Tryjanowski P., Sparks T.H. & Jerzak L. (eds.)
The White Stork in Poland: studies in biology, ecology and conservation
Bogucki Wydawnictwo Naukowe, Poznań 2006

Food composition and energy demand of the White Stork *Ciconia ciconia* breeding population. Literature survey and preliminary results from Poland

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ABSTRACT: This paper presents broad literature survey and preliminary results of study of food composition of breeding White Stork *Ciconia ciconia* population from Poland. The fieldwork was conducted in the farmland landscapes and river valleys at three areas near Strzelce Opolskie, Leszno and Ostrów Wiekopolski. During the standard nest visits in the nestling period we noted prey remains both vomited by chicks as a stress reaction or delivered at nest by adult birds. The above data on the White Stork's food composition in the discussed populations are represented in tables 1–3. Energy value of the food was assessed only for the population from southern Poland. Use of several method of data collection are discussed in the paper.

KEY WORDS: food, foraging, energy consumption, food examination methods, White Stork, *Ciconia ciconia*

Introduction

The quality and quantity of food that parents provide to their chicks is the most important environmental factor influencing reproduction success of many bird species (Martin 1987), including the White Stork *Ciconia ciconia* (Tryjanowski et al. 2005). Thus the availability of food resources in breeding areas and wintering grounds is a key factor that regulates survival, number and condition of the White

Stork population (see Mrugasiewicz 1972, Dallinga & Schoenmakers 1984, 1987, 1989, Profus 1991, 2006a, Struwe & Thomsen 1991, Tryjanowski & Kuźniak 2002, Schaub et al. 2005, Sæther et al. 2006).

Many hypotheses about the influence of food quantity and quality on White Storks have not been verified in a credible way. This is because our knowledge about the stork's food composition and quality is still limited. In the majority of papers there are no quantitative analyses of the contribution of particular species and systematic groups in the food composition, and – what is even more vital – no assessment of the energy significance of particular components of the White Stork's diet has been made (see Bauer & Glutz 1966, Creutz 1985, Làzaro 1986, Pinowski et al. 1986, 1991, Lakeberg 1995, Struwe & Thomsen 1991, Antczak et al. 2002).

Habitat changes observed in the past ten years in the agricultural environment which are unfavourable for storks, for example, the increase of arable monocultures (e.g. maize *Zea mays* and rape *Brassica napus*) at the cost of grassland, excessive mechanization and intensification of agriculture, may all account for the diminishing population of the White Stork. Apparently, as a result of such human activities, 16–24% of stork breeding sites disappeared in the provinces of Silesia and Lubuskie (Jerzak et al. 2006, Profus 2006b, c, Wuczyński 2006); whereas in other parts of Poland the size of populations was observed to be stable or increase significantly (Guziak & Jakubiec 2006). Therefore, research conducted on the composition and quality of food can contribute to efficient protection of the White Stork species.

Results presented in this paper, both a literature survey and field data, aim at filling in the gaps in our knowledge about the composition and energy values of the stork's food. This paper partially presents data and conclusions contained in Profus' (2006a) study, however, it is supplemented by new methods of gaining materials and field data collected in the region of Wielkopolska.

Methodological assumptions

Methods used in specifying the White Stork diet: a literature review

Stomach analysis and leather cap put on chicks' beaks

The first attempts to describe diet composition were from stomach content analyses of storks killed and of those found dead (Rörig 1903, Eckstein 1907, Steinbacher 1936, Stammer 1937, Putzig 1938, Radkiewicz 1984, Nachtigall et al. 1998).

Leather caps put on chicks' beaks (Fig. 1) so they could not eat food brought to the nest. The food brought by adult birds to the nest and spat out was collected for analysis, and after specifying its animal content, returned for the chicks to eat (Krapivnyj 1957, Körös 1992). For species protection and ethical reasons, both methods are not used any more.

Direct observation of foraging and feeding birds

Data about the White Stork's food composition mainly come from direct observations of foraging birds (Schüz 1940, Pinowski et al. 1986, 1991, Pinowska & Pinowski 1989, Struwe & Thomsen 1991, Böhning-Gaese 1992, Ranner 1995, Skov 1999), and observations made when chicks were fed (Berndt 1938). Using this method of specifying food composition, it is necessary to realise its drawbacks. Among the caught animals, it is easier for the observer to identify more sizeable prey (moles, rodents, fish, tailless amphibians, reptiles, and leeches) (e.g. Lakeberg 1995).

Permanent recording by a camera situated close to the nest is a new variation of direct observation of feeding (Dolata 2006), which makes it possible to identify the prey better than with the use of a telescope or binoculars, not only thanks to the proximity to the nest but particularly the view from above into the centre of the nest (i.e. where the parent spits out food for chicks), which cannot be seen when observing from the ground.

Analysis of spat-out items

The most frequent method is spat-out item analysis (e.g. Putzig 1935, Drescher 1936, Szijj & Szijj 1955, Schierer 1962, Baudouin 1973, Sackl 1987, Làzaro 1982, 1986, Mužinič & Rasajski 1992, Pinowska et al. 1991, Pinowski et al. 1991, Antczak et al. 2002).

This method allows specifying the biomass of particular animals that were eaten (e.g. Antczak et al. 2002). However, we need to consider its constraints because the stork greatly digests vertebrate cartilage and bones (Steinbacher 1936, Szijj & Szijj 1955, Schulz 1998), which – for this reason – are recorded in the spat-out bits to a much smaller degree than expected when analysing the stork's food. For instance, in Antczak's et al. studies (2002) bones constituted only 8% of the pellets, while a hair analysis showed that the remains of voles *Microtus* sp. only amounted to 86.5% of the spat-out items. In this situation, identifying prey, i.e. mammals, through the presence of its hair in the spat out items is a crucial method (Dziurdzik 1973). Earthworms *Lumbricidae* poses yet another problem as their identification must be performed more precisely than in the case of bones, and a microscope must be used for analysis (Antczak et al. 2002).

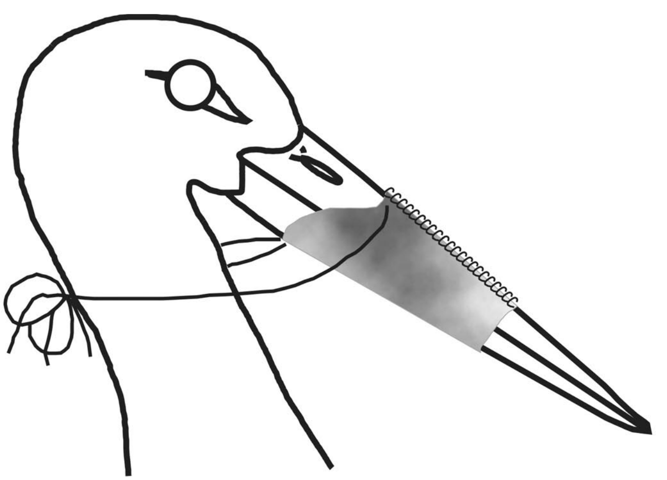

Fig. 1. Schematic drawing leather cap put on chicks' beak (after Krapivnyj 1957)

Energy value of food; specifying energy demand of individuals and populations

Specifying caloric demand, being an element of the energy budget of an individual or the population, is based on a theoretical model which evaluates the assimilated energy quantity in the period between the arrival and the departure from the breeding area, as well as the energy that is necessary for the young to grow and become independent. This method, however, has serious constraints because obtaining good results is only possible for birds raised in captivity (e.g. Kushlan 1977, Keller & Visser 1999).

Specifying the energy value of food

The calorific content of animal food depends mainly on the fat content and not so much on carbohydrates, proteins or minerals. The energy value of animal fat exceeds 39 kJ/g of fresh mass (Górecki 1967, Dolnik et al. 1982). The energy value of other vital elements of the body (proteins and carbohydrates) is nearly half as much (carbohydrates and animal proteins respectively: 17.58 and 23.66 kJ/g; Dolnik et al. 1982). So a change in the animal's fat content is responsible for a substantial change in the calorific value of the whole body.

There are three methods for calorific value measurements. The first one is the value obtained directly from burning in the calorimeter, i.e. a top burning value. also called the dry mass calorie value. The second is obtained from the calorific value of the dry mass by means of subtracting the ash content, which is the ash-free calorific value. The third is the biomass calorific value. This value – just like the previous ones – is reached by taking into account the water content in the initial sample (Górecki 1967).

Specifying food and energy demand of a breeding pair and a chick: field methods

Double labelled water (DLW) is an isotope method of testing animal metabolism (Nagy 1987, Nagy & Obst 1991, Nagy et al. 1999). This technique of establishing field metabolic rate (FMR) also covers the cost of base metabolic rate (BMR), thermoregulation and basic life functions. Food-energy needs of birds are determined by a number of independent factors, but the most important one is the mass of the body (Nagy & Obst 1991). The energy demand of a breeding stork can be calculated by a general equation:

$$\text{FMR (kJ/d)} = 10.9\ M^{0.64}$$

where M = live body mass of the animal in grams (Nagy 1987, Bozinovic & Medel 1988).

The body mass of breeding storks of both sexes comes from information (recalculated) contained in the literature (Sasvári & Hegyi 2001). Field metabolic rates obtained for an average male and female are respectively: 2136 and 1976 kJ/day, so for the pair: 4112 kJ. The birds' daily energy requirement is in fact higher because the bird is not able to use the entire energy derived from food. Assuming that the bird derives 75% of the energy from food on average (Bezzel & Prinzinger 1990) –

specific data for fish and invertebrates respectively: 77.2% and 73.9% according to Castro et al. (1989); for fish, amphibians and mammals respectively: 81%, 78% and 74% (Dolnik et al. 1982) – gross energy disposal for a male amounts to 2847 kJ/day, and the female 2634 kJ/day. So energy requirement of a pair of storks is 5481 kJ/day.

Once we know the daily energy requirement of a pair of storks, it is possible to calculate the daily food intake (DFI). The amount of food necessary to cover daily energy requirement may be calculated by dividing DDE by the energy value of 1 g of food biomass.

In the case of chicks, food and energy demand depends on the individual stage of development as well as the body mass. Total metabolised energy (TME) (kJ/chick) is the quantity of energy needed from birth till the bird is able to fly, and it is proportional to the body mass of a mature individual of the given species (Drent et al. 1992, Weathers 1996). To calculate total metabolised energy, an equation published by Weathers (1996) was used:

$$\mathrm{TME} = 6.65\ M^{0.85} \times t_{fl}^{\ 0.71}$$

A chick's energy requirements (gross energy content of food consumed) is also higher than the field metabolic rate (FMR), because not all the energy in food is used. Thus it is also necessary to consider the degree to which energy is used from food. In fact, this is not known for the stork's chicks, but it is known that young birds use energy more efficiently than adults, which is well proven, for example, for owls (e.g. Ceska 1980). The daily maximum energy demand (max. DME) of a White Stork's chick can be calculated with the use of an equation by Weathers (1996):

$$\mathrm{DME} = 11.7\ M^{0.91} \times t_{fl}^{-0.43}$$

where M is chick mass (in grams), and t_{fl} defines the length of time the chicks remain in the nest (in days).

With 85% assimilated food, the value calculated per chick is 3450 kJ. Such energy is contained in 784 g of food of an average caloric value (4.4 kJ/g of live body mass). Extreme values are: 3287 kJ for a 2934 gram chick, and 3750 kJ for a 3392 gram chick, which corresponds to a biomass of 747 and 852 g at a food density of 4.4 kJ/g of fresh mass.

The quantity of food that ensures breeding success for a pair of birds

In order to assess food quantity – that a pair of storks must find in the breeding area to cover their food needs and to raise their offspring – the following conditions must be fulfilled, according to Profus (2006a):

a) a pair remains in the breeding area for 144 days;
b) average energy value of the food amounts to 4.4 kJ/g of the biomass;
c) a pair of weaker condition (parents of smaller mass and those raising 1–2 offspring) consume 1141 g food/day, while strong pairs (parents of bigger mass with 3–6 offspring) consume on average 1317 g of food a day;

d) one chick receives 34.3 kg of food from its parents from hatching to the first flight, and after the first flight (for the next 10 days) the chick gets 3 kg of food, while it finds 2.5 kg on its own.

From arrival till departure the food demand of parents was assessed at 179.4 kg, while a pair without young must consume a total of 141.7 kg of food within 130 days. The potential food resources that storks may use have not yet been fully assessed (see Profus 2006a).

Research on the White Stork's food in Poland

The food composition of the White Stork in Poland has not been studied extensively (see Profus 1985, Ptaszyk 1998).

The first studies on the Polish territory were conducted by German ornithologists in the area that belonged to Germany at the time. Steinbacher's work (1936) was performed on the basis of materials from the then Eastern Prussia (storks from the present Kaliningrad Region, with only a few samples came from Warmia and Masuria). Publications by Drescher (1936) and Stammer (1937) concerned only a part of Silesia (in the past German, now Polish). Scarce information about the species' food can also be found in Czudek's paper (1935) which relates to the area of Pszczyna and Cieszyn (Silesia).

In later times only Mrugasiewicz (1972) mentions "numerous" observations of the young spitting out food during a nest check in the valley of the Barycz river (Milicz district). Between 1959 and 1968 he stated that the main food there was the Common Frog *Rana temporaria* and probably the Swamp Frog *Rana arvalis*.

Quality and quantity of results improved only after studies carried out in 1976 in the Masurian Lakeland in North-Eastern Poland (Pinowski et al. 1986, 1991, Pinowska & Pinowski 1989, Pinowska et al. 1991), and then in Southern Poland at the end of the 20th century (Profus 2006a).

The only publication about the food of the non-breeding storks in Poland was made by Antczak et al. (2002) on the basis of studies in the valley of the Barycz river in the province of Wielkopolska (SW Poland), where also breeding birds were observed. The results of the observations have been used in this paper (Table 2).

Field data

Methods of collecting material

Field observations were carried out during the whole breeding season. Most material was collected when nests were checked, and dangerous plastic string removed, as well as material which fell from nests with fledgling, and when ringing the young in the second half of June and the beginning of July. The composition of the stork's food was identified on the basis of animals or their remains found during nest checks. They were sometimes vomited by the young as a stress reaction to the checking person (very rare in comparison with the Black Stork *Ciconia nigra*) (P.T. Dolata unpubl.). Whole prey or their remains were also collected under nests where they had fallen when the young had been fed, or they had been thrown out due to problems with swallowing.

Table 1. Food composition of breeding White Stork population near Strzelce Opolskie (Southern Poland)

	No. of pray	Mass (g)	%biomass
Fishs *Pisces*			
Brown Trout *Salmo trutta m. fario*	2	137.5	3.6
Chub *Leuciscus cephalus*	1	150	3
Gudgeon *Gobio gobio*	13	104	2.1
Carp *Cyprinus carpio*	19	845	17
Pike *Esox lucius*	1	400	8
Crucian *Carassius carassius*	1	300	6
Stickleback *Gasterosteus aculeatus*	2	2.5	0.05
Amphibians *Amphibia*			
Fire-bellied Toad *Bombina bombina*	2	12	0.2
Grass Frog *Rana temporaria*	3	45	0.9
Edible Frog *Rana esculenta*	1	32	0.6
Frogs indeterminate *Rana* sp.	4	160	3.2
Reptails *Reptilia*			
Sand Lizard *Lacerta agilis*	1	15	0.3
Grass Snake *Natrix natrix*	2	300	6
Birds *Aves*			
Mallard *Anas platyrhynchos* (juv.)	1	150	3
White Stork *Ciconia ciconia* (juv.)	1	100	2
Mammals *Mammalia*			
Mole *Talpa europea*	9	684	13.8
Common Shrew *Sorex araneus*	1	9	0.2
Common Vole *Microtus arvalis/M. agrestis*	22	488	9.8
Water Vole *Arvicola terrestris*	3	274	5.5
Hare *Lepus europaeus* (juv.)	2	260	5.2
Mouse *Apodemus* sp.	1	30	0.6
Invertebrate *Invertebrata*			
Tapeworm *Ligula intestinalis*	2	2	0.04
Caracoles *Planorbis* sp.	1		
Crayfish *Astacus* sp.	1		
Horse Leech *Haemopis sanquisunga*	3	8	0.2
Cockchafer *M. melolontha*	3	2	0.04
Earthworms *Lumbricidae*	several hundreds	455	9.3

Moreover, some data come from visual observations with the use of binoculars. A supplementary method was to massage the necks of just fed chicks in order to make them regurgitate their food.

These methods of collecting material, however, have many constraints because the material obtained was not homogeneous. So the results, except those from southern Poland, mainly show particular elements of the diet expressed as a percentage.

Composition of the White Stork's food

This paper uses results of research on food from the following regions in Poland:

a) Southern Poland, an area rich in fish ponds near Strzelce Opolskie [50°31'N, 18°18'E] in Opolskie province, Pszczyna [49°58'N, 18°57'E] and Gliwice [50°17'N, 18°40'E] in Śląskie province (for details see Profus 2006a).
b) An agricultural landscape of western Poland, near Leszno [51°51'N, 16°35'E]. In this area of 810 km^2, arable fields are interspersed with meadows, pasture, human settlements and small woods (for details see Kuźniak 1994). The White Storks build nests mainly on roofs of buildings, trees and electric poles. During

Table 2. Food composition of breeding White Storks near Ostrów Wielkopolski and Jarocin

Fishs *Pisces*	A	B
Carp *Cyprinus carpio*		2
Pike *Esox lucius*	5	
Crucian *Carassius carassius*	1	
Gudgeon/Mullet *Gobio gobio*		1
Amphibians *Amphibia*		
Green Frogs *Rana esculenta complex*		4
Common Spadefoot *Pelobates fuscus* – froglets		ca 45
Reptails *Reptilia*		
Grass Snake *Natrix natrix*	3	
Mammals *Mammalia*		
Small indeterminate mammals *Mammalia*		3
Rodent indeterminate *Rodentia*		1
Mole *Talpa europea*	3	
Water Vole *Arvicola terrestis*	1	
Invertebrate Invertebrata		
Earthworms *Lumbricidae*		several hundreds
Leeches *Hirudinea*		ca. 12
Colorado Beetle *Chrysomela decemlineata*		several items
Bush-cricket *Tettigonia viridissima*	ca. 10	

Explanations: A – the food collected under the nest and in nests, B – the food vomit in stress reaction

recent years the number of nests located on poles increased rapidly (Kuźniak 1994).
The Obra river valley, Western Poland [52°07'N; 16°04'E], material collected from 1997–2000. The study area covers 417 km^2, where the proportions of different habitat are: arable field 49%, meadows and pastures 28%, forests 14%, and 9% inhabited areas, roads, etc. (for further details see Kuźniak 1994).

c) Southern Wielkopolska: 17 sites in the Ostrów Wielkopolski district [51°30'–51°49'N, 17°31'–18°11'E], and three sites in the Jarocin district [51°56'–52°06'N, 17°27'–17°38'E]. This area consists of intensive arable land, and even more extensively farmed valleys of rivers such as the Barycz (with many fish ponds), the Prosna and the Warta. The following were collected: three prey (only vertebrates) from three nests, 13 prey (only vertebrates) found under eight nests, and 11 portions of food (5× vertebrates, 5× invertebrates, 1× both) from eight nests. They were either food spat out by parents for the young or food vomited by the young during nest checks. The data were gathered from 1994 to 2005.

Table 3. Food composition of breeding *White Storks* near Leszno

Fishs *Pisces*	A	B
Bream *Abramis brama*	2	
Crucian *Carassius carassius*	1	
Eel *Anguilla anguilla*	1	
Stickleback *Gasterosteus aculeatus*	1	
Amphibians *Amphibia*		
Grass Frog *Rana temporaria*	2	
Fire-bellied Toad *Bombina bombina*	1	
Reptails *Reptilia*		
Grass Snake *Natrix natrix*	1	
Birds *Aves*		
Pied Wagtail *Motacilla alba*	1	
Skylark *Alauda arvensis*	2	
Mammals *Mammalia*		
Mole *Talpa europea*	5	
Hare *Lepus europaeus* (juv.)	2	
Common Vole and/or Field Vole *Microtus arvalis/M. agrestis*	8	
Rat *Rattus* sp.	2	
Inwertebrate *Invertebrata*		
Earthworms *Lumbricidae*	several items	1

Explanations – see Table 2

The above data on the White Stork's food composition in the discussed populations are represented in Tables 1–3.

The energy value of the food was assessed only for the population from Southern Poland. The total weight of storks' food was estimated at 4975 g (92 vertebrates and several hundred invertebrates, mainly earthworms). It means that vertebrates amounted to 90.4% of the food's mass, invertebrates 9.6%. Fish constituted the main part of food at 39% of the biomass. The biggest item was a Pike *Esox lucius* which at about 400 g contained an estimated 1900 kJ of energy. Smaller fish were also caught, for example, a Three-spined Stickleback *Gasterosteus aculeatus* of 1.1 g mass and calorific value of 3.80 kJ/g of the biomass (Massias & Becker 1990), however the energy value of an individual did not exceed 4.2 kJ. Vital components of the stork's diet were small mammals which amounted to 35.1% of the prey biomass. In this group the most frequently caught animals were voles *Microtus* sp. but also Moles *Talpa europaea*, especially in the areas of high ground water level. Apparently, moles are easier to catch in wet areas.

The death of chicks as a result of choking on big prey

Tables 1–3 do not include information gathered from nests from 1994 to 2005 about chicks that choked while eating. In two cases the cause of death was a Mole, in three cases a Grass Snake *Natrix natrix*. These data were gathered during studies in the Ostrzeszów district (1), and mainly from the Ostrów Wielkopolski district (4). Also, in the same area a Grass Snake (length 80 cm, weight about 200 g) was found in a alive stork's oesophagus. It had stuck in such a way that its ribs blocked the oesophagus. Previously, in Polish literature it was only noted that such big animals were difficult to swallow (Jakubiec & Szymoński 2000), and, they were not mentioned as a cause of chicks' death in Poland (e.g. Jakubiec 1991, Profus & Chromik 2001). Five cases from a small area suggests that such death is not rare.

Discussion

The only way a bird can obtain energy is by expending metabolic energy while foraging for food items that contain appropriate amounts and forms of energy. Birds must actively pursue, capture, and consume the food that they obtain their energy from. Furthermore, in order to maintain a positive energy balance and hence sufficient energy available for reproduction, birds must choose among food items that vary in their energy and nutrient contents (Maurer 1996).

The White Stork is an opportunist as regards its food because it uses resources that are most easily available, a notion which is proved by observations carried out at various types of habitat (cf. Pinowski et al. 1991, Profus 2006). Calorific value of the food shall be also considered as a significant factor. Studies performed in the Obra river valley showed that there was a strong relationship between the quantity of potential food, i.e. voles, and the White Stork brood size (Tryjanowski & Kuźniak 2002). A positive correlation between the brood size and the quantity of food was also noticed in other areas in Central Europe (Tantzen 1962, Profus & Mielczarek 1981, Bairlein & Henneberg 2000).

Data analysis with respect to collection methods, and a comparison with check results of spat-out-bits show that prey found under nests or that found uneaten in nests (e.g. Table 2 A) cannot be reliably treated as the species' food. Presumably is because some of the prey were either spat out by storks or too large to be digested. Fresh prey either brought for the young by parents or vomited by chicks in the nest as a reaction to stress just before or during a nest check constitutes another group of material that most probably appears to reflect the real food composition. Intentional provocation of the birds to vomit, for example by giving them an emetic, could be supplementary to the method. Such a method was used during research on the Hooded Crow's *Corvus cornix* food (Zduniak 2005).

Invertebrates play a really vital role in storks' food (Pinowska & Pinowski 1989, Pinowski et al. 1991). They are the basic component of the diet since storks arrive in the breeding ground. The most frequent groups are predatory Water Beetles *Dytiscidae*, Ground Beetles *Carabidae*, Scarab Beetles *Scarabaeidae*, Snout Beetles *Curculionidae*, and the *Orthoptera*. Due to the long ontogenetic development of the *Orthoptera*, they become the stork's food in mid June (Pinowski et al. 1991). Another numerous group of invertebrates in the stork's diet are earthworms *Lumbricidae*. They are the main food component just after arriving from the wintering grounds (Hornberger 1967). Earthworms are caught throughout the whole season on pastures, meadows, and alfalfa fields, and in late summer during ploughing. Research carried out in Germany support these findings (Böhning-Gaese 1992).

In the Belorussian part of the Białowieża Forest storks mainly eat various species of frogs (Krapivnyj 1957), such as the Common Frog *Rana temporaria*, the Swamp Frog *Rana arvalis* and the Water Frog *Rana esculenta complex*, which altogether amount to 60.6% of the prey biomass and meet about 53% of the chicks' food and energy needs. Vertebrates constitute total of 72.5% of the caught biomass, and meet about 64% of the energy demand of the chicks (compare Profus 1986). The remaining 27.5% of the prey biomass is made up of invertebrates, with the Mole Cricket *Gryllotalpa gryllotalpa* being the main one. The Diving Beetle's larva *Dytiscus marginalis* (3.5% of the biomass) is a quite frequent item, which along with remaining insect species amount to 10.4% of the food biomass, and about 14% of the energy the chicks need. Surprisingly, in the diet of storks in this area there is a low contribution of earthworms at only 1% of the biomass, and a quite high proportion of leeches (1.1% of the biomass). In July and August the main food of chick are insects from the *Acrididae* and *Tettigoniidea* families (Krapivnyj 1957).

Additionally, studies from North-Eastern Poland (Mazuria) show that among animals caught by storks invertebrates dominate at 75.3%, while vertebrates constitute 24.7%. In the invertebrate group there are small insects (54.7%), earthworms (19.3%), snails *Mollusca* (0.6%) and big insects (0.7%); and in animals the vertebrates such as rodents (2.7%), moles (0.15%) and fish (0.2%) (Pinowska & Pinowski 1989, Pinowski et al. 1991).

Acknowledgments

We thank J. Grześkowiak, P. Tryjanowski, M. Antczak and T.H. Sparks for their comments on this manuscript. Thank also go to M. Antczak, J. Fijał, T. Ekiert,

J. Pietrowiak, S. Kuźniak and PwG OTOP members for their help in field work. The study was supported by UAM grant: PBWB 703/2006.

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