ECOFRAM Terrestrial Exposure Team Members

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Abstract

The Ecological Committee on FIFRA Risk Assessment Methods(ECOFRAM) was formed in June 1997. The committee's purpose is to developing tools and processes within the FIFRA framework for predicting the magnitude and probabilities of adverse effects to nontarget aquatic and terrestrial species resulting from the introduction of pesticides into their environment. The Committee is divided into two workgroups, Aquatic and Terrestrial, which are both subdivided into two subgroups, Effects and Exposure. Working closely with the Terrestrial Effects Subgroup, the Terrestrial Exposure Subgroup's task is to identify and/or develop probabilistic methods for terrestrial exposure assessments and develop recommendations for future use by EPA. Initial discussions of the Terrestrial Exposure Subgroup focused on defining the questions the Workgroup could address given time and resource constraints. It also examined various tools and methods available to address magnitude and probability of exposure of terrestrial species. While the Workgroup recognized the significance of indirect effects, given the state of the art and time and resource constraints, the Terrestrial Workgroup initial effort will focus on direct effects. The Terrestrial Exposure Group's initial objective is to develop a set of tools to predict the distribution (probability and magnitude) of pesticide doses to relevant terrestrial species within agroecosystems, provide guidance on the tools' general principals and use, and provide recommendations for additional work to develop further and validate probabilistic tools for estimating the dose to nontarget terrestrial species. This poster outlines the overall approach the Terrestrial Exposure Subgroup has developed and the initial progress the Subgroup has made in identifying major variables that influence exposure levels of terrestrial species. In addition, the initial efforts to define or estimate the distributions for these variables are presented.

Objectives

- To develop a set of tools which will be used to predict the probability and magnitude of pesticide doses to relevant terrestrial species within agroecosystems.
- To provide guidance on the general principles and use of the tools.
- To provide a set of recommendations for additional work to further develop and validate probabilistic tools for terrestrial exposure.

Steps to Produce Terrestrial Exposure End Products

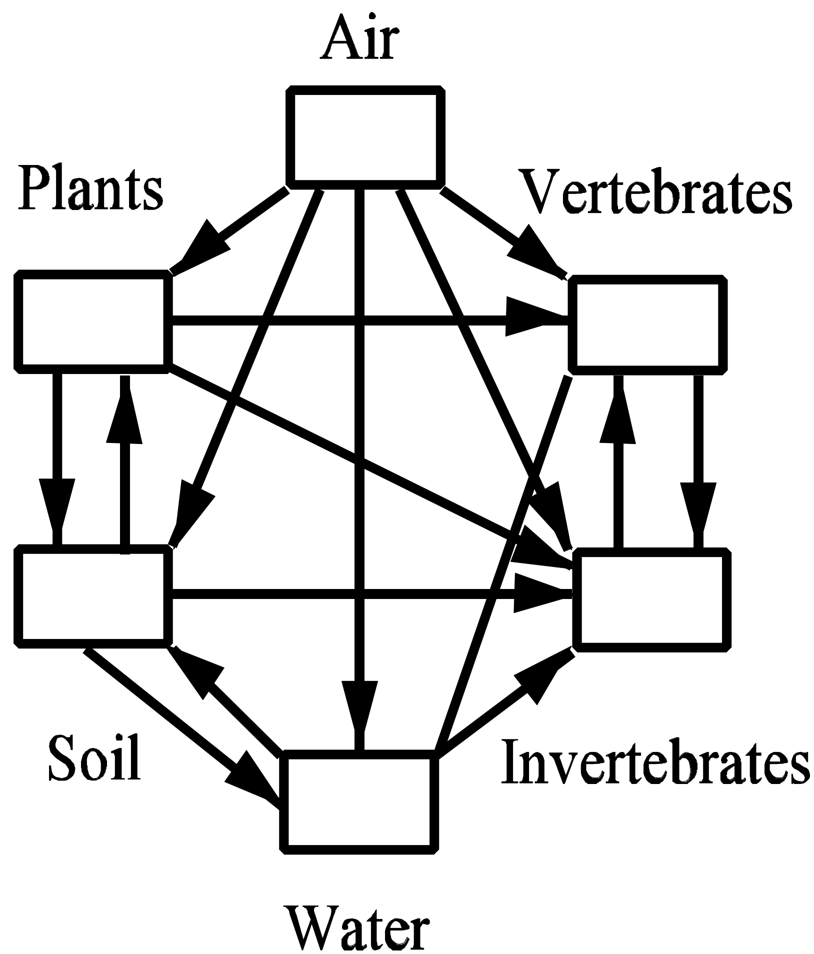
- Define Terrestrial Exposure Assessment Endpoints.
- Develop conceptual model for exposure.
- Identify major variables that influence exposure of nontarget species.
- Define distribution for these variables or determine how they can be estimated.
- Define what type of an assessment the available data will support and what can be developed in time frame of ECOFRAM.
- Develop the structure of the exposure model.
- Test the model using three or four case study scenarios.
- Identify data needed to support model(s).
- Define additional developmental work , verification and validation required.
- Develop, in conjunction with Effects Subgroup, a risk assessment process incorporating the models.

Terrestrial Exposure Conceptual Model

Compartments & Components

The terrestrial exposure modeling group identified 6 distinct compartments which need to be considered to estimate distribution of doses to terrestrial wildlife species.

A few of the more important connections (pesticide transfers) among these compartments are indicated by arrows.



Terrestrial Exposure Conceptual Model

Compartments and Connections

From the Conceptual Model, we devised an interaction matrix that identified transfers of pesticides among pools that were likely to be important in influencing the dose to terrestrial wildlife species.

INTERACTION MATRIX

COLUMNS =DONOR COMPARTMENT

ROWS = RECIPIENT COMPARTMENT

	X_1	X_2	X_3	X_4	X_5	X_6	X_7
X_1							
X_2	**ab**		**ab**	**a**	**ab**		
X_3	**a**	**a**		**a**	**a**		
X_4		**a**	**a**		**a**		
X_5	**ab**	**ab**	**a**	**a**			
X_6	**b**	**ab**	**ab**	**ab**	**ab**		**b**
X_7	**b**	**ab**	**ab**	**ab**	**ab**	**b**	

a = Abiotic Links, b = Biotic Links

Subscript	Compartment
1	Air
2	Plants
3	Soil Solution
4	Soil Solids
5	Free Water
6	Invertebrates
7	Vertebrates

Terrestrial Exposure Conceptual Model

Operational Model

A general compartment model has some standard features:

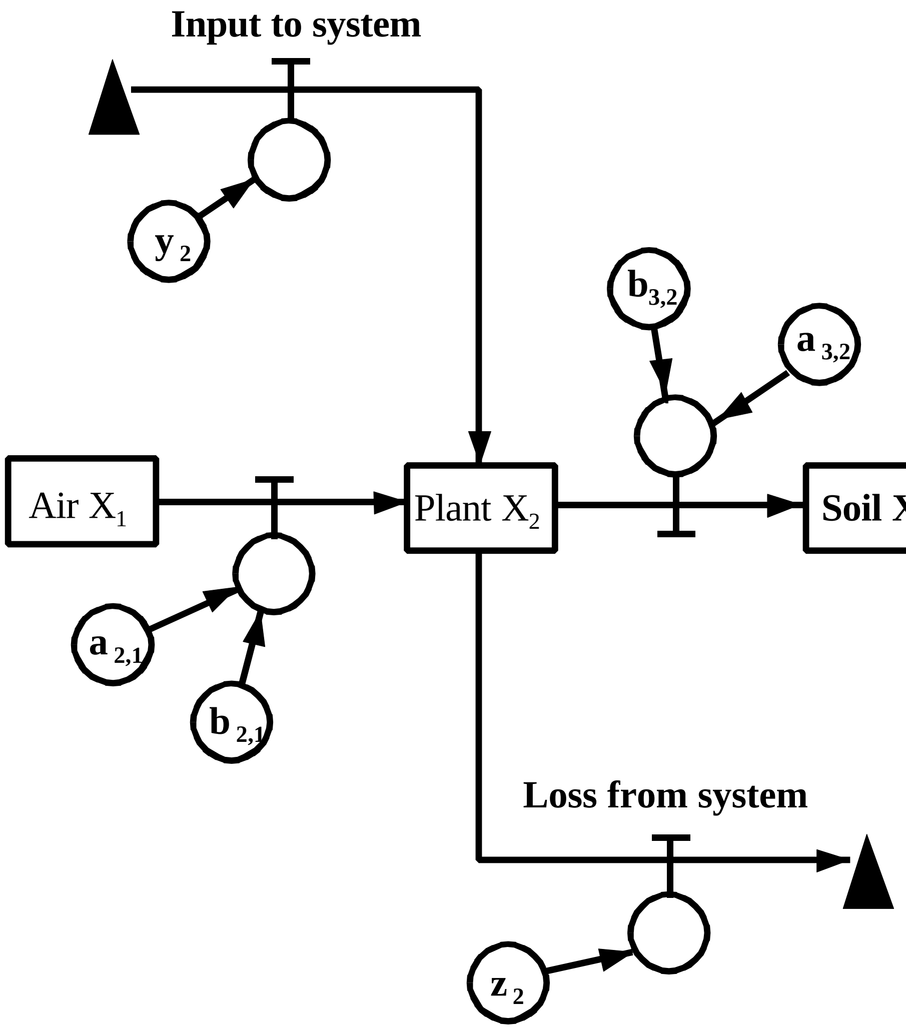
- distinct pools of material: X_i where I designates pool

- donor controlled flow, given rate constants (a,b):

  $flow_{3,2} = (a_{3,2} + b_{3,2}) \bullet X_2$

- possible inputs and losses from the system (x,y)

  .... e.g., total flux of pool X_2 is:
  Gains = $(a + b) \bullet X_1 + y_2$
  Losses = $(a + b) \bullet X_2 + z_2$



Terrestrial Exposure Conceptual Model

Example Mass Balance on Environmental Compartment X_2

The value of X_2 after time Δt if given by:

$$\mathbf{X_{2,(t+\Delta t)} = X_{2,t} + (a_{2,1} + b_{2,1}) \bullet X_{1,t} + y_2 - (a_{3,2} + b_{3,2}) \bullet X_{2,t} - z_2}$$

••• or in standard matrix form:

$$\mathbf{x_{(t+\Delta t)} = (A + B) \bullet x_t + y - z}$$

••• where x is the vector of state variables (pools), A and B are matrices for transfer coefficients, and y and z are vectors of inputs and losses fro the system, respectively.

In this simplified approach we assumed the transfer coefficients, inputs and losses were constant. However:

1) they are likely to vary over time and space,
2) they are likely to vary among systems, and
3) our ability to measure fluxes is limited.

Thus, model uncertainty and natural variation must enter the effort at this point.

Defining/Estimating the Distribution of Major Variables

EXPOSURE (Dose) = Residues + Biology

To facilitate defining/estimating the distribution of major variables, the Exposure Modeling Group categorized the compartments of the interactive matrix into either residues or biology.

Residues Team Responsibility

- To define or estimate the distribution of concentrations of a pesticide over time on/in air, plants, soil solution, soil solids, free water and invertebrates.

Biological Team Responsibility

- To define the biological characteristics of species of concern which can influence dose of a pesticide.
- To define and/or estimate the distribution of these parameters in relation to dose. These characteristics include food habits, food ingestion rates, portion of habitat contaminated, repellency, etc.

Residue Modeling Team Progress

Graphical conceptual models have been developed depicting the source, transformation and transport of pesticides between and within environmental compartments. Based upon the graphical conceptual models, matrices have been developed which could serve as a mathematical foundation for the development of computer models for estimating residue concentrations in various environmental compartments over time and location. In addition,

- existing equations for estimating pesticide input, transformation and transport between and within environmental compartments (primarily from PRZM or other literature sources) have been summarized.

- conversations are underway with the U.S. EPA Laboratory in Athens GA concerning their possible resurrection and improvement of the Terrestrial Exposure Assessment Model (TEAM). A possible alternative to TEAM - the EcoFate module of the Total Risk Integrated Model (TRIM) developed by the U.S. EPA Office of Air and their contractors.

- efforts are underway to develop pesticide mass transfers between environmental compartments in the residue portion of a bird "random walk" model being developed by Ron Parker for screening purposes.

- a computer literature search is being conducted for information concerning foliar dissipation, foliar volatilization, foliar washoff, and plant uptake.

Biology Teams Progress

INVERTEBRATE UPTAKE OF RESIDUES (SOIL AND WATER)

It is apparent that some pesticide have the potential to move from the soil to soil invertebrates and accumulate at concentrations which present significant risk to terrestrial vertebrates. It has been shown select organochlorine compounds can accumulate in earthworms to levels which present a risk to robins (Gish, 1970). Pesticide transfer and accumulation could result from direct ingestion of soil pore water and soil particles or via direct contact with contaminated soils and subsequent absorption of the chemical. Beyer et al., (1994) demonstrated the potential importance of this exposure route by showing that soil can comprise <2 % to 30% of the diet in some bird species. Models are available which could estimate the accumulation of pesticide concentrations in earthworms and other soil invertebrates (Ross et. al., 1989; Connell and Markwell, 1990; Trapp, 1995)

This subgroup will perform three tasks:

- assess the status of current data on soil invertebrates in relation to the transfer of pesticides from soil solution and particles to soil invertebrates.

- evaluate the availability and applicability of current soil to invertebrate transfer models.

- offer an estimate of the overall importance of this exposure route in general and, if necessary, recommend methods for incorporation into probabilistic models.

Biology Teams Progress

DIETARY DOSE ESTIMATION: VERTEBRATES

- The partial doses contributed by each of a series of food types are determined, then summed to yield the total dietary dose. This must be done for each species of species group under consideration since key parameters change with species and body size.

- Concentrations present immediately after application may be estimated for broad food types such as vegetation, fruits/seeds and invertebrates from available residue data (Hoerger and Kenaga 1972, Fletcher et al. 1994, Pfleeger et al. 1996 Fischer et al. in prep., Brewer et al. In prep.). These data may be plotted probabilistically (examples below) and the resulting distributions used in the above equation.

- The work group is investigating ways in which the other factors in the equation may also be estimated from probabilistic distributions.

Biology Teams Progress

A modification of equation 1 of Pasterock et. al. (1996, Human & Ecol. Risk Assess., 2:449) is being investigated to estimate dietary doses of terrestrial vertebrates.

$$\text{(Dietary Dose) } DD_{\text{(mg/kg b.w./time)}} = {}_{I}\,[FIR \bullet AV \bullet PD_i \bullet PT_i \bullet C_i \bullet DWF_i \,/\, W]$$

where,

FIR = Food Ingestion Rate (kg food on dry weight basis per unit time), a species specific value which may be obtained from Nagy's (1987) allometric equations,

AV = Avoidance factor: Fraction of normal FIR that birds exhibit when provided only pesticide-treated food.

PD_i = Proportion of food type I in the diet.

PT_i = Proportion of food type I obtained in treated area (i.e., with pesticide residues).

C_i = concentration (mg/kg) of pesticide in food type I.

DWF_i = Dry to Wet Factor: ratio of fresh weight to dry weight.

W = Weight (kg) of the species under consideration.

Biology Team Progress

DERMAL AND INHALATION EXPOSURE

Diet is usually considered to be the predominant route of exposure to pesticides for birds and mammals. Consequently, exposure by inhalation or dermal contact is rarely considered in risk assessment. However, there is evidence that dermal and inhalation exposure may be important under some conditions. For bobwhite quail foraging in a simulated cotton crop, inhalation was the most important route of exposure in the first hour after spraying with methyl-parathion. Eight to 48 hours after spraying the dermal route was most important, while dietary exposure accounted for only 10-20% (Driver et al, 1991). Furthermore, dermal exposures to OP pesticides inhibit plasma cholinesterases for much longer than dietary exposures, increasing the potential for birds to accumulate a lethal dose (Henderson et al., 1994).

ECOFRAM will draw on these and other relevant studies to assess the feasibility of including non-dietary routes in risk assessment. We plan to construct a simple model, then use sensitivity analysis to identify the conditions under which dietary and inhalation routes are important. The results will be used to decide when and if these routes should be considered, and to guide the further development of assessment methods.

Biology Team Progress

VERTEBRATE FORAGING BEHAVIOR

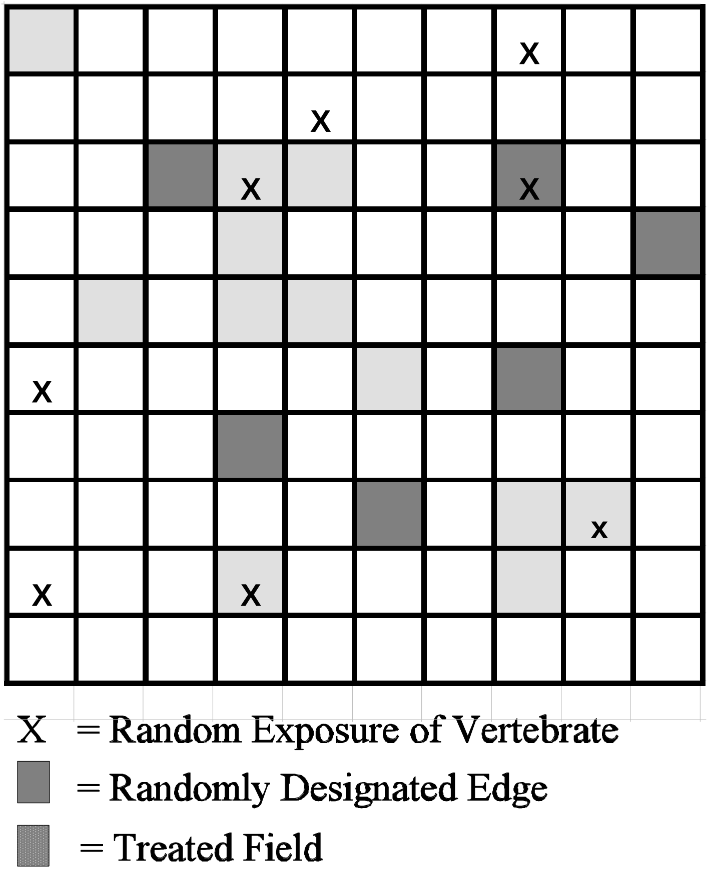
This subgroup is working on the development of a variable residue - behavior modified foraging exposure scenario. The underlying assumption of the model is that dose is related to mass (M) of the daily food intake and the pesticide concentration on the food items (C) divided by the body weight of the animal.

$$\text{Dose} = \frac{(M_{\text{time, location}} \bullet C_{\text{time, location}})}{\text{Body Weight}}$$

The following assumptions are made:

- Pesticide is applied randomly to a selected fraction of the fields in the grid.
- Spray drift occurs on the field immediately down wind
- Degradation on the food items begins on the day of application.
- Animals move on a behavior-modified random path through the fields and ingest pesticide if feeding in a treated field.
- Behavior pattern, diet composition, percent edge and treated area and simulation length are user specified.

Simulated Field



Challenges to developing probabilistic exposure methods

- Predicting the uptake of granular formulations by birds and mammals.
- Producing models of animal movements between treated and untreated habitats which are both realistic and general enough to be useful.
- Developing ways to assess non-dietary routes of exposure, especially dermal exposure.
- The challenge of moving from the idea of risk as a 'thing' we are trying to predict, to the idea of risk assessment being the process of QUANTIFYING UNCERTAINTY in predicting IMPACTS.
- If both exposure and effects profiles are to be focused on units of dose (i.e., mg/kg/day), what modifications will be needed in wildlife toxicity tests to produce and endpoint expressed as dose rather than bioavailibility (i.e., ppm on food)?
- How can the avian reproduction study be modified to estimate the dose response relationship rather than determine only NOEL and LOEL values expressed in units of bioavailability (i.e., ppm on food)?
- How can toxicity tests be modified to test effects when exposure is declining, rather than assuming exposure is constant?

- What modifications to the current EPA acute and dietary toxicity test methods are necessary for defining other points on the dose-response relationship beside the mid-point (i.e., LD_{50} or LC_{50})?

- Does data from standardized laboratory tests and the Kenaga nomogram provide the exposure and response information needed to make probabilistic risk assessments worth while?

- Available data on pesticide residues on/in foliage and invertebrates is somewhat limited.

- Data on foliar washoff, foliar dissipation, uptake by plants, uptake/depuration by invertebrates, and uptake/depuration by vertebrates is also somewhat limited.

- Information allowing for extrapolation of pesticide fate characteristics obtained under a limited set of experimental conditions and or sites to various ranges of actual environmental conditions and sites is limited.

Assessment Endpoints

ECOFRAM recognized the need to consider endpoints up to the system-level. However, due to time constraints and the lack of easily adaptable community and system-level models, the primary assessment endpoints will be survival, reproduction and persistence of valued ecological entities.

INDIVIDUAL ENDPOINTS

- Survival of valued ecological entity*
- Reproduction of valued ecological entity*
- Growth and development of ecological entity
- Morbidity of valued ecological entity

POPULATION-LEVEL EFFECTS

- Population size of valued ecological entity
- Demographics of valued ecological entity
- Persistence of valued ecological entity*

COMMUNITY AND SYSTEM VALUES

- Patterns of taxonomic diversity
- Patterns of function diversity
- Changes in compositional integrity
- Nutrient cycling
- Energetics

(*) Primary endpoint to be considered by ECOFRAM

Terrestrial Exposure Assessment Endpoint

Estimation of the distribution of pesticide doses to relevant terrestrial species within Agroecosystems.