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Estimating the potential effects of pesticide seed treatments on the reproductive success of arable birds

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ABSTRACT

In temperate zones, seeds of spring-sown crops may be an attractive food source for breeding farmland birds. We modelled the effects of pesticide seed treatments on the reproductive success of 4 UK arable bird species (Rook, Linnet, Skylark, Yellowhammer) exposed to treated seeds of 3 spring-sown crops (beans, barley and linseed).

We ran three types of model, 1) a "broods-at-risk" model looking at the temporal overlap between nesting and seed-sowing dates, and estimating the proportion of those nests that suffered toxicity-exposure ratios < 5; 2) a "seasonal success" Markov chain model estimating the number of chicks successfully raised in the course of a breeding season.; and 3) the potential effects of pesticides on population growth rates.

Based on physiology, Rooks, should be less at risk from treated seeds than smaller species because bigger birds eat less as a proportion of their bodyweights. However, in nearly all our scenarios, Rooks were more vulnerable, followed by Skylark and Linnet, with Yellowhammer being least affected. A principal cause is that Rooks are more likely to be breeding at a time when treated seeds are being sown. Furthermore, whereas the other species may make several breeding attempts and early failures from pesticide exposure may be compensated by later successes, Rooks breed only once in a season. The results are also supported by historical evidence of Rook population declines following pesticide seed treatments.

1. Introduction

Crop seeds are often treated with pesticide prior to drilling in order to protect the growing plant during early developmental stages from pests and disease. In temperate zones, spring-sown crops are likely to coincide with bird breeding seasons. Treated seed may be attractive to farmland birds as a food source and as such these treatments are subject to an ecotoxicological risk assessment prior to approval.

European Union Regulation (EC) 1107/2009 requires manufacturers of plant protection products (pesticides) to submit evidence of their potential long term effects on the reproduction, as well as the mortality, of non-target animals. A tiered risk assessment is required. At Tier 1, the risk a pesticide poses to wild birds is considered acceptable if the Toxicity-Exposure Ratio (TER) for reproductive effects equals or exceeds 5 (EFSA, 2009). Reproductive toxicity is taken from laboratory tests as the lowest No Observable Adverse Effect Level (NOAEL mg as/kg bodyweight). The risk assessment assumes exposure of non-target animals to be the result of ingesting pesticide residues with their food. EFSA (2009) gives guidance on how to calculate likely exposure of different animal species eating different food types.

Pesticides that indicate potential for concern with Tier 1 TERs < 5 need more refined (scenario-specific) assessments to consider their potential consequences. In the case of standard acute toxicity tests (usually measured as LD_{50}) the consequence of a low TER is an increasing probability of death. For reproductive TERs the consequences are less obvious. Toxic effects will usually be sub-lethal as far as the adult ingesting the product is concerned, but they can be lethal to offspring and eggs. Toxins may affect different phases of the breeding cycle and, depending on which phase of the breeding cycle is affected, the timing and duration over which effective exposure occurs may also vary.

Standard avian reproductive toxicity tests (e.g. OECD Test Guideline 206, or US EPA OCSPP 850.2300) usually measure adult pre-laying bodyweight, number of eggs laid, eggshell thickness, %fertile eggs, % hatched eggs and survival of young to 14 days. Each of these measures may have associated NOAEL values. Bennett et al. (2005) constructed a framework for translating these toxic effects into likely consequences for breeding success (Fig. 1). For example, pesticides that reduce % eggs hatching are assumed to disrupt the Incubation phase of reproduction. When exposure (calculated using time weighted average (TWA)

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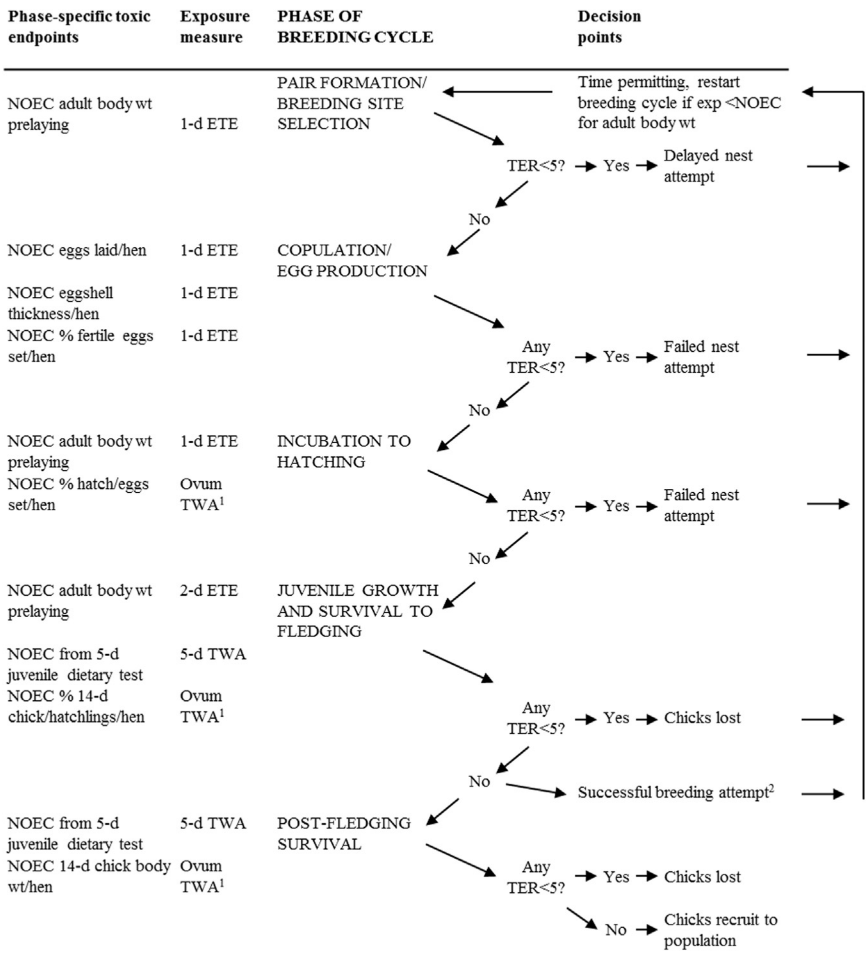

Fig. 1. Example of the relationship between endpoints of laboratory toxicity tests and consequences for breeding cycle. Five phases of avian breeding cycle are associated with phase-specific toxicity endpoints (NOECs = No-Observed-Effect Concentrations) and exposure estimates (ETE = Estimated Theoretical Exposure concentrations) used in Toxicity-Exposure Ratios (TER). ([1] TWA means time-weighted average for exposure where the time period is equivalent to length of time for an ovum to develop; [2] Although some species typically have only one successful breeding attempt per year, others attempt multiple broods.) This Figure is taken from Bennett et al. (2005).

exposure equivalent to time taken for ovum development e.g. TWA of 3 days) exceeds the NOAEL then, according to the framework, the particular breeding attempt will be aborted and the female will wait 7 days before starting again. Roelofs et al. (2005) developed a probabilistic model to explore the consequences of pesticide exposure for seasonal breeding success of individual Skylarks on arable land. An alternative model based on a spatially explicit arable landscape gave similar results (Topping et al., 2005). Bennett and Etterson (2007, 2013) have gone on to develop a general model using Markov chain transition matrices. Crocker (2009) used similar simple matrix models to investigate breeding success of Skylarks exposed to a variety of spraying regimes typical of insecticides, fungicides and herbicides.

In this paper we model the potential effects of pesticide seed treatments on the reproductive success of birds of arable land. Using EFSA (2009) guidance for calculating likely exposure of birds to seed treatments, it is not uncommon for products to fall below the trigger TER of 5. However, the EFSA guidance assumes, at Tier 1, that breeding birds will always encounter freshly sown treated seeds. In reality, most birds in the UK tend to breed between April and June, whereas most spring crops are sown in March and April (Supplemental Data 1) (see also Lawrence, 2012). There will be an overlap, but many small arable species make several breeding attempts and it is possible that early failures may be made good later. We investigate the effect of the timing of seed sowing of 3 spring crops on the breeding success of 4 arable bird species.

We assume that exposure to pesticides in excess of the reproductive effects threshold outside of the breeding season has no impact on reproductive success - this is consistent with the assumptions of the guidance of EFSA (2009; in the absence of antiandrogenic or antiestrogenic activity, it is assumed that exposure outside of the reproductive phase is unlikely to cause reproductive effects). We also focus only on exposure to pesticide treated seed, and do not consider exposure to residues in germinating seedlings.

2. Materials and methods

2.1. Seeds

Data on sowing times of spring crops were obtained from Fera (Food and Environment Research Agency, UK) pesticide usage group and from ADAS Sustainable Food and Farming group. For each crop we divided the calendar into 2-weekly periods to estimate the proportion of the crop sown in each period. In the simulation models we randomly sampled sowing dates in proportion to these distributions. We focused on 3 representative crops to achieve the broadest range of sowing dates. Beans are sown earliest in February and March, while Linseed is sown latest in April and May. Barley is one of the largest, in terms of area, Spring-sown arable crops in the UK and its peak sowing month is April (Supplemental Data 1).

2.2. Birds

When food intake is estimated as a proportion of bodyweight, then small birds eat relatively more than large birds and are likely to be at greater risk from toxins ingested with food. We chose 3 small bird species known to feed in arable land, Linnet (*Carduelis cannabina*), Skylark (*Alauda arvensis*) and Yellowhammer (*Emberiza citrinella*). We also included one larger bird, the Rook (*Corvus frugilegus*) because it has a close association with arable land and is well known to take newly sown seeds (e.g. Prosser et al., 2009; Kennedy and Connery 2008;