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Original Research

Changes in Groups of Noctuids (Lepidoptera, Noctuidae) of Xerothermic Rock Swards in the Pieniny Mountains, Caused by Operation of Czorsztyn–Niedzica and Sromowce Wyżne Water Reservoirs

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Abstract

The study presents the results of investigations on changes in groups of Noctuidae (Lepidoptera) of xerothermic rock sward ecosystems in the Pieniny caused by storage reservoirs in the Pieniny foothills, operating for over a decade now. A comparative analysis, taking into consideration exclusive characteristic species and indexes of similarity between groups investigated 40 years ago and at present (in 2003–06) at the same sites clearly shows that changes in the Noctuidae fauna are regressive in character only in the immediate vicinity of the water reservoirs and as the distance from a reservoir increases, the negative effect decreases until it disappears completely. Considerable regressive changes may be observed in the following spots: Zielone Skałki (index of similarity), Niedzica Biała Skała (15.74) or Czorsztyn Hill (22.86). In contrast, at present these changes are not observed on Zamczysko (index of similarity 55.55) or Macelowa Góra (53.3).

Keywords: Pieniny, noctuids (Lepidoptera, Noctuidae), ecosystems of xerothermic rock swards, changes after the construction of water reservoirs

Introduction

Despite many negative phenomena Poland is a refuge for populations of many animal species threatened with extinction throughout Europe due to a relatively small degree of environment degradation. This also pertains to numerous Polish species of Lepidoptera [1, 2].

One of the more interesting objects in the country in terms of natural value are the Pieniny Mountains. They gained the status of a National Park as early as 1932 [3]. Although those mountains are a small klippen range within the Western Carpathians, they are special because of their unique ecosystems, which constitute a separate geobotanical unit. A diversity of forms and surface features, a specific character of the bedrock and microclimate resulted in the formation of unique biocenoses, with plant and animal species not found in other regions of the country [4, 5, 6]. The nature in the Pieniny is relatively well-known in comparison to most regions of Poland. The bibliography presenting the flora and fauna of the Pieniny includes over 1,500 items [7].

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In 1975, in spite of a common public dispute about a threat to the flora and fauna of the Pieniny [6], the construction of the Czorsztyn – Niedzica, Sromowce Wyżne water reservoir complex was initiated. A dam was built across the River Dunajec at Niedzica in 1988 and in 1994 the construction was completed and the compensating Sromowce Wyżne reservoir was filled. The Czorsztyn dam reservoir started to be filled in 1995. For over 10 years now the two reservoirs have been operating at the foot of the Pieniny: the Czorsztyn–Niedzica reservoir with an area of 1226 to 1335 ha, capacity of 234 million m^3 and water table at an altitude of 529–534.5 m above sea level and the Sromowce Wyżne reservoir with an area of 88 to 95 ha, capacity of 6.7 million m^3 and water table at an altitude of 482–488.5 m.

It is obvious that the construction of the above-mentioned water reservoirs must have caused considerable changes in the ecosystems previously found in that area. Almost 1.5 thousand ha were turned into the bottom of the reservoir. The presence of those reservoirs, affecting the microclimate, is also of importance for xerothermic rock swards, characteristic for the Pieniny Mountains. Much has been written about the forecast changes in the fauna of the Pieniny that would be caused by the construction of the Niedzica dam, including the effect on the invertebrate fauna [8], as well as the predicted changes in the Lepidoptera fauna [9, 10]. In the 1990s an inventory was conducted of numerous Pieniny habitats threatened by the impact of the water reservoirs [11].

The last 10 years of the impact of the Czorsztyn–Niedzica and Sromowce Wyżne reservoirs on the Pieniny ecosystems provide an excellent moment to make a first assessment of their impact and of direction of changes in the fauna of those ecosystems. Such an analysis may be conducted in a reliable way using a group of animals which meets two basic criteria: the species composition in the Pieniny ecosystems is well-known and, secondly, it is a good bioindicator of changes in the environment. The above criteria are met by Lepidoptera, including noctuids (Noctuidae). The analyzed Noctuidae family, which in Poland consists of almost 500 species, has been relatively thoroughly investigated in the Pieniny region. Studies on Lepidoptera of the Pieniny were initiated already in the 19th century by M. Nowicki [12], and continued by many lepidopterologists: Sitowski, J. W. Razowski and J. Razowski, Żukowski, Miodoński, Palik, Toll, Błeszyński and summed up in a monograph reporting 1.555 Lepidoptera species in the Pieniny Mountains [13, 14]. In the above-mentioned paper, all the presented species were characterized in terms of its occurrence in specific habitats and at specific test sites. A total of 310 noctuid species was reported. At a later time, in a limited scope, similar investigations were also conducted by Dąbrowski [9], Witkowski [11], Nowacki and Wąsala [15] and Nowacki et al. [16]. The exceptional character of the Leptidoptera fauna found in the Pieniny ecosystems of xerothermic swards is shown by the occurrence of the apollo butterfly (*Parnassius apollo* (L.)), at the last site documented in

Fig. 1. Study area.

Poland. Similarly, *Catocala nymphagoga* (Esp.), *Auchmis detersa* (Esp.), *Polymixis xanthomista* (Hbn.), *Apamea platinea* (Treit.), and *Chersotis margaritacea* (Vill.) of the Noctuidae family are found in Poland only on sites in the Pieniny Mountains.

Forecasts of changes caused by the construction and operation of the Czorsztyn–Niedzica reservoir, concerning the Lepidoptera fauna in the Pieniny, definitely assumed a considerable reduction in the number of species, as well as their populations and the number of sites in which they occur [9, 10]. This pertained primarily to stenotopic species, connected with and found solely in ecosystems of xerothermic rock swards. They are most frequently the species threatened with extinction in Poland, to a significant degree found only on sites in the Pieniny.

The aim of the investigations was to address the following issues:

- do changes occur in the noctuid fauna of selected ecosystems in Pieniny National Park as a result of the construction of water reservoirs in the Pieniny?
- if so, what is the scope and direction of those changes?
- are those changes limited to ecosystems found in the nearest vicinity of the reservoirs, or are they also observed in ecosystems located farther from the reservoirs?

Study Area

Investigations were conducted in the Pieniny, which are a mountain range situated in southern Poland, being a part of the Western Carpathians. They are small mountains running latitudinally for approx. 40 km, up to 5.5 km wide, formed by Jurassic and Cretaceous sedimentary rocks. Almost the entire area of the Pieniny constitutes the montane forest zone from 450 m above sea level (the water table of the River Dunajec) to 982 m above sea level (the peak of Trzy Korony). The exceptional diversity of vegetation

cover in comparison to the neighbouring mountain ranges needs to be emphasized here. As many as 49 plant communities of various rank were distinguished here. Forest communities, covering northern slopes and, to a lesser degree, southern slopes predominate [17]. Calcareous rocks and screes, especially with southern exposure, are covered by communities of sward vegetation, represented by two classes: xerothermic swards *Festuco- Brometea* and mountain rock swards *Seslerietea varia*; among them several are exceptionally valuable, indicating the geobotanical uniqueness of the Pieniny Mountains [18].

Material and Methods

In order to ensure that study aims are achieved, which were to verify the posed research hypothesis, the species composition of groups of Noctuidae were analyzed in xerothermic rock swards, distributed at different distances from the banks of the water reservoir. In total, 7 permanent sites were established: Czorsztyn Zamek, Grabczychy, Macelowa Góra, Niedzica Biała Skała, Podskalnia Góra, Zamczysko and Zielone Skałki (Fig. 1.) In 2003–06, from April to the end of October, observations of Lepidoptera were conducted on those sites. Two of them were located in the direct vicinity of the Czorsztyn reservoir and the others were situated a growing distance from it, between 0.4 and 6 km. As far as it was possible, the observations were repeated at the sites where studies on Lepidoptera were conducted in the historic period, before construction of the water reservoirs (5 sites: Czorsztyn Zamek, Macelowa Góra, Niedzica Biała Skała, Zamczysko, and Zielone Skałki) (Fig. 1.).

In order to determine the complete composition of the fauna, specimens were attracted to light and food baits. They were caught by light directly in the analyzed ecosystems on all seven sites with Philips ML 160W mercury discharge lamps powered by a portable generator. A lamp was placed in front of a screen made of white canvas, 1.8m high and 2.4m wide. Moreover, light traps equipped with low-power UV lamps (3 x Philips TL 6W/08) supplied by a battery were used on a regular basis. A basic structural element of a light trap is a funnel through which months drop into the trap. A narrow outlet of the funnel makes it impossible for them to get out. The trap is equipped with a shade to protect it from rain. The insects, lured by UV radiation, fly to the trap, hit one of the three walls reflecting radiation and drop down into the trap container through the funnel. The container itself is a plastic bucket of five liters (dm^3) filled with corrugated cardboard to enable the insects to hide.

Experimental material caught with the above-mentioned methods was collected at irregular intervals: 3 to 5 days every 2-3 weeks during 4 years. The material obtained with those methods, most often used in studies of Lepidoptera (including Noctuidae), cannot be directly used in classic statistical analyses, as the effect of catch is modified by various environmental factors that influence it independently of the researchers' control. Those are: temperature, humidity, precipitation, clouds, phases of the Moon, etc. As a result, it is possible to analyze the species composition only of particular groupings, but it is virtually impossible to conduct effective quantitative analyses due to those reasons. But the material collected with the above methods helped establish the general number of Noctuide species per site. Among them characteristic species were indicated, the stenotopic ones, occurring only in xerothermic rock swards. Below only those characteristic species will be used to analyze changes in the studied ecosystems. In the results part of the study solely those species are analyzed. The similarity indexes between Noctuidae groups on particular sites were calculated with the use of characteristic species, too. That comparative analysis of the Noctuidae groups was performed with consideration for the current state as well as the historic one.

In order to calculate similarity indexes the Jaccard formula [19] was used.

$$J = \frac{j}{a + b - j} \times 100$$

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

As a result of investigations conducted in the period from 2003 to 2006 on sites selected for observations, a total of 272 Noctuidae species was recorded, found in different numbers on individual sites (Table 1).

Out of all the Noctuidae reported for the Pieniny, exclusive characteristic species were determined, which are stenotopic species of xerothermic rock sward ecosystems. Those species were identified for all the sites in the investigations conducted by the authors of this study and for those from earlier investigations (Table 2). For the total number of 29 characteristic species identified for the Pieniny, 27 had also been reported in the historic period. Two species: *Calyptra thalictri* and *Lygephila craccae* had not been reported before. The highest number of characteristic species was shown for the sites Czorsztyn Zamek and Niedzica Biała Skała. The present investigations on all sites proved the total of 20 characteristic species, with 9 species not confirmed. The highest numbers of characteristic species were recorded at Podskalnia Góra (18 species), followed by Grabczychy, Zamczysko (15 species each) and Macelowa Góra (14 species) (Table 2).

The indexes of similarity calculated for the 5 sites where groups of Noctuidae were investigated both in the historic period and at present indicate slight changes in the groups of Zamczysko and Macelowa Góra. On the other hand, similarity indexes of characteristic species were

Table 1. The number of Noctuidae species caught in the Pieniny, including exclusive characteristic species, at individual sites in the investigations conducted by the authors and quoted after Błeszyński et al. [13], with calculated indexes of similarity for characteristic species.

Site*	Błeszyński et al.[13]		Authors' data (2003 – 2006)		Index of similarity J
	Number of species	Number of characteristic species	Number of species	Number of characteristic species	
NBS	173	17	118	5	15.74
CZ	210	20	163	10	22.86
GR	-	-	161	15	-
MG	128	9	148	14	53.30
PG	-	-	208	18	-
ZA	146	13	180	15	55.55
ZS	126	6	127	6	10.00
Total	310	27	272	20	-

* Sites: NBS- Niedzica Biała Skała, CZ – Czorsztyn Zamek, GR – Grabczychy, MG – Macelowa Góra, PG – Podskalnia Góra, ZA – Zamczysko, ZS – Zielone Skałki

much lower for Zielone Skałki, Niedzica Biała Skała and Czorsztyn Zamek, which means considerable changes in their groups of Noctuidae (Table 1).

An analysis of similarity indexes for characteristic species between individual groups of Noctuidae at all the seven sites currently investigated makes it possible to identify several groups of sites where those indexes take similar values (Table 3). The group of Noctuidae at the Podskalnia Góra site should be deemed the most typical of xerothermic rock sward ecosystems in the Pieniny, as 18 exclusive characteristic species were recorded there. The most similar sites are Macelowa Góra (index of similarity 77.77, 14 characteristic species) and Zamczysko (73.68 and 15), followed by Grabczychy (65 and 15). The Czorsztyn Zamek site was found less similar to a typical group, with the index of similarity of 55.55 and 10 characteristic species. The lowest index of similarity and at the same time a small number of characteristic species was shown for groups of Noctuidae at the sites of Niedzica Biała Skała (27.77, 5) and Zielone Skałki (33, 6).

Discussion

When the present-day groups of Noctuidae of xerothermic rock sward ecosystems in the Pieniny in individual sites and current data are compared with the results given by Błeszyński et al. [13], the results of the conducted investigations make it possible to show changes which have occurred in those ecosystems in the period of operation of the water reservoirs. Even a comparison of the compositions of exclusive characteristic species at selected sites, thoroughly investigated in the historic period and at present, shows that considerable changes in these species have occurred in the ecosystems at sites of Czorsztyn Zamek, Niedzica Biała Skała and Zielone Skałki (Table 2). At the Czorsztyn Zamek site out of 20 characteristic species 11 species were not recorded and 1 species not observed in the previous study was found. At the Niedzica Biała Skała site out of the 17 characteristic species 14 species were not confirmed, while 2 species not observed in earlier studies were reported. Similarly, at the Zielone Skałki site with 6 characteristic species 4 species were not confirmed, while 4 other species reported at present had not been observed before. Those drastic changes in the composition of exclusive characteristic species of Noctuidae groups in the analyzed ecosystems were confirmed by low values of indexes of similarity (Table 1): Czorsztyn Zamek 22.86, Niedzica Biała Skała 15.74, Zielone Skałki 10, which are an unquestionable effect of changes, which have occurred in these ecosystems. The changes are not surprising, as the above-mentioned ecosystems at the Czorsztyn Zamek and Zielone Skałki sites are now practically adjacent to the water table of the compensating reservoir. The changes which must have occurred in the microclimate of the discussed ecosystems, including increased humidity, diurnal and seasonal temperature changes result in the ecosystem being quickly overgrown by shrubs and trees. Increased shading leads to irreversible changes in the ecosystems, as xerothermophilous species of plants and animals are being eliminated. The xerothermic sward ecosystems at the Niedzica Biała Skała site, located at a distance of approx. 0.4 km from the water reservoir, are undergoing similar processes. As shown by archival pictures of that habitat presented in the study by Żukowski [10], at present those ecosystems are greatly shaded as the foot and southern slope have been overgrown by a high forest. The character of xerothermic swards is preserved only on small fragments of rock swards on steep slopes located in the highest parts.

Completely different conclusions may be drawn from a comparison of Noctuidae groups presented by

Tabele 2. Noctuidae species characteristics only of xerothermic rock sward ecosystems caught at individual sites in the Pieniny in the study period and quoted after Błeszyński et al. [13].

Species	Authors' data from the period of 2003 – 2006							Data after Błeszyński et al. [13]				
	Niedzica Biała Skała	Czorsztyn Zamek	Grabczychy	Macelowa Góra	Podskalnia Góra	Zamczysko	Zielone Skałki	Niedzica Biała Skała	Czorsztyn Zamek	Macelowa Góra	Zamczysko	Zielone Skałki
Eublemma purpurina (Den. et Shiff.)			X			X			X			
Calyptra thalictri (Borkh.)					X							
Lygephila craccae (Den. et Shiff.)					X	X						
Abrostola asclepiadis (Den. et Shiff.)	X	X	X	X	X	X	X		X	X	X	X
Euchalcia modestoides Poole								X				
Panchrysia deaurata (Esp.)								X				
Acontia lucida (Hbn.)								X				
Acronicta euphorbiae (Den. et Shiff.)								X	X		X	
Cucullia scopariae Dorfmeister								X				
Cucullia lactucae (Den. et Shiff.)	X			X	X							X
Cucullia lucifuga (Den. et Shiff.)	X	X	X	X	X	X	X	X	X			
Cucullia prenanthis (Boisd.)			X						X	X		X
Cryphia ereptricula (Treitschke)		X	X	X	X	X			X	X	X	
Cryphia domestica (Hufn.)		X	X	X	X	X		X	X	X	X	
Hoplodrina superstes (Ochsenh.)									X			
Hoplodrina respersa (Den. et Shiff.)	X	X	X	X	X	X	X	X	X		X	
Chloantha hyperici (Den. et Shiff.)								X	X			
Auchmis detersa (Esp.)		X	X	X	X	X		X	X	X	X	
Apamea platinea (Treit.)		X	X	X	X	X	X	X	X	X	X	X
Polymixis xanthomista (Hbn.)		X	X	X	X	X					X	
Diachagyris forcipula (Den. et Shiff.)								X				
Diachagyris signifera (Den. et Shiff.)					X			X	X		X	X
Euxoa birivia (Den. et Shiff.)									X		X	X
Euxoa decora (Den. et Shiff.)			X	X	X	X			X			
Epipsilia latens (Hbn.)					X			X	X			
Epipsilia grisescens (F.)		X	X	X	X	X	X	X	X	X	X	
Chersotis multangula (Hbn.)		X	X	X	X	X	X	X	X	X	X	
Chersotis margaritacea (Villers)			X	X	X	X			X		X	
Xestia ashworthii (Doubl.)	X		X	X	X	X		X	X	X		
Total number of species (29)	**5**	**10**	**15**	**14**	**18**	**15**	**6**	**17**	**20**	**9**	**13**	**6**

Table 3. Jaccard's similarity indexes for Noctuidae exclusive characteristic species of xerothermic rock sward ecosystems in the Pieniny between individual sites according to data from the authors' study (2003 – 2006).

Site	NBS	CZ	GR	MG	PG	ZA	ZS
NBS	X	25.00	25.00	35.71	27.77	25.00	37.50
CZ		X	66.66	71.43	55.55	66.66	60.00
GR			X	81.25	65.00	87.50	40.00
MG				X	77.77	81.25	42.86
PG					X	73.68	33.00
ZA						X	40.00
ZS							X

Błeszyński et al. [13] with the results of the authors's investigations at the Zamczysko site, at a distance of approx. 1.5 km from the compensating reservoir and the Dunajec river bed, located 150 m above the water table of the above reservoirs. There only 3 species were not confirmed out of the 13 characteristic ones, while an additional 5 characteristic species were shown. The index of similarity for those groups analyzed after 40 years was 55.55.

Similar results, justifying the final conclusions as to the scope of changes in the fauna of Noctuidae in rock xerothermic sward habitats in the Pieniny, are yielded by a comparison of current Noctuidae groups of all seven analyzed sites. It turned out that the group at ecosystems of rock xerothermic swards at Podskalnia Góra is the richest in exclusive characteristic species: as many as 18 species were recorded there. In terms of number of such species next came Grabczychy (15), Zamczysko (15) and Macelowa Góra (14). The biggest number of characteristic species found at the Podskalnia Góra site is understandable in view of the fact that it is located 5 km from the compensating reservoirs and approx. 1 km from the Dunajec river bed, as well as approx. 200 m above the Dunajec water table.

The presented investigations clearly prove that the changes in the fauna of Noctuidae characteristic of rock xerothermic ecosystems of the Pieniny, are regressive only in the immediate vicinity of the water reservoirs and as the distance from the reservoir increases the negative effect decreases as well, until it disappears completely. Considerable regressive changes may be observed in the ecosystems of Zielone Skałki, Niedzica Biała Skała and the Czorsztyn Hill. On the other hand, they are not currently observed in the ecosystems located east of Zamczysko.

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