Biological diversity: effects on ecosystem functioning and implications for restoration ecology

PhD. Thesis
University of South Bohemia
Faculty of Biological Sciences
Department of Botany

Vojtěch Lanta
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Summary

Supervisor: Prof. RNDr. Jan Lepš, CSc.

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In the first part of this thesis I present results from the biodiversity experiments conducted using plant assemblages combining various levels of species and functional group richness, investigated under various field and greenhouse conditions. In this way the experiments are able at least partly to resolve basic uncertainties in the biodiversity-ecosystem functioning approach. Experimental designs allow me to test between conflicting hypotheses and to attribute effects of biodiversity on ecosystem processes to particular components of plant biodiversity such as species and functional group richness.

According to some hypotheses, large proportion of native species richness is required to maximize ecosystem stability and to sustain function. The assessment of diversity-productivity relationships is important for conservation strategies because sustainability of ecosystem functions has been used as an argument for a precautionary approach in conservation of species and for decision-making processes. The restoration of ecological communities previously intensively managed is a major tool to counteract biodiversity losses. In this way, we need to recognize if loss of biodiversity can have negative impacts on ecosystem functioning, which is combined with uncertainty over the current and future roles of most species in many ecosystem processes. These facts led me to present here results of manipulated experiments carried out in man-disturbed habitats of mined peatlands because there is a lack of knowledge about the effects of changing biodiversity on these ecosystems (the second part of the thesis).

Outline of the thesis

Effect of functional group richness and species richness in manipulated productivity-diversity studies: a glasshouse pot experiment (Lanta V. and Lepš J.; Acta Oecologica 2006, 29: 85-96)

Species and functional group (grasses, legumes, creeping nonlegume forbs, rosette nonlegume forbs) richness of species assemblages composed of 16 species from four functional plant groups were manipulated to evaluate the productivity-diversity relationships in a greenhouse pot experiment. Pots were filled with sand, and supplied at two levels of nutrients. The plants were grown in monocultures, 2, 4, 8 and 16 species mixtures. Individual 2, 4, and 8 species mixtures differed in the richness of functional groups. Although the two characteristics of biodiversity, i.e. species and functional group richness, were necessarily correlated, it was shown that it is possible to separate their effect statistically, and also test for their common effect without pronounced loss of test power. There was a pronounced increase of average aboveground biomass and a mild increase in belowground biomass with biodiversity. The effect of functional group richness was more pronounced than the effect of the number of species. By using the method of Loreau and Hector (2001), selection and complementarity effects were statistically separated, and the overyielding index was calculated as a ratio of the productivity of a mixture to the productivity of its most productive component (to demonstrate transgressive overyielding). Positive values of complementarity and transgressive overyielding were both found, particularly in some rich communities and under high nutrient levels. Complementarity significantly increased only with functional group richness and mainly under high nutrients in the belowground biomass. Some species, when grown in monocultures, had decreased productivity under higher nutrients, and thus were more productive in mixtures than in

monocultures. It seems that those species suffered from too high nutrient levels when grown in monocultures, but not in the presence of other species, which were able to use the nutrients in high concentrations and effectively decrease the nutrient levels. As a consequence, mixtures of high diversity were always more productive under high nutrients. The difference in species proportions between high and low nutrients, characterized by chord distance, increased with species richness. The relative change in productivity decreased with the number of functional groups. This suggests that species richness might lead to stabilization of aggregate characteristics (like total productivity) under changing environmental conditions by changing the proportions of individual species.

Effects of species and functional group richness on production in two fertility environments: an experiment with communities of perennial plants (Lanta V. and Lepš J.; submitted)

The effects of species and functional group richness of sown species and fertilization on productivity was studied in a three year field experiment. Both species and functional group numbers positively affect the average yield of sown species, but the effect changed among the three years. The biomass of weeds (i.e. unsown species) generally decreased with the biomass of sown species, and so was negatively affected by the diversity characteristics of sown species. All three characteristics of biodiversity (selection, complementarity and overyielding effects) varied greatly during the study period, depending on both species and functional group richness and nutrient amendment. Functional differences among species led to the detection of high values of complementarity (resource use complementarity and/or facilitation), however this effect was not sufficient to cause transgressive overyielding. This result suggests that greater production with higher diversity may be restricted to particular species combinations or environmental conditions. The compositional difference between fertilized and nonfertilized control plots increased with both time and species richness, whereas the relative difference in productivity decreased. This shows that the changes in species composition toward the one best suited to the given environment can lead to optimal resource use and, in consequence, diminish variation in community functioning in a changing environment.

Effect of plant species richness on weed invasion in experimental plant communities (Lanta V. and Lepš J.; mns)

Invasion of weeds (defined as all unsown species) to artificially created assemblages of grassland species was investigated in a three years field experiment. In the experiment, species richness (1, 2, 4, 8 and 16 species) and functional group richness (grasses, legumes, rosette forbs, creeping forbs) were combined in factorial design with fertilization. No hand-weeding was done. Relationships between species diversity and aboveground biomass were positive for sown species in all studied years 2003, 2004 and 2005. In the two latter years, biomass of weed invaders decreased significantly with the biomass of sown species, with their functional group richness, but not with their species diversity. The negative relationship between the number of functional groups of residents and weed biomass suggested that species assembled into groups according to similar traits could have large effect on species invasibility. Additionally, species composition of weeds significantly related to initial composition of sown residents. It showed that the resultant composition of weeds depends on the presence and proportion of individual sown species.

Effect of slug grazing on biomass production of a plant community during a short-term biodiversity experiment (Lanta V.; submitted)

While recent theoretical work has demonstrated several mechanisms whereby more diverse communities can exhibit greater resistance against herbivore pressure, empirical examinations have been few and the subject of much debate. The aim of this aquarium experiment was to determine how the selectivity of herbivores affected relationships between species number and productivity within artificially created grassland communities. The influence of the slug, *Arion lusitanicus*, was assessed at three levels of plant species diversity (1, 2, 4 and 6 species per aquarium). The proportion of biomass of particular species eaten by a slug was estimated on the basis of comparison of paired plots. The biomass in control (ungrazed) plots was compared with the biomass in grazed plots. A significant interaction between the number of species and slug grazing for aboveground biomass was found, indicating a gradual decrease in effect of grazing pressure with increased species richness. Positive average values of the complementarity effect and overyielding index, and negative values of the selection effect indicated niche resource partitioning between species in both grazed and control plots. The electivity index of food selectivity suggested that food selectivity was more pronounced under higher plant species diversity.

Vegetation patterns in a cut-away peatland in relation to abiotic and biotic factors: a case study from the Šumava Mts., Czech Republic (Lanta V., Doležal J. and Šamata J.; Suo - mires and peat 2004, 55: 33-43)

We studied the natural regeneration of a cut-over peat bog in the Šumava Mountains, Czech Republic. The spontaneous revegetation by vascular plants has been limited by extreme abiotic conditions left after peat mining. Only 1-2 % of the total area was recolonized by *Sphagnum* mosses. This was mainly because drainage channels are still drying out the bog. Only plants tolerant to water stress such as *Juncus effusus, Molinia caerulea, Eriophorum angustifolium* and *E. vaginatum* were able to establish there. A key species colonizing bare surface is a clonal plant *E. angustifolium*. It forms circular polycormons of densely aggregated ramets. As in other radially spreading phalanx plants, the oldest (central) part of the system gradually dies, previously connected ramets become separated, and ring polycormon becomes open to recolonization by other plant species. We analyzed the relationships between species richness of the ring and their size, percentage litter cover, distance to seed sources, and soil fertility. The number of plant species was higher in the middle of the polycormons. The soil was more fertile in the central area than in the surroundings. We conclude that the restoration of highly disturbed habitats can be facilitated by clonal behavior of pioneer populations.

Growth response of downy birch (Betula pubescens) to moisture treatment at an cut-over peat bog in the Šumava Mts., Czech Republic (Lanta V. and Hazuková I.; Annales Botanici Fennici 2005, 47: 247-256)

The factors affecting the adaptation of downy birch (*Betula pubescens*) to the different environmental conditions were studied in 2002-2003 by measurement of production characteristics of saplings, experimentally planted in contrasting habitats at the cut-away peatland in the Šumava Mts, Czech Republic. These habitats varied in groundwater table depth. Together with this factor, we tested for the effect of shading by shade cloth on sapling growth. We conducted greenhouse manipulative experiment to investigate the growth response of the downy birch saplings to varying groundwater table depth and soil type. We searched whether

spatial distribution of naturally established birch stems changes along pronounced moisture gradient represented by transects placed at three distances from draining ditches. In the field, birch plants exhibited higher growth increments as well as higher leaf production under high water table depth. This result is fully opposite to manipulated greenhouse experiment that showed higher biomass increments for saplings under low water table. This was probably because downy birch, in principle, indicate terestrification of peat bogs and high water table depth in greenhouse inhibited its growth. In field, birch saplings were stressed by drought and overheating. Positive shading effect on sapling growth was proven by leaves production measurement. The two term local variance method (TTLQV) revealed two contrasting dispersion patterns, for the birch population at drier and wetter sites of the post-mined peatbog. The aggregation was obvious mainly at the drier site with lower abundance of birch plants within each sampled square. Higher abundance of individuals were found in squares of the wetter site, whereas the pattern was random there.

The effect of dam construction on the restoration succession of spruce mires in the Giant Mountains (Czech Republic) (Lanta V., Mach J. and Holcová V.; Annales Botanici Fennici, accepted)

Spruce mires are rare and endangered plant communities of Central and Western Europe. In the Czech Republic, they were intensively destroyed and drained during 1970`s. To start the regeneration of spruce mires, palisade dams sealed with peat were used to block draining ditches in the Giant Mountains. Four years after dams construction, there were significant differences in vegetation above and below the dams. Vegetation above dams successfully developed towards plant communities characteristic to spruce mire forests. Below dams, the colonization by forest floor species continued. These differences indicate that palisade dams effectively retain water and help the regeneration of spruce mire forests. Our results support construction of palisade dams in such habitats.