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Agri-environment schemes do not effectively protect biodiversity in Dutch agricultural landscapes

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Roughly 20% of the European Union's farmland is under some form of agri-environment scheme to counteract the negative impacts of modern agriculture on the environment[1]. The associated costs represent about 4% (1.7 billion euros) of the European Union's total expenditure on the Common Agricultural Policy and are expected to rise to 10% in the near future[2]. Although agri-environment schemes have been implemented in various countries for well over a decade, to date no reliable, sufficiently replicated studies have been performed to test whether such measures have the presumed positive effects on biodiversity[1,3,4]. Here we present the results of a study evaluating the contribution of agri-environment schemes to the protection of biodiversity in intensively used Dutch agricultural landscapes. We surveyed plants, birds, hover flies and bees on 78 paired fields that either had agri-environment schemes in the form of management agreements or were managed conventionally. Management agreements were not effective in protecting the species richness of the investigated species groups: no positive effects on plant and bird species diversity were found. The four most common wader species were observed even less frequently on fields with management agreements. By contrast, hover flies and bees showed modest increases in species richness on fields with management agreements. Our results indicate that there is a pressing need for a scientifically sound evaluation of agri-environment schemes.

Agri-environment schemes cover a wide range of measures, which differ depending on aim, country or even region, but have in common the basis that farmers are paid to adapt the management on (parts of) their farms to the benefit of biodiversity, environment or landscape. Farmers participate on a voluntary basis, but once they enter a 'management agreement' they are obliged to adhere to a specified set of management prescriptions. We have investigated how effectively the most common form of agri-environment scheme—the management agreement[5]—conserves biodiversity on farms in The Netherlands.

The Netherlands has been implementing this type of agri-environment scheme since 1981, which is considerably longer than comparable European-Union-based measures (EEC regulation 2078/92) that have been introduced after 1992. Dutch agricultural landscapes are particularly important with respect to meadow birds in general, and the wader species black-tailed godwit (*Limosa limosa*) and oystercatcher (*Haematopus ostralegus*) in particular. Roughly 50% and 30–40%, respectively, of the European populations of these two species breed in The Netherlands[6]. As a consequence, most management agreements are aimed to support wader populations. Such agreements oblige farmers to postpone agricultural activities on individual fields until a set date, in June or July, allowing the birds to safely hatch their chicks.

A second type of management agreement is aimed at the conservation of species-rich vegetation in (edges of) grasslands and generally restricts the use of fertilizer and/or postpones the first mowing or grazing date. To evaluate their effectiveness, we used a pair-wise comparison of grassland fields that had long-running management agreements (on average 6 years) with nearby conventionally managed fields (for details see Supplementary Information).

Management agreements designed to enhance the botanical diversity of entire fields or field edges did not have any positive effect on vascular plant species richness in field edges (Fig. 1). No significant differences were found in the composition of the vegetation in edges of fields with or without management agreements. Furthermore, we did not find any correlation between age of the agreement and effect (the difference between each pair of control field and field with management agreement; data not shown). In 31,000 m^2 of field edge, we found 268, mostly very common, vascular plant species. A comparison between plant species composition of centre and edge (outer 2 m) of the fields showed that plant diversity in agriculturally used Dutch grasslands is a marginal matter indeed. On average, edges accounted for 96% of the total species richness of a field, and 66% of encountered species were never found in the field centre.

Interviews with farmers revealed that nitrogen inputs on fields with management agreements were lower than on conventionally managed fields (106 versus 246 kg N ha^{-1} yr^{-1}; t-test, $t_{34} = -2.62$, $P = 0.013$). Despite this considerable reduction in fertilizer inputs, the current level of inputs, in combination with nitrogen deposition rates of 35–55 kg N ha^{-1} yr^{-1} (ref. 7), may still be too high to promote the development of more species-rich vegetation or to enable less-competitive plant species to establish. In addition, seed

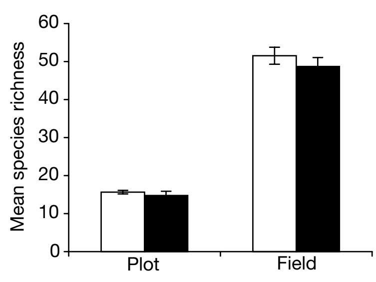

Figure 1 Effects of management agreements aimed at enhancing botanical diversity on number of plant species (mean ± s.e., $n = 22$) at plot (20 m^{-2}) and at field scale (400 m^{-2}; sum of 20 plots per field). Open columns, fields with management agreements; filled columns, conventionally managed fields.

sources in intensively used agricultural landscapes are scarce, so even if site conditions are favourable to the establishment of new plant species, dispersal limitations may prevent actual establishment[8].

There were no positive effects of management agreements on the number of territories or the diversity of all bird or wader species that were observed to nest in the area (Fig. 2a, b). The lack of any positive effect of management agreements on densities or species numbers was independent of the spatial scale that was applied (Fig. 2a, b). Notably, fields with management agreements that aimed to support wader populations by postponing first farming activities had lower counts of the target species lapwing, oystercatcher, common redshank and black-tailed godwit (Table 1). Differences in sward height did not explain the observed preference of waders, because fields with management agreements were avoided both at the start of the growing season (March) and later in the year (June). Many previous studies have shown the selectivity of foraging farmland birds with respect to the management on individual fields[9,10]. Our study, however, was executed during the breeding season and most observed waders showed territorial behaviour. Lower counts therefore indicate an aversion to use these fields as nest sites, which is highlighted by the significantly fewer oystercatcher territories on fields with management agreements.

Postponing the first mowing or grazing date forced farmers to reduce fertilizer inputs (management agreement compared with conventional: 96 versus 277 kg N ha^{-1} yr^{-1}; $t_{30} = -3.72$, $P < 0.001$), which probably adversely affected the abundance of the soil animals that waders use for food[11]. However, management agreements do have a positive effect on reproductive success[12,13]. Thus, the introduction of management agreements in Dutch agricultural landscapes might have led to an "ecological trap"[14]; that is, it might have decoupled the cues that individuals use to select their nesting habitat (for example, food availability) from the main factor that determines their reproductive success (delayed mowing/grazing). Only the starling, an extremely common bird of all lowland habitats including large cities, preferred to forage on fields with management agreements.

Species richness of hover flies was higher on fields with management agreements than on control fields; however, only the initial survey in May contributed significantly to this difference (Fig. 3a; general linearized model (GLM): $G_{\mathrm{m.a.May}} = 15.226$, 1 degree of freedom (d.f.), $P < 0.001$). In contrast to most conventionally managed fields, fields with management agreements had not been mown or grazed in May. Including sward height in the analysis of the May survey showed that the effect of management agreements could be attributed completely to the delayed mowing of these fields, as there were no significant effects of management agreements when fields with similar vegetation heights were compared (Fig 3b; $G_{\mathrm{m.a.May}} = 3.369$, 1 d.f., not significant; $G_{\mathrm{sward\ height.May}} = 18.734$, 1 d.f., $P < 0.001$).

Adult hover flies are generalist flower visitors using ubiquitous species from a wide range of families; some hover fly species even feed on grass pollen[15]. The observed positive effect of management agreements on the number of hover fly species in the May sample is therefore probably a direct consequence of the delayed mowing date and the resulting prolonged food supply on fields with management agreements.

The bee fauna in Dutch agricultural landscapes is very poor. On average we found only 1.7 species per field and 85% of all caught individuals belong to just three species: the honeybee *Apis mellifera*; and the bumblebees *Bombus pascuorum* and *Bombus terrestris*. But species richness was enhanced by management agreements (Fig. 3a; GLM: $G_{\mathrm{m.a.June}} = 14.608$, 1 d.f., $P < 0.001$; $G_{\mathrm{m.a.July}} = 4.097$, 1 d.f., $P < 0.05$). For bees, sward height was important but could not explain the observed positive effect (Fig 3b; $G_{\mathrm{m.a.June}} = 8.716$, 1 d.f., $P < 0.01$; $G_{\mathrm{sward\ height.June}} = 11.396$, 1 d.f., $P < 0.001$). Apparently, bees perceived a qualitative difference between the two field types that was not shown by the other species groups that we studied.

Our results point out that management prescriptions that have proved to be effective under experimental conditions[8] do not have the desired effects (plants) or have even unexpected adverse side-effects (birds) when implemented on farms. The motivation and expertise of the farmers may have a crucial role. The primary concern of farmers is necessarily to secure an income. As a result, nature conservation will be of secondary importance to them, and will be fitted into a farming system that, owing to economic pressure, is still increasing in intensity[16,17].

Most farmers lack the knowledge to judge in what way measures taken to improve the economic position of their farm (such as grass silaging, lowering the groundwater table) may interfere with nature

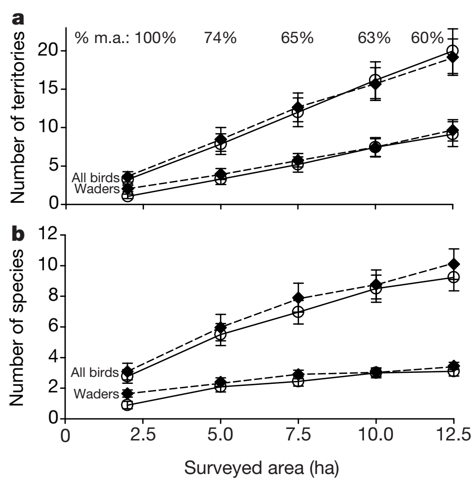

Figure 2 Effects of management agreements on breeding birds at a range of spatial scales. Mean field size 2.0 ha; $n = 20$. % m.a., mean proportion of the management agreement plots actually covered by management agreements (this proportion is 0 at all scales in the control plots). **a**, Density of breeding bird territories; **b**, species richness. Open circles, fields with management agreements; filled diamonds, conventionally managed fields.

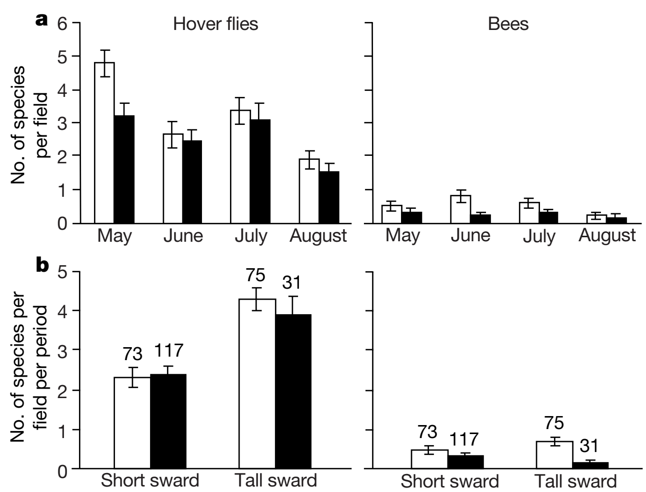

Figure 3 Effects of management agreements on species richness of hover flies and bees. **a**, Mean number of species not previously found on a field. **b**, Interaction between effects of sward height and management agreement (short sward less than ~10 cm, tall sward more than ~10 cm). Open column, fields with management agreements; filled column, conventionally managed fields. $n = 37$. Numbers above columns indicate sample size.

Table 1 Effects of management agreements on mean number of observations and territories per field

Bird species	Counts MA	Counts Control	Territories MA	Territories Control
Mallard (*Anas platyrhynchos*)	3.17	4.00	0.43	0.39
Meadow pipit (*Anthus pratensis*)	1.17	1.09	0.48	0.39
Oystercatcher (*Haematopus ostralegus*)*	1.52§	2.91	0.13†	0.52
Black-tailed godwit (*Limosa limosa*)*	2.74†	3.74	0.43	0.43
Starling (*Sturnus vulgaris*)	5.74§	1.52	0	0
Common redshank (*Tringa totanus*)*	1.44‡	2.61	0.39	0.48
Lapwing (*Vanellus vanellus*)*	1.30§	3.17	0.26	0.61

The most frequently observed bird species are shown. MA, fields with management agreement. Control, conventionally managed fields. Field size 2.0 ± 0.17 ha (mean ± s.e., n = 23).
* Wader species.
† $P < 0.05$.
‡ $P < 0.01$.
§ $P < 0.001$.

conservation measures that are taken concurrently. By contrast, schemes to promote cirl buntings (*Emberiza cirlus*) in Devon, UK, have been successful, but these were supervised intensively by scientists[18]. Agriculture in The Netherlands is extremely intensive, but can be considered representative for large areas in western Europe (particularly Belgium, France and the UK)[3]. Many researchers from these countries have come-up with suggestions to extend agri-environment schemes for the specific needs of certain species or ecosystems[10,19,20]. Our findings indicate that it is imperative to evaluate current agri-environment schemes in all participating countries, and to ensure that any new agri-environment scheme is accompanied by a scientifically sound evaluation plan. □

Methods

Sampling protocol

In 2000, we surveyed plants, birds, hover flies and bees, in nine different areas (3 clayey soil, 3 peat and 3 sandy soil areas were selected randomly from all available areas) throughout the Netherlands. In each area we selected 3–7 field pairs (total 78 fields). The two fields within a pair were located within 1 km of each other; they were similar in size, located in similarly structured parts of the landscape, and had the same soil type and groundwater table.

As diverse vegetation in Dutch grasslands (and the associated insect groups) is predominantly limited to the edges and many farmers declined us access to the centre of the field, the sampling of vascular plants, hover flies and bees focused on the field edges. On each field, plant species composition was determined in 20 quadrats of 2×10 m, bordering and parallel to the ditches separating the fields (some very small fields were sampled with fewer quadrats). A single estimate of the species composition of the field centre was made by walking around the field and noting all observed species. Hover flies and bees were sampled simultaneously by collecting all observed specimens in a 1-m wide 'belt', while walking a transect for 15 min at a constant pace along the field edge (see ref. 21). Specimens were subsequently identified in the laboratory. Samples were taken four times from May to August at monthly intervals. Fields within a pair were always sampled on the same day and by the same person.

The effect of management agreements on birds was measured at different spatial scales ranging from the chosen fields (2.0 ± 0.18 ha; mean ± s.e.) to 12.5-ha plots around the fields. Birds were surveyed during five field visits between 22 March and 20 June, when all contacts with birds were noted on a map. Subsequently, the numbers of birds holding territory on each field were assessed by methods developed by the Breeding Bird Monitoring Project[22], a method bearing resemblance to the one used by the Common Bird Census in the UK. The 12.5-ha plots surrounding control fields contained only other conventionally managed fields; however, the 12.5-ha plots surrounding fields with management agreements contained fields with management agreements as well as conventionally managed fields, because it was impossible to find 12.5-ha plots homogeneously covered by management agreements. The 12.5-ha plot maps were subdivided into progressively larger areas by means of ARCVIEW (mean field size, 5, 7.5, 10, 12.5 ha), which allowed us to analyse the effect of management agreements on bird densities at a range of sampling scales.

Statistical analysis

We distinguished between management agreements aimed at waders and those aimed at plant species richness. Thus, analysis of the effects on waders was performed on a subset of field pairs from which pairs with only 'botanical agreements' were removed. Many fields had both 'meadow bird agreements' and 'botanical agreements'; these were included in both subsets. Effects on the non-target groups, bees and hover flies, were analysed irrespective of the type of agreement. The study had an unbalanced design (unequal number of pairs nested within areas). We therefore used the residual maximum-likelihood method (REML)[23] followed by Wald-tests[24], rather than analysis of variance to test for effects of management agreements.

The data of most individual species, as well as some species groups, contained a high number of zero counts. These data were analysed by means of GLM with a logistic link function and assuming a binomial error distribution, followed by a likelihood ratio test (or G-test). The models included the factors area, pair and management agreement, where both area and pair were considered as replications. As effects of management agreements on the insect groups differed markedly per sampling period, analysis of these species groups was performed on individual sample periods. Furthermore, the factor sward height at the time of sampling was included in the model. All proportional data were arcsin transformed before analysis.

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Supplementary information is available on *Nature*'s World-Wide Web site (http://www.nature.com) or as paper copy from the London editorial office of *Nature*.

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