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Woodland key habitat contribution to preserve biological diversity in Lithuania: assessing the difference between 2005 and 2017

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Abstract: In response to the degradation of forest ecosystems, their habitats and the loss of species, many formal conservation policies and voluntary forest conservation tools have been proposed and implemented. The woodland key habitat (WKH) is one such initiative that aims to protect biodiversity. This generally involves two key actions: (*i*) the creation of policy (conservation action) and (*ii*) the consequences of the policy or initiative in the field. However, the final step of measuring their success in the field is often missing. The aim of this study is to assess the contribution of the WKH initiative to conserve biodiversity in Lithuania. We compared the changes in spatial distribution, species assemblages and richness within the WKH network between 2005 and 2017. Results showed that the spatial distribution of WKHs decreased in number and by area after 12 years. However, species occurrence, abundance and richness of the WHK network generally increased. In conclusion, we found the WKH initiative has contributed to the conservation of forest habitats and biodiversity in Lithuania. However, the future of the WKH network is uncertain due to the current voluntary system, lack of support and funding.

Keywords: boreal forests; threatened species; conservation; species richness; high conservation value forests

Intensified forest management for sustained high yield wood production has negatively affected the natural ecological patterns and processes of forest ecosystems (Hunter, Schmiegelow 2011; Naumov et al. 2018). This includes forest spatial heterogeneity, stand dynamic regimes, stand structure, age profiles, deadwood amounts and condition as well as the habitat of species and species communities (Angelstam 1997; Brazaitis 2014; Petrokas et al. 2020). In response to this degradation of forest ecosystems and species habitats, many forest policy instruments have been initiated to conserve, protect and restore the natural ecological patterns and processes of forests and their biodiversity (e.g., Natura 2000; CBD 2010; European Commission 2019, 2020). The implementation of policy targets and conservation approaches about ecological sustainability towards successful conservation of species, habitats and processes is a paramount contemporary challenge (Sabogal et al. 2015). The concept of biodiversity (Noss 1990) is a good example for the analysis of generating evidence-based knowledge of performance targets, measures for managing and restoring habitats for species (e.g., Svancara et al. 2005; Lele et al. 2013; Manton et al. 2021). To support the implementation of policies aiming at sustainable forest management, non-formal conservation approaches, such as the Woodland Key Habitat (WKH) initiative, have been developed.

According to Rauschmayer et al. (2009) outcomes of policy processes can be divided into two parts. Firstly, the implementation of policy tools and initiatives to be employed by planners and managers (Angelstam, Andersson 2001; Manton et al. 2021),

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as well as tactical planning and operational management approaches (e.g., Eriksson, Hammer 2006; Angelstam et al. 2011). Secondly, the consequences of the implementation of these plans and actions in the field (e.g., Angelstam et al. 2011). However, this second step in the policy implementation process is often poorly studied (e.g., Mansourian, Vallauri 2014, Popescu et al. 2014). Thus, there is a need to assess the consequences in the field (Rauschmayer 2009; Manton et al. 2021). Following two decades in action, the woodland key habitat (WKH) initiative provides an excellent opportunity to fill this gap.

The WKH concept was introduced in Sweden in the 1990s, as a conservation tool to help protect biodiversity in the production forest matrix by mapping, describing and preserving small forest habitat patches with high conservation values (Timonen et al. 2010). Thus, WKHs aim towards protecting high value conservation forests with elevated levels of naturalness and biodiversity. Accordingly, a WKH is defined as an intact forest area with a high probability of the present non-accidental occurrence of an endangered, vulnerable, rare or care-demanding habitat species (Andersson, Kriukelis 2002; Andersson et al. 2005; Stončius 2011). There are two main criteria for selection: (*i*) the presence of structural elements, such as old trees, uneven age and mixed tree species composition and deadwood and (*ii*) the presence of specialist and indicator species belonging to the organism groups of vascular plants, bryophytes, lichens and macro-fungi (Gustafsson et al. 1999).

Subsequently the WKH concept was further developed and adopted in other Nordic (Norway, Finland, Denmark) and Baltic countries (Estonia, Latvia and Lithuania). The commencement of the WKH network in Lithuania started in 2001 and involved a pilot study to develop field assessment methodology and a classification system adapted to Lithuania's environmental conditions (Andersson, Kriukelis 2002). The first inventory of all Lithuania's forests, regardless of ownership and protection status, was completed in 2005 (Andersson et al. 2005). The protection of WKHs in state forests is mainly covered by the 10% voluntary set-aside criteria in the Forest Stewardship Council's (FSC) National Certification Standard for Lithuania (FSC 2020), while private forest owners were initially able to receive limited time incentive payment provided by the European Union support for non-application of wood harvesting. Currently WKHs continue to provide an essential instrument towards the conservation of biological diversity in production forests. However, after close to two decades the consequences on the ground of this forest protection initiative remain unknown.

The aim of this study is to assess the contribution of Lithuania's WKH initiative to conserve biodiversity between 2005 and 2017. To do this we (*i*) measured the spatial distribution and temporal change of the WKHs, and (*ii*) compared their species assemblages and richness. Finally, we discuss whether the WKH initiative has conserved, protected or locally improved the biodiversity of Lithuania's forests as well as the political commitments to continue as a conservation tool.

MATERIAL AND METHODS

Study area. Lithuanian forests belong to the European hemiboreal mixed broadleaved-coniferous forest type in the transitional zone between the boreal coniferous forests and the nemoral broadleaved forests (Karazija 1988; Bohn et al. 2003). The Lithuanian landscape is relatively flat and undulating (0–293 m a.s.l.) and hosts a variety of forest site types that determine the tree species occurrence. The forest sites range from rich fertile sites with deciduous broadleaf species to dry nutrient-poor sites dominated by pine (Karazija 1988; Petrokas et al. 2020). According to the State Forestry statistics (2018), the forest land in Lithuania was 2 195.6 thousand ha and accounts for 33.6% of the country's territory.

Methods. This study used inventory data of Lithuania woodland key habitats. The WKH database is maintained by the State Forest Service (SFV) of the Ministry of Environment of the Republic of Lithuania which consists of habitats inventoried from 2001 till the end of 2017. Although the WKH pilot project commencement was in 2001, the first full database was not complete until 2005. Therefore we use the first completed 2005 WKH database as the baseline for analysis. After 2005 the WKH database was updated sporadically until 2017, when a major inventory of Lithuania's WKHs was conducted. It should be noted that the 2017 inventory was also the last comprehensive assessment of Lithuania's WKH, thus we selected the 2017 database as the assessment year. For this research we compared the results of the initial 2005 and 2017 WKH datasets. This allows for a 12-year comparative analysis

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to assess the consequences of the WKH initiative to improve biodiversity in the field. At the end of 2017, the Lithuanian WKH database consisted of 8 027 WKHs (25 100 ha) (Figure 1).

WKHs represent a high variety of forest types from dry and moderately humid deciduous forests, wet forests to dry either moderately humid coniferous and mixed forests. They are grouped to 13 different main types (Table 1) which are subsequently classified into a total of 30 subtypes that depend on tree species, soil fertility and wetness as well as landscape structural features.

The Lithuanian definition of WKH identifies both real or actual (rWKH) and potential (pWKH) woodland key habitats. Potential WKHs are defined as an area which (in a few decades) may develop into a woodland key habitat, if it is managed to maintain its naturalness and thus increasing the stand biological value (Andersson, Kriukelis 2002; Andersson et al. 2005; Stončius 2011). All WKH areas were assessed and inventoried in the field according to the unified methodology developed by Andersson and Kriukelis (2002). One of the most important features of habitat determination was the finding of indicator and specialist species in the stand. Specialist species are dependent on certain quality specific forest habitats that do not survive in forests that are managed for high yield wood production. Indeed, many of the nominated indicator species are included in the Red Data Book of Lithuania (Rašomavičius 2021) and have high habitat needs, but also they have poor adaptation ability to deal with forest change within the surrounding forest matrix. Indicator species are more common than specialist ones, easily observed species that are quite demanding for the quality of living conditions and are often found in WKH (Andersson et al. 2005; Stončius 2011).

The data about indicator and specialist species were used to assess the value and changes of WKHs in this study. Species of organism groups (bryophytes, lichens, vascular plants, fungi, beetles, and

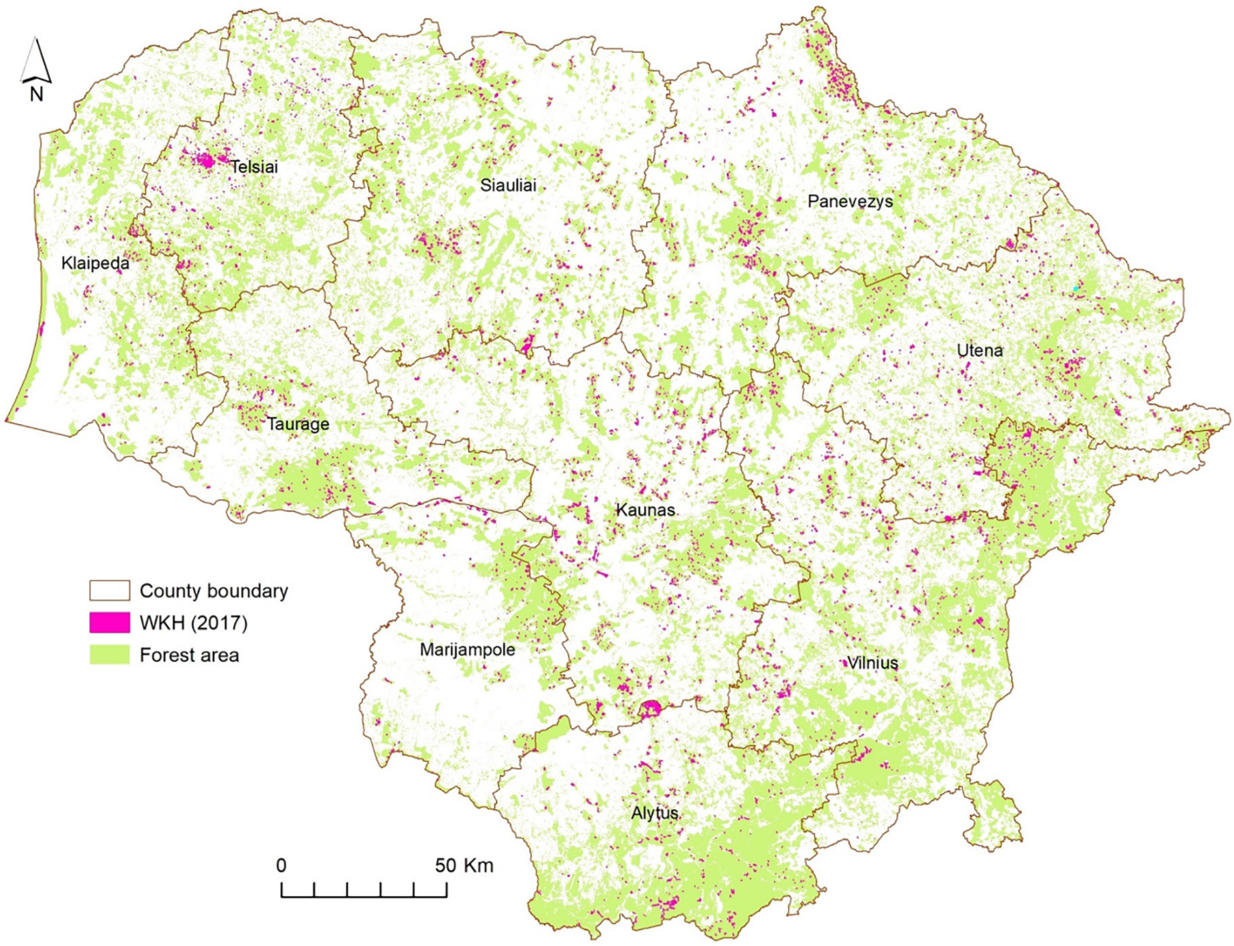

Figure 1. Location of woodland key habitats and forest area in Lithuania

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Table 1. Woodland key habitat (WKH) types and their important indicator and specialist species (Andersson 2005) in Lithuania

WKH type and description	On logs	On the ground	On trees
A – Dry and moderately humid coniferous and mixed forests	*Phlebia centrifuga*, *Pycnoporellus fulgens*, *Nowellia curvifolia*, *Odontoschisma denudatum*, *Anastrophyllum hellerianum*, *Peltis grossa*	*Linnaea borealis*, *Diphasiastrum complanatum*	*Arthonia leucopellea*, *Phellinus pini*
B – Dry and moderately humid deciduous forests	*Polyporus badius*, *Xylobolus frustulatus*, *Clavicorona pyxidata*	*Lunaria rediviva*, *Allium ursinum*, *Corydalis cava*	*Arthonia byssacea*, *Lobaria pulmonaria*, *Anomodon longifolius*, *Neckera pennata*, *Frullania dilatata*
C – Wet forests	*Chaenotheca brachypoda*, *Chaenotheca chlorella*, *Jungermannia leiantha*, *Riccardia latifrons*, *Nowellia curvifolia*, *Polyporus badius*	*Dryopteris cristata*, *Listera cordata*, *Allium ursinum*, *Lunaria rediviva*	*Hypotrachyna revolute*, *Arthonia leucopellea*, *Lecanactis abietina*, *Phellinus chrysoloma*
D – Riparian slopes of water bodies	*Polyporus badius*	*Lunaria rediviva*, *Matteuccia struthiopteris*	*Ulota crispa*, *Hypotrachyna revolute*
E – Shallow slopes of water bodies (flooded forests)	*Riccardia latifrons*, *Jungermannia leiantha*	*Dryopteris cristata*, *Huperzia selago*	*Flavoparmelia caperata*, *Hypotrachyna revolute*
F – Other forest habitats affected by water	*Riccardia latifrons*, *Geocalyx graveolens*	*Palustriella commutate*, *Trichocolea tomentella*, *Poa remota*, *Cantharellus lutescens*	*Arthonia leucopellea*
G – Small islands and peninsulas in water bodies; wetlands	depends on the composition of the stand		
H – Steep slopes	depends on the composition of the stand	*Matteuccia struthiopteris*, *Poa remota*	*Arthonia leucopellea*, *Ulota crispa*
I – Fire-scared forests	–	–	*Chalcophora mariana**, *Melanophila acuminata**
J – Used or abandoned meadows and pastures overgrown with trees	–	–	*Bacidia rubella*, *Chaenotheca phaeocephala*, *Ramalina baltica*, *Liocola marmorata*, *Osmoderma eremita*
K – Giant trees	–	–	*Calicium adspersum*, *Microbregma emarginatum*
L – Old parks	–	–	*Chaenotheca phaeocephala*, *Ramalina baltica*, *Calicium adspersum*
M – Forest island in cultivated fields	depends on the composition of the stand		

*species was not recorded during the inventories; WKH – woodland key habitat

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molluscs) during the inventory were assessed on a scale by grades: 1 – single individual, 2 – moderately abundant, 3 – very abundant. In addition, any traces (e.g., excavated tunnels, holes) left by insects on a tree object were kept as an individual (1).

WKH overall changes (GIS analysis). Data analysis consisted of WKH databases and GIS data analysis. The spatial WKH layers were used to assess the overall changes in habitats according to Lithuanian counties. Together with the information of WKH database, the data of WKH area on species distribution and occurrence were analysed to compare and assess the changes between the initial (2005) and interim (2017) WKH datasets. The data for research were systematized and processed using MS Excel program (Version 14.0, 2010).

Species change analysis (Statistical analysis). In this study, the number of different species was considered as species richness (Wiens, Donoghue 2004; Gotelli, Colwell 2011). For a more efficient comparison of the selected datasets the species abundance index was evaluated which was calculated by summing the abundance grades of one type of biological elements or species for a certain group of organisms. This index was suitable for estimating species abundance when due to the situation where the habitat is rich in one species but the species diversity itself was relatively small. In addition, the Shannon biodiversity index was used to analyse the species change which characterized species diversity in a community. Shannon biodiversity index *(H)* was calculated according to the formula:

$$H = -\sum_{i} p_i \times \ln\left(p_i\right)$$

where:

p_i – the part of individuals in the population that belong to the species *i*.

To assess the changes and understand whether the preservation of WKH contributes to biodiversity, we analysed only WKHs that were assessed twice (initially in 2005 and re-assessed in 2017) for the study of species changes (N = 3 634 WKHs). These WKHs were grouped into 4 scenarios according to how the status of the WKH changed after the re-inventory:

(*i*) The real key habitat remained real key habitat (rWKH → rWKH);

(*ii*) The real key habitat downgraded to potential habitat (rWKH → pWKH);

(*iii*) The potential habitat remained potential habitat (pWKH → pWKH);

(*iv*) The potential habitat upgraded to key habitat (pWKH → rWKH).

Statistical processing of the data was performed with Statistica 12 software package by the factor analysis method.

RESULTS

WKH overall distribution and changes. Comparing initial 2005 and 2017 WKH datasets showed that both the total number and the total area of WKHs decreased by 839 habitats and 1 144 ha, respectively. However, the mean patch size of individual WKHs showed a small increase by 0.17 ha from 2.96 ha in 2005 to 3.13 ha in 2017 (Table 2). In both datasets the smallest mean patch size was recorded for giant trees (type K), the mean area slightly decreased from 0.67 ha in 2005 to 0.61 ha in 2017. The largest mean patch size was identified in forests with fire scars (type I), 47.55 ha in 2005 and 59.58 ha in 2017.

Analysing WHKs by type, we found that three types (A, B and C) contributed 71–73% of all habitats by quantity and 79–80% by habitat area. Thus, these are the main habitat types in the identified WKHs and represent the majority of Lithuania's WKHs. The largest losses of habitat area were found in dry and moderately humid deciduous forests (B) as well as dry and moderately humid coniferous and mixed forests (A) – 730.8 ha and 592.6 ha, respectively. Meantime the largest increases of habitat area were found in forests within riparian slopes of water bodies (D) and steep slopes (H) – 206.2 ha and 155.8 ha, respectively. The decreases of habitat areas were due to forest harvesting in more accessible WKHs (like A and B types). Whereas, increases of habitat areas were caused by the decision of forest managers to replace harvested WKHs with other areas where clear-cuts are restricted (like type D) or unplanned due to the complex landscape structure (like type H). It should be noted that WKHs of type H are also generally adjacent or related to the river network and riparian zones in Lithuania.

The analysis of WKH area distribution showed that the total WKH area in Lithuanian forests decreased from 1.22% in 2005 to 1.14% in 2017. Counties with the largest forest cover did not contain the highest number of habitats (Table 3). Kaunas county contained the highest proportion of WKHs and recorded the largest decrease in WKHs from

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Table 2. Distribution of WKH in initial 2005 and interim 2017 WKH datasets by habitat type (see Table 1 for details on the WKH type)

WKH type	Initial 2005 number of habitats all	rWKH	pWKH	mean area (ha)	min. area (ha)	max. area (ha)	total area (ha)	Interim 2017 number of habitats all	rWKH	pWKH	mean area (ha)	min. area (ha)	max. area (ha)	total area (ha)	Number of habitats change	Area change (ha)
A	1 736	1 019	717	3.08	0.05	42.41	5 353.0	1 473	1 116	357	3.23	0.08	42.57	4 760.4	–263	–592.6
B	2 476	1 301	1 175	3.43	0.07	55.54	8 496.3	2 145	1 518	627	3.62	0.06	55.54	7 765.5	–331	–730.8
C	2 243	1 437	806	3.30	0.03	76.71	7 406.1	2 064	1 633	431	3.54	0.03	76.89	7 301.9	–179	–104.2
D	481	336	145	3.74	0.13	52.28	1 801.1	542	433	109	3.70	0.08	44.81	2 007.3	61	206.2
E	72	59	13	3.39	0.28	29.26	243.8	108	91	17	3.05	0.35	18.83	329.6	36	85.8
F	74	61	13	3.09	0.18	18.77	228.8	87	78	9	3.31	0.15	19.52	288.2	13	59.4
G	46	33	13	1.26	0.16	11.58	58.1	59	52	7	1.21	0.10	11.06	71.6	13	13.5
H	197	122	75	2.87	0.05	18.64	566.1	199	147	52	3.63	0.15	41.75	721.9	2	155.8
I	8	6	2	47.55	0.20	206.80	380.4	6	6	–	59.58	0.20	206.78	357.5	–2	–22.9
J	326	236	90	2.19	0.17	24.60	715.1	243	201	42	2.44	0.18	22.96	592.4	–83	–122.7
K	1 095	905	190	0.67	0.01	22.06	733.0	978	872	106	0.61	0.01	18.75	600.5	–117	–132.5
L	99	71	28	2.57	0.17	13.84	254.8	109	81	28	2.57	0.07	14.07	280.2	10	25.4
M	13	2	11	1.25	0.12	7.29	16.3	14	5	9	2.29	0.09	7.30	32.0	1	15.7
Total	8 866	5 588	3 278	2.96	–	–	26 253	8 027	6 233	1 794	3.13	–	–	25 109	–839	–1 144

WKH – woodland key habitat; rWKH – real woodland key habitat; pWKH – potential woodland key habitat

Table 3. Distribution of forest area and WKHs in initial 2005 and interim 2017 WKH datasets for each Lithuanian county (see Figure 1 for county locations)

County	Forest area (ha) 2009	Forest area (ha) 2018	Initial 2005 rWKH	pWKH	total	area (ha)	WKH area in county forests (%)	Interim 2017 rWKH	pWKH	total	area (ha)	WKH area in county forests (%)
Alytus	266 274.4	267 775.9	497	196	693	2 752.78	1.03	525	123	648	2 644.69	0.99
Kaunas	239 325.8	240 421.0	972	691	1 663	4 812.90	2.01	1 029	318	1 347	4 037.15	1.68
Klaipėda	137 798.7	138 701.0	247	129	376	939.36	0.68	239	85	324	857.41	0.62
Marijampolė	96 798.7	98 303.3	221	45	266	1 024.59	1.06	246	34	280	1 108.62	1.13
Panevėžys	222 183.2	225 687.6	458	603	1 061	3 907.57	1.76	647	251	898	3 479.59	1.54
Šiauliai	232 946.6	239 566.2	549	320	869	2 573.58	1.10	652	158	810	2 544.55	1.06
Tauragė	145 447.7	146 377.6	350	134	484	1 314.35	0.90	368	83	451	1 325.62	0.91
Telšiai	156 909.2	159 355.3	659	352	1 011	2 010.91	1.28	666	257	923	1 871.95	1.17
Utena	239 753.2	248 738.8	574	393	967	2 589.54	1.08	790	208	998	2 905.95	1.17
Vilnius	412 862.6	430 693.6	1 061	415	1 476	4 327.47	1.05	1 071	277	1 348	4 333.42	1.01
Total	2 150 300.1	2 195 620.3	5 588	3 278	8 866	26 253.05	1.22	6 233	1 794	8 027	25 108.95	1.14

WKH – woodland key habitat; rWKH – real woodland key habitat; pWKH – potential woodland key habitat

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2.01% to 1.68% in forest area. Meantime, the lowest proportion of WKH areas was in Klaipėda county, where the proportion of WKH decreased from 0.68% in 2005 to 0.62% in 2017.

Changes in species richness, abundance, and biodiversity. A total of 272 species in 2005 and 266 species in 2017 were inventoried (Table 4). Indicator and specialist species are highly dependent on the composition of the WKH type and quality. The most commonly identified species can be found in Table 1. Species occurrence in WKHs had different trends according to the species richness and the species abundance index. Overall, comparing initial and interim datasets, changes in both total species richness and species abundance index decreased slightly in 2017 although these indices were found to vary in different groups of organisms.

Distribution of the species richness by groups of organisms showed the largest part (34–35%) consisting of fungal species, to a lesser extent – lichens (20–21%) and bryophytes (17–18%). However, the species abundance index showed that most species were bryophytes (41–49%) and even about 3 times less – lichens (16–18%) and fungi (14–15%).

We compared the species richness of the WKHs that have been inventoried twice in 2005 and 2017 to determine their development in terms of the different scenarios (Figure 2). Accordingly, we identified two trends of the species richness change: firstly, species increased significantly in the scenarios rWKH → rWKH and pWKH → rWKH, and, secondly, the scenarios pWKH → pWKH and rWKH → pWKH showed decreases.

The results showed that by rWKH → rWKH and pWKH → rWKH scenarios the species richness increased 1.3 and 2.1 times, respectively. However, for pWKH → pWKH and rWKH → pWKH results showed a decline of species richness by 1.2 and 1.5 times, respectively. In real WKHs were on average 2.6–3.1 species per habitat while in potential WKHs there were 1.1–1.4 species per habitat according to the 2017 data.

The species abundance and Shannon biodiversity indices significantly changed in all 4 WKH development scenarios (Figure 3). Similar positive and negative trends were observed for both species richness indices calculated for different groups of taxa.

The pWKH → rWKH scenario showed the greatest increase of abundance and Shannon biodiversity indices by 2.3–3 and 2.5–4.1 times, respectively, for all groups of organisms (except vascular plants). Both indices of vascular plant species decreased under all other scenarios. The reasons for such

Table 4. Occurrence of species richness and species abundance index in initial 2005 and interim 2017 WKH datasets

Group of organisms		Initial 2005				Interim 2017			
		species richness		species abundance index		species richness		species abundance index	
		units	(%)	units	(%)	units	(%)	units	(%)
Lichens	indic.	16	20	2 505	18	17	21	2 411	16
	spec.	39		3 046		40		2 297	
Bryophytes	indic.	26	17	9 047	41	28	18	11 339	49
	spec.	20		3 135		20		2 947	
Vascular plants	indic.	25	11	1 605	6	21	10	1 210	5
	spec.	5		93		6		107	
Fungi	indic.	28	34	2 747	14	29	35	2 969	15
	spec.	64		1 474		63		1 371	
Beetles	indic.	9	12	507	19	10	10	793	13
	spec.	24		5 296		17		2 936	
Molluscs	indic.	14	6	467	2	13	6	413	2
	spec.	2		118		2		149	
Total		272	100	30 040	100	266	100	28 942	100

indic. – indicator species; spec. – specialist species

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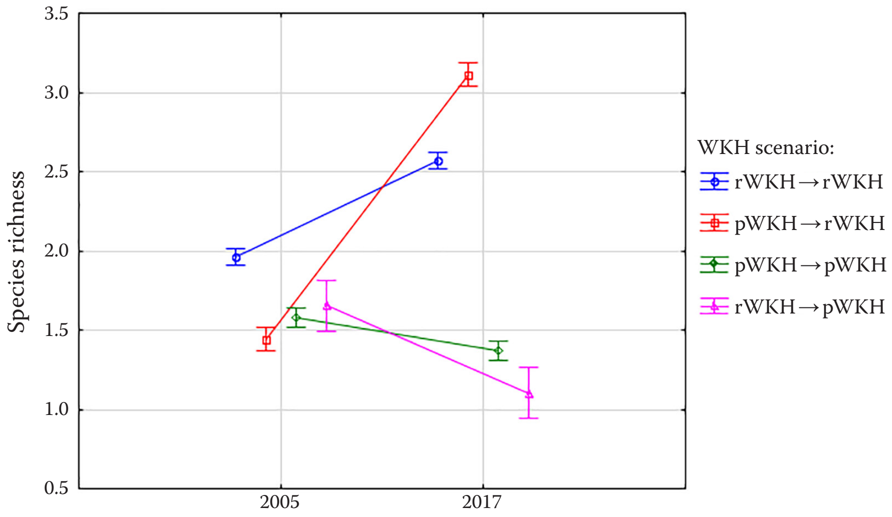

Figure 2. Change in species richness for different WKH change scenarios between 2005 and 2017

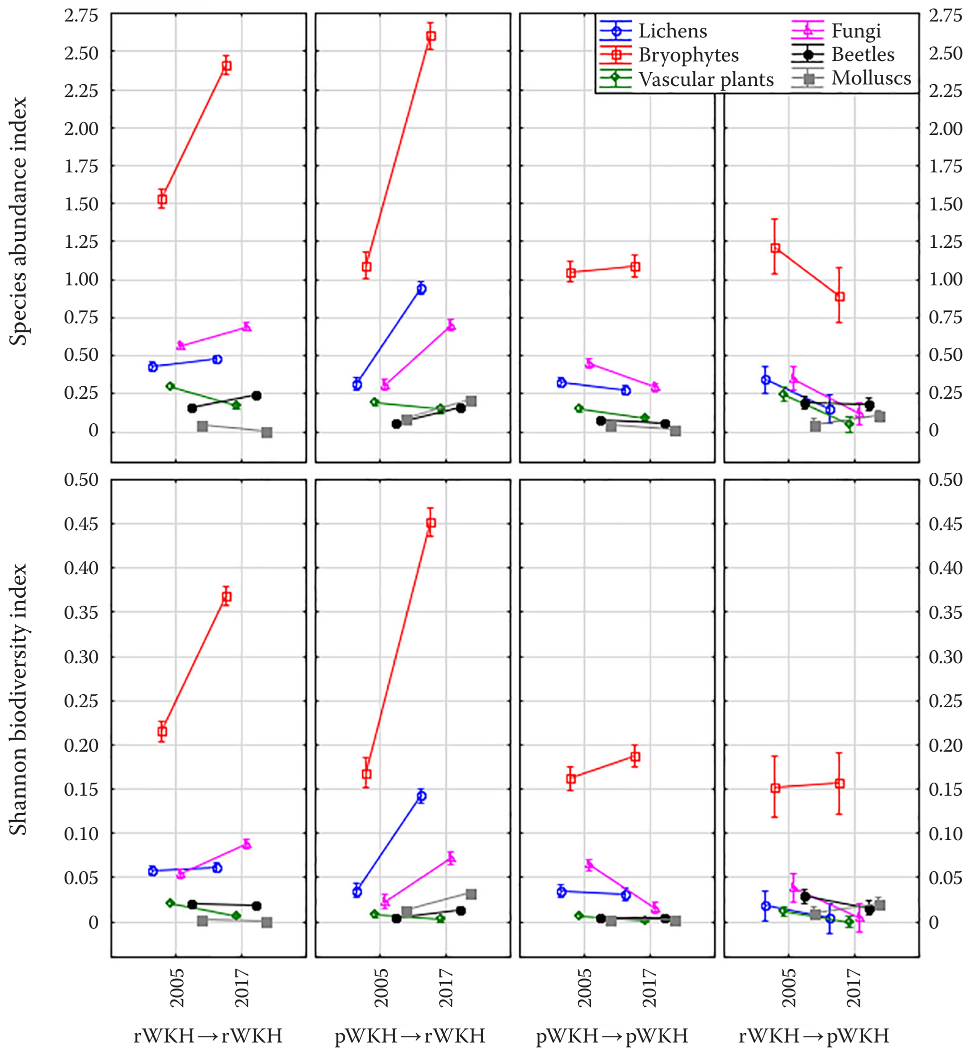

Figure 3. Changes in Shannon biodiversity and species abundance indices for different groups of organisms for different woodland key habitat change scenarios in 2005 and 2017

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decreases were unclear although it is most likely they were affected by improper inventory time or specialist's skills. However, a real decrease of vascular plants in the WKHs should also be considered. The biggest decreases were determined in the rWKH → pWKH scenario where species abundance and Shannon biodiversity indices decreased 1.1–5.1 times (except for molluscs) and 1.8–9 (except for bryophytes) times, respectively. The Shannon biodiversity index for bryophytes increased under all scenarios 1.2–2.7 times within the studied period.

Species abundance and Shannon biodiversity indices varied in different types of WKH (Figure 4). In rWKHs the highest values of both indices were in deciduous forests (B), on riparian slopes of water bodies (D) and steep slopes (H) and increased by 2017. Meanwhile, in pWKHs both indices declined in most habitat types from 2005 to 2017.

Species abundance and Shannon biodiversity indices in rWKHs showed an increase compared to potential habitats. In 2005, the Shannon biodiversity index was 1.3–1.5 times higher in rWKH compared to pWKH and after the re-inventory this index increased 1.4–3.8 times in rWKH. Similarly, in rWKH the species abundance index was mostly 1.5–2.1 times higher in 2005 and 2.4–4.6 times higher in 2017 compared to potential habitats.

In 2017, the species abundance and Shannon biodiversity indices in rWKHs increased for all habitat types 1.1–1.8 and 1.1–2.2 times, respectively, except for the habitat types of shallow slopes of water bodies (E) and small islands and peninsulas in water bodies (G). In addition, both indices increased even 3.1–3.2 times in the habitat type of other forest habitats affected by water (F) in 2017. Meanwhile, species abundance and Shannon biodiversity indices in pWKHs declined for all habitat types by 1.1–2.0 times and 1.1–4.8 times, respectively.

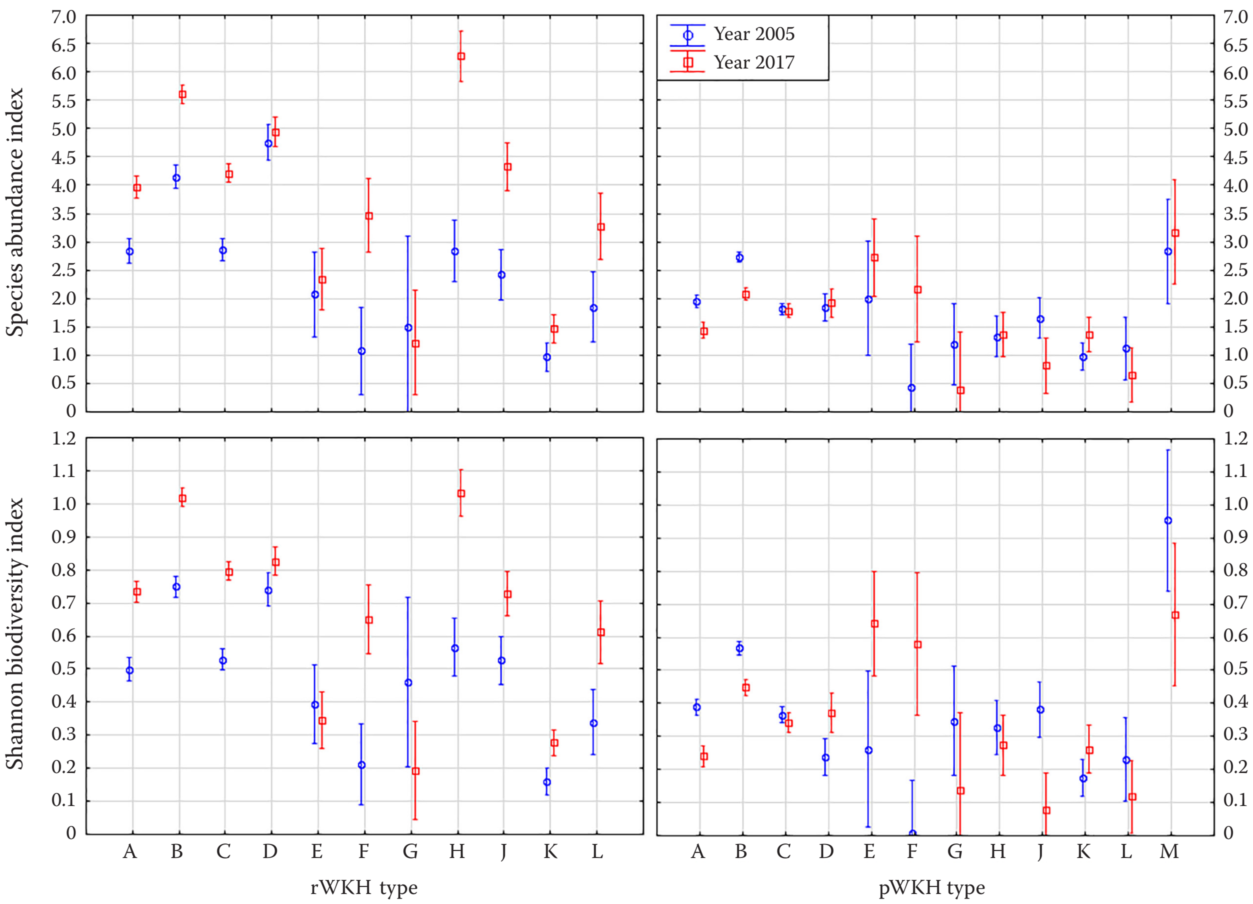

Figure 4. Changes in Shannon biodiversity and species abundance indices for different woodland key habitat (WKH) types in 2005 and 2017 (see Table 1 for a description of the WKH types)

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DISCUSSION

National Protected Areas are reported by size in many countries. International, EU and national level policy documents set protection goals based on the size or proportion of an area, thus the area is a good indicator to measure the trends of patch size change and distribution. The WKH size in Lithuania is not limited and varies from 0.004 ha to 206.78 ha according to 2017 WKH dataset. Our results show that the mean patch size was 3.13 ha for 2017 in Lithuania. For comparison, the mean patch size in Latvia and Estonia was 2.1 and 2.9 ha, respectively, whereas in Sweden it was even 4.63 ha. Laita et al. (2010) indicated that the smaller the patches, the more important it becomes for the functional connectivity of protected areas.

As WKHs are hotspots for maintaining biodiversity throughout the surrounding forest, the spatial distribution of WKHs is an important feature. The total WKH area covered 1.14% of the Lithuanian forest area according to 2017 WKHs dataset, at the county level this varies from 0.62% to 1.68%. This supports the idea of Karazija (2003) that 1% of the forest area should be protected under the WKH initiative. However, a review on WKHs by Brazaitis (2014) recommended that an optimal amount of WKHs is 2–5% of the forest area, but this varies depending on the protected area network in the landscape. Therefore, 1.14% of the total forest coverage of WKHs could be expanded by the addition of high value conservation forest stands.

Solving the issue of biodiversity conservation, WKHs cannot be valued equally (Karazija 2003). The visual qualitative ranking by the WKH value was implemented since 2013, however, it was performed for most but not all WKHs. Habitats are highly diverse in environmental conditions, protected values and they even require different management strategies and measures to conserve biodiversity. While in most types of WKH no applied management measures are recommended, in others like J (Used or abandoned meadows and pastures overgrown with trees; e.g. grazing and mowing), K (Giant trees; e.g. cutting down other trees and shrubs) and L (Old park; e.g. protecting old trees from young decaying trees) management measures are necessary because they were formed as a result of human activity. Therefore, visual assessments and non-action management strategies are not often the best options. This is also highlighted in the Natura 2000 Network. Consequently, we express the need for an individual habitat-based evaluation system for all WKHs.

Due to the seasonality of growth and sometimes complicated identification of species as well as the specialist's personal knowledge and experience, the information collected during re-inventories is not comparable at the level of one WKH. According to Brazaitis (2014), the information collected during re-inventories must complement the already existing data on WKH indicator and specialist species. Consequently, timing of field inventory (undertaking field work outside of the growing season) and specialist's skills may affect observations of species in the WKHs. Furthermore, the size of the habitat patch and the structure of the surrounding landscape have been shown to affect species occurrences (Siitonen et al. 2001; Gu et al. 2002). However, the 12-year period for assessment used in this study seems long enough to determine the substantial species changes whereas our results showed the respective 2.3–3 and 2.5–4.1 times increase of species abundance and biodiversity indices in the pWKH → rWKH scenario in twice assessed WKHs. Nevertheless, additional research is needed to reveal the magnitude of the impact of various environmental factors on the occurrence, abundance, and diversity of WKH species.

Our results suggest that the habitats within rWKH → rWKH and pWKH → rWKH scenarios maintained or even increased their species richness during the evaluated 12-year period (Figure 2). Due to the small patch size of WKH (i.e. < 1 ha), the establishment of a protection zone in adjacent stands is necessary to prevent negative effects of non-ecologically friendly activities (clearcuts, drainage, etc.). A protection zone around the highly rated WKHs should be applied, as the edge effect of the forest impacts humidity up to 50 m into the forest interior and WKHs < 1 ha cannot maintain full species diversity for long periods (Ylisirniö et al. 2016). Furthermore, harvesting of the forest matrix surrounding WKHs should also be included as an important factor for species richness and biodiversity. To help monitor WKHs and the effects of forest harvesting Brazaitis (2014) recommended implementing the WKH monitoring every 3–5 years and full habitat assessment every 10–15 years. However, due to the relatively intensive destruction of some WKHs by logging and

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the impact of the surrounding managed forests on WKHs, we call for a program of continuous monitoring to support the WKH initiative for the future. This means monitoring both the WKHs and the impact of adjacent harvesting that can have undesirable effects on biodiversity.

WKHs are only one part of the nature protection system that must ensure preservation of forest biodiversity and the function of this part can only be effective in a well-functioning chain (Karazija 2003). Currently, WKHs in Lithuania are not protected by law, so there is a real threat of them being damaged or destroyed through forest harvesting. WKHs have proved to be very important for forest biodiversity – they have 2.5 times more cryptogam species and 3 times higher abundance than the forests without such status (Preikša, Brazaitis 2011). Our study also confirms the increasing value of habitats for rWKH → rWKH and pWKH → rWKH scenarios. Therefore, their voluntary protection status and lack of national support in Lithuania's forest policy undermines their long-term ability and contribution towards maintaining forest ecosystems.

The designation of WKHs is not yet a determination of the conservation status but it could only be a starting point for further adjustment of the system of protected areas and additions to the Natura 2000 Network. Therefore, WKHs should be included in the system of protected areas as one of its elements. Many WKHs were assigned as being Sites of Community Importance during a nationwide inventory in 2012–2015. However, it has not ensured their conservation outside the Natura 2000 Network or in private forests. The National Lithuanian Forest Certification standard of FSC requires at least 10% of forests to be set aside from forest harvesting to improve the biological values of forests (FSC 2020). This can currently only stimulate the protection of WKHs in state forests. The European Green Deal stipulates that 30% of forests should be protected, of which 10% should be under strict protection by 2030 (European Commission 2019, 2020). Given that in Lithuania approximately only 1.2% of forests are strictly protected (Forestry Statistics 2020), WKHs and other high conservation value forests, such as Natura 2000 areas, will become vital in reaching such targets and could provide opportunities towards increasing the area of strictly protected forests. Finally, under the measure "Forest Environmental Payments" of the European Union's Rural Development Program 2007–2013 (RDP) the private forest owners had the opportunity to receive payment for non-management (i.e., no harvesting) of WKHs areas for a 7-year period. The measure was not prolonged. Indeed, programs such as the WKH initiative are at risk by a lack of support and funding. For instance, Sweden has stopped its mapping of high conservation value forests, which includes WKHs (Angelstam et al. 2020).

CONCLUSION

This study provided new information about the trends of WKHs in a relatively long-term perspective. Main conclusions derived from this paper analyses are as follows:

(*i*) The mean patch size of individual WKHs showed a small increase by 0.17 ha from 2.96 ha in 2005 to 3.13 ha in 2017.

(*ii*) The analysis of the WKH area distribution showed that the total WKH area in Lithuanian forests decreased from 1.22% in 2005 to 1.14% in 2017.

(*iii*) Species richness during the 12-year period increased within the rWKH → rWKH and pWKH → rWKH scenarios 1.3 and 2.1 times, respectively, however, for the pWKH → pWKH and rWKH → pWKH scenarios species richness declined 1.2 and 1.5 times.

(*iv*) The highest species abundance and Shannon biodiversity indices according to 2017 WKHs dataset were determined in the types of deciduous forests (B), riparian slopes of water bodies (D), and steep slopes (H).

(*v*) This study shows the importance of the WKH initiative after 12 years as a management tool that contributes to the protection of the high conservation value forest ecosystem. However, more government support is needed to ensure the future of the WKH initiative and the biodiversity of Lithuania's forests.

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