to plants. In many places attempts to establish and maintain green failed. Many trees get sick and die. Herbaceous vegetation is little resistant to unsuitable climatic conditions, and frequently dies in the middle of the growing season.

The climate of Warsaw, as compared with the climate of surrounding areas, is characterized by a higher mean annual temperature (by 1°C), a lower (by 2—4°C) relative air humidity (despite a higher annual sum of precipitation), and a lower input of solar energy (Kossowska 1973) because of significant cloudiness and large amounts of dust in the air above the town. Obviously, these tendencies are of different intensity under different weather conditions and in different years. During the period of zoocoenological investigations there were significant differences in weather from one season to another. These differences concerned mean monthly temperatures and air humidity, and also sums of precipitation (Table 1).

Table 1. Mean daily temperatures, relative air humidity, and sums of precipitation in successive months of the growing seasons of 1974, 1975, and 1976 in Warsaw [after Kossowska et al. (1976)]

Variables	Year	Months							
		March	April	May	June	July	August	September	October
Temperature (°C)	1974	5.4	8.2	12.0	15.6	17.2	19.1	14.6	7.2
	1975	5.4	7.9	16.0	17.4	20.7	20.0	17.0	—
	1976	−0.4	8.8	13.3	16.4	20.0	16.9	13.8	7.0
Relative humidity (%)	1974	63	58	72	72	76	72	76	86
	1975	74	70	65	69	71	69	74	—
	1976	75	67	64	65	69	70	74	80
Precipitation (mm)	1974	2	11	66	83	—	45	20	136
	1975	26	37	27	74	128	24	22	
	1976	—	1	42	30	48	36	58	26

Water balance in the area of the town showed disturbances caused by flowing of most precipitation water through the network of sewers. In addition, the water-sewage, gas, and electric systems crossing the subsoil account for lowering the water table.

Most of the Warsaw area lies in the zone of poor linden-oak-hornbeam forests (*Tilio-Carpinetum*). All the study areas, except for the Praski Park, were located in this zone (Fig. 1). Trees and shrubs of urban green areas of Warsaw were mostly planted, hence many species are alien to these site conditions. The species composition of herbaceous plants is a net result of two opposing processes: artificial sowing of particular plant species, mostly grasses, coupled with their cultivation (fertilization, watering, mowing), and a spontaneous regrowth of the community adapted to local site conditions. Generally, herbaceous plants of the study lawns were characterized

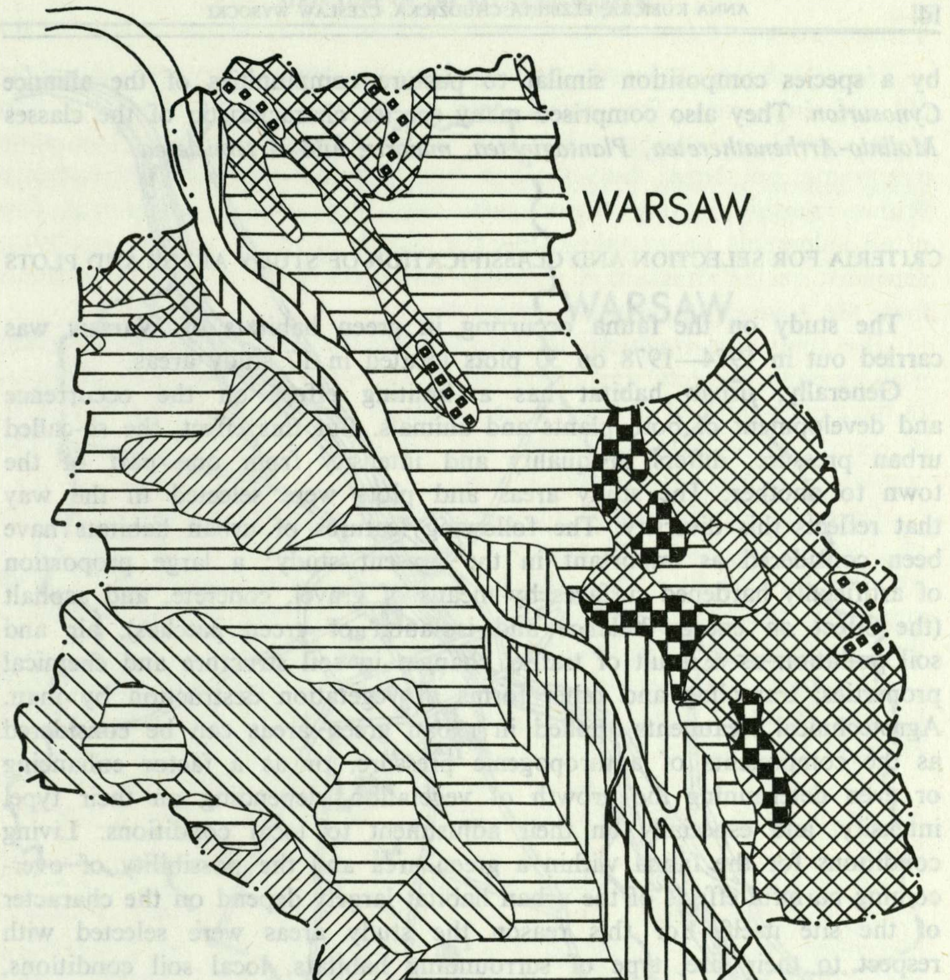

Fig. 1. Potential vegetation of Warsaw (after Matuszkiewicz 1966): 1 — riverine alder-ash carrs (*Circaeo-Alnetum*); 2 — subcontinental lime oak-hornbeam forests (*Tilio-Carpinetum*), Mazovian variety, poor form; 3 — xerothermal oak forest (*Potentillo albae-Quercetum*); 4 — subcontinental lime-oak-hornbeam forests (*Tilio-Carpinetum*), Mazovian variety, rich form; 5 — ash-elm carrs (*Fraxino-Ulmetum*); 6 — riverine willow-poplar carrs (*Salicetum albae-fragilis*); 7 — continental mixed forest (*Pino-Quercetum*); 8 — alder swamps (*Caricielongatae-Alnetum*); 9 — continental pine forest (*Peucedano-Pinetum*); 10 — administrative boundaries of Warsaw

by a species composition similar to pasture communities of the alliance *Cynosurion*. They also comprised many species characteristic of the classes *Molinio-Arrhenatheretea, Plantaginetea, maioris,* and *Artemisietea*.

CRITERIA FOR SELECTION AND CLASSIFICATION OF STUDY AREAS AND PLOTS

The study on the fauna occurring in green habitats of Warsaw was carried out in 1974—1978 on 30 plots located in 17 study areas.

Generally, urban habitat has a limiting effect on the occurrence and development of both plants and animals. But this effect, the so-called urban pressure, differs in quality and intensity from one part of the town to another. The study areas and plots were selected in the way that reflects this diversity. The following features of urban habitats have been considered as important in the present study: a large proportion of artificially hardened surfaces by means of gravel, concrete, and asphalt (the effect on energy balance and isolation of green patches), air and soil pollution as a result of traffic, changes in soil structure and chemical properties, trampling and other forms of vegetation destruction by man. Agrotechnical treatments applied in urban green areas can be considered as the components of anthropogenic pressure, or as a factor enhancing or even determining the growth of vegetation, depending on their type, intensity, and especially on their adjustment to local conditions. Living conditions for the fauna within a green area and the possibility of overcoming harmful effects of the urban habitat largely depend on the character of the site itself. For this reason the study areas were selected with respect to their size, type of surrounding habitats, local soil conditions, and the structure and composition of vegetation. Using these criteria, three main types of green have been distinguished: parks, green areas of housing estates, and streetside green.

Parks. These are green habitats covering large areas, with multilayer vegetation of different age, and made up of many species carefully cultivated. Most frequently, the study plots formed a transect from the plot located at the street bordering on the park towards central part of the park (100—150 m from the street), along which urban pressure gradually declined.

The study plots were located in four study areas (Fig. 2): the Royal Łazienki Park (4 plots), the park at the Cemetery-Mausoleum of Soviet Soldiers (3 plots), the Saxon Garden (3 plots), and the Praski Park (3 plots).

Green areas of housing estates. Two groups of these habitats have been distinguished: in loosely built-up and closely built-up housing estates.

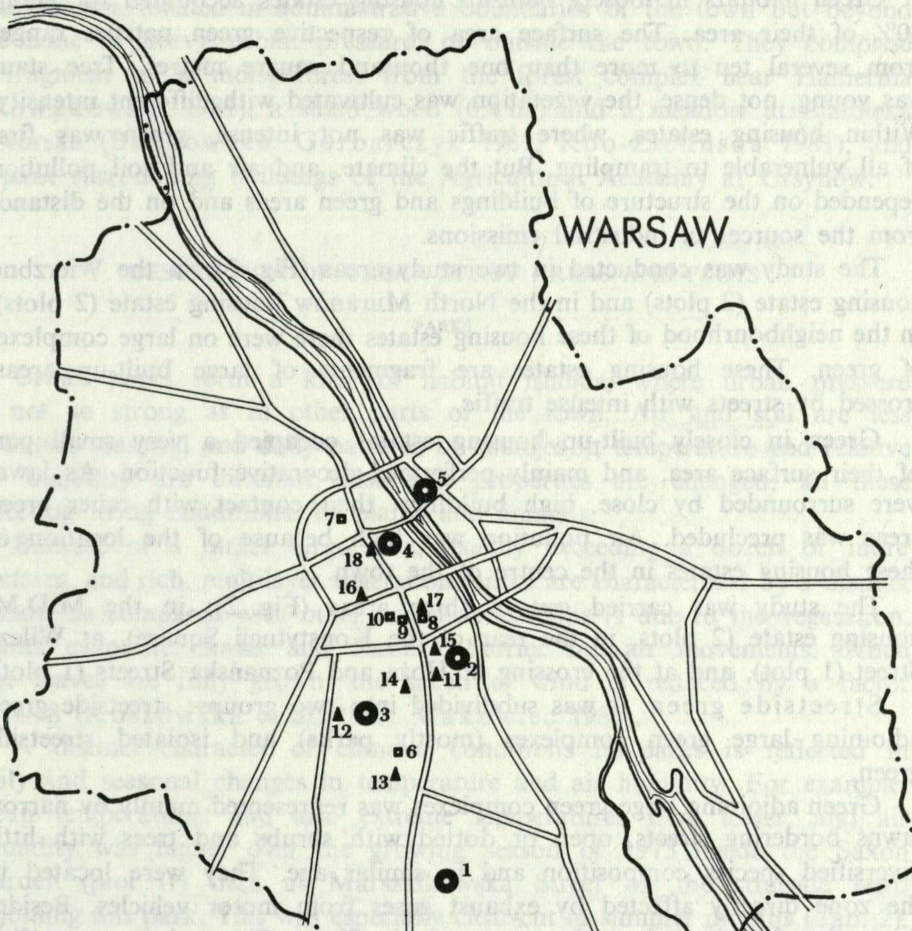

Fig. 2. Location of study plots in Warsaw: suburban park: 1 — Ursynów; urban parks: 2 — Łazienki Park, 3 — park at the Cemetery of Soviet Soldiers, 4 — Saxon Garden, 5 — Praski Park; housing estates: 6 — Wierzbno, 7 — North Muranów, 8 — M.D.M., 9 — Wilcza St., 10 — Hoża St.; streetside 11 — Ujazdowskie Ave., 12 — Żwirki i Wigury Ave., 13 — Woronicza St., 14 — Niepodległości Ave., 15 — Zbawiciela Sq., 16 — Marchlewskiego St., 17 — Konstytucji Sq., 18 — Marszałkowska St

Green habitats in loosely built-up housing estates accounted for about 50% of their area. The surface area of respective green patches ranged from several ten to more than one thousand square metres. Tree stand was young, not dense, the vegetation was cultivated with different intensity. Within housing estates, where traffic was not intense, green was first of all vulnerable to trampling. But the climate, and air and soil pollution depended on the structure of buildings and green areas and on the distance from the sources of industrial emissions.

The study was conducted in two study areas (Fig. 2): in the Wierzbno housing estate (2 plots) and in the North Muranów housing estate (2 plots). In the neighbourhood of these housing estates there were on large complexes of green. These housing estates are fragments of large built-up areas, crossed by streets with intense traffic.

Green in closely built-up housing estates occupied a very small part of their surface area, and mainly performed decorative function. As lawns were surrounded by close, high buildings, their contact with other green areas was precluded. Air pollution was high because of the location of these housing estates in the centre of the town.

The study was carried out in three areas (Fig. 2): in the M.D.M. housing estate (2 plots, in the rear of the Konstytucji Square), at Wilcza Street (1 plot), and at the crossing of Hoża and Poznańska Streets (1 plot).

Streetside green. It was subdivided into two groups: streetside green adjoining large green complexes (mostly parks) and isolated streetside green.

Green adjoining large green complexes was represented mainly by narrow lawns bordering streets, open or dotted with shrubs and trees with little diversified species composition and in similar age. They were located in the zone directly affected by exhaust gases from motor vehicles. Besides decorative function, they also serve as air filters. Six such were studied (Fig. 2): at Ujazdowskie Avenue (1 plot adjoining the Łazienki Park), Żwirki i Wigury Avenue (2 plots adjoining the park at the Cemetery of Soviet Soldiers), Woronicza Street (1 plot adjoining green areas of the Wierzbno housing estate), and at Niepodległości Avenue (1 plot).

The isolated streetiside green was represented by small lawns isolated from other green habitats by closely built-up areas. These lawns perform a decorative function. Their plant cover can serve as a filter only to a very limited degree, as these are usually open spaces, with flower-beds, sometimes with a hedgerow.

Three study areas were selected (Fig. 2); at Zbawiciela Square (1 plot), at the crossing of Marchlewskiego Street and Świętokrzyska Street (1 plot), and at Konstytucji Square (1 plot).

For comparison, plant communities were studied on the site of *Tilio-*

-*Carpinetum*, located in administrative boundaries of the town but beyond the zone of heavy urban pressure, or outside the town. They comprise a fragment of a moist forest from the forest complex near Hamernia (Nowakowski 1981), a small wood (0.4 ha) and a meadow at Białołęka Dworska (Bańkowska, Garbarczyk 1981, Roo-Zielińska 1981), and a park surrounding buildings of the Agricultural Academy at Ursynów.

DESCRIPTION OF URBAN STUDY AREAS AND PLOTS

PARKS

Urban parks form a kind of habitat islands, where urban pressure is not so strong as in other parts of the town. Air and soil are less polluted, seasonal and daily patterns of changes in temperature and relative air humidity are different, also soil properties are changed, all these affecting living conditions for plants and animals.

Because of a rather large area, usually exceeding a dozen or more hectares, and rich, multilayer vegetation, parks are characterized by a distinct climate as compared with other urban areas. This is due to the vegetation. Plants evaporate water and form a barrier for air movements. When tree leaves are fully grown, the speed of wind is reduced by a factor of 4—8 (Kossowska et al. 1976, Makowiec 1981).

A distinct character of climatic conditions in parks is reflected in daily and seasonal changes in temperature and air humidity. For example, mean temperatures and also extreme temperatures were lower, and air humidity was higher over the growing season of 1975 inside the Saxon Garden (plot II) than at Marszałkowska Street on the stretside lawn adjoining this park. This was especially clear-cut in summer months (Tab. 2).

Mean daily temperature in parks in July of 1975 was 20.1°C. Temperature measurements during the day in this month have shown that the air in parks is not so warm as in other types of urban green (Kossowska et al. 1976) (in Tab. 3 this is not always clear because these are mean results for many days observation).

Relative air humidity during the day is higher in parks than in other areas. The differences in air humidity above a lawn deep in the park and close to its periphery at the street can amount to 10% (plots I and II in Praski Park, Tab. 4). The greater the distance from the street, the cooler and more humid the air (Tabs 3 and 4).

The results of temperature and humidity measurements 0.25 and 1.5 m above the ground level by means of Assamann's psychrometer were very similar for different parks (Tabs 3 and 4). The similarity of the results increased with distance from the street. This implies that the effect of

Table 2. Mean, maximum, and minimum 24-h daily temperatures and mean relative air humidity in successive months of the growing season of 1975 on some plots in Warsaw (thermohygrographic records 2 m above the ground level) [after Kossowska et al. (1976)]

Variables	Plot	Value	Months						
			March	April	May	June	July	August	September
Temperature (°C)	Marszałkowska Street	mean	5.3	7.8	15.9	17.4	20.4	19.7	17.0
		max.	9.6	11.6	20.5	21.6	25.2	25.0	22.4
		min.	1.5	4.1	10.9	12.9	15.6	14.8	12.4
	MDM I	mean	5.7	8.3	16.6	18.2	21.1	20.4	17.1
		max.	9.8	12.0	21.2	22.3	25.9	25.1	22.4
		min.	2.6	5.1	12.2	13.9	16.8	19.9	12.7
	Saxon Garden II	mean	5.0	7.5	15.5	16.3	20.1	19.7	16.5
		max.	9.1	11.5	20.9	21.0	25.3	25.0	22.2
		min.	1.9	4.0	10.7	12.0	15.3	14.6	11.8
Relative humidity (%)	Marszałkowska Street		73	71	66	70	70	68	74
	MDM I		72	69	61	70	64	68	75
	Saxon Garden II		74	72	68	72	73	72	74

park vegetation is not limited to the air layer at the soil surface, but it also reaches higher layers (Kossowska et al. 1976, Makowiec 1981).

Local microclimatic conditions depend on vegetation structure. Differences were observed between wooded and open areas over the growing season. Soil temperature was lower by 4.5°C in spring and by 7°C in summer under tree canopy, as compared with an open lawn, while the relative humidity was higher by 6%. In the area covered with trees, soil temperature was lower than air temperature, while an opposite was true for open lawns (Bednarek, Huculak, in print).

The content of dust, nitrogen oxides, and carbon oxides in the air was lower for all the parks, as compared with sites located at streets with similar traffic intensity. Dust fall within parks can be even one-third of this at the park edge (plots I and II in the Praski Park), and the density of carbon and nitrogen oxides was lower by half (Tab. 5). The highest air pollution was noted in the Saxon Garden. This is related to the location of this park in the centre of the town and to the way of managing this area. The main avenues in the park are directly connected with the streets bordering the park, forming suitable pathways of pollution penetration into the park (Skorupski 1975).

Table 3. Daily changes in air temperature in July at heights of 0.25 and 1.5 m (Assmann's aspiratory psychromater records), and also of 2 m above the ground level (thermohydrographic records) at some plots in Warsaw. Data for Muranów and Wierzbno are from 1970 [after Dąbrowska (1970)]; the data for other plots are from 1975 [after Kossowska et al. (1976)]

Plot	Height m	Hour														
		700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2030
Marszałkowska Street	2.0	18.4	19.9	21.1	22.1	22.8	23.2	23.8	23.9	23.7	23.4	23.3	22.9	22.1	20.8	19.9
Żwirki i Wigury Avenue I	0.25	19.8	21.1	23.1	23.9	24.7	25.3	26.0	25.6	25.0	25.4	24.4	23.8	22.5	20.7	20.0
	1.5	19.5	21.0	22.9	23.6	24.4	24.9	25.2	25.4	24.8	25.2	24.4	23.7	22.3	20.7	20.0
MDM I	2.0	18.3	19.6	21.4	22.6	23.5	23.9	24.4	24.5	24.0	23.9	23.8	23.5	22.9	22.2	21.4
Muranów I	2.0	16.0	16.9	18.1	18.9	19.5	19.3	20.4	20.8	21.8	21.1	20.8	20.4	19.9	19.0	18.1
Wierzbno I	2.0	15.6	16.4	17.7	18.7	18.9	19.8	20.5	20.9	20.8	21.2	20.7	20.1	20.0	19.3	18.1
Praski Park I	0.25	20.2	22.3	24.2	25.9	25.9	26.2	26.0	26.6	25.9	25.1	24.2	23.5	22.3	20.7	20.0
	1.5	19.7	21.7	23.9	24.8	25.3	25.5	25.5	25.9	25.3	24.8	23.9	23.4	22.5	21.0	20.4
Praski Park II	0.25	19.0	20.8	23.4	24.4	25.3	25.0	25.5	25.7	24.9	24.5	23.6	22.9	21.4	20.0	19.8
	1.5	18.9	20.6	23.0	23.8	24.7	24.7	25.3	25.4	24.6	24.4	23.7	23.0	21.9	20.5	20.1
Saxon Garden II	0.25	19.2	20.6	22.8	23.9	24.5	25.3	25.2	24.9	24.5	24.5	23.3	23.1	21.4	19.5	19.8
	1.5	19.1	20.2	22.5	23.6	24.0	24.9	25.2	24.9	24.4	23.8	23.1	21.9	20.2	20.0	19.9
	2.0	17.7	19.0	20.2	21.7	22.8	23.6	23.7	24.1	23.9	23.7	23.4	22.8	21.9	20.5	19.6
Cemetery of Soviet Soldiers I	0.25	19.6	21.3	23.6	24.6	25.2	25.2	25.5	25.5	24.6	24.4	23.9	23.2	22.0	20.3	19.6
	1.5	19.6	21.2	23.2	24.2	24.8	25.3	25.4	25.1	24.6	24.5	23.9	23.4	22.3	20.4	19.7
Cemetery of Soviet Soldiers II	0.25	18.9	20.3	22.6	24.0	24.4	25.1	25.1	24.8	23.9	24.3	23.7	23.2	21.3	19.7	19.3
	1.5	18.9	20.4	22.4	23.6	24.1	25.1	25.1	24.8	24.0	24.3	23.8	23.1	21.6	19.9	19.5

Table 4. Daily changes in relative air humidity at heights of 0.25 and 1.5 m (Assmann's aspiratory psychrometre records), and at height of 2 m above the ground level (thermohydrographic records) at some plots in Warsaw. Data for Muranów and Wierzbno are from July of 1970 [after Dąbrowska (1970)]; data for the other plots are from July of 1975 [after Kossowska et al., (1976)]

Plot	Height (m)	Hour														
		700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2930
Marszałkowska Street	2.0	79	73	68	63	59	58	57	56	56	57	57	58	64	68	72
Żwirki i Wigury Avenue I	0.25	74	66	58	54	51	50	46	48	51	46	49	52	58	66	70
	1.5	72	65	58	54	55	50	46	46	50	46	48	51	58	65	79
M.D.M. I	2.0	75	74	65	58	54	53	51	48	51	52	53	54	56	59	63
Muranów I	2.0	77	73	70	65	64	62	60	59	59	59	59	61	63	64	71
Wierzbno I	2.0	81	77	72	69	67	66	63	62	62	62	63	64	66	71	78
Praski Park I	0.25	74	67	59	52	52	51	48	48	50	51	54	58	61	68	72
	1.5	74	65	56	51	49	47	47	46	48	47	53	55	59	66	69
Praski Park II	0.25	82	75	67	63	60	62	56	56	59	58	62	64	70	75	78
	1.5	80	73	65	61	58	59	54	54	57	55	58	63	65	72	74
Saxon Garden II	0.25	78	72	68	64	60	61	58	56	56	52	59	60	68	74	72
	1.5	77	72	66	61	56	55	50	50	52	52	54	58	61	67	70
	2.0	81	75	70	64	60	58	58	57	57	58	60	62	68	72	76
Cemetery of Soviet Soldiers I	0.25	74	70	62	58	54	54	50	50	57	53	54	55	52	68	75
	1.5	74	67	60	55	51	52	49	50	51	49	51	54	58	69	73
Cemetery of Soviet Soldiers II	0.25	80	76	65	60	56	54	55	53	58	54	54	59	68	75	78
	1.5	79	71	62	56	55	53	52	50	55	51	54	56	64	71	75

Table 5. Air pollution with dust falling down and suspended, nitrogen oxides and carbon oxides at some study plots in Warsaw (mean monthly values for the period from November 1973 to October 1974) [after Skorupski (1975)]

Plot	Dust fall t/km²/year	Suspended pollutants mg/m³/20 min			
		dust	N_2O	CO	CO_2
Marszałkowska Street	341	0.69	0.35	4.74	775
Żwirki i Wigury Avenue I	271	0.52	0.49	4.02	1605
Praski Park I	301	0.48	0.45	4.50	1015
Praski Park II	90	0.34	0.34	1.21	499
Saxon Garden II	257	0.54	0.27	3.65	715
Cemetery of Soviet Soldiers II	180	0.34	0.23	0.49	711

The level of air pollution was closely correlated with the pollution and some properties of soil (Tabs 5 and 6). The pH of soil surface layer in urban parks was 6.4, on the average, thus it was similar to that of farmland surrounding Warsaw (Czarnowska 1980). Soil pH in parks established on rubble soils was neutral or slightly alkaline. This was the case of the Praski Park (Tab. 6) and the Saxon Garden (Dobrzański et al. 1977). Soil pH was correlated with the content of calcium carbonate: generally $CaCO_3$ did not occur in park soils (Łazienki II, Praski Park III), or accounted for a small percentage (Łazienki III, Cemetery of Soviet Soldiers II, Praski Park I and II). In soils of the Saxon Garden, the concentration of calcium carbonate fluctuated between 0.04 and 1.93%, depending on the sampling site (Dobrzański et al. 1977).

Soil pollution with heavy metals was relatively low in parks as compared with other types of urban green, but higher than in the suburban park at Ursynów (Tab 6). The highest content of heavy metals was noted in the Praski Park'on plot I (393 ppm in the 0.5 cm layer), the lowest one on plots Łazienki II and Cemetery of Soviet Soldiers II (120 and 125 ppm respectively). Soil pollution with heavy metals decreased with increasing distance from the street (plots Łazienki II, Cemetery of Soviet Soldiers II, Praski Park II and III). This was true for the total content of zinc, copper, lead, and cadmium, and for each of these elements separately (Tab. 6).

The content of organic matter in park soils was rather high, ranging

Table 6. Soil characteristics of the study plots in Warsaw (Niepodległości Avenue, Marszałkowska Street and Ursynów — data from 1973; Saxon Garden — from 1974; Żwirki i Wigury Avenue, I, — Praski Park and Cemetery of Soviet Soldiers — from 1974 and 1975; Ujazdowskie Avenue, Hoża Street, MDM I, Wilcza Street, Wierzbno and Łazienki Park — from 1976) [after Czarnowska et al., (1976), Czarnowska and Konecka-Betley (1977), Czarnowska (1980), and Konecka-Betley et al., in print]

Type of green	Plot	Depth (cm)	Percent fraction ∅ < 1 mm			ph (KCl)	Percent $CaCO_3$	Percent organic matter	C: N	Content of heavy metals			
			1–0.1	0.1–0.02	< 0.02					Zn	Cu	Pb	Cd
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Streetside green	Niepodległości Avenue	0–5	37	41	22	7.1	1.43	5.09	20.2	150	70	230	no data
		5–10	57	27	16	7.0	1.52	2.41	16.4	375	70	190	
		10–20	55	35	10	7.3	1.01	1.74	16.4	160	59	40	
	Woronicza Street	0–5	60	21	19	7.1	1.43	3.99	22.5	266	32	212	1.50
		5–10	55	30	15	7.1	0.76	3.10	24.6	254	57	50	1.00
		10–20	51	32	17	7.1	0.67	1.78	16.6	180	15	24	0.80
		70–80	53	19	28	7.0	0.34	0.84	13.6	74	9	10	0.12
	Marszałkowska Street	0–5	74	10	16	6.9	1.65	7.89	18.0	275	52	170	1.50
		5–10	56	31	13	7.2	1.40	6.10	13.4	225	40	70	0.85
		10–20	60	25	15	7.0	1.60	3.55	18.9	250	40	50	0.42
		75–85	61	27	12	7.0	1.40	2.78	15.6	130	45	76	0.12
	Żwirki i Wigury Avenue I	0–5	61	23	16	7.0	1.96	3.91	19.0	187	18	177	0.42
		5–10	57	25	18	7.1	5.95	1.44	22.3	79	13	90	0.38
		10–20	58	21	21	7.2	3.74	0.48	11.3	30	5	32	0.21
		70–80	25	46	29	7.1	0.34	0.25	1.3	48	10	13	0.11
	Ujazdowskie Avenue	0–5	44	26	30	6.4	0.29	6.20	15.0	246	44	196	0.48
		5–10	46	34	20	6.4	0.08	5.05	15.5	182	50	72	0.40
		10–20	46	32	22	6.6	0.20	3.48	15.9	146	47	38	0.30
		80–90	55	28	17	7.0	2.14	1.69	16.8	96	34	80	0.93
Green of housing estates	Hoża Street	0–5	43	39	18	7.1	2.48	2.16	14.0	156	29	40	no data
		5–10	42	39	19	7.2	2.69	1.34	14.7	120	25	44	
	MDM I	0–5	75	16	9	6.9	1.30	3.19	11.0	280	33	70	0.40
		5–10	78	13	9	7.3	1.26	1.22	13.0	110	38	76	0.36
	Wilcza Street	0–5	58	28	14	6.8	4.07	10.05	15.8	1024	114	157	1.25
		5–10	53	28	19	7.2	3.44	1.95	10.9	190	17	34	0.21
	Wierzbno I	0–5	25	54	21	6.9	0.68	3.98	13.2	240	21	58	0.74
		5–10	53	32	15	7.0	1.28	4.60	14.4	220	18	60	0.58
		10–20	38	41	21	6.8	0.64	4.76	14.5	174	22	52	0.50
		70–80	71	20	9	6.9	0.16	0.60	8.7	27	9	12	0.24
	Wierzbno II	0–5	40	35	25	6.5	0.13	4.03	13.6	186	22	82	0.27
		5–10	32	45	23	6.6	0.13	2.74	16.5	82	21	20	0.19
		10–20	44	35	21	6.7	0.17	2.34	15.8	96	22	24	0.17
		60–70	45	33	22	6.1	2.18	2.19	23.0	106	30	27	0.15
Urban parks	Praski Park I	0–5	75	14	11	6.7	0. 52	4.66	18.9	430	63	181	0.90
		5–10	75	15	13	6.9	0.55	4.42	15.2	181	73	191	0.40
		10–20	72	14	14	7.1	0.50	3.26	14.9	181	86	157	0.32
		70–80	84	7	9	6.7	1.43	0.51	10.8	121	64	82	0.29
	Praski Park II	0–5	69	18	13	6.8	0.00	3.50	9.8	241	41	111	no data
		5–10	69	17	14	6.8	0.11	3.19	4.5	146	47	102	
		10–20	72	15	13	7.0	0.58	2.91	4.4	88	43	80	
		70–80	78	11	11	7.1	0.70	0.94	6.5	71	29	34	
	Praski Park III	0–5	72	17	11	5.9	0.00	3.43	10.9	109	21	61	no data
		5–10	76	13	11	6.0	0.00	2.89	11.7	43	26	48	
		10–20	73	12	15	6.0	0.00	4.69	7.0	83	28	30	
		70–80	76	10	14	6.1	0.00	1.15	4.1	35	12	12	
	Saxon Garden II	0–5	47	31	22	no data	no data	no data	no data	63	27	64	no data
		5–10	46	34	20					68	18	64	
		10–20	48	29	23					89	16	54	
		90–100	38	38	24					28	5	24	
	Cemetery of Soviet Soldiers I	0–5	24	50	26	6.4	0.30	2.12	11.5	163	15	25	no data
		5–10	18	55	27	6.4	0.78	1.73	11.4	95	20	28	
		10–20	19	54	27	6.4	0.59	2.89	11.0	77	20	33	
		70–80	22	52	26	5.8	0.00	0.18	5.3	30	5	8	
	Cemetery of Soviet Soldiers II	0–5	22	49	29	6.1	0.00	3.55	12.3	83	14	28	0.19
		5–10	20	49	31	6.5	0.17	2.45	14.3	72	13	25	0.19
		10–20	22	49	29	6.6	0.87	2.06	10.4	81	12	14	0.17
		70–80	17	48	35	5.0	0.00	0.25	5.2	35	7	13	0.08
	Łazienki I	0–5	36	45	19	5.9	0.00	4.29	15.1	270	20	26	0.27
		5–10	40	37	23	6.3	0.00	3.31	15.7	226	17	38	0.36
		10–20	35	32	33	6.2	0.00	3.15	14.8	72	11	30	0.23
		70–80	62	19	19	6.5	0.25	0.52	7.8	44	10	22	0.15
	Łazienki II	0–5	44	33	23	6.5	0.12	4.38	13.0	93	13	14	0.19
		5–10	52	24	24	6.7	0.25	3.88	13.9	91	12	10	0.17
		10–20	43	31	26	6.7	0.67	2.94	14.3	89	12	2	0.17
		80–90	64	16	20	7.0	0.71	1.41	16.7	33	11	2	0.06
Suburban park	Ursynów	0–5	54	28	18	6.3	0.21	3.28	9.0	30	5	24	no data
		5–10	45	35	20	7.2	0.29	2.07	6.4	40	9	24	
		10–20	49	31	20	7.2	1.02	1.57	13.6	35	9	25	
		75–85	46	35	19	7.1	0.28	0.82	7.2	30	5	20	

from 3.05% to 4.29%. The highest values were noted in surface layers. Decomposition of organic matter was usually normal, this being indicated by an approximately normal C:N ratio (from 10:1 to 12:1). This relationship was most adequate in the Praski Park and in the park at the Cemetery of Soviet Soldiers (Tab. 6). But in the Saxon Garden, where the organic matter content was 1.57—3.94, the C:N ratio was 15.7:1, which implies that humification processes were somewhat delayed, and humus poor in nitrogen tended to accumulate (Dobrzański et al. 1977).

The number of microorganisms in soils of urban parks was similar to their abundance in the suburban zone (Ursynów), like the activity of two enzymes: dehydrogenase and urease (Tab. 7). But the activity of cellulase was significantly lower in urban parks than in the suburban

Table 7. Indices of soil biological activity for some plots in Warsaw [after Żukowska-Wieszczek (1980)]

Type of green	Plot	Depth (cm)	No. microorganisms mln/g dry wt	Dehydrogenase activity ul H_2/10 g dry wt	Urease activity mg NH_3/10 g dry wt
Street-side	Marszałkowska Street	5–10	0.78	4.1	0.07
		10–20	1.31	1.6	0.07
		20–40	1.37	0.2	0.07
	Żwirki i Wigury Avenue I	5–10	0.02	2.3	0.02
		10–20	0.02	0.7	0.02
		20–40	0.03	0.0	0.02
Urban parks	Praski Park I	5–10	0.56	14.2	1.54
		10–20	0.75	7.9	1.34
		20–40	1.09	5.1	1.39
	Praski Park II	5–10	36.2	53.0	2.62
		10–20	31.5	24.7	2.57
		20–40	37.4	12.6	2.48
	Saxon Garden II	5–10	39.6	52.6	2.53
		10–20	48.7	25.6	2.45
		20–40	44.0	14.8	2.49
	Cemetery of Soviet Soldiers II	5–10	26.1	36.9	3.87
		10–20	36.2	18.3	3.14
		20–40	37.2	5.6	3.10
Suburban park	Ursynów	5–10	39.9	55.7	2.71
		10–20	43.4	30.1	2.73
		20–40	42.7	16.6	2.62

park (Tab. 8). There were differences in the activity of this enzyme from year to year, which seem to be related in part to weather conditions (Tabs 1 and 8).

Table 8. Cellulase activity in soils of some plots in Warsaw (expressed as percentage cellulose decomposition in layer of 0–30 cm over 100 days) [after Żukowska-Wieszczak (1980)]

Type of green	Plot	Year		
		1974	1975	1976
Streetside	Marszałkowska Street	20.3	28.1	15.1
	Żwirki i Wigury Avenue I	10.4	15.1	6.6
Urban parks	Praski Park I	25.1	18.1	21.3
	Praski Park II	80.2	50.4	44.1
	Saxon Garden II	75.0	82.3	49.3
	Cemetery of Soviet Soldiers II	50.1	46.2	26.0
Suburban park	Ursynów	85.0	98.0	90.2

The vegetation of the herb layer of lawns in urban parks was similar to a plant community of the aliance *Cynosurion*. On respective park plots the species characteristic of this alliance accounted for 25—50% of the total number of species (Scamoni 1967). The other, little abundant species, belonged to other orders and classes of vegetation. The species composition of the herb layer largely differed from one plot to another, even in the same park (Tab. 9). This was related to the diversity of local site conditions.

The number of species in the herb layer of the lawns of urban parks ranged from 11 (plot Łazienki I) to 24 (plot Cemetery of Soviet Soldiers I) (Tab. 10).

Plant cover in parks was very large. It ranged from 77 to 100%, depending on the plot. These values did not deviate from those in the suburban park at Ursynów.

The ratio of monocotyledonous to dicotyledonous plants was close to one. Only in park at the Cemetery of Soviet Soldiers, monocotyledons slightly predominated (Tab. 10).

The annual production of aboveground biomass in the herb layer of parks varied from 198.6 to 285.6 g dry wt per m^2, on the average. Only on plot Praski Park I it was much lower (130.7 g/m^2) because of the unfavourable effect of the street on plant growth. The high biomass production in parks, much higher than in other types of urban green, was lower, however, than in the suburban zone (Ursynów). This was true

Table 9. Plant communities of urban plots in Warsaw. Łazienki Park — data from 1973; Wierzbno, Marchlewskiego Street, and Zbawiciela Square — from 1979; Hoża Street, MDM I, and Wilcza Street — from 1983; The other plots — data from 1976 [after Zimny and Wysocki (1976)]. Classification of plant communities after Matuszkiewicz (1981).

Taxonomic units	Streetside green					Green of housing estates				Urban parks									
	Marchlewskiego Street	Zbawiciela Square	Niepodległości Avenue	Marszałkowska Street	Żwirki i Wigury Avenue	Wilcza Street	MDM I	Hoża Street	Wierzbno	Praski Park I	Praski Park II	Praski Park III	Saxon Garden II	Cemetery of Soviet Soldiers I	Cemetery of Soviet Soldiers II	Łazienki I	Łazienki II	Łazienki IV	
Class: *Molinio-Arrhenatheretea* (R. Tx. 1937)																			
Poa pratensis L.	1.2	3.3	2.3	2.3	1.2	3.4	–	1.2	2.3	2.3	2.3	2.3	2.3	2.3	3.3	3.3	2.3	2.3	2.3
Festuca rubra var. *genuina* Hack.	2.3	1.2	2.3	3.3	2.3	2.2	–	–	2.3	2.3	2.3	2.3	2.3	1.2	2.3	2.3	2.3	–	1.2
Achillea millefolium L.	1.2	2.3	1.2	1.2	1.2	–	–	–	+.1	1.2	–	1.2	1.2	–	1.2	1.2	1.2	–	1.2
Plantago lanceolata L.	1.2	–	+.1	–	–	–	–	–	+.1	–	–	–	–	+.1	+.1	2.3	1.2	–	–
Festuca pratensis Huds.	–	–	–	+.1	+.1	+.1	1.2	–	–	–	–	–	+.1	–	+.1	–	+.1	1.2	1.2
Cerastium vulgatum L.	–	+.1	–	+.1	–	–	–	–	–	–	–	+.1	–	+.1	+.1	–	–	–	–
Trifolium pratense L.	+.1	–	–	–	1.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Phleum pratense L.	–	–	–	–	–	–	–	1.2	–	–	–	+.1	–	–	–	–	–	+.1	–
Ranunculus acer L.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+.1	+.1	1.2
Alopecurus pratensis L.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2.3	–
Symphytum officinale L.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.2	–
Rumex acetosa L.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+.1	–
Poa trivialis L.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+.1	–
Cardamine pratensis L.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+.1	–
Holcus lanatus L.	–	–	–	–	–	–	–	–	–	–	–	–	–	2.3	–	–	–	–	–
Order: *Arrhenatheretalia* (Pawł. 1928)																			
Taraxacum officinale Web.	–	1.2	1.2	1.2	1.2	–	1.2	–	1.2	–	+.1	+.1	1.2	1.2	1.2	2.3	1.2	+.1	2.3
Dactylis glomerata L.	+.1	+.1	1.2	–	1.2	1.2	1.2	–	1.2	+.1	1.2	1.2	1.2	+.1	–	–	–	1.2	1.2
Bromus mollis L.	–	–	–	+.1	–	–	–	–	–	+.1	–	–	–	1.2	1.2	–	–	–	–
Trifolium dubium Sibth.	–	–	–	–	–	–	–	–	–	–	–	–	–	1.2	+.1	–	–	–	–
Lotus corniculatus L.	–	–	–	–	1.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Chrysanthemum leucanthemum L.	–	–	–	–	–	–	–	–	–	–	–	–	–	+.1	–	–	+.1	–	–
Anthriscus silvestris (L.) Hoffm.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+.1	–
Daucus carota L.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.2
Alliance: *Arrhenatherion elatioris* (Koch 1926)																			
Crepis biennis L.	–	–	1.2	1.2	–	–	–	–	1.2	–	–	–	2.3	1.2	1.2	–	–	–	2.3
Arrhenatherum elatius (L.) P.B.	–	–	–	–	–	–	–	–	–	+.1	+.1	+.1	–	–	–	–	–	–	–
Alliance: *Cynosurion* (R. Tx. 1947)																			
Trifolium repens L.	1.2	+.1	1.2	2.3	1.2	–	+.1	1.2	1.2	2.3	1.2	1.2	2.3	1.2	1.2	+.1	2.3	–	2.3
Leontodon autumnalis L.	–	–	–	–	1.2	–	–	–	2.3	–	–	–	1.2	2.3	1.2	–	–	–	–
Bellis perennis L.	–	2.3	–	–	–	–	–	–	–	–	–	+.1	–	–	–	2.3	–	–	1.2
Order: *Molinietalia* (Koch 1926)																			
Deschampsia caespitosa (L.) P.B.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.2	–
Geum rivale L.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	+.1	–
Filipendula ulmaria (L.) Maxim.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.2	–
Class: *Plantaginetea maioris* (R. Tx. et Prsg. 1950)																			
Lolium perenne L.	1.2	+.1	2.3	1.2	1.2	–	5.5	1.2	2.3	–	2.3	2.3	2.3	2.3	2.3	2.3	–	–	1.2
Poa annua L.	–	–	2.3	–	–	1.2	1.2	4.4	–	–	2.3	1.2	–	2.3	1.2	+.1	–	+.1	–
Ranunculus repens L.	–	–	–	–	–	1.2	–	–	–	–	–	–	+.1	–	–	1.2	1.2	2.3	–
Agrostis alba L. var. *prorepens* Aschers.	+.1	–	–	–	–	–	–	–	–	–	–	–	–	+.1	–	–	–	1.2	+.1
Plantago maior L.	–	–	–	–	–	–	+.1	1.2	–	–	–	–	–	–	+.1	–	–	–	–
Potentilla anserina L.	–	–	–	–	–	–	–	–	–	–	–	–	+.1	–	–	–	–	–	–
Capsella bursa-pastoris (L.) Med.	–	–	–	–	–	–	+.1	1.2	–	–	–	–	–	–	1.2	–	–	–	–
Polygonum aviculare L.	–	–	–	–	–	–	–	1.2	–	–	–	–	–	–	–	–	–	–	–
Alliance: *Lolio-Plantaginetum* (Lincola 1921) Beger 1930																			
Matricaria discoidea D.C.	–	–	–	–	–	–	+.1	1.2	–	–	–	–	–	–	–	–	–	–	–
Class: *Sedo-Scleranthetea* (Br. Bl. em. Müll. 1961)																			
Festuca ovina L.	3.4	–	–	3.4	–	–	–	–	–	2.3	–	–	–	–	–	–	–	–	–
Class: *Artemisietea Lohm.*, Prsg. et R. Tx. 1950																			
Artemisia vulgaris L.	+.1	+.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Urtica doica L.	–	–	–	–	–	1.2	–	–	–	–	–	–	–	–	–	–	–	–	–
Alliance: *Eu-Arction* R. Tx. 1937 em. Siss. 1946																			
Arctium lappa L.	–	–	–	–	–	–	1.2	–	1.2	–	–	–	–	–	–	–	–	–	–
Lamium album L.	–	–	–	–	–	+.1	–	–	–	–	–	–	–	–	–	–	–	–	–
Armoracia lapathifolia Gilib.	–	–	–	–	–	–	+.1	–	–	–	–	–	–	–	–	–	–	–	–
Companions																			
Agrostis tenuis Sibth.	–	–	2.2	–	1.2	–	–	–	1.2	1.2	2.3	2.3	2.3	+.1	2.3	–	–	–	–
Medicago lupulina L.	–	–	1.2	+.1	1.2	–	–	–	+.1	–	–	–	+.1	+.1	+.1	1.2	1.2	–	–
Prunella vulgaris L.	–	+.1	–	–	–	–	–	–	1.2	–	–	–	2.3	2.2	1.2	–	1.2	1.2	–
Convolvulus arvensis L.	2.3	+.1	1.2	1.2	–	–	–	–	–	–	–	–	+.1	+.1	–	–	–	–	–
Agropyron repens (L.) P.B.	+.1	–	+.1	–	–	–	–	–	1.2	2.3	+.1	–	1.2	–	–	–	–	–	–
Stellaria media Vill.	–	–	–	–	–	–	–	–	–	+.1	+.1	+.1	–	+.1	+.1	–	–	–	–
Veronica chamaedrys L.	–	–	–	–	–	–	–	–	–	1.2	1.2	–	–	–	–	–	1.2	1.2	–
Setaria viridis L.P.B.	–	–	+.1	+.1	+.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sonchus oleraceus L.	–	+.1	+.1	–	–	–	–	–	–	–	–	–	–	+.1	–	–	–	–	–
Cirsium arvense (L.) Scop.	+.1	–	+.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lysimachia nummularia L.	–	–	–	–	–	–	–	–	–	–	–	–	–	+.1	+.1	–	–	–	–
Agrostis stolonifera L.	–	–	1.2	–	–	–	–	–	–	–	–	2.3	–	–	–	–	–	–	–
Hypochoeris radicata L.	–	–	–	–	–	–	–	–	–	–	–	–	+.1	+.1	–	–	–	–	–
Urtica urens L.	–	–	–	–	–	–	+.1	–	–	–	–	–	–	–	–	–	–	–	–

Sporadic species

Geranium pusillum L. (Praski Park I, 1.2), *Erigeron canadensis* L. (Niepodległości Avenue, +.1), *Veronica sp.* (Cemetery of Soviet Soldiers II, +.1), *Glechoma hederacea* L. (Marchlewskiego Street, +.1, and Ursynów, +.1), *Cicorium intybus* L. (Marchlewskiego Street, +.1), *Thlapsi arvense* L. (Niepodległości Avenue, +.1).

Table 10. The number of plant species in the herb layer of lawns, and plant cover of the plots in Warsaw. Łazienki Park — data from 1973 [after Zimny et al., (1973)]; Wierzbno, Marchlewskiego Street, and Zbawiciela Square — from 1979; Hoża Street, M.D.M. I, and Wilcza Street — from 1983; other data from 1974–1976 [after Zimny, Wysocki (1976)]

Type of green	Plot	No. species	Percent coverage 1974	1975	1976	Mean total	monocot.	dicot.
Streetside	Marchlewskiego Street	16	—	—	—	90	60	40
	Zbawiciela Square	13	—	—	—	100	65	35
	Niepodległości Avenue	19	90	96	91	92	45	55
	Marszałkowska Street	14	85	93	87	88	65	35
	Żwirki i Wigury Avenue I	14	65	72	53	63	65	35
Housing estate	Hoża Street	10	—	—	—	95	70	30
	MDM I	10	—	—	—	100	75	25
	Wilcza Street	9	—	—	—	90	65	35
	Wierzbno	14	—	—	—	92	60	40
Urban parks	Praski Park I	13	80	80	72	77	55	45
	Praski Park II	12	96	98	93	96	45	55
	Praski Park III	15	90	91	88	90	50	50
	Saxon Garden II	18	92	98	92	94	50	50
	Cemetery of Soviet Soldiers I	24	95	96	93	95	60	40
	Cemetery of Soviet Soldiers II	22	92	96	78	89	60	40
	Łazienki I	11	—	—	—	100	50	50
	Łazienki II	14	—	—	—	100	50	50
	Łazienki IV	20	—	—	—	95	40	60
Suburban park	Ursynów	15	98	100	86	94	45	55

for mean values and for particular growing seasons (Tab. 11). There was a relationship between weather conditions in successive years of the study and plant production and cover. In particular, biomass production and plant cover were markedly reduced in the growing season of 1976 because of the prolonged drought (Tabs 1, 10 and 11).

After the growing season, lawns are covered with litter made up of dead parts of herbaceous plants and dead leaves of trees and shrubs. The dry weight of litter in urban parks ranged from 108 g/m^2 (Łazienki I) to 530.9 g/m^2 (Praski Park III). Generally it was higher than the aboveground biomass produced over the growing season, since dead organic matter accumulated for many years. No correlation was found between the biomass

Table 11. Annual biomass production of aboveground plant parts on the lawns of some plots in Warsaw (in g dry wt/m^2) [after Zimny, Wysocki (1976)]

Type of green	Plot	Year 1974	1975	1976	Mean
Streetside	Niepodległości Avenue	210.5	135.8	168.8	171.7
	Marszałkowska Street	248.0	201.1	153.5	200.9
	Żwirki i Wigury Avenue I	117.5	94.0	33.1	81.5
Housing estate	Wierzbno I	—	—	—	216.4
Urban park	Praski Park I	205.0	68.3	118.8	130.7
	Praski Park II	447.0	277.8	132.1	285.6
	Praski Park III	468.0	121.3	145.5	244.9
	Saxon Garden II	341.5	374.4	136.8	284.2
	Cemetery of Soviet Soldiers I	274.0	347.8	165.0	262.3
	Cemetery of Soviet Soldiers II	251.0	276.5	68.3	198.6
Suburban park	Ursynów	512.0	408.0	168.4	362.8

produced over a growing season and litter biomass (Tabs 11 and 12). Biomass production can be considered as an index of local site conditions, and litter biomass first of all reflects the effect of gardening treatments such as mowing and raking, the intensity of which differed from plot to plot and from year to year. For example, lawns in the park at the Cemetery of Soviet Soldiers must have been mown and raked very frequently, as the biomass production during the growing season of 1976 was similar to the biomass of plant litter after the season. Instead, on the plot Praski Park II, where litter biomass was several times as high as the biomass produced in 1976, these treatments must have been rare or nonexistent.

SUBURBAN PARK AT URSYNÓW

This 5-ha park is located at the southern edge of the town. This is an old palace park with the house of Julian Ursyn Niemcewicz, nowadays the dwelling of the Agricultural Academy. The parks is established on the escarpment and upper terrace of the Vistula. During the study period it adjoined vast meadows from one side and crop fields from the other sides.

The soil of this park consists of medium sand, characterized by a weakly acid pH in the surface layer and low content of calcium carbonate (Tab. 6) The content of zinc, copper, and lead compounds was small, reaching 59 ppm jointly. The content of organic matter in the surface layer was 3.38%, and gradually declined with depth. The C:N ratio was

Table 12. Litter biomass after the growing season on the study plots in Warsaw (in g dry wt/m^2; data of the Laboratory of Soil Fauna of the Institute of Zoology from 1976)

Type of green		Plot	Litter biomass
Streetside		Niepodległości Avenue	146.6
		Woronicza Street	199.6
		Zbawiciela Square	72.4
		Marszałkowska Street	209.6
		Żwirki i Wigury Avenue II	152.6
		Żwirki i Wigury Avenue I	144.5
		Ujazdowskie Avenue	257.1
Housing estate	closely built-up	M.D.M. I	39.9
		Wilcza Street	86.1
	closely built-up	Wierzbno I	208.5
		Wierzbno II	214.5
Urban park		Praski Park I	232.6
		Praski Park II	288.7
		Praski Park III	530.9
		Saxon Garden II	225.6
		Cemetery of Soviet Soldiers I	227.1
		Cemetery of Soviet Soldiers II	135.1
		Łazienki I	108.3
		Łazienki II	286.1
		Łazienki IV	180.9
Suburban park		Ursynów	213.2

a little below the optimum (Czarnowska et al. 1976). This was related to very intense humification processes due to soil microorganisms (Tabs 7 and 8), and also to gardening treatments: nitrogen was supplied in the from of mineral fertilizers, and dead plant parts were removed.

The vegetation of the study lawn was represented by species characteristic of fertile pastures of the alliance *Cynosurion*. They accounted for 60% of all the species. The herb layer of lawns consisted of 15 species. They were dominated by *Poa pratensis, Crepis biennis, Trifolium repens,* and *Taraxacum officinale*.

Plant cover was 94%, on the average. Monocotyledons accounted for 40% and dicotyledons for 60% of the herbaceous plants (Tab. 10). Mean annual production of aboveground biomass was high, reaching 362.8 g dry wt per m^2 (Tab. 11). In 1976 both plant cover and biomass production were drastically reduced to 86% and 168.4 g, respectively (one-third of the maximum production noted here), because of a prolonged drought (Tabs 1, 10, and 11).

Species composition and age of trees and shrubs were largely diversified. Many alien species were present. Shrubs were dispersed singly and in groups, while most trees formed double rows along alleys.

The fauna studied in this park comprised soil meso- and macrofauna, epigean fauna, fauna of the herb layer, and fauna of linden (*Tilia cordata*) canopy.

LAZIENKI PARK

This park was established in the 18th century in place of a former forest surrounding the palace at Ujazdów and the adjoining prince's zoological garden. The present form of the park was designed at the times of king Stanisław August Poniatowski. Gardening and constructional works were started in 1766 and continued for almost 30 years. In the first period it was designed in the style of French symmetrical gardens, then most of its area was transformed into an English landscape park. Great changes in the tree stand were made (many trees mostly of native origin were planted) and ponds were established. For a long time this was a suburban park. It was included in Warsaw as late as the end of the 19th century. During World War II some buildings were destroyed (their reconstruction was completed in 1965), as well as some trees (Mórawski, Głębocki 1982).

This park occupies 86ha. There are ponds and a network of canals in it. Its relief is diversified. This park is located on two accumulation--errosive terraces of the Vistula, which were formed in the ice age. These are the lower terrace, the so-called "praski" and the upper terrace, the so-called "warszawski" (Warsaw) terraces. They are joined together with an escarpment up to 25 m high (Nowakowski 1981).

Soils of this park belong to the group of anthropogenic soils; though mechanically transformed, they preserved some original properties. They has been classified as anthropogenic black- and brown soils (Dobrzański et al. 1975).

The vegetation of higer layers had rich species composition. The age of trees and shrubs ranged from several to several hundred years (Majdecki et al. 1977). This park was surrounded by other parks and leisure areas. Only from the western side the Łazienki Park bordered on a street with much traffic (Ujazdowskie Avenue). The park showed a downward slope from this side, which enhanced the penetration of exhaust gases from motor vehicles into the park.

Within this park there were four study plots (Fig. 3)

Plot I. This was a small lawn located on the upper terrace at a distance of 50 m from the street (Fig. 4). It was heavily shaded by a dozen

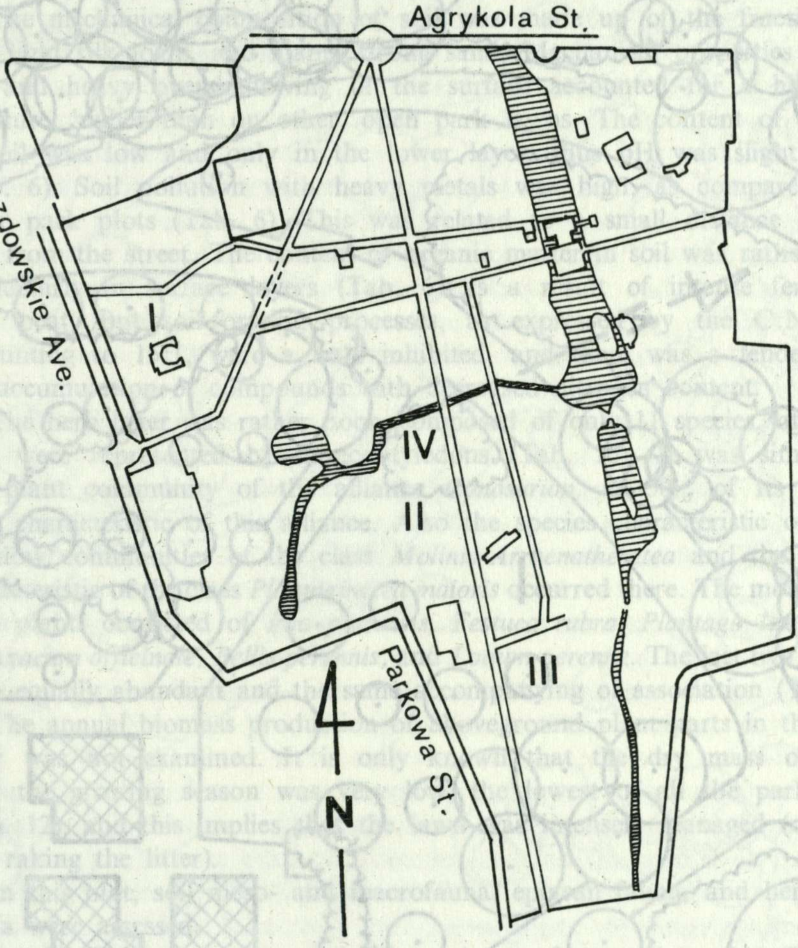

Fig. 3. Location of the study plots in the Łazienki Park

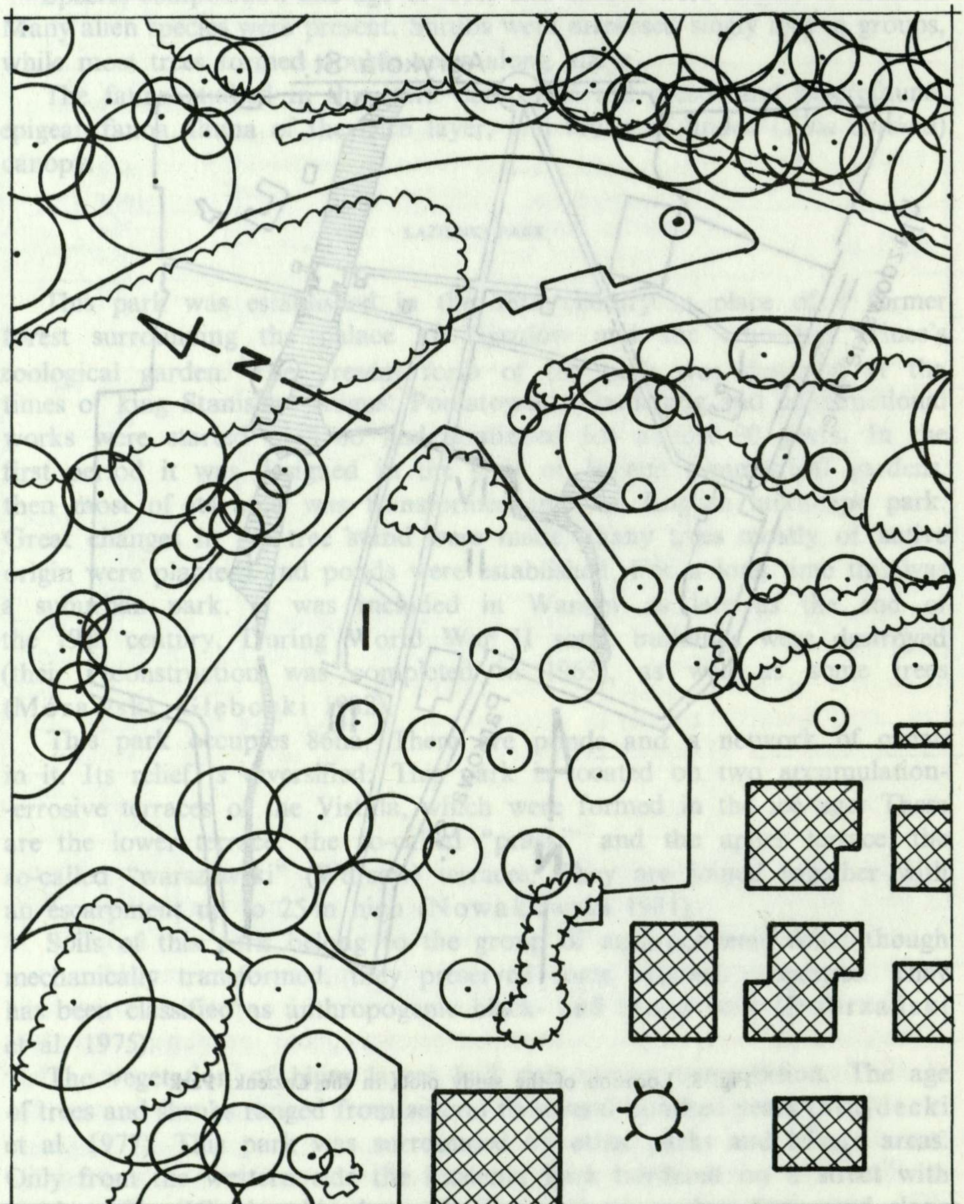

Fig. 4. Łazienki Park — plot I

or so oaks (*Quercus borealis*), the canopy of which covered 60% of this plot. Its southern part was shaded by *Thuja occidentalis* hedges.

The mechanical composition of soil was made up of the fractions of silk, light silk loam, and loamy strong sand, Mechanical properties of the soil and heavy overshadowing of the surface accounted for a high soil moisture, higher than on other, open park lawns. The content of $CaCO_3$ in soil was low and only in the lower layer, thus pH was slightly acid (Tab. 6). Soil pollution with heavy metals was high, as compared with other park plots (Tab. 6). This was related to a small distance of this plot from the street. The content of organic matter in soil was rather high, particularly in surface layers (Tab. 6) as a result of intense fertilizing with peat. But soil-forming processes, as expressed by the C:N ratio amounting to 15:1, were a little inhibited, and there was a tendency to the accumulation of compounds with decreased nitrogen content.

The herb layer was rather poor, composed of only 11 species, of which 55% were represented by monocotyledons (Tab. 10). It was similar to the plant community of the alliance *Cynosurion,* as 50% of its species were characteristic of this alliance. Also the species characteristic of other meadow communities of the class *Molinio-Arrhenatheretea* and the species characteristic of the class *Plantaginetea maioris* occurred there. The most abundant plants consisted of *Poa pratensis, Festuca rubra, Plantago lanceolata, Taraxacum officinale, Bellis perennis,* and *Lolium perenne*. The last five species were equally abundant and the same accompanying of association (Tab. 9).

The annual biomass production of aboveground plant parts in the herb layer was not examined. It is only known that the dry mass of litter after the growing season was very low, the lowest of all the park plots (Tab. 12), and this implies that the lawn was intensely managed (mowing and raking the litter).

In this plot, soil meso- and macrofauna, epigean fauna, and herb-layer fauna were assessed.

Plot II. This was an open, insolated lawn of a medium size (Fig. 5). It was located, like the plots described below, on the lower Vistula terrace. It was bordered by trees, mostly poplars (*Populus berolinensis*) and several species of lindens (*Tilia cordata*, *T. platyphyllos*, *T. pyramidalis aurea*). Shrubs included many old *Syringa vulgaris* and *Spiraea chamaedryfolia*. *Ribes alpinum* formed a hedge at the border of the lawn. Both trees and shrubs were in good condition (Majdecki et al. 1977).

Mechanical composition of soil contained fractions of light silk loam, light loam, and strong sand. The mechanical composition of soil and heavy insolation of the lawn accounted for a very low moisture content, one of the lowest on park plots. $CaCO_3$ occurred in this soil, especially in a layer more than 5cm deep. As a result, pH was neutral (Tab. 6). Soil pollution

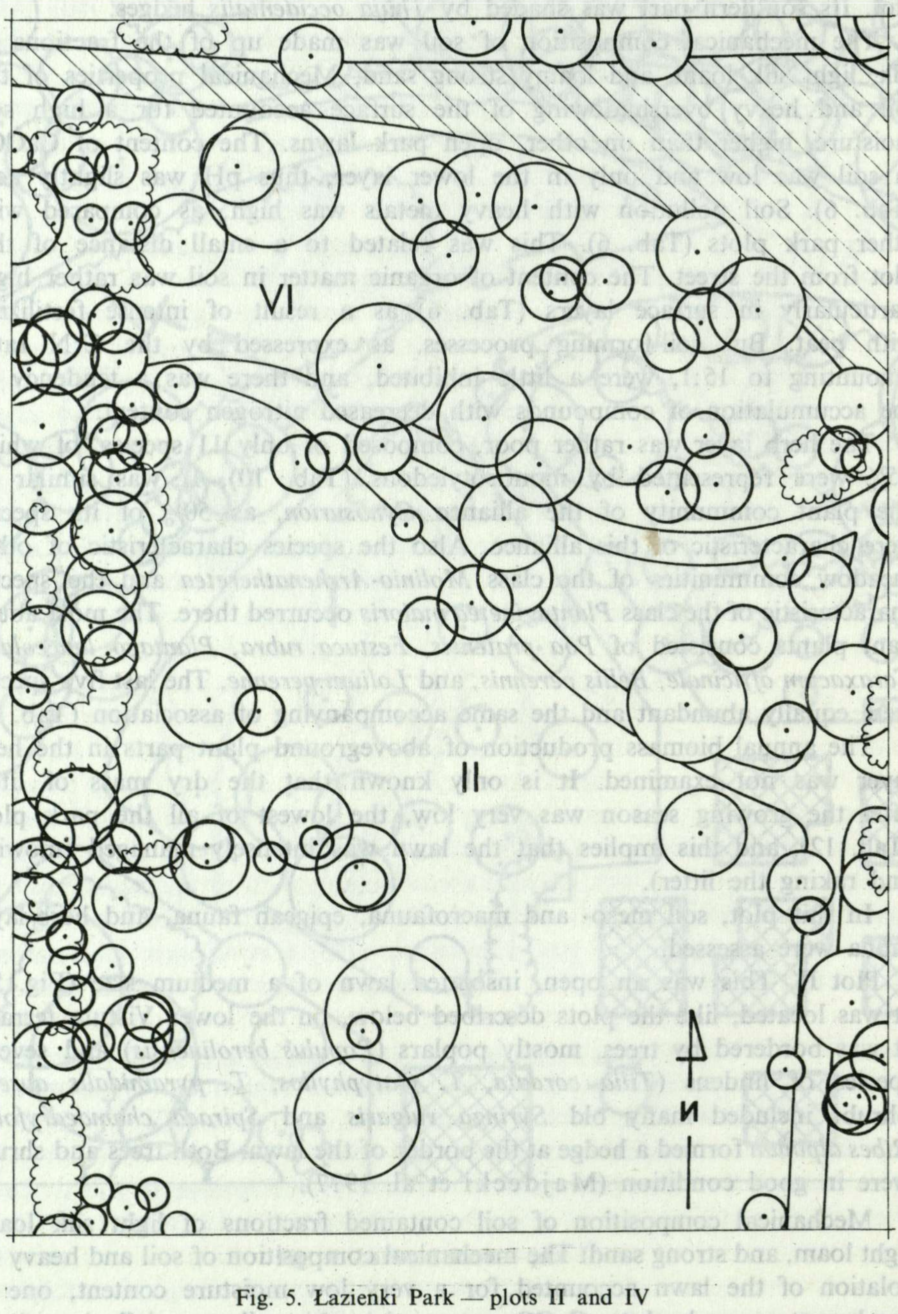

Fig. 5. Łazienki Park — plots II and IV

with heavy metals was low, characteristic of the park sites located far from streets. It was lower at least by half than on plot I, which was located on the upper terrace, near to the road. The content of organic matter was high, the highest of all the other park plots (Tab. 6), which shows that this lawn was well cultivated and fertilized. The decomposition of organic matter was normal, which is reflected in the C:N ratio close to the optimum.

The herb layer of lawn consisted of 14 species, and the mono- to dicotyledon ratio was 1:1 (Tab. 10). Three plant species were most abundant: *Poa pratensis*. *Festuca rubra*, and *Leontodon autumnalis*. The first two species are characteristic of the class *Molinio-Arrhenatheretea*, and the third of the alliance *Cynosurion*. These species were also abundant on other plots of urban green areas of Warsaw, except for the plot Łazienki IV (Tab. 9).

The annual production of aboveground plant parts in the herb layer was not examined. It is only known that the dry litter weight was high after the growing season (Tab. 12).

In this plot, soil meso- and macrofauna, epigean fauna, herb-layer fauna, and (in 1975) linden canopy fauna were examined, on lindens bordering the plot. In 1976 the material was also collected from the canopy of a solitary linden growing near this plot.

Plot III. This was a large lawn with diverse vegetation. Large fragments of this lawn were open, as trees and shrubs occurred mainly along its borders, especially from the northwestern side. The age of trees ranged from 50 to 140 years. They included lindens (*Tilia cordata*) and maples (*Acer platanoides*). Some trees and shrubs were in poor condition. In addition to densely spaced trees, there were also four single trees, including two oaks (*Quercus robur*) 370 years old (Majdecki et al. 1977).

No data on soil are available. Detailed data on the species composition of the vegetation are lacking as well. It is only known that the species composition differed from that on the majority of other park plots. In 1974—1975 it was similar to the vegetation of moist meadows of the alliance *Arrhenatherion*. At present it is similar to a plant community of the alliance *Cynosurion*.

On this plot only epigean fauna and herb-layer fauna were examined.

Plot IV. This lawn bordered on the canal (Fig. 5). It was spotted with 10 species of deciduous trees and two species of shrubs. These were oaks (*Quercus robur*), hornbeams (*Carpinus betulus*), and alders (*Alnus glutionosa*). Many tress showed signs of poor condition (withering, fungus diseases, abnormal leaves and branches). The age of trees ranged from 30 to 360 years (Majdecki et al. 1977).

No data on the mechanical composition of soil, its moisture and pollution are available. It is only known that the herb layer was rich, and it consisted of 20 species: 60% of the cover was due to dicotyledons (Tab. 10). In addition, a higher soil moisture, as compared with that on other plots, was reflected in the species composition of the herb layer. It included species of the order *Molinietalia*, not occurring on other park plots. They accounted for about 20% of the species composition. Many species of the class *Plantaginetea maioris* were also present (Tab. 9).

On this plot only soil meso- and macrofauna and canopy fauna were under study.

PARK AT THE CEMETERY OF SOVIET SOLDIERS

This was the youngest of the study parks. It was estabilished in 1949—1950, on the former arable land. It occupies an area of 20.5 ha (Mórawski, Głębocki 1982). It is surrounded with green of different types: allotment gardens and plantations of the Municipal Contractor of Green Areas, which further merge into a vast park on the Mokotowskie Fields. One side of the park borders on Żwirki i Wigury Avenue, where there is much traffic. This streeet is used by heavy trucks, thus air pollution in the park was significant, though it is located rather far from the centre of the town (Tab. 5).

Soils of this park were classified as anthropogenic, mechanically transformed (Czarnowska et al. 1976).

Vegetation is diversified. There are many species of trees and shrubs both deciduous and coniferous, often of foreign origin. They are at most 30—40 years old. Their condition is good (Olizar, Mędrzycki 1976). The location of trees is characteristic of this park. They form rows along the street adjoining the park, along alleys running to the central part of the park, and in its central part. Such a distribution of trees of single species favours animal migrations from the border to the central part and back. This is particularly important to insects that do not fly well, and to oligo- and monophagous phytophages.

The material was collected from two plots located at different distances from the street (Fig. 6).

Plot I. This was a large lawn adjoining a high hedge made up of elms (*Ulmus laevis*) which separated the park from the street (Fig. 7). The samples were taken at a distance of about 50 m from this hedge. It was dotted with a dozen or so species and varieties of decidous and coniferous trees and shrubs in a loose configuration, and with a large, dense clump of coniferous trees. The distribution of trees and shrubs allowed an easy access of light to the herb layer. Generally trees were in good condition. Only single cases of branch withering were noted (Olizar, Mędrzycki 1976).

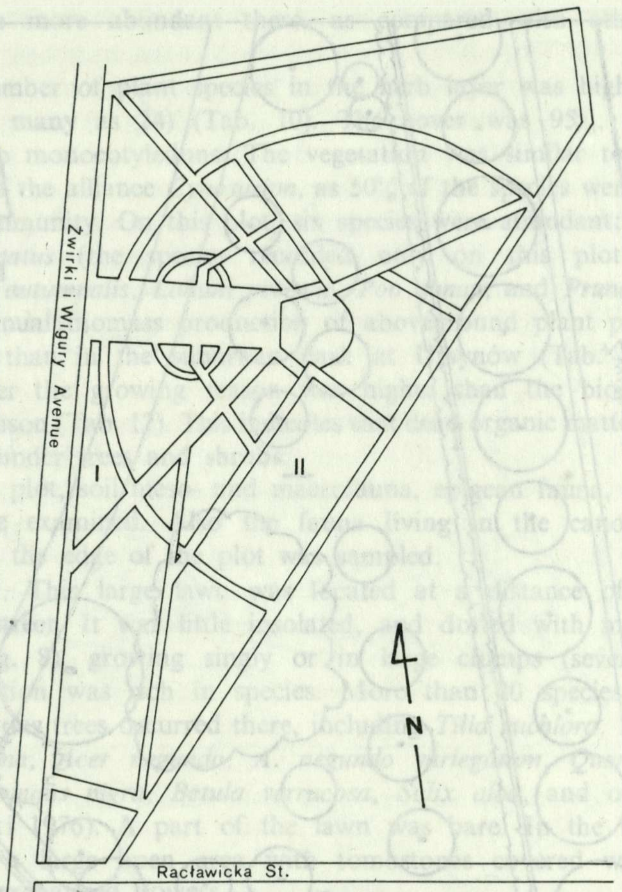

Fig. 6. Location of the study plots in the park at the Cemetery of Soviet Soldiers

The mechanical composition of soil was represented by one fraction — very fine sand. Due to some content of $CaCO_3$, pH was neutral. Soil pollution with heavy metals was high (Tab. 6). This was related to a small distance of the plot from the street. The content of organic matter was low, one of the lowest for park plots, implying that this area was not fertilized much. The decomposition of organic matter was normal, this being indicated by the C:N ratio close to optimum (Tab. 6).

The number of soil microorganisms was lower than on other park plots, probably as a result of a small content of organic matter (humus) in soil. Similarly, the dehydrogenase activity in soil was lower, as compared with other park plots. This was particularly clear-cut in deeper soil layers. The urease activity, however, was the highest. This may imply that soil

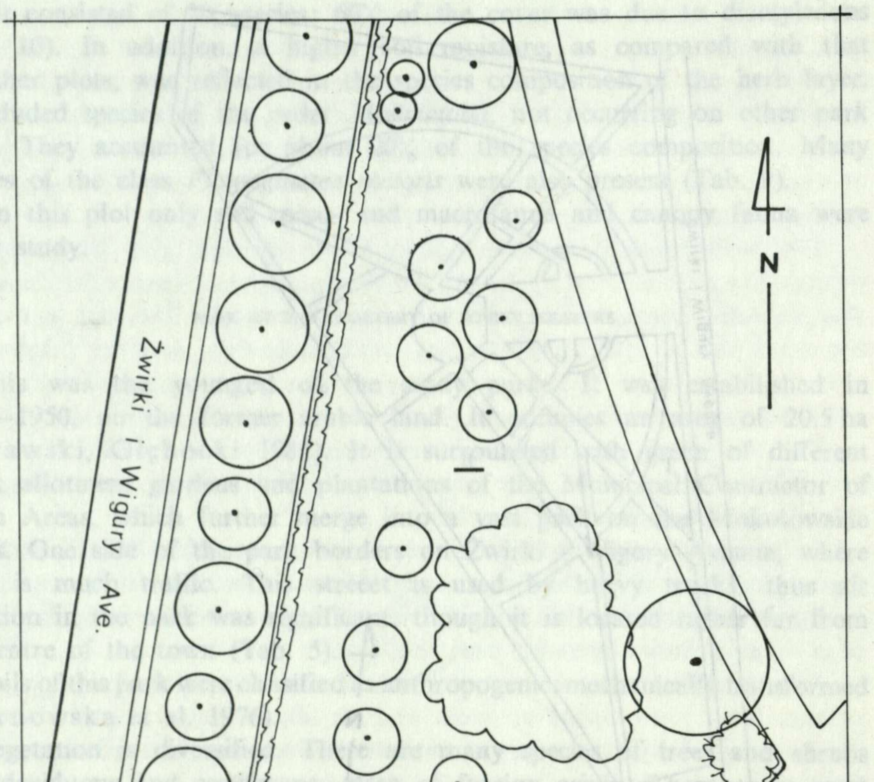

Fig. 7. Park at the Cemetery of Soviet Soldiers — plot I

fungi were more abundant there, as compared with other park plots (Tab. 7).

The number of plant species in the herb layer was high as for urban lawns (as many as 24) (Tab. 10). The cover was 95%, of which 60% was due to monocotyledons. The vegetation was similar to pasture communities of the alliance *Cynosurion,* as 50% of the species were characteristic of this community. On this plot, six species were abundant: *Poa pratensis, Halcus lanatus* (the species recorded only on this plot in Warsaw), *Leontodon autumnalis, Lolium perenne, Poa annua,* and *Prunella vulgaris.*

The annual biomass production of aboveground plant parts was high, but lower than in the suburban park at Ursynów (Tab. 11). Dry litter weight after the growing season was higher than the biomass produced over the season (Tab. 12). This indicates that dead organic matter accumulated, especially under trees and shrubs.

On this plot, soil meso- and macrofauna, epigean fauna, and herb-layer fauna were examined. Also the fauna living in the canopy of lindens growing at the edge of the plot was sampled.

Plot II. This large lawn was located at a distance of about 150 m from the street. It was little insolated, and dotted with many trees and shrubs (Fig. 8), growing singly or in large clumps (several ten trees). The vegetation was rich in species. More than 20 species of deciduous and coniferous trees occurred there, including *Tilia euchlora, T. platyphyllos, T. americana, Acer negundo, A. negundo variegatum, Quercus robur, Q. borealis, Populus nigra, Betula verrucosa, Salix alba*, and others (Olizar, Mędrzycki 1976). A part of the lawn was bare. In the neighbourhood there was a large open area with tombstones covered with grass and seasonally exchanged flowers.

The mechanical soil composition was represented by very fine sand merging into silk loam. The soil composition and poor insolation accounted for a high soil moisture with little seasonal variation. In 1977, for example, relative soil moisture was 21% in April and 22% in July. $CaCO_3$ distribution in soil was uneven (Tab. 6), and soil pH was acid in deeper layers (70—80 cm) and neutral in a layer from 5 to 20 cm. Soil pollution with heavy metals was low (Tab. 6), typical of the sites distant from streets. Organic matter content in soil was low, especially in deeeper layers. The decomposition of organic matter was normal, as indicated by the C:N ratio (Tab. 6).

The vegetation of the herb layer was similar to a plant community of the alliance *Cynosurion*. It was rich, as compared with other lawns of Warsaw, and consisted of 22 species. Monocotyledons accounted for 60% of plant cover (Tab. 10). The most abundant species was *Poa pratensis*, then *Festuca rubra, Lolium perenne*, and *Agrostis tenuis* (Tab. 9).

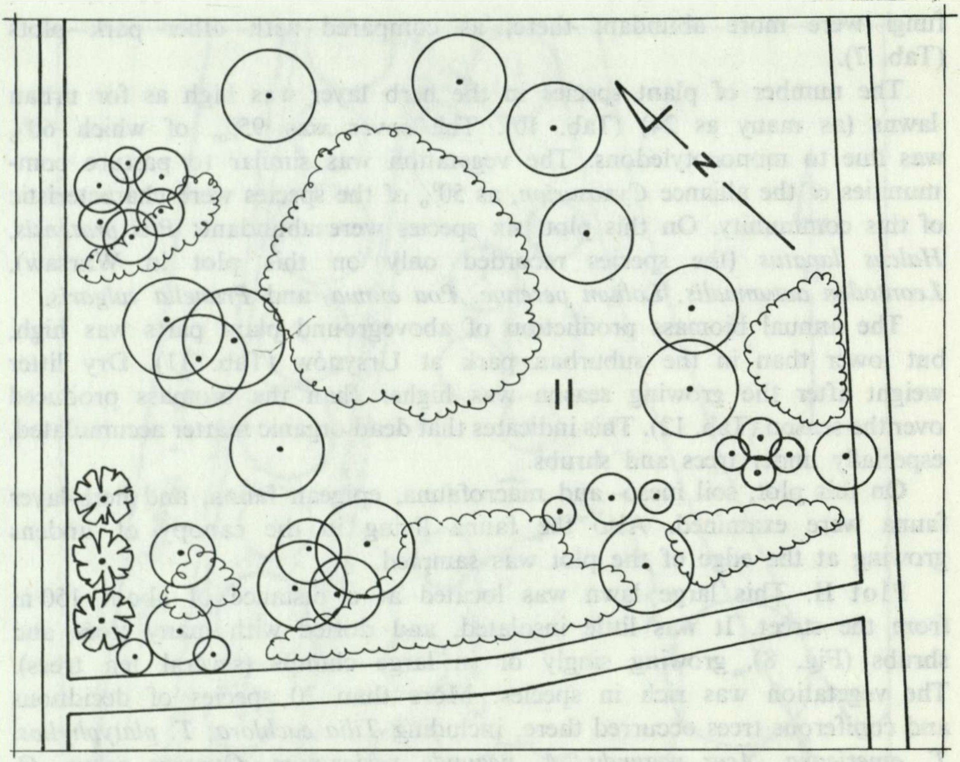

Fig. 8. Park at the Cemetery of Soviet Soldiers — plot II

The annual biomass production of aboveground plant parts was high (Tab. 11), especially in the years of sufficient precipitation. Dry litter weight after the growing season was low, showing that mowing and raking was frequent.

On this plot, soil meso- and macrofauna, epigean fauna, and herb-layer fauna were examined. Also the fauna occurring in the canopy of lindens forming a double row near the plot was sampled.

Plot III. This plot was located in the park near the border with allotment gardens. Only the fauna occuring in linden crowns was analysed there.

SAXON GARDEN

This park was established in 1713. Until the beginning of the 19th century this was a French-style park. Its vegetation design was changed many times, and finally an English-style landscape park was developed there in 1816—1827. During the World War II the Saxon Garden was devastated, and then restored (Mórawski, Głębocki 1982).

The park covers an area of 16ha. There is a pond in its central part. The park is surrounded with closely built-up areas and streets with intense traffic. The main source of air pollution is Marszałkowska Street. This was the most polluted park of all the study parks in Warsaw. A long-term human activity completely transformed the ground surface. These are anthropogenic heaps characterized by a high proportion of rubble, slag, and other waste products. The humus layer was imported. The natural material occurred at least 1 m deep (Dobrzański et al. 1977).

The age of trees largely varied. Most trees were 30—40 years old, but also 100—150 year-old trees occurred. Most trees were planted in parallel rows and very densely, which inhibits their development. These are mainly different species of lindens (*Tilia*), maples (*Acer*), and also chestnuts (*Aesculus hippocastanum*). Old trees are in good condition (Olizar, Mędrzycki 1976).

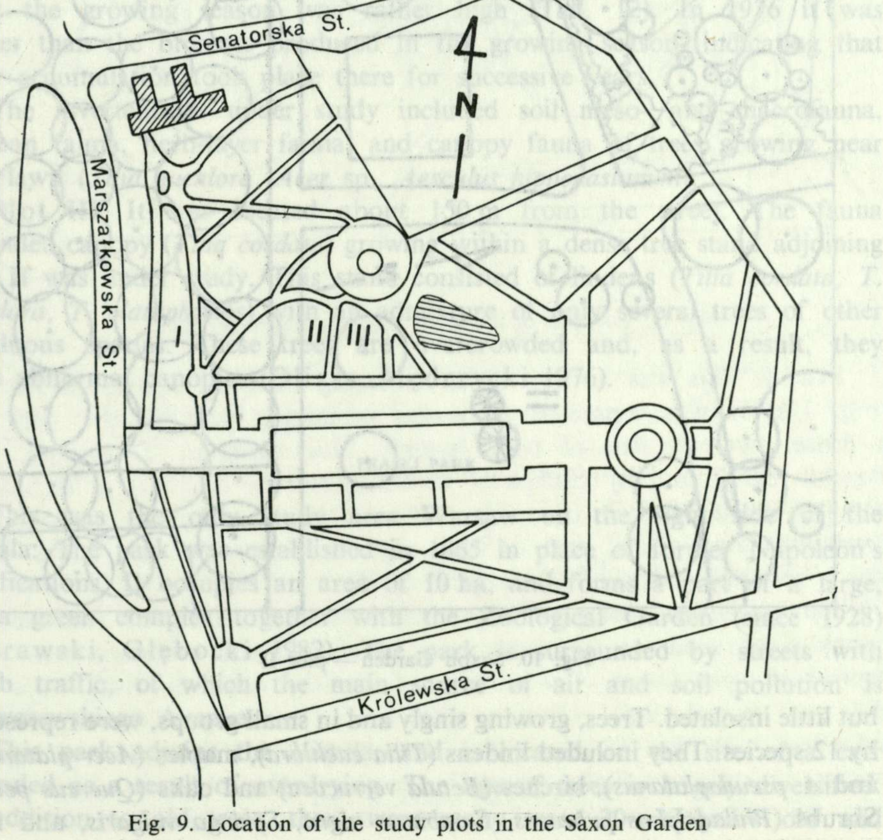

Fig. 9. Location of the study plots in the Saxon Garden

The study was conducted on three plots (Fig. 9).

Plot I. It was located in peripheral part of the park. The material was collected from a row of lindens (*Tilia euchlora*) growing at the border of the park at Marszałkowska Street, separated by a hedge (*Ligustrum vulgare*) from the street. Only the fauna occurring in linden canopy was examined.

Plot II. This was a within-park lawn located at a distance of about 150 m from the street (Fig. 10). A large part of the lawn was open

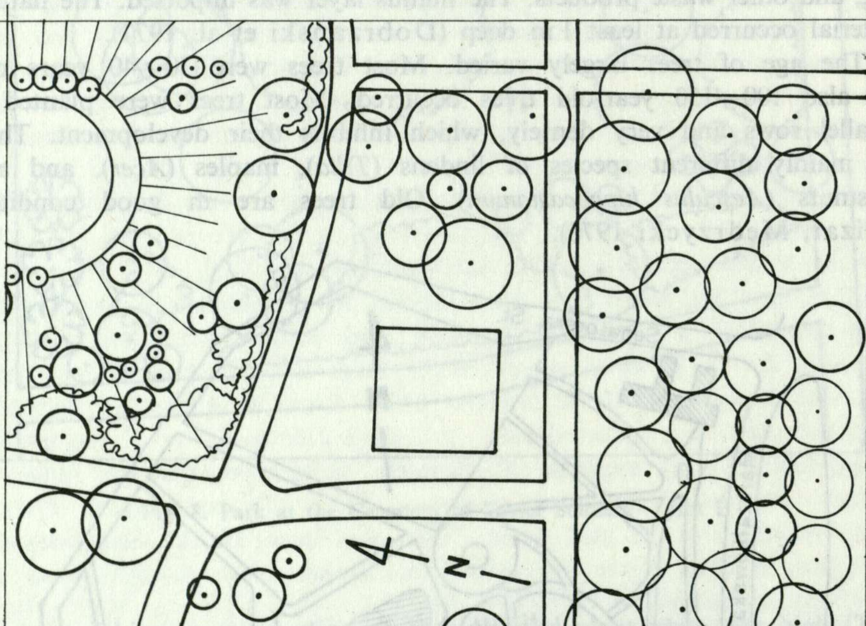

Fig. 10. Saxon Garden — plot II

but little insolated. Trees, growing singly and in small groups, were represented by 12 species. They included lindens (*Tilia euchlora*), maples (*Acer platanoides* and *A. pseudoplatanus*), birches (*Betula verrucosa*) and oaks (*Quercus petrea*). Shrubs (*Philadelphus pubesens, Sambucus nigra, Syringa vulgaris*, and *Ribes* *alpinum*) occurred in three large clumps at the northern edge of the lawn. This plot adjoined lawns of similar vegetation structure. Only its southern part bordered on dense rows of trees (Olizar, Mędrzycki 1976).

The mechanical composition of soil included fractions of light silk loam. Mechanical soil properties and overshadowing of the site by trees and shrubs allowed a high soil moisture, typical of wooded lawns. There is no data on other properties of soil. The content of heavy metals, especially copper and lead, was one of the highest for park plots (Tab. 6).

The herb layer was rather rich, made up of 18 plant species. The proportion of mono- to dicotyledons was 1:1 (Tab. 10). This vegetation was similar to a plant community of the alliance *Cynosurion*. The proportion of one species of the alliance *Arrhenatherion elatioris* was also high. The 7 dominant species of the herb layer occurred in equal numbers. These were *Poa pratensis, Festuca rubra, Crepis biennis, Trifolium repens*, *Lolium perenne*, and *Prunella vulgaris* (Tab. 9).

The annual biomass production of aboveground plant parts was one of the highest for the study park plots (Tab. 11). Also litter dry weigth after the growing season was rather high (Tab. 12). In 1976 it was higher than the biomass produced in the growing season, indicating that litter accumulation took place there for successive years.

The invertebrates under study included soil meso- and macrofauna, epigean fauna, herb-layer fauna, and canopy fauna of trees growing near this lawn (*Tilia euchlora, Acer* sp., *Aesculus hippocastanum*).

Plot III. It was located about 150 m from the street. The fauna of linden canopy (*Tilia cordata*) growing within a dense tree stand adjoining plot II was under study. This stand consisted of lindens (*Tilia cordata, T. euchlora, T. platyphyllos*) with an admixture of only several trees of other deciduous species. These trees are overcrowded and, as a result, they have abnormal canopies (Olizar, Mędrzycki 1976).

PRASKI PARK

This was the only study area Warsaw on the right side of the Vistula. The park was established in 1865 in place of former Napoleon's fortifications. It occupies an area of 10 ha, and forms a part of a large, 90 ha green complex together with the Zoological Garden (since 1928) (Mórawski, Głębocki 1982). The park is surrounded by streets with much traffic, of which the main source of air and soil pollution is Świerczewskiego Avenue.

This park adjoins the Vistula, and is located on the site of a carr degraded as a result of overdrying. The age of trees is largely diversified. In addition to old trees, there were many trees 20—30 years old and younger. Deciduous trees and shrubs predominated (Olizar, Mędrzycki 1976).

The study was carried out on three plots (Fig. 11).

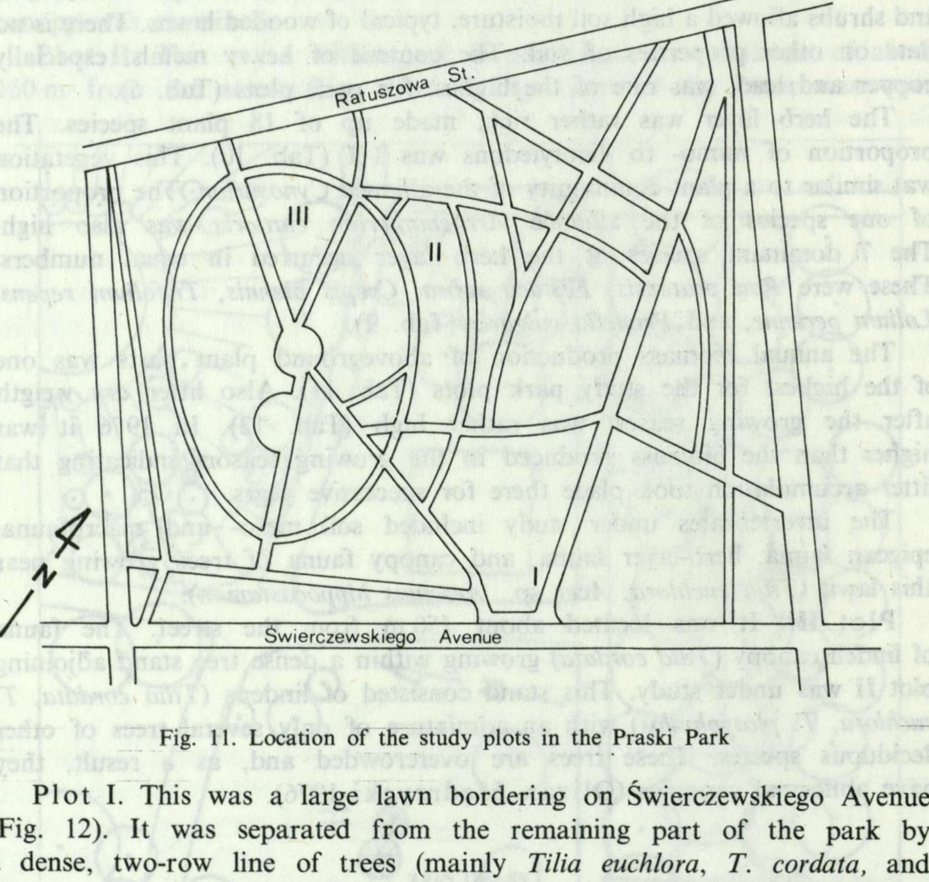

Fig. 11. Location of the study plots in the Praski Park

Plot I. This was a large lawn bordering on Świerczewskiego Avenue (Fig. 12). It was separated from the remaining part of the park by a dense, two-row line of trees (mainly *Tilia euchlora*, *T. cordata,* and *Populus nigra*), and by clumps of shrubs (*Lonicera tatarica*) . This lawn was well insolated. In its central part there were three *Populus berolinenensis* regrowing from roots, and at the edge bordering on the street there was a rose-bed (Olizar, Mędrzycki 1976).

The mechanical composition of soil was represented by fractions of loamy light sand on a coarse sand. Relative soil moisture was low, typical of open lawns. The content of $CaCO_3$ was 0.5—1.4%, thus soil pH was neutral. Soil pollution with heavy metals was the highest, as compared with that in other park plots (Tab. 6). The content of organic matter in soil was high, especially in the surface layers, which shows that the soil was fertilized. Soil processes were delayed, and there was

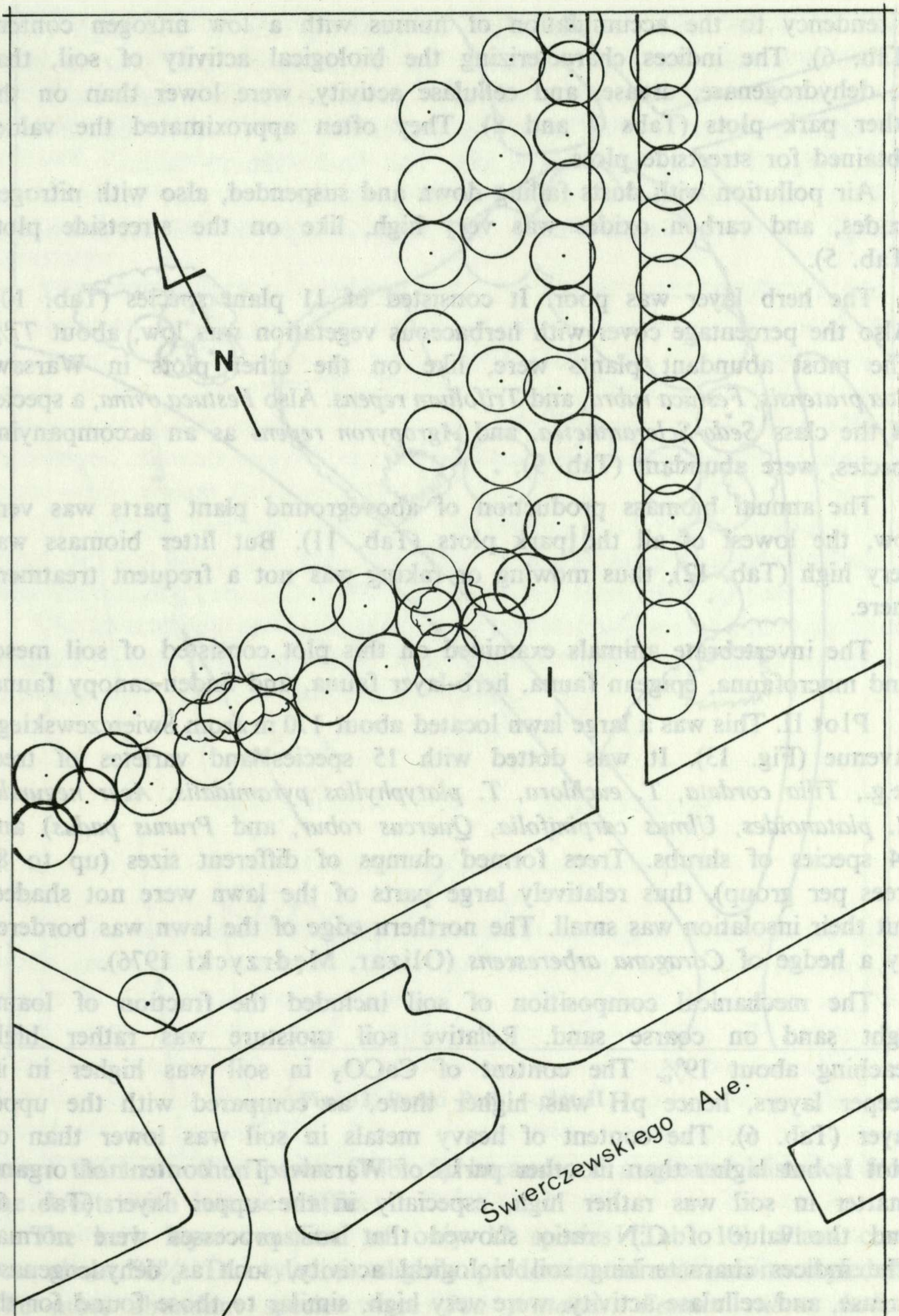

Fig. 12. Praski Park — plot I

a tendency to the accumulation of humus with a low nitrogen content (Tab. 6). The indices characterizing the biological activity of soil, that is, dehydrogenase, urease, and cellulase activity, were lower than on the other park plots (Tabs 7 and 8). They often approximated the values obtained for streetside plots.

Air pollution with dusts falling down and suspended, also with nitrogen oxides, and carbon oxides was very high, like on the streetside plots (Tab. 5).

The herb layer was poor. It consisted of 11 plant species (Tab. 10). Also the percentage cover with herbaceous vegetation was low, about 77%. The most abundant plants were, like on the other plots in Warsaw, *Poa pratensis, Festuca rubra,* and *Trifolium repens*. Also *Festuca ovina*, a species of the class *Sedo-Scleranthetea*, and *Agropyron repens* as an accompanying species, were abundant (Tab. 9).

The annual biomass production of aboveground plant parts was very low, the lowest of all the park plots (Tab. 11). But litter biomass was very high (Tab. 12), thus mowing or raking was not a frequent treatment there.

The invertebrate animals examined on this plot consisted of soil meso- and macrofauna, epigean fauna, herb-layer fauna, and linden-canopy fauna.

Plot II. This was a large lawn located about 170 m from Świerczewskiego Avenue (Fig. 13). It was dotted with 15 species and varietes of trees (e.g., *Tilia cordata, T. euchlora, T. platyphyllos pyramidalis, Acer negundo, A. platanoides, Ulmus carpinifolia, Quercus robur,* and *Prunus padus*) and 14 species of shrubs. Trees formed clumps of different sizes (up to 80 trees per group), thus relatively large parts of the lawn were not shaded, but their insolation was small. The northern edge of the lawn was bordered by a hedge of *Caragana arberescens* (Olizar, Mędrzycki 1976).

The mechanical composition of soil included the fraction of loamy light sand on coarse sand. Relative soil moisture was rather high, reaching about 19%. The content of $CaCO_3$ in soil was higher in its deeper layers, hence pH was higher there, as compared with the upper layer (Tab. 6). The content of heavy metals in soil was lower than on plot I, but higher than in other parks of Warsaw. The content of organic matter in soil was rather high, especially in the upper layer (Tab. 6), and the value of C:N ratio showed that soil processes were normal. The indices characterizing soil biological activity, such as dehydrogenase, urease, and cellulase activity, were very high, similar to those found for the suburban park at Ursynów (Tabs 7 and 8). Their highest values were noted in the upper soil layer.

Air pollution with dust, nitrogen oxides, and carbon oxides was much

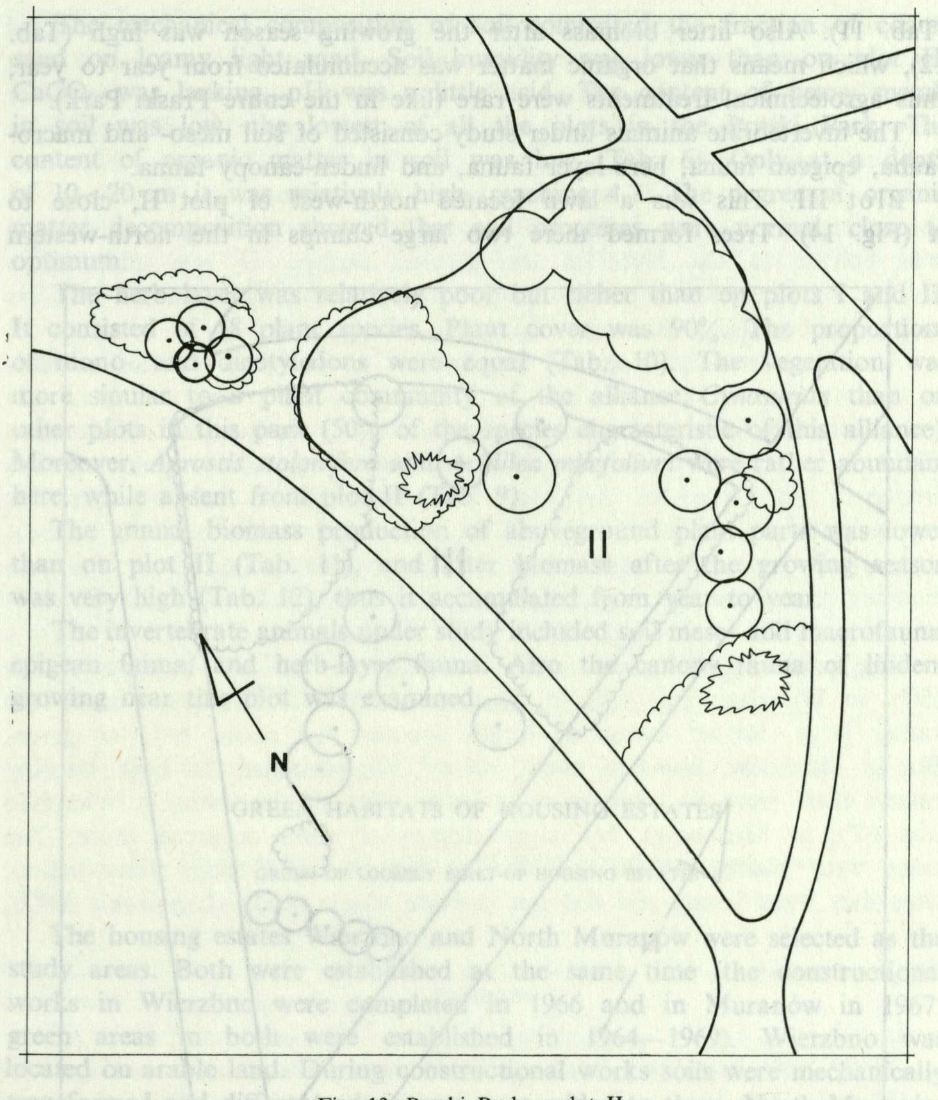

Fig. 13. Praski Park — plot II

lower than in other parks (Tab. 5) because of a greater distance from the streets with intense traffic.

The herb layer consisted of only 12 species (Tab. 10). Plant cover was about 96%. Dicotyledons slightly predominated over monocotyledons. The most abundant species were *Poa pratensis, Festuca rubra, Lolium perenne, Poa annua,* and *Agrostis tenuis,* that is, the species characteristic of the classes *Molinio-Arrhenatheretea* and *Plantaginetea maioris*.

The annual biomass production of aboveground plant parts was high

(Tab. 11). Also litter biomass after the growing season was high (Tab. 12), which means that organic matter was accumulated from year to year, thus agrotechnical treatments were rare (like in the entire Praski Park).

The invertebrate animals under study consisted of soil meso- and macrofauna, epigean fauna, herb-layer fauna, and linden-canopy fauna.

Plot III. This was a lawn located north-west of plot II, close to it (Fig. 14). Trees formed there two large clumps in the north-western

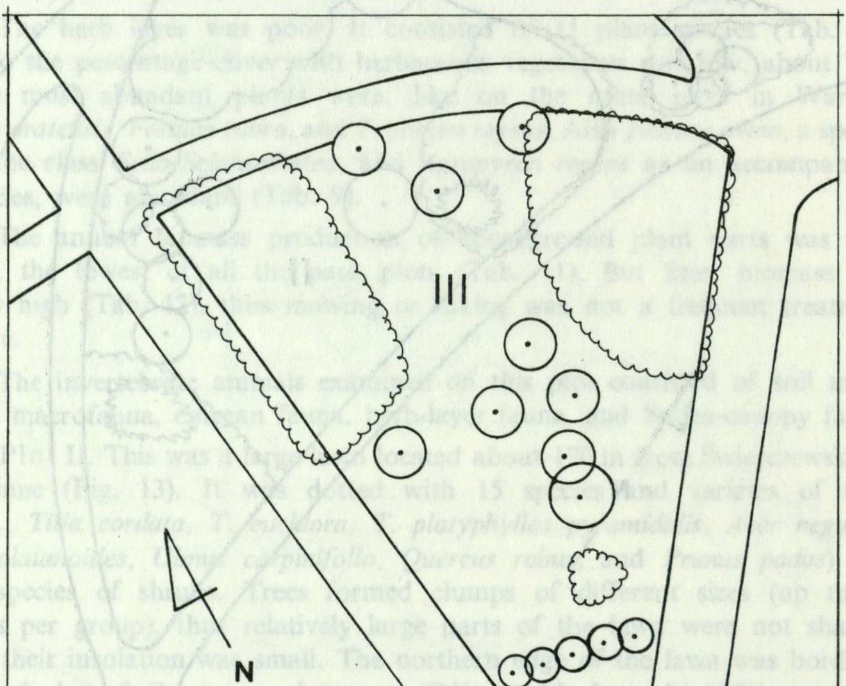

Fig. 14. Praski Park — plot III

and north-eastern corner of the lawn. A dozen or so trees and shrubs grew singly. There were 11 tree species, including *Acer negundo*. *A. platanoides*, *A. tataricum*, *Aesculus hippocastanum*, *Sambucus nigra*, and *Betula verrucosa*, and 9 shrub species. Branches and trunks of some trees showed losses of tissue (Olizar, Mędrzycki 1976).

The mechanical composition of soil comprised the fraction of coarse sand on loamy light sand. Soil humidity was lower than on plot II, $CaCO_3$ was lacking, pH was a little acid. The content of heavy metals in soil was low, the lowest of all the plots in the Praski Park. The content of organic matter in soil was low (Tab. 6). Only at a depth of 10—20 cm it was relatively high, reaching 4.7. The degree of organic matter decomposition showed that soil processes were normal, close to optimum.

The herb layer was relatively poor but richer than on plots I and II. It consisted of 18 plant species. Plant cover was 90%. The proportions of mono- and dicotyledons were equal (Tab. 10). The vegetation was more similar to a plant community of the alliance *Cynosurion* than on other plots in this park (50% of the species characteristic of this alliance). Moreover, *Agrostis stolonifera* and *Achillea milefolium* were rather abundant here, while absent from plot II (Tab. 9).

The annual biomass production of aboveground plant parts was lower than on plot II (Tab. 11), and litter biomass after the growing season was very high (Tab. 12), thus it accumulated from year to year.

The invertebrate animals under study included soil meso- and macrofauna, epigean fauna, and herb-layer fauna. Also the canopy fauna of lindens growing near this plot was examined.

GREEN HABITATS OF HOUSING ESTATES

GREEN OF LOOSELY BUILT-UP HOUSING ESTATES

The housing estates Wierzbno and North Muranów were selected as the study areas. Both were established at the same time (the constructional works in Wierzbno were completed in 1966 and in Muranów in 1967: green areas in both were established in 1964—1969). Wierzbno was located on arable land. During constructional works soils were mechanically transformed and different admixtures were added to them. North Muranów was built on rubble. The soil of lawns was carried from other areas, like the soil of lawns in closely built-up areas of the centre of the town.

In the study housing estates, built-up areas account for 20% of the area. These are 5—11 storey buildings (Lipińska 1977). Hardened surfaces such as roads, pavements, and playing grounds, occupy 30—35%. The remaining area is occupied by green spaces. Within the housing estates there is little traffic, but they are surrounded by streets with intense traffic, which is the source of exhaust gases, dust, and noise. Green areas of these housing estates are isolated from larger green complexes.

The climate was typical of the entire town, that is, it was characterized by higher temperatures and a greater thermal inertia, as compared with non-urban habitats. There were differences in temperature and humidity between closely located sites, depending on their exposure, distance from buildings and type of surface material (Gacka-Grzesikiewicz, Różycka 1972). Green areas were too small to have an effect on the climate of the entire housing estate. The effect of plant cover (cooling, humidifying) was limited to the layer at the ground surface. It was additionally reduced by permanent air movements between lawns and adjacent concrete and asphalt surfaces (Kossowska et al. 1976).

A rather dense and regular distribution of buildings (blocks of flats in rows) and the location of North Muranów near the centre of the town accounted for higher temperatures and lower humidity than in Wierzbno (Tabs 3 and 4). The structure of built-up areas also influenced the frequency and force of the wind. Wierzbno, where buildings are less regularly distributed, is better protected from winds (calm is more frequent and winds have less force) than Muranów. Air pollution in the two housing estates is at the upper admissible limit (Różycka, Gacka-Grzesikiewicz 1972).

The percentage of green areas is similar in the two housing estates (50% in Wierzbno and 45% in Muranów). In Wierzbno green areas are rather large. 500 m^2 lawns or larger account for about 60% of green. But in Muranów, lawns of about 100 m^2 predominated. In both housing estates there were no trees on most lawns (72% of the lawns in Wierzbno and 67% in Muranów). No large clumps of trees occurred there. The trees were planted when the housing estates were under construction, thus they were young and did not provide much shade (Lipińska 1977).

WIERZBNO

There were two study plots in the housing estate Wierzbno (Fig. 15).

Plot I. This was a large open lawn not cultivated carefully (Figs 16 and 17). It covered an area of about 7 thousand m^2, and was dotted with sparse trees (*Aesculus hippocastanum*), very young, not casting much shade.

The mechanical composition of soil contained a fraction of silk, loamy sand, silk sand, and light silk loam on coarse sand. Soil moisture was low, typical of open lawns. The content of $CaCO_3$ in soil was rather high, especially at a depth of 5—10 cm (Tab. 6), and pH was neutral. The content of heavy metals in soil was low, and similar to that in park plots located far from streets. Also the content of organic matter

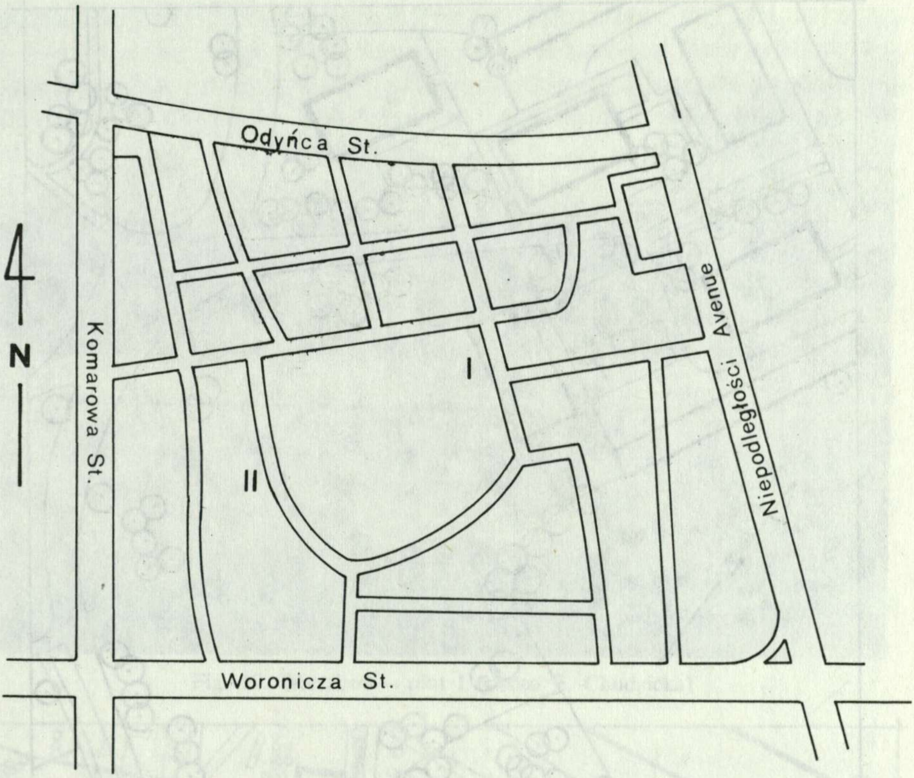

Fig. 15. Location of the study plots in the Wierzbno housing estate

in soil was rather high, and their decomposition, an expressed by C:N ratio, was normal, close to optimum.

The herb-layer consisted of 14 species forming a community similar to the alliance *Cynosurion* (50% of the species characteristic). Most of the plant cover (60%) was made up of monocotyledons (Tab. 10). The proportion of plants of the class *Plantaginetea marioris,* resistent to mechanical injury, was low, as compared with other plots in Warsaw (Tab. 9). Dominant species consisted of *Poa pratensis*, *Festuca rubra*, *Lolium perenne,* and *Leontodon autumnalis*. The annual biomass production of aboveground parts was high (Tab. 11), similar to that of park lawns. Litter biomass after the growing season was relatively small, thus it was often mown and raked (Tab. 12).

The invertebrates under study consisted of soil meso- and macrofauna, epigean fauna, and herb-layer fauna.

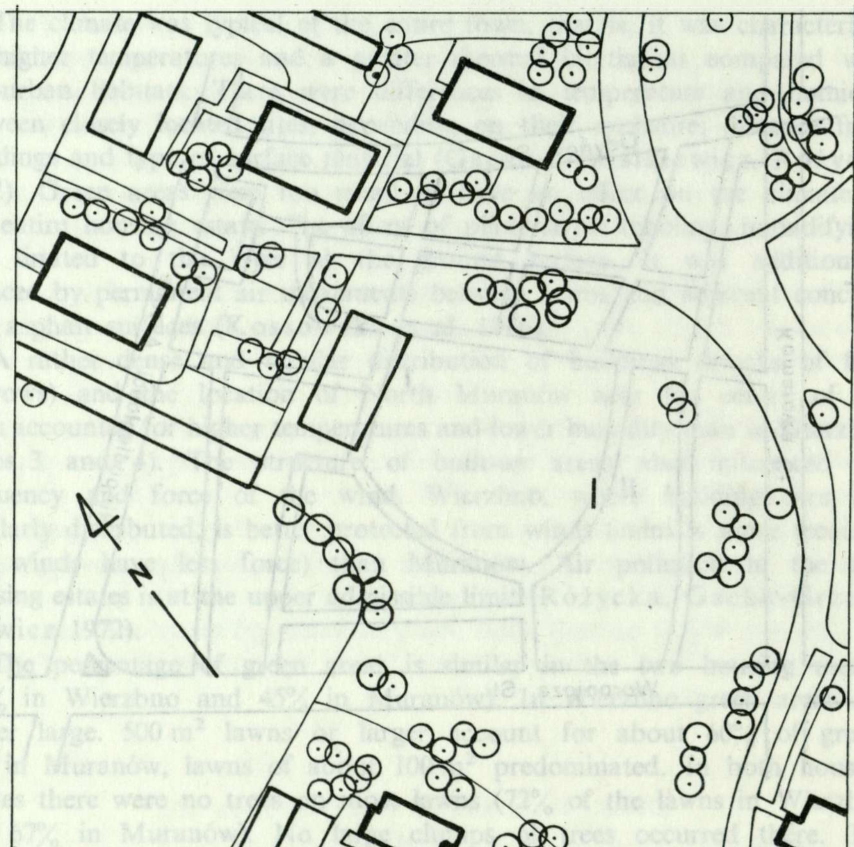

Fig. 16. Wierzbno — plot I

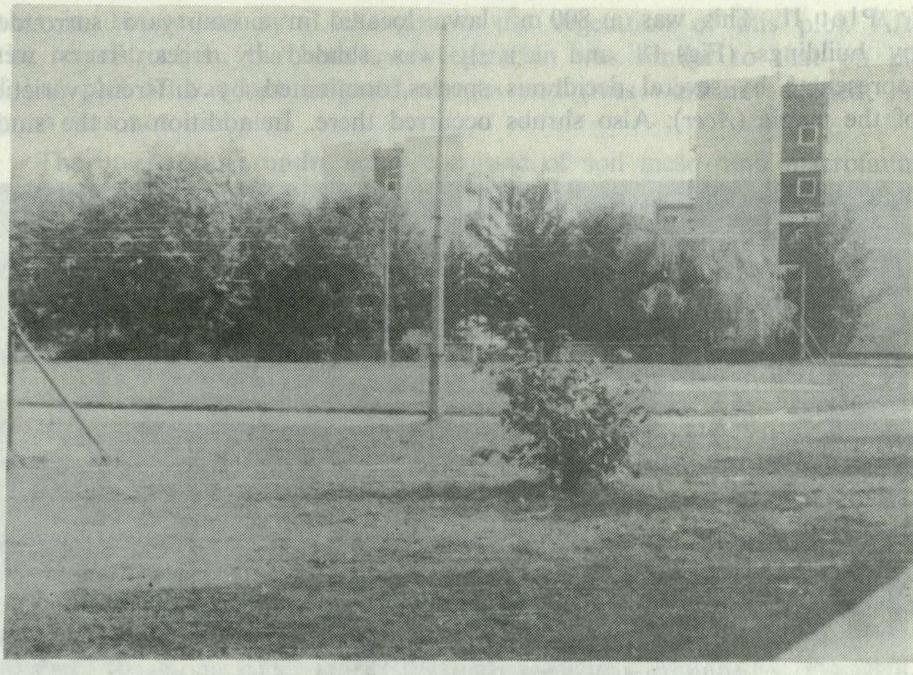

Fig. 17. Wierzbno — plot I (photo E. Chudzicka)

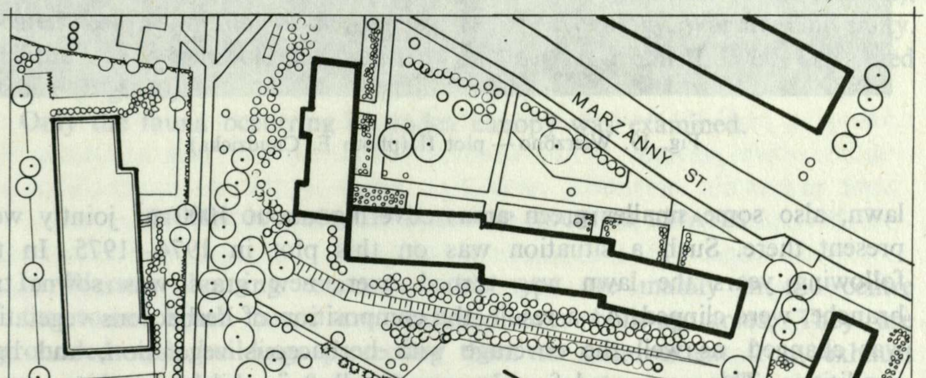

Fig. 18. Wierzbno — plot II

Plot II. This was a 800 m^2 lawn located in a courtyard surrouded by buildings (Figs 18 and 19). It was shaded by trees. Trees were represented by several deciduous species dominated by different varieties of the maple (*Acer*). Also shrubs occurred there. In addition to the study

Fig. 19. Wierzbno — plot II (photo E. Chudzicka)

lawn, also some smaller green areas covering about 1000 m^2 jointly were present there. Such a situation was on this plot in 1974—1975. In the following years the lawn was turned over, new grass was sown, tree branches were clipped. As a result, the composition of herbaceous vegetation was changed, as well the coverage with herbaceous vegetation, and light conditions. This accounted for changes (smaller) in soil moisture.

The mechanical composition of soil was represented by fractions of light silk loam with a 5—10 cm layer of very fine sand. The mechanical composition of soil and heavy shading accounted for a high soil moisture, the highest of all the study plots in Warsaw. Soil pH was neutral, and almost did not change with depth. Soil pollution with heavy metals was rather low, only the content of zinc was high. The content of organic matter was rather high, especially in the surface layer (data from 1976), showing that the soil was fertilized with peat (Tab. 6).

No data are available on the herb-layer composition in 1974—1975, that is, before structural changes in the vegetation of this plot. After the reconstruction, the herb-layer vegetation was similar to that on plot I but plot II was not irrigated, shrubs and trees were not clipped, and grass was not trampled.

The invertebrates under study consisted of soil meso- and macrofauna, epigean fauna, herb-layer fauna, and canopy fauna of young lindens (*Tilia cordata*) growing singly close to the plot.

NORTH MURANÓW

In the housing estate Muranów, two plots were established (Fig. 20).

Plot I. It was located in a courtyard surrounded with buildings. The vegetation was many-layered, with diversified structure and species composition. Trees were dominated by maples (*Acer*). Lawns areas were divided into small patches. Roses and other flowers were planted there, often replaced by new species. The lawns were watered, mown, and raked.

No detailed data are available on soil pollution, air pollution, and species composition of the vegetation.

Only the fauna occurring in the herb layer was examined.

Plot II. This was a lawn with a single young linden (*Tilia cordata*), located near the building of the Department of Psychology, Warsaw University. On the other side of the building there was a small, well cultivated garden (Fig. 20).

Only the fauna occurring in linden canopy was examined.

GREEN OF CLOSELY BUILT-UP HOUSING ESTATES

In Warsaw, housing estates of this type are mainly in the centre of the town. Small lawns are scattered over built-up areas. They are surrounded with buildings protecting them to some extent from exhaust gases, and completely isolated from other green areas. Often they are markedly shaded by high buidings. Three study areas were selected: courtyards in M.D.M. (Marszałkowska Dzielnica Mieszkaniowa) and at Wilcza Street, and a square at Hoża Street.

In M.D.M. two plots were established, completely isolated from each other, located at either side of the large Konstytucji Square.

The soils of these housing estates are totally anthropogenic. They overlay the rubble substrate from the times of the World War II. A thin, often only 10cm deep soil was transported there, and became partly mixed with the substrate. As a result, the proportion of soil skeleton was high (up to 25%), and the content of $CaCO_3$ was also high (1.30—4.07). Mean pH in a layer of 0—10cm was 7.1 (Tab. 6).

The study areas were located in a heavily polluted environment (near Marszałkowska Street with very intense traffic). Soil pollution with heavy metals was high, mostly with zinc, and also lead. Differences in the degree of soil pollution (the highest pollution at Wilcza Street and the lowest at Hoża Street) were significant in a layer of 0—5cm, but almost disappeared in a layer of 5—10 cm. Soil pollution in these study areas can be compared to that in Wierzbno, especially on plot I (Tab. 6).

Soil pollution with heavy metals reduced the decomposition of peat and compost used as fertilizers of lawns in the centre of Warsaw. The content of soil organic matter was very high. The C:N ratio was too high, unsuitable for plant growth. The content of undecomposed organic matter was particularly high (10%) in the soil of the lawn at Wilcza Street (Tab. 6).

There were 19 plant species of these plots (9—10 per plot). This vegetation cannot be classified to any plant community. It contained species of three classes: *Molinio-Arrhenatheretea, Plantaginetea maioris*, and *Artemisietea*. The species composition largely differed from one plot to another (the plots at Wilcza and Hoża Streets, and also those at Wilcza Street and M.D.M. I shared only two species. M.D.M. I and Hoża Street shared 7 species). The proportion of species characteristic of plant community typical for trampled sites of the class *Plantaginetea maioris* was high. They are resistant to trampling and grow on soils with small porosity. On plot M.D.M. I they accounted for 50% of the species composition. with *Lolium perenne* as the dominant, and on the plot at Hoża Street their proportion was 60%, with *Poa annua* as the dominant. The lawns of these plots were particularly vulnerable to human pressure.

With respect to the species composition of vegetation, the lawn at Wilcza Street was the most similar to the lawns representing other types of urban green, and, at the same time, it differed most from the lawns of other plots in closely built-up housing estates. It was dominated by synanthropic plants of the class *Plantaginetea maioris* and by ruderal weeds of the class *Artemisietea*, typical of strongly nitrophilous communities. The species of the latter class did not occur in other types of urban green studied in Warsaw. This implies that green areas of closely built-up housing estates were extremely heavily polluted with wastes of organic origin. Also some species of the class *Molinio-Arrhenatheretea* occurred there (*Poa pratensis* and *Festuca rubra* were particularly abundant), while the species characteristic of the alliance *Cynosurion* were absent.

Plant cover of these lawns was 90—100% (Tab. 10). Monocotyledons predominated. On the plot M.D.M. I and at Hoża Street, the proportion of monocyteledons reached 70—75%, implying that grasses must have been sown there in the study year.

M.D.M.

Plot I. This plot was located in a courtyard at Piękna Street. It was established in 1952. It was surrounded by buildings and covered an area of about 150 m^2. There were some trees on it (*Acer pseudoplatanus* and *A. platanoides scheweidleri*), and a row of shrubs (*Syringa vulgaris*) in its eastern part.

Air temperature was higher and humidity lower than in park green both in successive months of the growing season (Tab. 2) and during the day (Tab. 3 and 4).

The mechanical composition of soil comprised coarse sand with rubble. $CaCO_3$ content was rahter high, thus pH was neutral in a layer of 0—5 cm and alkaline in deeper layers. The content of heavy methals in soil was rather high, especially of zinc (Tab. 6). It was lower, however, than in the lawns bordering on the streets. The content of soil organic matter was lower by half than for lawns in parks and loosely built-up housing estates. It was particularly low at a depth of 5—10cm. The decomposition of organic matter was close to optimum, especially in the upper soil layer (Tab. 6).

The herb layer of lawn consisted of a small number of 10 species. Plant cover was 100%. Dicotyledons accounted for as many as 75% of the vegetation. The most abundant species was *Lolium perenne*, a species characteristic of the class *Plantaginetea maioris*. The degrees of abundance and acompanying were equal to 5. Species abundant on other sites in Warsaw, such as *Poa pratensis* and *Festuca rubra*, were absent. There are no data on the annual biomass production of aboveground plant parts. Litter biomass after the growing season was the lowest of all the plots (Tab. 12). This was mostly due to a poor condition of the vegetation, which was damaged by numerous dogs and cats.

The invertebrates under study consisted of soil meso- and macrofauna, epigean fauna, and herb-layer fauna.

Plot II. This plot was located in a courtyard at Koszykowa Street. This was a lawn similar to the preceding one with respect to the vegetation structure and site conditions. It was dotted with single lindens (*Tilia cordata*).

Only the fauna occurring in linden canopy was examined there.

WILCZA STREET

This was a 300 m^2 lawn located in the courtyard of the Institute of Zoology, PAS. It was surrounded by buildings from three sides and the fourth side bordered on Wilcza Street. This lawn was established in 1968 in place of a ruined building. In 1974—1975 its vegetation was poor. Then new shrubs and trees were planted, thus humidity and light conditions changed during the study period. Trees were represented by young maples (*Acer negundo* and *A. platanoides*). Also some species of decorative shrubs were planted there in 1978. The lawn was watered and mown but on rare ocasions.

The mechanical composition of soil was represented by a fraction of medium sand mixed with rubble. Soil moisture in 1974—1977 was typical of open lawns. $CaCO_3$ content in soil was very high, and pH was neutral in the upper layer, while alkaline in deeper layers (Tab. 6). Soil pollution with heavy metals was very high, similar to that in streetside green areas. The content of zinc in the surface layer was particularly high. The content of organic matter was very high in the surface soil layer, and very low at a depth of 5—10 cm (Tab. 6). The degree of organic matter decomposition showed that soil processes were inhibited in the upper layer and compounds rather poor in nitrogen were accumulated.

The herb layer was poor, represented by only 9 species. Monocotyledons accounted for 65% of the plant cover (Tab. 10). *Poa pratensis* was the dominant, also *Festuca rubra* was abundant (Tab. 9). Also species characteristic of ruderal plant communities of the class *Artemisietea* and of the alliance *Eu-Arction* were present.

The invertebrate animals under study consisted of soil meso- and macrofauna, epigean fauna, herb-layer fauna, and canopy-fauna of maples.

HOŻA STREET

This lawn was located at the crossing of Hoża and Poznańska Streets. It was established in 1976 in place of a ruined building. It was large than the other lawns of this category, covering an area of 1300 m^2. Single young trees (*Crategus* sp.) were scattered on it. This lawn adjoined a playing ground for children and was located on the way to nearby houses, thus heavily trampled.

The mechanical composition of soil comprised very fine sand with rubble. $CaCO_3$ content in soil was high, pH was alkaline (Tab. 6). Soil pollution with heavy metals was lower than in other courtyards in the centre of the town, probably because unpolluted soil was transported there in 1976. The content of organic matter was low, especially in deeper soil layers, and its decomposition showed that soil processes were inhibited (Tab. 6).

The herb layer consisted of 10 species. Monocotyledons accounted for

75% of the plant cover (Tab. 10). The dominant species was *Poa annua*, which is characteristic of the class *Plantaginetea maioris*. The other species were equally abundant.

Only soil *Acarina* and the fauna occurring in the herb layer were examined.

STREETSIDE GREEN

STREETSIDE GREEN NEAR LARGE GREEN COMPLEXES

All the study areas of this type were represented by narrow, several meters wide green belts running along streets at the edges or between lanes. They were separated from neighbouring large green complexes by hardened surfaces of different breadth.

Since these lawns covered small areas, the effect of their vegetation on thermal and humidity conditions was limited to the air at the ground surface. Higher air layers were affected by the areas adjoining the lawn as a result of turbulent mixing of the air from the lawn with the air from the areas covered with concrete and asphalt (Kossowska et al. 1976).

Mean and extermal monthly air temperatures above streetside lawns were higher than within parks, the climate of which was largely independent of the surrounding areas.

Comparative studies on changes in temperature and humidity during the day were conducted in two areas of Warsaw: in the Saxon Garden with the adjoining site at Marszałkowska Street (thermohygrographic records) and in the park at the Cemetery of Soviet Soldiers with the adjoining site at Żwirki i Wigury Avenue (psychrometric records). Because the measurements were taken by different apparatuses, the results for these two regions cannot be compared directly. But it can be seen that in both cases air temperature during the day was higher on the streetside lawn than in the park (Tab. 3). The greatest differences in air temperature between these two types of green were noted in the afternoon.

The air above streetside lawns was drier than in parks. Differences in temperature and, especially, in humidity between plots within the park at the Cemetery of Soviet Soldiers and the plots at Żwirki i Wigury Avenue were lower at a height of 1.5 m than 0.25 m above the ground (Tab. 4). The herb layer of the lawn at Żwirki i Wigury Avenue was characterized by a small plant cover (72% in 1975) and by a very low production of aboveground biomass (94.0 g/m^2 in 1975). Thus this vegetation was not a good source of vapour, and its effect on air humidity and temperature was small. But in the higher air layers the content of vapour could increase due to the transpiration of trees growing there in a dense row.

Air pollution with dust, carbon oxides, and nitrogen oxides was particularly high on streetside lawns because of a direct effect of traffic (Tab. 5).

The soils of streetside lawns were of anthropogenic character. The pressure of traffic and also a seasonal input of large amounts of calcium chloridae and natrium chloridae used against ice in winter accounted for large changes in soil chemical properties. On the average, pH was higher than for other types of green areas, generally alkaline (Tab. 6). The content of $CaCO_3$ in a layer of 0—5 cm varied from 29% (Ujazdowskie Avenue) to 2.07% (Żwirki i Wigury Avenue), and in a layer of 5—10 cm from 0.08 to 2.15%. The occurrence of this substance in the soils of streetside lawns was mainly related to the fall of alkaline dust, and for this reason it was lower than in housing estates where rubble was an additional source of $CaCO_3$ in soil. Soils of streetside green contained large amounts of heavy metals. The content of zinc and lead were similar to and often even higher than those in the soils of housing estates in the centre of the town (Table 6). Besides heavy metals, also other substances can accumulate in soil, for example, soluble chlorine, in amounts toxic to trees and shrubs (Czarnowska et al. 1976). These processes and changes in the soil absorbing complex have not only direct but also indirect effects on living organisms. It has been found that they affect the intake of different elements by plants. For example, the intake of manganium and iron is reduced (though the content of these elements in soil is high), while the intake of calcium is stimulated, and the excess of this element disturbs water economy in plants (Konecka-Betley et al. in print).

The content of organic matter was high in soils of streetside lawns. It ranged from 3.19% (Żwirki i Wigury Avenue) to 7.86% (Marszałkowska Street). The C:N ratio largely varied, being even as high as 22.5:1 (Woronicza Street). This implies that the decomposition of humus, which was supplied mostly by man, was slow. The balance between humification and mineralization processes was disturbed as a result of soil slkalization and accumulation of different substances, especially heavy metals and sulphur (Czarnowska et al., 1976. Czarnowska, Konecka-Betley 1977), reducing the activity of soil microorganisms.

Biological activity of the soil of streetside lawns was severely reduced. This was indicated by a low abundance of microorganisms and by a lower, as compared with soils in parks, activity of cellulase, dehydrogenase, and urease (Tabs 7 and 8).

The vegetation of streetside lawns was dominated by a group of species of the class *Molinio-Arrhenatheretalia*. Then there was a group of plants resistant to mechanical injuries, which belonged to the class *Plantaginetea*

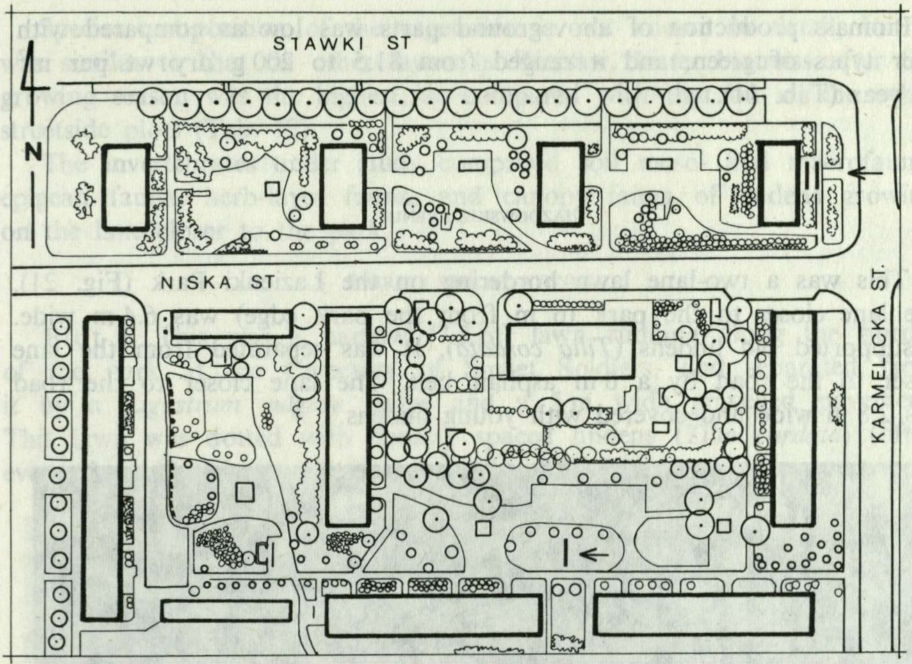

Fig. 20. Location of the study plots in the North Muranów housing estate

maioris. The communities of herbaceous plants on streetside lawns adjoining parks (Marszałkowska Street, Żwirki i Wigury Avenue) were very similar to the communities within these parks (the similarity was much greater than within the group of stretside plots). But the number of species was lower than in parks and the proportion of associated species was higher [class 2 of fidelity according to Szafer and Zarzycki (1972)], as well as the proportion of sporadic species [first degree of constancy according to Szafer and Zarzycki (1972)]. At Marszałkowska Street, *Festuca ovina* was abundant, which represents the class *Sedo-Scleranthea* (Tab. 9).

A total of 14—19 plant species were recorded on respective plots. The most abundant were *Poa pratensis, Festuca rubra var. genuina, Lolium perenne, Achillea millefolium*, and *Trifolium reprens*.

Plant cover was diversified and ranged from 63 to 92%. The herb layer was dominated by monocotyledons (Tab. 10).

Biomass production of aboveground parts was low as compared with other types of green, and it ranged from 81.5 to 200 g dry wt per m^2 per year (Tab. 11).

UJAZDOWSKIE AVENUE

This was a two-lane lawn bordering on the Łazienki Park (Fig. 21). The lane closer to the park (6 m from the park edge) was 6.4 m wide. It supported old lindens (*Tilia cordata*). It was separated from the lane closer to the road by a 6 m asphalt belt. The lane closer to the road was 2.8 m wide and covered with young lindens.

Fig. 21. Ujazdowskie Avenue (photo E. Chudzicka)

The mechanical composition of soil comprised a fraction of sandy loam. Soil pH was a little acid in the upper layer and neutral in deeper layers. Soil pollution with heavy metals was very high, typical of all streetside plots (Tab. 6). The content of soil organic matter was high, especially in upper layers, which implies that peat was applied as fertilizer. The decomposition of organic matter was unsuitable for plants, as indicated by a high C:N ratio (Tab. 6).

Species composition of the vegetation is not known in detail, but it was similar to that on other lawns in Warsaw. Litter biomass after the growing season was the highest, as compared with that on all the other streetside plots (Tab. 12).

The invertebrates under study comprised soil meso- and macrofauna, epigean fauna, herb-layer fauna, and canopy fauna of lindens growing on the lane closer to the park.

ŻWIRKI I WIGURY AVENUE

Plot I. This was a narrow (7.5 m) lawn running along the border of the park at the Cemetery of Soviet Soldiers, and separated from it by a *Ligustrum vulgare* hedge and a 5 m wide gravelled pavement. This lawn was dotted with densely spaced lindens (*Tilia cordata*) (often every 5 m), forming a dense row (Fig. 22). The herb layer was only

Fig. 22. Żwirki i Wigury Avenue — plot I (photo E. Chudzicka)

on peripheral parts, and it was completely lacking under the canopy.

The mechanical soil composition comprised a fraction of sandy loam on very fine sand. Relative soil moisture was low, but higher than in other, open streetside lawns, and amounted to about 16%. The content of $CaCO_3$ in soil was high, pH was neutral, and in lower layers alkaline (Tab. 6). Soil pollution with heavy metals was high, especially with zinc and lead. The content of organic matter was low in deeper layers but higher in the upper layer. Soil processes were clearly inhibited (Tab. 6).

The herb layer consisted of 14 species. Plant cover was very low (63%) because of overshadowing by trees. Monocotyledons accounted for 65% of the cover (Tab. 10). The most abundant species was *Festuca rubra*. Other abundant species were represented by *Poa pratensis, Achillea millefolium, Trifolium pratense,* and *T. repens* (Tab. 9). The vegetation of this lawn can be classified as a plant community of the alliance *Cynosurion*, as 50% of its plants were characteristic of this alliance.

Annual biomass production of aboveground parts was small, the lowest for all the plots in Warsaw (Tab. 11). Litter biomass after the growing season was high, thus there was an accumulation of organic matter from year to year.

The invertebrates under study comprised soil meso- and macrofauna, epigean fauna, herb-layer fauna, and linden-canopy fauna.

Plot II. This was an interline lawn 19.4 m wide at Żwirki i Wigury Avenue (Fig. 23). A row of lindens spaced every 10 m run along its middle part. As a result, herb layer occurred only at the edges of this lawn.

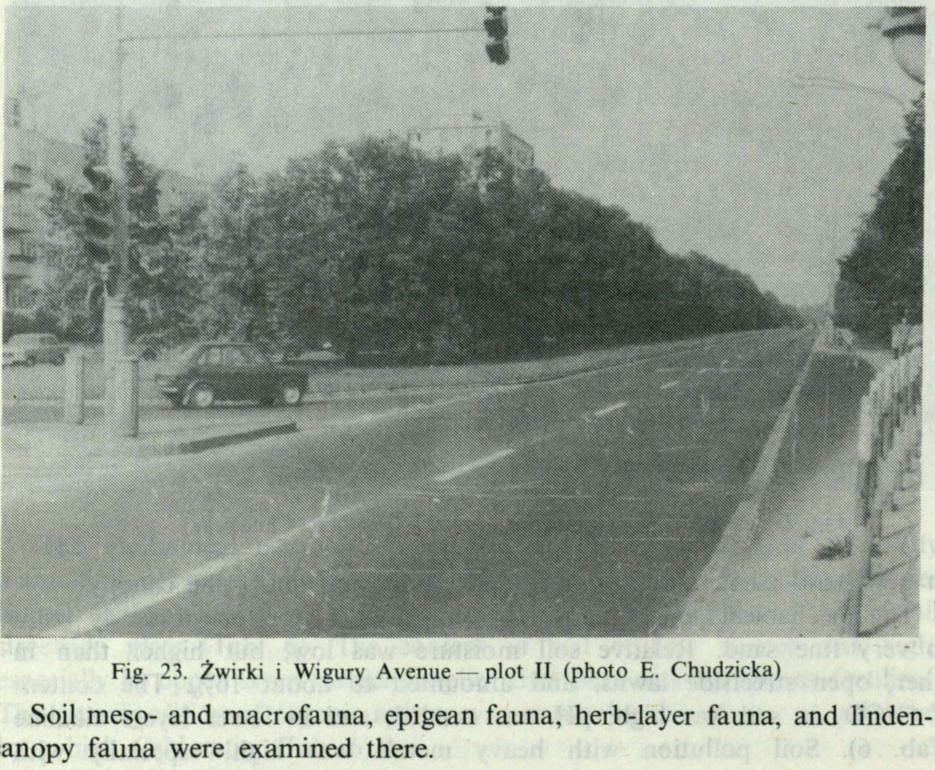

Fig. 23. Żwirki i Wigury Avenue — plot II (photo E. Chudzicka)

Soil meso- and macrofauna, epigean fauna, herb-layer fauna, and linden-canopy fauna were examined there.

MARSZAŁKOWSKA STREET

This was a large interlane lawn extending over an area of about 4200 m^2, separated from the Saxon Garden by a road lane and a tramwayline. Three apple trees (*Malus domestica*) and a maple (*Acer sp.*) were scattered on it. This lawn was heavily insolated (Fig. 24).

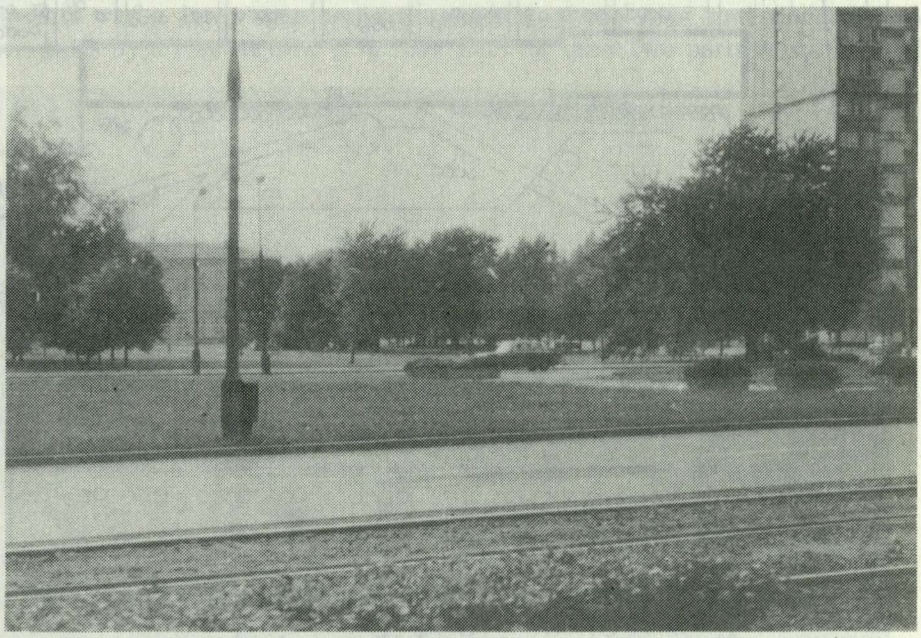

Fig. 24. Marszałkowska Street (photo E. Chudzicka)

The mechanical soil composition comprised a fraction of loamy strong sand on loamy light silk sand. Soil pH was neutral and moisture was one of the lowest in the town (12%). Soil pollution with heavy metals was high, especially with zinc and lead (Tab. 6). The content of organic matter was high, especially to a depth of 10 cm, but a high C:N ratio showed that soil processes were inhibited (Tab. 6).

The herb layer consisted of 14 species. They were dominated by monocotyledons (Tab. 10). The most abundant were *Festuca rubra* and *F. ovina*. The annual biomass production of aboveground parts was high, similar to that on park plots (Tab. 11). Litter biomass after the growing season was also high, and a small difference between biomass production and litter biomass indicates that this lawn was mown and raked.

Invertebrate investigations comprised soil meso- and macrofauna, epigean fauna, and herb-layer fauna.

WORONICZA STREET

This was a wide green belt about 20 m wide running between the road and the first line of buildings in the housing estate Wierzbno (Fig. 25). A narrow pavement separated it into two parts: a narrow lawn

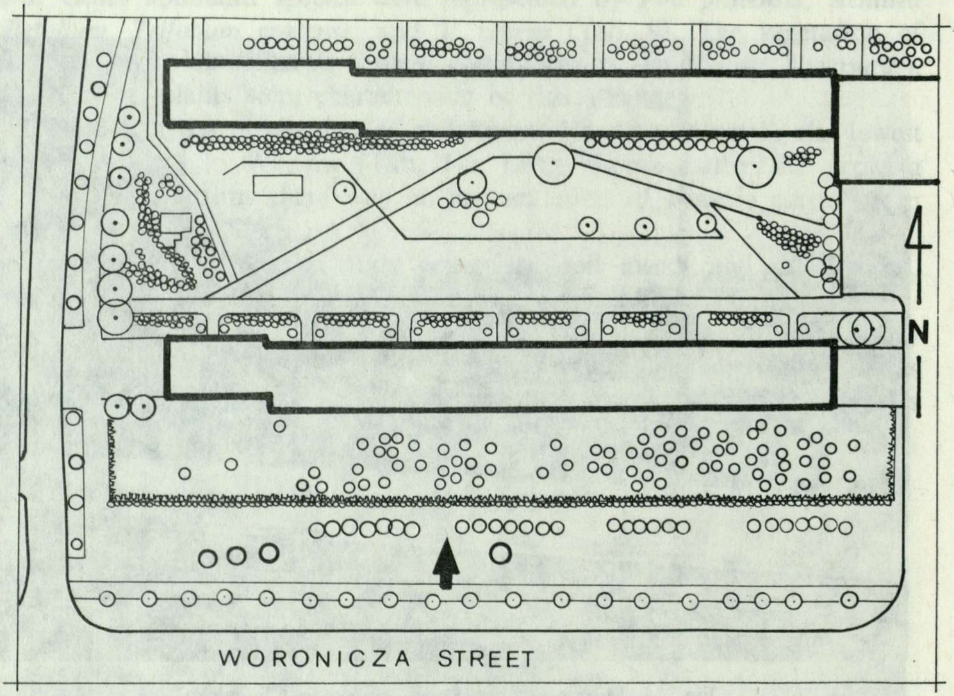

Fig. 25. Woronicza Street

bordering on the road, covered with young lindens, and a lawn with a more diverse plant cover, merging into flower-vegetable gardens near buildings, sheltered by a hedge.

The mechanical composition of soil comprised fractions of coarse sand and loamy silk sand on sandy loam. Relative soil moisture was low, typical of streetside lawns. The content of $CaCO_3$ was rather high, especially in the upper soil layer, and pH was a little alkaline (Tab. 6). Soil pollution with heavy metals was high, especially with zinc and lead (Tab. 6). The content of organic matter was high, but the C:N ratio showed that humus decomposition was delayed.

There are no detailed data on the species composition of herbaceous plants and plant cover. It may be assumed that they did not differ much from those on the plot Wierzbno I. Litter biomass after the growing season was similar to that on the plot Wierzbno I (Tab. 12).

Soil meso- and macrofauna, epigean fauna, and herb-layer fauna were examined.

NIEPODLEGŁOŚCI AVENUE

This was a lawn running in the middle of the road and divided into two parts by a tramwayline (Fig. 26). Each of these two parts was separated

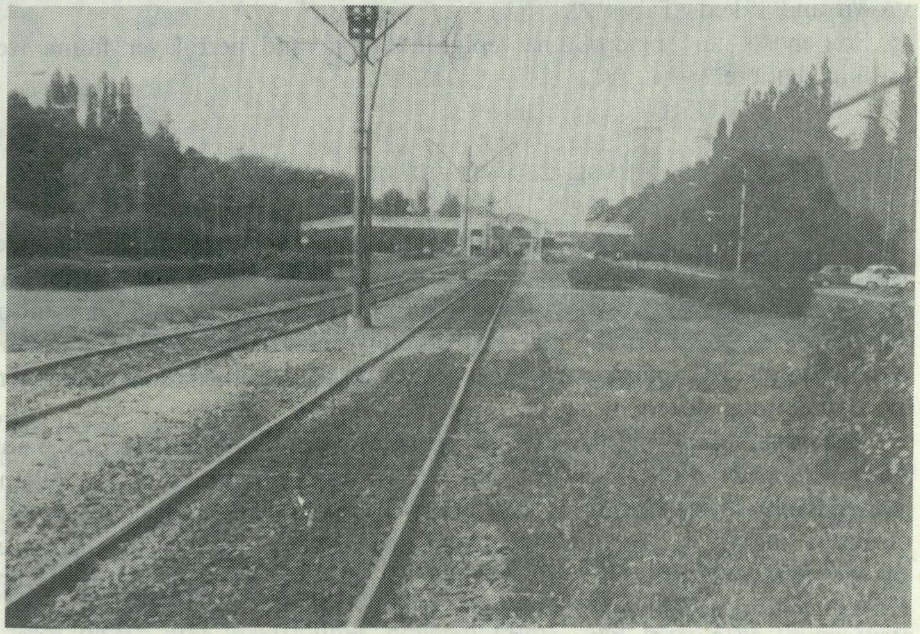

Fig. 26. Niepodległości Avenue (photo E. Chudzicka)

by a low hedge of the privet (*Ligustrum vulgare*) from this line. They were 5.5 m wide, each. This plot adjoined green areas of the Academy of Agriculture, green areas of the housing estate Batory, and a vast park called Pola Mokotowskie (Mokotowskie Fields).

The mechanical composition of soil comprised fractions of silk, loamy light silk sand, and light silk loam with rubble. The mechanical composition of soil and shrub cover accounted for a rather high relative soil moisture of about 17%. The content of $CaCO_3$ in soil was high and did not vary with depth (Tab. 6). Soil pH was neutral in the upper layer and alkaline in deeper layers. The content of organic matter in soil was high, especially in the upper layer. The C:N ratio was high, and indicated a heavily disturbed balance between humification and mineralization processes. The content of heavy metals was very high, especially of lead (Tab. 6), as the lawn was located at the street with intense traffic.

The herb layer consisted of as many as 19 species (Tab. 10). Plant cover was 92%. The proportion of dicotyledons was 55%. The most abundant species consisted of *Poa pratensis, Festuca rubra, Lolium perenne,* and *Poa annua*, that is, the species typical of urban lawns. The biomass production of aboveground parts was rather high and did not vary from year to year (Tab. 11). Litter biomass was low, thus the lawn was frequently mown and raked (Tab. 12).

Soil meso- and macrofauna, epigean fauna, and herb-layer fauna were examined there.

ISOLATED STREETSIDE GREEN

These study areas were located in the centre of the town at streets with very intense traffic. Green areas accounted there for a small percentage of the surface area, mostly covered with concrete and asphalt, or built-up. The effect of green on thermal and humidity conditions was unnoticeable. Air pollution was particularly heavy, and exceeded the admissible norms by several to a dozen or so per cent (Skorupski 1976).

Individual plots supported from 13 to 16 species of herbaceous plants. They belonged to the class *Molinio-Arrhenatheretea* (species of the alliance *Arrhenatherion* were absent, as they are too vulnerable to high concentrations of heavy metals in soil and frequent mowing), and a few of them were of the class *Plantaginetea maioris*. On the plot at Marchlewskiego Street, *Festuca ovina* accounted for much of the plant cover. This species is characteristic of acidophilous plant community typical for dry sandy and warm sites of the class *Sedo-Scleranthetea* (Tab. 9).

The density of the herb layer ranged from 90 to 100% (Tab. 10). The proportion of monocotyledons was 60% of the plant cover.

ZBAWICIELA SQUARE

This was a round, insolated lawn located in the central part of a traffic circle, divided into three parts by tram-lines (Fig. 27). The joint area of the lawn was about 1000m^2. Tress and shrubs were absent, but annal flower-beds lined the border.

There no data on the mecanical composition of soil, soil pollution, and content of organic matter. Obviously, soil pollution must have been high there, like on other streetside plots. The herb layer consisted of 13 species.

Fig. 27. Zbawiciela Square (photo E. Chudzicka)

Plant cover was 100%, and monocotyledons accounted for 60% (Tab. 10). The most abundant was *Poa pratensis*, but also *Festuca rubra*, and *Bellio perennis* were abundant (Tab. 9). *B. perennis* occurred only on this plot and on the park plot Łazienki I.

There are no data on plant production. Litter biomass was one of the lowest recorded in urban green (Tab. 12).

Soil meso- and macrofauna, epigean fauna, and herb-layer fauna were examined there.

MARCHLEWSKIEGO STREET

This lawn was located on a traffic circle at the crossing of Marchlewskiego Street and Świętokrzyska Street (Fig. 28). There were no trees on it.

The only data available concern the species composition of the vegetation. The herb layer consisted of 16 species. predominated by monocotyledons (Tab. 10). The most abundant was *Festuca ovina*, a species characteristic of plant community typical for dry sandy and warm sites of the class *Sedo-Scleranthetea* (Tab. 9). Also *Convolvulus arvensis* was abundant. It occurred also on other streetside plots but was less abundant. It was absent from other lawns of Warsaw, or occasionally present.

Only herb-layer fauna was examined there.

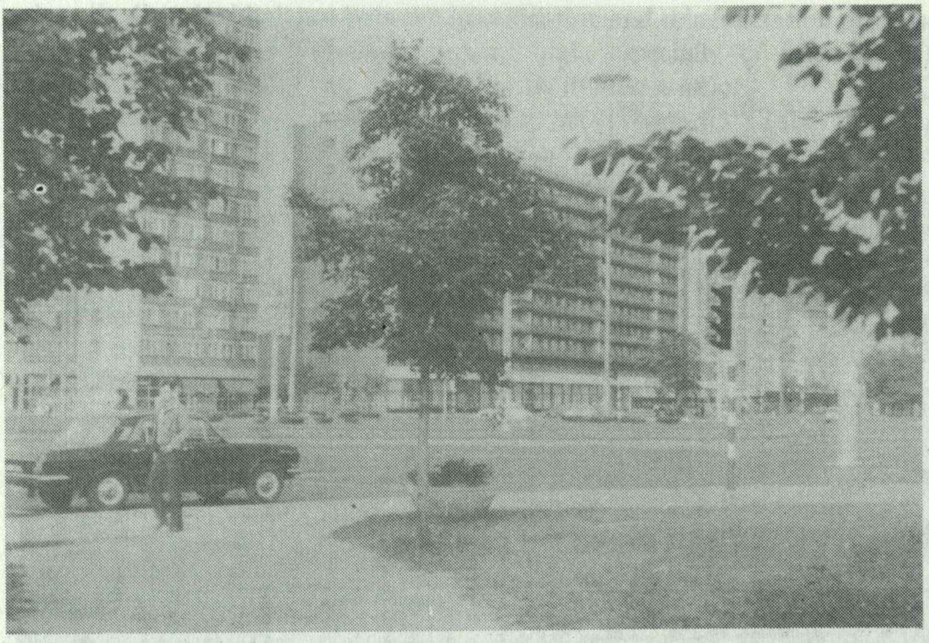

Fig. 28. Marchlewskiego Street (photo E. Chudzicka)

Fig. 29. Konstytucji Square (photo E. Chudzicka)

KONSTYTUCJI SQUARE

This plot was located on a vast square, which is an enlargement of Marszałkowska Street. The only vegetation in this area totally covered with concrete and asphalt was represented by lindens (*Tilia cordata*), forming a row on the pavement (Fig. 29).

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STRUKTURA FAUNY WARSZAWA — CHARAKTERYSTYKA TERENU BADAŃ

STRESZCZENIE

Warszawa jest obszarem o specyficznych warunkach siedliskowych, wyraźnie odmiennych niż na terenach otaczających miasto. Gleby terenów zielonych Warszawy są silnie przekształcone, czego przejawami są zmiany struktury mechanicznej, alkalizacja warstwy wierzchniej, zmiany zawartości substancji organicznej, wysoka wartość stosunku ilości węgla do azotu i obniżona aktywność enzymów glebowych, a także akumulacja metali ciężkich. Temperatura powietrza w mieście jest wyższa, a wilgotność względna niższa niż na obszarach nie zabudowanych. Wpływ zieleni na klimat miejski jest znikomy. Jedynie duże tereny zieleni, odznaczające się urozmaiconą, wielowarstwową roślinnością, jakimi są parki, wykazują odrębność klimatyczną w stosunku do innych rejonów miasta. W powietrzu zawarte są znaczne ilości tlenków azotu, węgla oraz pyłów: największe ich stężenie występują w pobliżu arterii komunikacyjnych. Roślinność w obrębie zieleni miejskiej Warszawy jest ukształtowana przez człowieka i pozostaje pod jego kontrolą. Roślinność trawników zbliżona jest składem do naturalnych zbiorowisk z klasy *Molinio-Arrhenatheretalia*, choć uboższa pod względem liczby gatunków. Występują również odporne na wydeptywanie gatunki z klasy *Plantaginetea maioris*, wybitnie nitrofilne gatunki z klasy *Artemisietea* oraz, na terenach bardzo przesuszonych i zasolonych, gatunki z klasy *Sedo-Scleranthetea*. Pokrycie roślinności i produkcja zróżnicowane są w zależności od lokalnych warunków siedliskowych i najczęściej są niższe niż na terenach podmiejskich. Roślinność wysoka składa się z posadzonych w różnym czasie (od kilku do kilkuset lat temu) drzew i krzewów pochodzenia rodzimego i obcego.

Wyżej wymienione parametry charakteryzujące środowisko miejskie wykazują znaczny zakres wahań w obrębie badanych typów zieleni miejskiej Warszawy. Dla celów badań zoocenologicznych wyróżniono w Warszawie 3 główne typy zieleni miejskiej: parki, zieleń osiedli mieszkaniowych i zieleń uliczną. W obrębie zieleni osiedlowej wyróżniono zieleń osiedli o zabudowie luźnej i zieleń osiedli o zabudowie zwartej. W obrębie zieleni ulicznej wyróżniono obiekty mające zaplecze w postaci dużego obszaru zielonego (parku, zieleni osiedlowej) oraz zieleń izolowaną. W pracy zawarta jest charakterystyka wymienionych typów zieleni miejskiej oraz opis konkretnych obiektów i stanowisk badawczych.

СТРУКТУРА ФАУНЫ ВАРШАВЫ — ХАРАКТЕРИСТИКА ИССЛЕДУЕМОЙ ТЕРРИТОРИИ

РЕЗЮМЕ

В статье дается подробное описание 30 стаций, расположенных в городских зеленых насаждениях Варшавы, в которых в 1974—1978 гг. проводили исследования по структуре фауны беспозвоночных. При характеристике отдельных стаций учтены следующие элементы: механическая структура почвы, ее pH, содержание углекислого кальция и органического вещества, соотношение C:N, содержание тяжелых металлов и активность почвенных энзимов; суточная и созонная динамика средных и экстремальных температур и средней относительной влажности воздуха, запыление воздуха и содержание окисей углерода и азота, состав флоры, степень развития растительного покрова, биомасса и соотношение покрытия одно- к вдулистными растениями в ярусе травы, а также общее описание высокой растительности.