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Indirect effects of herbicides on bird food resources and beneficial arthropods

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Abstract

This study examined effects of agricultural herbicides on food webs to quantify how herbicide induced changes in the plant community affect arthropod abundance. The study focused on insects eaten by ring-necked pheasant and gray partridge chicks and on beneficial arthropods that prey on insect pests and weed seeds. The experiment, conducted in 1998 and 1999 at Montana State University's Arthur H. Post Experimental Farm, contained three arable plant communities blocked against a nearby fencerow. Plants were sampled by volume measurements in 0.5 m^2 rings. Ground dwelling arthropods were collected with pitfall traps, and vegetation dwelling insects were collected with a sweep net. Beneficial arthropods and vegetation dwelling, chick-food insects were more common in the weedy community than in the more monocultural communities. This study demonstrates that herbicides do affect arthropods that serve as avian food resources and as beneficial predators in a North American agroecosystem, and that these effects are most likely mediated by changes in the plant community. Management implications for beneficial arthropods, chick-food insects and game birds are discussed.

Keywords: Birds; Carabidae; *Perdix perdix*; Herbicides; *Phasianus colchicus*; Weeds

1. Introduction

In Great Britain, herbicides have been shown to change the abundance of weeds and chick-food insects (Chiverton and Sotherton, 1991; Moreby, 1997) resulting in partridge (Southwood and Cross, 1969; Green, 1984; Rands, 1985; Potts, 1986; Sotherton and Robertson, 1990) and pheasant (Hill, 1985) chick mortality and population declines (Potts and Vickerman, 1974; Potts, 1986; Sotherton et al., 1989; Potts and Aebischer, 1995). In contrast to the strength of evidence in Britain, results in continental Europe have varied (Panek, 1992, 1997; Chiverton, 1999), and the little information available on indirect trophic effects of herbicides on birds in North America is circumstantial (Warner, 1984; Freemark and Boutin, 1995). This controlled experiment was conducted in a North American agroecosystem and was designed to determine if herbicides indirectly affect arthropods that are preyed upon by game birds or those that are beneficial to farmers.

2. Methods

The experiment was conducted in 1998 and 1999 at Montana State University's Arthur H. Post Experimental Farm (T. 2 R. 5 S. 7; 45°68′30″N, 111°15′W) in Gallatin County, Montana. Three cultivated treatments, one monocultural, one weedy and one intermediate, were assigned to plots on Amsterdam silt loam that were unsprayed, tilled and fallow in 1997 and unsprayed in 1996. The same 12 plots (each with an area of 0.024 ha) were used in both 1998 and 1999. Treatments were randomly assigned to each block in 1998 and were not randomized afresh in the second year. The seed mix was the same for the intermediate and weedy

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plots while the herbicide regime was the same for the intermediate and monocultural plots. Specifically, the intermediate and weedy plots were planted with spring wheat (*Triticum aestivum*), wild oat (*Avena fatua*), common pigweed (*Amaranthus retroflexus*), and fat hen (*Chenopodium album*). The monocultural plots were planted solely with spring wheat. The herbicide mixture used on both the monocultural and intermediate plots contained imazamethabenz (524 g ai/ha) for monocotyledonous weed control and bromoxynil (419 g ai/ha) for dicotyledonous weed control. The weedy plots remained unsprayed. Both the weed species and the herbicide regime were selected because they are common in the dry land cereal fields of Montana.

Treatments were blocked against a perennial fencerow community which was expected to be an arthropod source (Fig. 1). Sampling was conducted in the fencerow in the same manner as in the cultivated plots; however, because the fencerow was unreplicated, its results are used only to clarify trends found in the cultivated plots.

Plots were cultivated a week prior to planting, and untreated spring wheat was drilled on May 6, 1998 in 18 cm rows at 67 kg/ha. Weed seeds were planted on May 8, and herbicides applied on July 2. Weeds in the sprayed plots became stunted and chlorotic, but were not all killed, due to the late herbicide application. Consequently, on July 23, weedy patches were hoed and removed from the monocultural plots to simulate an effective herbicide treatment. Alleys between plots were tilled and fallow in both years to minimize arbitrary arthropod movement among plots. In 1998, the alley between the fencerow and the first block was 2.4 m and all other alleys were 4.9 m.

Enhancements to the study design in 1999 included increasing the width of the alley between the fencerow and the first block to be consistent with all other alleys, and conducting activities earlier to better coincide with avian breeding cycles. The plots were again cultivated a week before planting, weeds were planted on April 27, and untreated spring wheat was drilled on May 5 in 30 cm rows at 34 kg/ha. The wider row spacing encouraged more weed growth among the wheat, and the lower seeding rate simulated edges of farm fields where game birds usually forage. Herbicide application on June 14 achieved a high rate of weed kill more typical than the previous year's weed response.

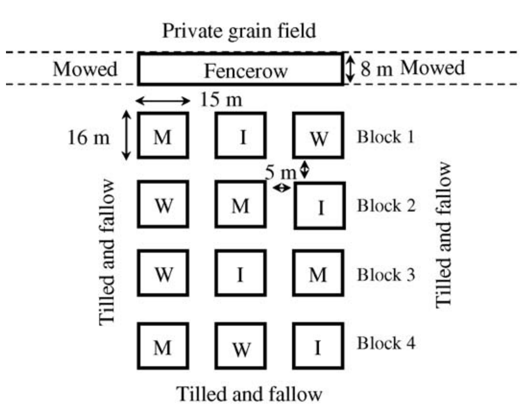

Fig. 1. Randomized block design. Treatments are monoculture (M), intermediate (I) and weedy (W).

Plants were sampled in each cultivated plot from five randomly placed 0.5 m^2 rings which remained fixed throughout the growing season. In order to assess the quantity of plants without destroying the habitat, the cylindrical above ground volume of each species was obtained by estimating its percent canopy cover and measuring the height of a typical individual. In 1998, rings were sampled before herbicide application on June 25–26, and again after spraying on July 19, 21 and 22. In 1999, rings were sampled before spraying on June 4–10, and after spraying on July 3–6.

Specific plant volumes were assigned to the following composite variables: wheat volume, dicotyledonous weed volume, monocotyledonous weed volume, total plant volume, species richness and species diversity. Species richness was defined as the total number of species encountered in a ring. Species diversity was indexed with Simpson's D, the probability that two random selections from a ring will be from different species. $D = 1 - \Sigma(p_i)^2$, where p_i is the proportion of volume belonging to the ith species in a ring (Krebs, 1985).

Relative abundances of ground dwelling arthropods and vegetation dwelling insects were sampled by pitfall trapping and by sweep netting, respectively. Five pitfall traps were systematically arranged in each plot. Traps had an opening of 35 cm circumference, contained a saturated salt solution and were protected by a rain guard. In 1998, traps were open before spraying from June 2 to June 18, and after spraying from July 16 to July 30. In 1999, traps were open before spraying from May 27 to June 11, and after spraying from June 29 to July 22. The delay in post-spray sampling was to avoid any possible direct, toxic effects on the arthropods and to allow the plant community to stabilize at its new composition. To adjust for the different lengths of the trapping periods, pitfall trap results were standardized to a per trap per day basis.

Vegetation dwelling insects were sampled with a 38 cm diameter muslin sweep net. The same person conducted all sweeping between 08:05 and 10:10 h. For every step taken, the net was swept in a 180° arc as low as possible to the ground, and this was considered one sweep. Forty-eight sweeps were collected per plot. Sweep netting was conducted in 1999 on June 12, July 8, and July 20, which included one pre-spray sampling period and two post-spray sampling periods.

Arthropods were sorted by taxon and size and counted in both years. In 1999, taxon–size groups were dried to a constant weight for 48 h at 60° C and weighed to 0.0001 g. Taxon–size groups were compiled into two functional groups: chick-food insects and beneficial arthropods.

Of the taxa found in samples from this study, chick foods included Homoptera, Hemiptera, Formicids, Orthoptera,