P O L I S H J O U R N A L O F E N T O M O L O G Y
P O L S K I E P I S M O E N T O M O L O G I C Z N E

VOL. **79**: 307-318 Bydgoszcz 30 September 2010

The influence of anthropogenic factors on the biodiversity of noctuid moths (Lepidoptera, Noctuidae) in marsh habitats of the Biebrza valley

JANUSZ NOWACKI*, KRZYSZTOF FRĄCKIEL**

* Department of Environmental Protection, Poznań University of Life Sciences, Dąbrowskiego 159, 60-594 Poznań, Poland, e-mail: jnowacki@up.poznan.pl

** Biebrza National Park, Osowiec Twierdza 8, 19-110 Goniądz, Poland
e-mail: frackiel@csk.pl

ABSTRACT. The study presents the results of research on the impact of anthropogenic factors on the biodiversity of the Noctuidae occurring in marsh ecosystems of the Biebrza valley. During the study 299 noctuid moths species were recorded, out of which 31 are stenotopic, characteristic of marsh and peat bog ecosystems. A comparative analysis which included exclusive characteristic species and similarity indices of the communities of the studied sites in the three basins of the Biebrza valley proved the highest biodiversity of Bagno Ławki in the southern basin. Consequently, it indicates the lowest transformation level of the marsh ecosystems of the basin. On the other hand, the most regressive changes were found on the sites located in the middle basin.

KEY WORDS: Poland, the Biebrza Valley, noctuid moths, Lepidoptera, Noctuidae, marsh and peat ecosystems, anthropogenic changes.

INTRODUCTION

The impact of anthropogenic factors, which intensified in the 20th century, resulted in substantial changes occurring throughout the country. As was proven by numerous inventory studies conducted in Poland on various insect groups, their biodiversity has been steadily decreasing. Many species have become very rare, withdrawn to few relict localities or even completely disappeared in the country. The data from the Polish red book of animals – invertebrate confirm that in the last century almost 200 insect species became extinct (GŁOWACIŃSKI & NOWACKI 2004). In the last 25 years the studies on the causes of threats to insects in natural habitats and possibilities to eliminate those threats have intensified.

Also the directions of fauna changes resulting from adverse impact of human activity are being studied (BANASZAK et al. 2000, BUSZKO & NOWACKI 2002, CZACHOROWSKI & BUCZYŃSKI 2000, GUTOWSKI & BUCHHOLZ 2000, MAZUR & KUBISZ 2000, NOWACKI 2000).

Marsh and peat bog ecosystems are of utmost interest and importance for the preservation of Europe's biodiversity. They are comparatively numerous in the Boreal regions of Europe, Asia and North America, where the climate is cool and humid and woods make up a large part of the area. Unfortunately, in western and central Europe those ecosystems have degraded to a great extent as a consequence of deforestation, intensified drainage, river regulation etc. Only few of those unique, relict habitats have been preserved unchanged until now. Among those are large, natural marsh river valleys, rare in European landscapes. Due to the causes mentioned above, one of the most strongly endangered insect groups in Europe are stenotopic species related to marsh and peat bog habitats, as they are extremely sensitive to changes in ecosystems. If their development habitat is degraded, those species as a rule have no chance to migrate elsewhere, hence they are seriously threatened with extinction. Due to this the Biebrza valley merits special consideration, as it is the largest marsh in Poland and central Europe with the area of about 90,000 ha.

It is obvious that agricultural cultivation of the Biebrza valley caused significant changes in its ecosystems. A great part of drained marsh ecosystems was transformed into meadows, pastures and fields. After land-improvement works the natural water system was disturbed.

Various ways of exploiting ecosystems in the three basins of the Biebrza valley help estimate the scale of impact and directions of changes in the ecosystems' fauna caused by the pressure of anthropogenic factors. Such an estimate may be reliably created on the basis of an animal group if it meets two key criteria: the species composition in marsh ecosystems is well known and it constitutes a good bioindicator of environmental change. These criteria are met by moths (Lepidoptera), including the noctuid moths family (Noctuidae).

The moth fauna (Lepidoptera) in Poland is composed of nearly 3,050 species, among which the most numerous is the family of noctuid moths (Noctuidae) with about 500 species (BUSZKO & NOWACKI 2000, 2002). Although the studies of moth distribution in Poland date back almost 180 years, Noctuidae have not yet been the subject of a comprehensive, monographic study which would detail their distribution throughout Poland. It is mainly due to uneven coverage of the country by studies of noctuid distribution. This also concerns the Biebrza valley, which, apart from some previous data on several rare, interesting species, has not been subject to a complete study of Noctuidae. The research on the family in question started there less than 20 years ago, but only butterflies have been described comprehensively (FRĄCKIEL 1991, 1999). The exceptional value of the moth fauna in the Biebrza valley ecosystems is proven by the occurrence of extremely rare butterfly species: *Parnassius mnemosyne (*L.*), Colias palaeno* (L.), *Lycaena helle* (DEN. et SCHIFF.), *Vacciniina optilete* (KNOCH), *Euphydryas maturna* (L.) and *Coenomympha hero* (L.).

There is little information on noctuid communities in marsh areas in other regions in the world. Moreover, most of them concern less degraded boreal areas, like Scandinavia in Europe or Canada in North America (MIKKOLA & SPITZER 1983, SPITZER et al. 1999, SPITZER & DANKS 2006). Also, a great part of the research only concerns typical raised peat bogs, and those ecosystems greatly differ from most ecosystems of Biebrza marshes.

The study assumed the hypothesis that noctuid moths communities (Noctuidae) occurring in the three basins of the Biebrza valley are abundant in species characteristic of marsh ecosystems (tyrphobionts and tyrphophiles) and differ within particular basins depending on the scope and impact of anthropogenic factors. It was also assumed that changes in noctuid moths fauna characteristic of marsh ecosystems of the Biebrza valley have a clear regressive character only in the immediate vicinity of the habitats considerably transformed anthropogenically, and the further from the transformed ecosystems, the less the negative impact till it fades altogether.

STUDY AREA

The Biebrza valley is the largest basin in north-eastern Poland. In physical-geographical division of Poland it is described as a mesoregion of the Biebrza valley within the macroregion of Podlasie Lowland. It is considered part of Eastern Europe (KONDRACKI 1998). In 1993 a great part of Biebrza marshes became protected as a national park. Biebrza National Park covers nearly all the valley of the river Biebrza (Fig. 1). It is the largest national park in Poland with 59,223 ha in area.

The Biebrza valley was formed during middle-Polish glaciation. The development of peat bogs in the valley started in late glaciation and lasted through pre-Boreal and Boreal phases to the Atlantic one (ŻUREK 1991). Currently peat bogs take up about 90,000 ha of the valley, making it the largest marsh area in Poland and Central Europe. The peaty Biebrza valley is surrounded by old-glacial moraine plateaus: from the north – the Ełk Lake District and Augustów Flatland, from the west Wysoczyzna Kolneńska (Kolno Plateau), from the south Wysoczyzna Wysokomazowiecka (Wysokomazowiecka Plateau), and from the east Wysoczyzna Goniądzka (Goniądz Plateau) (KONDRACKI 1998). Numerous mineral patches add variety to the valley's bottom. The Biebrza valley is divided by two narrowings (near Sztabin and Osowiec-Twierdza) into three parts called basins (Fig. 1). Those are: the northern basin, the middle one and the southern basin**.** The largest area is taken up by the middle basin shaped like a trapezoid measuring 20 x 40 km. The valley is from 2 km wide in the northern basin to 15 km in the middle one. The Biebrza valley's climate is similar to continental with some sub-Boreal features. In comparison with the neighbouring plateaus differences in precipitation levels, temperature distribution and humidity can be clearly seen particularly in summer. The mean relative humidity in the area reaches 80%. This results in numerous micro-habitats formed in the valley. In spring the Biebrza swells every year, flooding vast areas for several months. The natural water system has been disturbed as

a result of 150 years of draining marshes. A network of canals has been built (Rudzki, Kapicki, Kuwaski, Woźnawiejski and Augustowski), which changed the direction of surface waters outflow. This added to changing habitat conditions in large areas, mainly in the middle basin. The Biebrza valley peat bogs consist of low, transitional and raised ones. Low peat bogs are dominant; raised peat bogs are marginal and are concentrated mainly in the strict protection area of the previous Red Marsh reserve as well as around Osowiec-Twierdza. The largest and best preserved low peat bog complex is Ławki Swamp in the southern basin of the valley. In terms of geobotany the Biebrza valley is classified in the Northern Watershed, whose significant feature is the occurrence of the spruce and a high share of Boreal species. It should be highlighted that the plant life of Biebrza marshes is abundant in species and communities characteristic of marsh ecosystems. Almost 850 species of vascular plants have been recorded in the area so far (WERPACHOWSKI 2000) and 45 plant communities have been described (PAŁCZYŃSKI 1988). Among plant communities of marsh character the following can be found: rushes and sedge communities represented mainly by the alliance of *Phragmition* and *Magnocaricion*, wetlands belonging to *Molinion* and *Alopecurion* alliances and peat bogs represented by *Caricion festucae* and *Caricion lasicarpae* alliances.

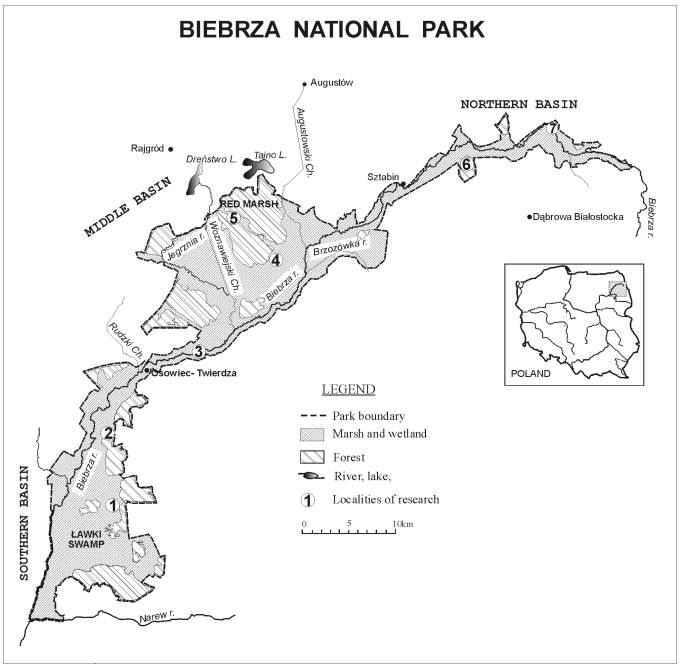

Fig. 1. Study area: 1 – Bagno Ławki, 2 – Gugny, 3 – Goniądz, 4 – Kopytkowo, 5 – Grzedy, 6 – Trzyrzeczki, 7 – Nowy Lipsk.

A series of marsh plant communities is completed with alder swamp forest (*Carici elongate-Alnetum*) occurring along the mineral edges of the valley. The forests make up c. 25% of the valley area.

MATERIAL AND METHODS

In order to complete the study aim correctly and verify the assumed hypothesis, a species composition of Noctuidae communities was specified in the Biebrza valley ecosystems of various level of man-caused transformation. As many as 7 permanent sites were defined, where in 1996-2008, from April to October, moths were recorded. Of the selected sites two were located on the edge of the Biebrza valley, and the remaining ones in the flooded part of the valley at various distances from the river bed. In the northern and southern basins 2 sites were located, and 3 in the middle one (Fig. 1). The sites in question are: in the northern basin: Nowy Lipsk and Trzyrzeczki; in the middle basin: Goniądz, Grzędy, Kopytkowo; in the southern basin: Bagno Ławki and Gugny.

In order to establish a full picture of noctuid moths fauna the method applied was luring imagines to light and food traps. Light traps with mercury lamps of 160 W, powered from portable generator, were used directly in the studied ecosystems. Also on all sites self-catching light traps were used on a regular basis with mercury lamps of 250 W powered from a stationary power source. Light catching was conducted every 3-4 days, so that 2 catches could be carried out weekly during all the vegetation season. This method of noctuid moths catching is a standard one in zoocenologic research of this group of moths. It definitely provides the most representative and numerous study material in terms of species and specimens. However, it is liable to some errors resulting from using it in natural conditions in the environment. The reaction of noctuid moths to light sources is directly related to their activity in the habitat, which in term is greatly dependent on changing weather conditions (BUSZKO & NOWACKI 1990). The differences in the material gathered, depending on the temperature, humidity, cloudiness, wind force or moon phase are so significant that it cannot be used to perform typical statistical analyses or calculate some indices widely used in ecological research. On the other hand, the study material collected with the above methods helped to establish the general number of species in a particular community for each site and to indicate characteristic and exclusive, i.e. stenotopic species that occur solely in marsh, peat bog or wetland ecosystems. It is the occurrence of characteristic species and their number that constitutes the perfect parameter indicating the natural character of the studied ecosystems. In order to define the similarity and transformation level of the studied marsh ecosystems similarity indices with Jaccard's formula (SZUJECKI 1983) will be calculated and compared for characteristic species of the studied Noctuidae community.

$$J = \frac{j}{a+b-j} x100$$

J – index of species similarity
j – the number of species common on both sites
a, b – the number of species on particular sites (surfaces)

RESULTS

The study carried out in Biebrza National Park resulted in 299 noctuid moths species recorded in various numbers on particular sites (Table 1). In the northern basin 203 species were found, 252 in the middle one, and 233 species in the southern one. However, it should be borne in mind that the number of recorded species is not a direct indicator of biodiversity or even natural value of the basins' ecosystems. The occurrence of characteristic species exclusive for marsh and peat bog ecosystems is definitely more essential and more indicative as proof of the importance of Biebrza marshes as a European refuge of noctuid moths fauna.

Table 1. The number of Noctuidae species recorded on particular sites in Biebrza National Park, including exclusive characteristic ones, in 1996-2008.

Site	Number of species	Number of characteristic species
Trzyrzeczki	133	4
Nowy Lipsk	151	20
Total northern basin	**203**	**20**
Grzędy	150	19
Goniądz	124	10
Kopytkowo	106	11
Total middle basin	**252**	**24**
Bagno Ławki	167	25
Gugny	173	20
Total southern basin	**233**	**27**
Total BNP	**299**	**31**

Among all the noctuid species recorded in Biebrza National Park exclusive characteristic species were singled out, namely those stenotopic for marsh ecosystems, peat bogs and wetlands. As many as 31 species were found in all the area in various numbers on particular sites and in the three studied basins (Table 2).

Table 2. Characteristic Noctuidae species exclusive for marsh ecosystems, peat bogs and wetlands recorded on particular sites in Biebrza National Park in 1996-2008.

Species	Northern basin			Middle basin				Southern basin		
	sites		total	sites			total	Sites		total
	Trzyrzeczki	Nowy Lipsk		Grzędy	Goniądz	Kopytkowo		Bagno Ławki	Gugny	
Acronicta menyanthidis (ESP.)	-	x	x	x	-	-	x	x	x	x
Simira albovenosa (GOEZE)	x	x	x	x	x	x	x	x	x	x
Hypenodes humidalis DOUBLEDAY	-	-	-	-	-	-	-	x	-	x
Catocala pacta (L.)	-	x	x	-	-	-	-	x	-	x
Diachrysia zosimi (HBN.)	-	x	x	x	x	x	x	x	x	x
Syngrapha microgamma (HBN.)	-	-	-	x	-	-	x	-	-	-
Chilodes maritima (TAUSCHER)	-	x	x	-	x	-	x	x	x	x
Athetis pallustris (HBN.)	-	x	x	-	x	-	x	-	x	x
Xylomoia graminea (GRAESER)	-	-	-	x	-	-	x	-	-	-
Lithophane lamda (F.)	-	x	x	-	-	-	-	-	-	-
Apamea unanimis (HBN.)	-	x	x	x	x	x	x	x	x	x
Apamea illyria FREYER	-	-	-	x	-	-	x	-	-	-
Photedes minima (HAW)	-	-	-	-	-	-	-	x	-	x
Rhizedra lutosa (HBN.)	-	-	-	x	-	-	x	x	-	x
Amphipoea lucens (FREYER)	-	-	-	x	x	-	x	x	-	x
Celaena haworthii (CURT.)	-	-	-	-	-	-	-	x	x	x
Nonagria typhae (THNBG.)	-	-	-	x	-	-	x	x	-	x
Phragmatiphila nexa (HBN.)	-	x	x	x	-	x	x	x	x	x
Archanara geminipuncta (HAW.)	x	x	x	-	-	x	x	x	x	x
Archanara dissoluta (TREIT.)	-	x	x	-	x	-	x	x	-	x
Archanara sparganii (ESP.)	-	-	-	-	-	x	x	x	x	x
Archanara algae (ESP.)	-	-	-	-	-	-	-	x	x	x
Sedina buettneri (HERING)	-	x	x	x	-	-	x	x	x	x
Arenostola phragmitidis (HBN.)	x	x	x	x	x	x	x	x	x	x
Mythimna straminea (TREIT.)	-	x	x	x	x	x	x	x	x	x
Mythimna flammea (CURT.)	-	x	x	x	-	x	x	x	x	x

Orthosia opima (HBN.)	-	x	x	x	-	-	x	-	x	x
Diarsia florida (F. SCHMIDT)	x	x	x	x	x	x	x	x	x	x
Paradiarsia punicea (HBN.)	-	x	x	-	-	-	-	x	x	x
Coenophila subrosea (STEPH.)	-	x	x	x	-	x	x	x	x	x
Cryptocala chardinyi (BOISD.)	-	x	x	x	-	-	x	x	x	x
Total number of species (31)	**4**	**20**	**20**	**19**	**10**	**11**	**24**	**25**	**20**	**27**

The highest number of characteristic species was reported from Bagno Ławki (25 species), next came Gugny and Nowy Lipsk (20 species each) and Grzędy (19 species). Considerably fewer characteristic species were reported from: Kopytkowo (11 species), Goniądz (10 species) and Trzyrzeczki (4 species). In proportion to all the basins the most characteristic species were reported from the southern basin (27 species), then from the middle one (24 species) and the northern basin (20 species) (Table 2).

Table 3. Jaccard's similarity indices for characteristic species exclusive to marsh ecosystems and peat bogs of the Biebrza valley among particular Noctuidae communities on all the studied sites.

Site	Bagno Ławki	Goniądz	Grzędy	Gugny	Kopytkowo	Nowy Lipsk	Trzyrzeczki
Bagno Ławki	X	34.6	51.7	66.7	44.0	60.7	16.0
Goniądz		X	31.8	36.4	40.0	42.9	27.3
Grzędy			X	50.0	43.9	50.0	15.0
Gugny				X	55.0	73.9	20.0
Kopytkowo					X	47.6	36.4
Nowy Lipsk						X	20.0
Trzyrzeczki							X

An analysis of similarity indices for characteristic species among various Noctuidae communities on all the seven sites allows for creating several groups of sites with similar index values (Table 3). The Noctuidae community occurring on Bagno Ławki site in the southern basin, where 25 characteristic exclusive species were found, can be assumed as the most typical of marsh ecosystems in Biebrza National Park. The most similar group of sites are: Gugny (similarity index 66.7 and 20 characteristic species) and Nowy Lipsk (60.7 and 20), next come Grzędy (51.7 and 19). More distant from a typical grouping were: Kopytkowo (similarity index 44.0 and 11 characteristic species) and Goniądz (34.6 and 10 characteristic species). The lowest similarity index combined with a low number of characteristic species was reported for the Noctuidae community on Trzyrzeczki site (16.0 and 4), while considering the Noctuidae communities of the whole basins of the Biebrza valley it should be assumed that the least transformed with the highest number of

should be assumed that the least transformed with the highest number of characteristic species is the southern basin, where 27 characteristic exclusive species were reported out of 31 recorded in all the study area.

DISCUSSION

The results obtained after the study prove that the ecosystems of Biebrza marshes are highly natural. This is proven by a high (31) number of characteristic species of tyrphobiont and tyrphophile groups. To compare: 28 species of this group were recorded in Augustów Forest (NOWACKI & RUDNY 1992), 29 in Polesie Lubelskie (NOWACKI & HOŁOWIŃSKI 1999), in central Podlasie - 21 (NOWACKI & WASILUK 2004), and more were reported only from Białowieża Primeval Forest, namely 32 species of that ecological group (BUSZKO et al. 1996) Among those species special attention should be paid to very rare species, for which the Biebrza valley constitutes the main refugium in western and central Europe, and their populations in the Biebrza valley are still comparatively numerous. Such species include: *Acronicta menyanthidis* (ESP.), *Catocala pacta* (L.), *Diachrysia zosimi* (HBN.), *Senta flammea* (CURT.), *Orthosia opima* (HBN.), *Diarsia florida* (SCHMIDT), *Paradiarsia punicea* (HBN.) and *Coenophila subrosea* (STEPH.). As an example: *C. pacta*, which in Poland is a rare and protected species, is steadily disappearing in central European area of its occurrence (NOWACKI 1998). In Poland it became extinct in localities in western, central and southern parts of the country. Besides Biebrza marshes it is known from single localities in Augustów and Białowieża Primeval Forests (GŁOWACIŃSKI & NOWACKI 2004). Similarly *D. zosimi, P. punicea* and *C. subrosea,* which are typical species of low and transitional peat bogs, are very rare in all their European occurrence area. In Europe they are recorded only in single, strongly isolated localities, the number of which is steadily decreasing. Undoubtedly Biebrza marshes constitute refugia for species of European-scale importance.

The comparative analysis of characteristic exclusive species occurring in Noctuidae communities in particular localities in the three basins of the Biebrza valley and species similarity indices between those communities helped to draw conclusions on the scope of changes in the noctuid moths fauna of marsh ecosystems in the Biebrza valley. It turned out that the Noctuidae communities occurring in particular localities differ significantly in terms of number and composition of characteristic species groups. The difference between the communities of particular localities are clearly reflected by the similarity indices of characteristic species similarity in those communities. The most abundant in characteristic exclusive species is the community of Bagno Ławki, where as many as 25 species were found out of 31 reported from the whole Biebrza valley. The result clearly indicates that the marsh ecosystems located in the southern basin, taking up a large part of the area, namely c. 7,000 ha, are of natural character. Man's economic activities in the last several hundred years have not disturbed the ecological balance of the area. According to the calculated similarity indices the closest to the mentioned model community is the community of

Gugny locality, its similarity index reaching 66.7. This is also the locality situated in the southern basin, however, on the edge of marsh and forest ecosystems, with a low share of synanthropic habitats, which might have resulted in a slightly lower share of characteristic species. Another site where the Noctuidae community reported 20 characteristic species, and the similarity index to the locality of Bagno Ławki reached 60.7, is the locality of Nowy Lipsk in the northern basin. This proves that a high level of natural character of marsh ecosystems of the northern basins has been preserved, although in Trzyrzeczki only 4 characteristic species have been recorded, and the similarity index to the community of Bagno Ławki was 16.0. This was influenced by the fact that the locality was situated on the edge of the Biebrza valley, outside of the flooded terrace, and wholly surrounded by forest ecosystems. Although the middle basin takes up the largest area of the three basins in question, only 24 exclusive characteristic species were reported for all the Noctuidae communities on the three sites. On Grzędy site 19 species were reported, and the similarity index to the community in Bagno Ławki was 51.7. In the remaining localities those numbers were even lower. The community of Kopytkowo was characterised by the occurrence of 11 characteristic species, and the similarity index to Bagno Ławki was 44.0 and the community in Goniądz - 10 and 34.6 respectively. The results obtained in the middle basin clearly indicate the highest level of degradation of marsh ecosystems there. It was influenced by both historical and present, comparatively intensive use of a significant part of that basin as harvested meadows and pastures. This was made possible only by the building of a dense network of draining ditches, which considerably sped up the draining of excess water in spring and lowered the water level during the vegetation season. It led to the liquidation of vast natural marsh ecosystems and wetlands, which in turn added to eliminating and limiting the occurrence of Noctuidae representatives of tyrphobionts and tyrphophiles.

The results of the study, on the basis of Noctuidae communities, allow to state that currently the most valuable marsh ecosystem in Biebrza Marshes is Bagno Ławki taking up a large part of the southern basin. There occur comparatively numerous populations of very rare noctuid moths species of tyrphobionts and tyrphophiles, whose range in Europe is systematically decreasing, and some have already become extinct in western Europe. It can be asserted with all certainty that Biebrza marshes constitute an important refugium for peat bog and marsh fauna and hence play an essential role in protecting the biodiversity of Europe.

REFERENCES

BANASZAK J., CZECHOWSKA W., CZECHOWSKI W., GARBARCZYK H., SAWONIEWICZ J., WIŚNIOWSKI B. 2000. Threats and perspectives of protection of Hymenoptera. in: Protection of insects in Poland on the threshold of European Union integration. Wiad. entomol. 18, Suplement **2**: 17-211. [In Polish]

BUSZKO J., KOKOT A., PALIK E., ŚLIWIŃSKI Z. 1996. Macrolepidoptera of Białowieża Forest. Parki Narod. i Rez. Przyrody, **15**(4): 3-46. [in Polish]

BUSZKO J., NOWACKI J. 1990. Catch activity of noctuid moths (Lepidoptera, Noctuidae) on light and sugar attractant in relation to the temperature and air humidity. Wiad. entomol., 9: 13-20. [In Polish]

BUSZKO J., NOWACKI J. (eds), 2000. The Lepidoptera of Poland, a distrbutional checklist. Polish entomol. Monogr. **1**: 178 pp.

BUSZKO J., NOWACKI J. 2002. Lepidoptera. [in:] Red List of Threatened Animals in Poland.(ed.) Z. GŁOWACIŃSKI. Kraków: 80-87. [In Polish]

CZACHOROWSKI S., BUCZYŃSKI P. 2000. Threats and protection of water insects in Poland. [in:] Protection of insects in Poland on the threshold of European Union integration. Wiad. entomol. 18, Suplement **2**: 95-120. [In Polish]

FRĄCKIEL K. 1991. Interesting species of noctuid moths (*Lepidoptera, Noctuidae*) from „Czerwone Bagno" Reserve. Wiad. entomol., **10**: 189. [In Polish]

FRĄCKIEL K. 1999. Butterflies (Lepidoptera: Papilionoidea, Hesperioidea) of the Biebrza National Park. Wiad. entomol., **18**: 85-98. [In Polish]

GŁOWACIŃSKI Z., NOWACKI J. (eds.) 2004. Polish red data book of animals, Invertebrates. Instytut Ochrony Przyrody PAN - AR im. A. CIESZKOWSKIEGO, Kraków - Poznań. 447 pp. [In Polish]

GUTOWSKI J.M., BUCHHOLZ L. 2000. Forest insects - threats and proposal of protection. [in:] Protection of insects in Poland on the threshold of European Union integration. Wiad. entomol. 18, Suplement **2**: 43-72. [in Polish]

KONDRACKI J. 1998. Geografia regionalna Polski. PWN, Warszawa, 441 pp. [In Polish]

MAZUR M., KUBISZ D. 2000. Protection of insects of xerothermic habitats in Poland. [in:] Protection of insects in Poland on the threshold of European Union integration.. Wiad. entomol. 18, Suplement **2**: 129-137. [in Polish]

MIKKOLA K., SPITZER K. 1983. Lepidoptera associated with peatlands in central and northern Europe: a synthesis. Nota Lepid., **6**: 216-229.

NOWACKI J. 1998. The Noctuids (Lepidoptera, Noctuidae) of Central Europe Bratislava. 51 pp.

NOWACKI J. 2000. Insect protection as a necessary component of nature conservation. [in:] Protection of insects in Poland on the threshold of European Union integration. Wiad. entomol. 18, Suplement **2**: 7-14. [in Polish]

NOWACKI J., HOŁOWIŃSKI M. 1999. The noctuids of the Lasy Sobiborskie forest on the Polish Polesie (Lepidoptera, Noctuidae). Wiad. Entomol. 18: suplement **1**: 3-60. [In Polish]

Nowacki J., Rudny J. 1992. Noctuid moths of Puszcza Augustowska Forest (Lepidoptera, Noctuidae). Wiad. Entomol., **11**: 37-57. [In Polish]

NOWACKI J., WASILUK D. 2004. The noctuids (Lepidoptera, Noctuidae) of the Central Podlasie. Wiad. Entomol., 23 suplement **1**: 3-54. [In Polish]

PAŁCZYŃSKI A. 1988. Bagna Biebrzańskie [Biebrza Marshes]. Liga Ochr. Przyr., Warszawa. 103 pp. [In Polish]

SPITZER K., BEZDEK A., JAROS J. 1999. Ecological succession of a relikt Central European peat bog and variability of its insect biodiversity. J. Insect Conserv., **3**: 97-106.

SPITZER K., DANKS H.V. 2006. Insect biodiversity of boreal peat bogs. Annu. Rev.Entomol., **51**: 137-161.

SZUJECKI A. 1983. Ekologia owadów leśnych [Ecology of forest Isects]. Warszawa, 604 pp. [In Polish]

WERPACHOWSKI C. 2000. List of vascular plant of the Biebrza Valley with particular emphasis of those present in the Biebrza National Park. Parki Narodowe i Rez. Przyr., 19: 19-52. [In Polish]

ŻUREK S. 1991 The Biebrza Valley geomorphology. Zesz. Probl. Post. Nauk Roln., 372: 29-61. [In Polish]

Received: May 23, 2010
Accepted: August 09, 2010