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Birds as control agents of caterpillars in oak forests

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Insectivorous birds provide a major ecosystem service by consuming herbivore insects, many of which are pests. In temperate deciduous forests caterpillars are the main defoliators. Their leaf consumption may decrease the growth of damaged trees, negatively influencing their health and fecundity, thereby inhibiting regeneration. The natural control provided by birds may result in a significant reduction of caterpillar numbers, leading to the mitigation of plant damage. Theory predicts that more abundant avian assemblages can be more effective in caterpillar control. However, we still lack detail about the mechanism of this ecosystem service and about how habitat naturalness and forest structural heterogeneity influence pest control in temperate forests. Thus, our main aims were: (1) to study avian predation intensity on caterpillars; (2) to investigate the relationship between density of bird assemblages and predation rate; (3) to examine the relationship between predation rate and caterpillar abundance; and (4) to reveal the role of forest structure variables on predation rate. The study was carried out in temperate oak forests (*Quercetum petraeae cerris*) in the southern slopes of the Mátra Mountains in North Hungary. The study area is between 400 and 500 m above sea level with a topography consisting of slopes and narrow valleys. Within the study area, we selected 20 tree pairs with different vegetation structure around them – one in structurally heterogeneous forest, the other member in a pair in homogeneous forest. Within the tree pairs, stand age, average height of the stand and environmental parameters were the same. The minimum distance between the two members of the pair was 100 m, while the minimum distance between two different pairs was 500 m. We quantified predation rate using artificial caterpillars made of green plasticine resembling real caterpillars of Winter Moth *Operophtera brumata*. Fifteen artificial caterpillars were attached to the end of branches of each selected tree (in total 600 artificial caterpillars) with 0.5 m distance among them between 1.5 and 2.5 m height. The size of artificial caterpillars was equal to fifth-instar Winter Moth larvae (length 25 mm, width 3.5 mm). The optimal prey exposure length (6 days) was calibrated based on preliminary experiments. The predation level was expressed as the number of attacked caterpillars per tree during the 6-day period. The abundance of insectivorous birds was investigated using 10-min point counts around each sample tree within a 100-m radius, and caterpillar abundance was measured by gathering of leaf samples on randomly selected trees around each sample tree. Caterpillar abundance was standardized to leaf number. On the same leaf samples, leaf damage was estimated as the percentage of leaves chewed by caterpillars. The forest structure variables examined were tree species richness, size distribution of trunk diameter, density of shrub and understorey layers, canopy closure, and availability of dead wood and cavities. The assessment of structure variables was carried out in 15-m circular plots around each focal tree. To investigate the differences of biological variables between the two type of forest (homogenous, heterogeneous), we used a paired *t*-test. The relationship between biological variables and explanatory factors was analysed with generalized linear modelling (GLMM), where the tree pair variable was

used as random factor. The predation rate of artificial caterpillars was 27%, of which 80.9% was bird predation. We recorded 26 insectivorous bird species and caterpillars of 23 lepidopteran species. The most abundant bird species were Chaffinch *Fringilla coelebs*, Blackcap *Sylvia atricapilla,* Great Tit Parus major and Blue Tit *Cyanistes caeruleus. The most abundant* caterpillars belonged to the families Tortricidae and Geometridae. We found that heterogeneous forests maintain significantly higher abundance of birds ($P = 0.02$) than homogenous forests, and suffer from significantly lower leaf damage ($P = 0.02$). Predation rate was positively related to bird abundance ($P = 0.02$) as well as to caterpillar abundance ($P = 0.02$) (Fig. 1). Bird abundance showed a positive relationship to the variability of size distribution of trunk diameter ($P < 0.0001$) and marginally with tree species richness ($P = 0.088$), while caterpillar abundance did not show a significant relationship to forest structure (Fig. 1). Our results demonstrate the efficiency of the natural control provided by birds, namely areas with higher caterpillar abundance maintain a higher predation rate than areas with lower caterpillar abundance. Furthermore, we found that forest management can contribute significantly to the increasing efficiency of natural control of caterpillar pests by maintaining tree species richness, and thereby promoting a high density of insectivorous bird assemblages.

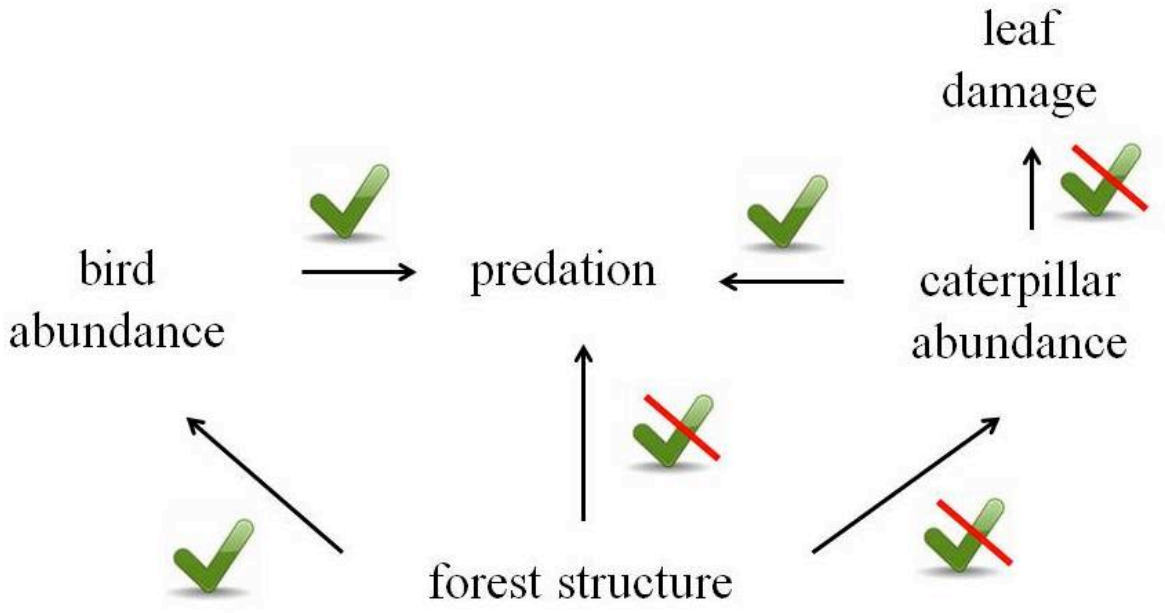

Figure 1. The relationships between the studied biological variables. The arrows show the examined relationships between the variables. The pipes above the arrows indicate the significant positive relationships, while the crossed out pipes show relationships that are not significant.