THE ASSESSMENT OF VEGETATION IN UNMANAGED NEMORAL FORESTS IN ZEMGALE

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Abstract
Zemgale geobotanical region historically was dominated by large broad-leaved forests, but last centuries the high anthropogenic pressure on these territories has reduced the area of these forests. In fragmented landscape small patches of natural broad-leaf forests are protected to preserve the forest structural features, which also function as habitats for rare and protected species. The aim of this study was to compare the natural broad-leaf forest habitats and structural elements and vegetation in woodland key habitats in production forests and protected areas (nature park 'Tērvete' and nature reserve 'Ukru gārša') in Zemgale. In total, 12 sample plots were established (the size of sample plot 0.1 ha) in Aegopodiosa forest type. In all sample plots forest structural features were measured and vegetation survey using Braun-Blanquet method was made. In this study, we found that average amount of dead wood varies between 78.7 m^3 ha^{-1} in woodland key habitats in production forests and 133.0 m^3 ha^{-1} special protected areas. Considerable amount of broad-leaf natural forests represented by nemoral species (50 – 58% of species richness), which corresponds to these forest type communities in the region.
Key words: Woodland key habitats, deciduous forest stands, forest vegetation, forest structural elements.

Introduction

Latvia is located in the hemiboreal zone – the contact zone of boreal coniferous forest and temperate broad-leaf forests (Krampis, 2011). Part of Latvian forests belong to the broad-leaved forest vegetation classes, where the dominant species is *Fraxinus excelsior*, *Quercus robur* and *Tilia cordata*, with other deciduous trees in admixture (Priedītis, 1999), sometimes also Scots pine (Ikauniece, 2013). The most important features for biodiversity are uneven age stand structure with large dimension trees, dead wood in various stages of decay, understorey dominated by decidous trees and shrubs, and the small proportion of Norway spruce (Priedītis, 1999). The gap dynamics is a common type of natural disturbance (Mežaka, 2009) where in open patches the development of first pioneer phase and broad-leaved tree species occurs (Ikauniece, 2013). Zemgale geobotanical region historically was dominated by large areas of broad-leaved forests, but in last centuries human activities affected the area and reduced the area of these forests (Zunde, 1999). Zemgale is one of the oldest and most deforested Latvian regions where forests are currently fragmented and occupy about 10-12% from region's area (Tabaka, 2001). The ancient broad-leaved forests where replaced by deciduous pioneer species, for instance, *Betula* spp., *Populus tremula*, *Alnus incana* and *A.glutinosa* (Suško, 1997; Ek *et al*., 2002). Consequently, the dominant tree species changed the structure of understorey (Laiviņš *et al.*, 2008; Laiviņš *et al.*, 2014). Woodland key habitats (WKH) are characterized by habitat specialist species, indicator species and stand structural features (Ek *et al.*, 2002; Lārmanis, Priedītis, & Rudzīte, 2002). These relatively small forest areas with high ecological value are considered to be cost-effective biodiversity conservation tool in fragmented production forests (Timonen, 2011). The high valuable broad-leaved forests is protected habitat type in EU level (code: 9020*) (Auniņš, 2013).

The aim of this study was to compare forest stand structural elements and vegetation in broad-leaved WKH in production forests and formally protected areas in Zemgale.

The hypothesis of this study is that structural elements and vegetation in broad-leaved WKH is significantly different in production forests and formally protected areas.

This aim requires following study objectives:

1. to analyze structural elements (living trees and dead wood – snags, stems and downed log pieces) of broad-leaved WKHs;
2. to assess the vegetation of broad-leaved WKH (tree, shrub, herbaceous and moss layers);
3. to compare broad-leaved WKH in production forests and formally protected areas.

Materials and Methods

Study area. The study was conducted in Southern part of Zemgale geobotanical region. The data were collected in 2012 – 2014. Altogether 12 study sites were chosen for analysis. The sites are in Aegopodiosa forest type – four broad-leaf WKH in production forests, four – the natural park 'Tērvete' and four – the nature reserve 'Ukru gārša' (Figure 1).

The properties of each site were measured on a sample plot size 20 × 50 m (size: 0.1 ha) with exposition S-N or SW-NE direction from stand edge to interior (Liepa & Straupe, 2012). Each plot was divided into five sublots (zones) with respective distance from edge to core: 0-10 m (1st), 10-20 m (2nd), 20-30 m (3rd), 30-40 m (4th) and 40-50 m (5th). The

Figure 1. Location of the studied area in Southern Latvia, Zemgale geobotanical region.

stand structural features were measured in all sample plots (20 × 50 m), but vegetation survey was done in the 1st, 3rd and 5th zone, which respresents the plant composition in all vegetation layers.

Stand structural elements. All live trees and standing dead wood was measured at breast height (DBH, 1.3 m) also downed dead logs and pieces (diameter ≥ 10 cm) were measured. For each element, the tree species were recorded. Live tree trunk volumes were computed using a species specific volume functions (Liepa, 1996). The volumes of individual snags, stems and logs were computed using formulas by Liepa (1996). The decay stages were characterized for all dead wood according to Hunter (Neville & Bastrup-Birk, 2006) where decay stage was determined using five classes: 1) dying recently before sampling, a knife penetrates less than 1 cm into bark; 2) fairly hard wood, a knife penetrates 1-3 cm into the wood; 3) soft wood, a knife penetrates over 3 cm into the wood; 4) wood soft throughout, a knife penetrates all the way; 5) wood almost decomposed and a hand penetrates throughout.

Vegetation survey. The Braun-Blanquet approach has been used to survey and describe plant communities: the total projective coverage of moss, herb, shrub and tree layers as well as coverage of each separate species was evaluated in each zone as percentage (%): tree layer (E3) (tree species from height 7.0 m), shrub layer (E2), (shrub and tree species at height from 0.5 to 7.0 m), herb layer (E1) (including vascular plants, dwarf shrub, schrub and tree species up to height 0.5 m) and moss layer (E0) (Liepa & Straupe, 2012). The nomenclature for vascular plants follows Garvrilova & Šulcs (1999) and that for mossess Āboliņa, Piterāns & Bambe (2015). For each separate species in herbaceous layer the constancy classes were described (Markov, 1965), which correspond to the index I (< 21%), II (21% – 40%), III (41% – 60%), IV (61% – 80%), V (81% – 100%) (Mueller-Dombois & Ellenberg, 1974). The plant ecological groups were described for abiotic conditions according to Ellenberg (Ellenberg *et al*., 1992), seed and spore dispersal types and life forms according to Raunkiaer (База данных Флора сосудистых растений Центральной России).

Data processing. In this study, descriptive methods were used for data of vegetation (mean, standard error (SE) with confidence interval 95%). A statistical distribution was assessed graphically. According to the results (symetrical distribution of data), parametrical methods were chosen. ANOVA test was used to estimate the significant variations between gradation classes and Tukey's HSD test. A risk level of 5% ($p < 0.05$) was used to define statistical significance (Arhipova & Bāliņa, 2006).

Results and Discussion

Stand structural elements. WKH structural elements are structures in forest, for example, living trees with various dimensions and dead wood, important for habitat specialist species (Ek *et al.*, 2002; Timonen *et al.*, 2010). We found significant differences ($p < 0.05$) in the volume of living trees: for broad-leaved WKHs in managed forests volume was on average 310.2 m^3 ha^{-1}, and the largest portion of it was *Populus tremula* L. (55%) – a pioneer species which colonises former broad-leaved stands with natural succession. In formally protected areas – the nature park 'Tērvete' and nature reserve 'Ukru gārša' – the volume of living trees was 321.4 m^3 ha^{-1} and 195.4 m^3 ha^{-1} respectively (made up by mostly *Fraxinus excelsior* L. – 48% and 58%)

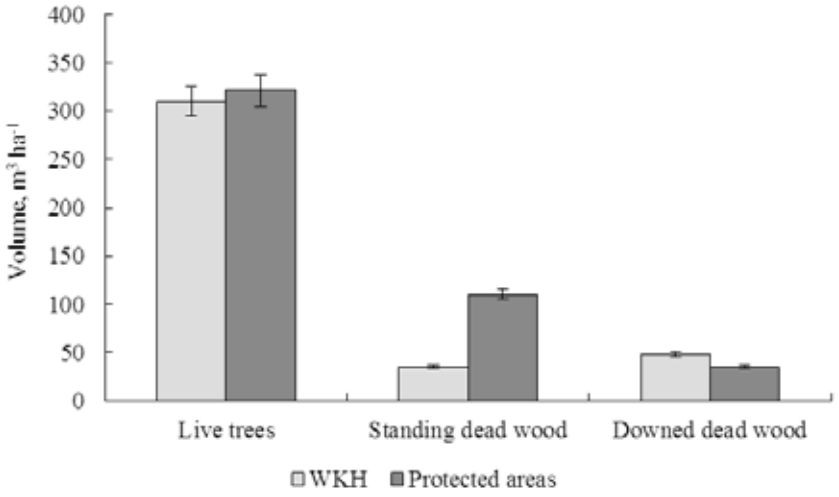

Figure 2. Diversity of forest stand structural elements. Values are means ± SE.

(Figure 2). In Eastern Europe and Latvia, stable are forest stands in which shade-tolerant tree species are dominant, for example, *Fraxinus excelsior* (Laiviņš, 2014). Average volume of living trees is significantly lower in the nature reserve 'Ukru gārša', which is explained by increased dieback of *Fraxinus excelsior* due to pathogenic fungus *Chalara fraxinea* (Kenigsvalde *et al.*, 2010; Pautasso *et al.*, 2013).

In sample plots, we found dead wood types - stumps, snags and pieces, and their volume in broad-leaved WKH differs significantly ($p < 0.05$) – in production forests dead wood volume reaches on average 78.7 m^3 ha^{-1}, but in formally protected areas volume is larger – on average 133 m^3 ha^{-1}. This is explained by natural dynamics in these forests – gap dynamics as well as with rapid dieback of *Fraxinus excelsior* trees. In production, forests dead wood volume is influenced also by the distance to populated places and the need for firewood by local inhabitants. Compared to the amount found in the Second cycle of Latvian National Forest inventory (23.5 m^3 ha^{-1}), dead wood volume in WKHs in production forests is almost three times larger, and in protected areas – almost six times larger (Meža nozares attīstības novērtējums, 1990 – 2013.). The average volume of stumps, snags and downed logs and pieces is significantly different ($p < 0.05$) between broad-leaved WKHs in production forests and protected areas. In the nature reserve 'Ukru gārša', the volume of stumps is larger (30.5 m^3 ha^{-1}), which is explained by recent dieback of ash trees. In the future stumps will form snags and pieces, thus securing the continuity of dead wood (Ek *et al.*, 2002). However, the largest volume of stumps (27.8 m^3 ha^{-1}) was found in WKHs in production forests. This is mostly due to the large proportion of *Populus tremula* in stands which have reached their biological age started to die or were damaged in windbreaks. Currently in Latvia standing dead wood volume is on average 9.1 m^3 ha^{-1} (Meža nozares attīstības novērtējums, 1990 – 2013.). In all study plots the largest portion of dead wood volume was made up by downed logs and pieces – on average 69% or 81.9 m^3 ha^{-1} (in average 14.4 m^3 ha^{-1}) (Meža nozares attīstības novērtējums, 1990 – 2013.). The volume of dead wood pieces in broad-leaved WKHs in production forests was 41.9 m^3 ha^{-1}, but in protected areas – 101.9 m^3 ha^{-1}. Dead wood pieces on forest floor decompose relatively faster, and they in the short term are inhabited by larger number of organisms – insects, mosses, lichens, fungi (Bobiec *et al.*, 2005). In broad-leaved WKHs in production forests the majority of dead wood volume is 18-26 cm in diameter which characterizes semi-natural forests (Bobiec *et al.*, 2005), but in protected forest it differs: in the nature reserve 'Ukru gārša' it is 20 – 32 cm but in nature park 'Tērvete' - 64 cm. In dry forest stands, dead wood is relevant for biodiversity with a diameter of at least 25 cm (Auniņš, 2013). Also, a study on moss species diversity managed forests shows that a larger diameter of dead wood correlates with a higher number of dead wood requiring species (Madžule, Brūmelis, & Tjarve, 2012). In broad-leaved WKHs in production forests strongly decayed dead wood (V stage of decay) was not found – this shows that the wood decay in these forests has started more recently (most common was dead wood at III stage of decay). In formally protected areas, dead wood was found at all five stages of decomposition that secures the continuity of dead wood and habitat for multiple organism groups (Blaser *et al.*, 2013). Dead wood volume is being used as an indicator of biodiversity qualities; however, diversity of dead wood and occurrence at different stages of decay is also important (Lassauce *et al.*, 2011). Furthermore, such forests are indicators of

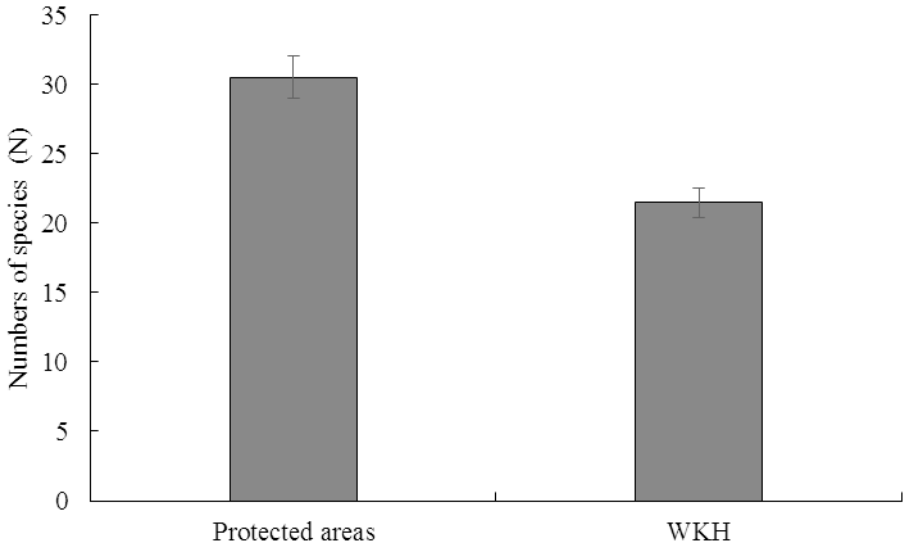

Figure 3. Numbers of species in protected areas and woodland key habitats (WKH). Values are means ± SE.

continuity (Bobiec *et al.*, 2005; Stokland *et al.*, 2012). Compared between WKHs in production forests and protected areas, a higher diversity of structural elements, environmental conditions and ecological niches is found in forests untouched by human activities (Brūmelis & Jankovska, 2013).

Vegetation survey. In broad-leaved WKHs in production forests in total 50 vascular plant and moss species were found (seven tree, nine shrub, 24 vascular and nine moss species) – on average 30 species per study site. Broad-leaved WKHs in the nature park 'Tērvete' contained 42 species (seven tree, six shrub, 24 vascular and five moss species), bet the nature reserve 'Ukru gārša' – 56 plant species (seven tree, seven shrub, 33 vascular and nine moss species) – on average 33 species (Figure 3). Numbers of species by vegetation layers and projective coverage in WKHs in production and formally protected areas was not significantly different.

In all study plots, nemoral biome species (50 – 58% of the total number of species) were most common. In broad-leaved WKHs in production forests, four European broad-leaved forest habitat specialist species were found, but in WKHs in protected areas – six habitat specialist species; thus, we conclude that studied forests correspond to European broad-leaved forests. Hemiboreal zone in Latvia is characterized by mosaic-type patterns determined mostly by soil richness (Laiviņš, 2014). In the study plots, *Fraxinus excelsior* L. (at tree, shrub and herbaceous layers), *Padus avium* Mill., *Corylus avellana* L., *Sorbus aucuparia* L. (shrub layer), *Rubus caesius* L., *Hepatica nobilis* Mill., *Oxalis acetosella* L. and *Paris quadrifolia* L. (herbaceous layer) were most common species. In broad-leaved WKHs in production forests the largest projective coverage was made up by a shrub layer (45%) (*Padus avium*, *Lonicera xylosetum* L.), but in protected areas – a herbaceous layer with *Aegopodiosa* forest type vascular species – *Aegopodium podagraria* L., *Anemone nemorosa* L., *Hepatica nobilis* (45% and 40% respectively). Species number and projective coverage in moss layer is small in all study plots characteristic to this forest type. Here, the most commonspecies was *Plagiomnium affine* T.J. Kop. – characteristic to broad-leaved forests on rich mineral soils (Liepa *et al.*, 2014). In all study sites, regeneration with *Fraxinus excelsior* was found, but in production forests it is hindered by a dense shrub layer. Plant communities of nemoral broad-leaved forests occur on rich soils, but if modifications of coniferous or broad-leaved plant communities are found, it demonstrates soil moisture and richness variability, anthropogenic actions or other environmental factors (Laiviņš, 2014). In all broad-leaved WKHs, perennial vascular plants or hemicryptophytes dominate (39%), ornitochorous are most common ones (39%), to a lesser degree – (20%) myrmecochores – mostly vernal plants which disperse with the help of ants as well as anemochorus plants (16%), (Bumbura *et al.*, 1967). Ecological variables for herbaceous layer in broad-leaved WKHs do not differ significantly ($p > 0.05$). In production, the forests' herbaceous layer is characterized by half-shade conditions moderately warm and moist neutral soils, rich in nitrogen; however, in protected areas half-shade to half-light conditions, moderately moist to moist neutral soils, rich in nitrogen are common.

Broad-leaved WKHs in production and formally protected forests differ, but production forests WKHs also contain the necessary diversity of structural elements and vegetation features.

Conclusions

1. In general, in broad-leaved WKHs in production forests and formally protected areas the volume of living trees is not significantly different ($p > 0.05$), dominated by respectively *Populus tremula* L. and *Fraxinus excelsior* L. The difference is significant in the nature reserve 'Ukru gārša' where rapid *Fraxinus excelsior* dieback was found.
2. Broad-leaved WKHs are characterized by all types of dead wood – standing dead wood and downed log pieces. Their volume differs significantly: in total, in WKHs in production forests, it is almost three times larger, but in protected areas – almost six times larger compared to the results of Second cycle of Latvian National Forest Inventory – 23.5 m^3 ha^{-1}.
3. In broad-leaved WKHs, the average volume of stumps is significantly different that is explained by a rapid dieback of *Fraxinus excelsior* in protected areas forests.
4. In all broad-leaved WKHs pieces are the dominant type of dead wood (on average 69% or 81.9 m^3 ha^{-1}).
5. Broad-leaved WKHs in production forests are dominated by dead wood with a diameter 18-26 cm in four decay classes, but in protected areas forests – 32 cm and 64 cm diameter in five decay classes which is a sign of forest continuity.
6. In broad-leaved WKHs in production forests, vegetation is formed by on average 24 species, but in formally protected areas by 33 species on average. Species richness by vegetation layers and projective coverage does not differ significantly. Since the species of nemoral biome dominates (50 – 58%), study plots correspond to European broad-leaved forests.
7. All broad-leaved WKHs were dominated by perennial vascular plants or hemicryptophytes (39%) and ornitochorous plants were common (39%).
8. Ecological variables for herbaceous layer in broad-leaved WKHs were not significantly different. In production forests, herbaceous layer is characterized by half-shade conditions moderately warm and moist neutral soils, rich in nitrogen; however, in protected areas half-shade to half-light conditions, moderately moist to moist neutral soils, rich in nitrogen are common.

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