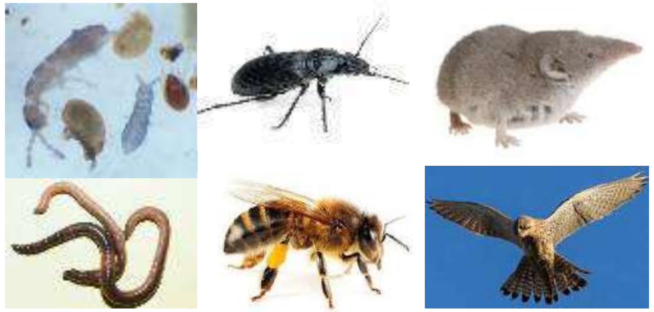
WORKSHOP – *11 & 12 October 2021, Montpellier*
Reducing the use of pesticides in tropical agriculture: key challenges and strategies

Ecotoxicological indicators : How to assess and link pesticides' exposure and impacts in agricultural landscapes?

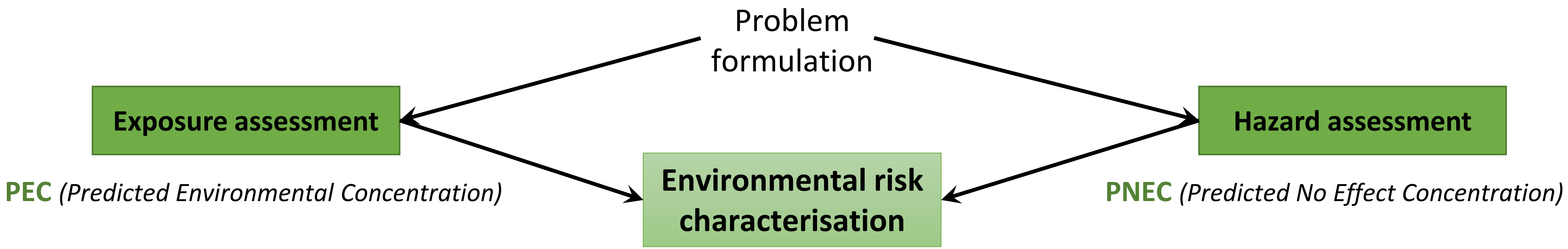




Colette BERTRAND
Pôle Ecotoxicologie - UMR EcoSys
INRAe

Clémentine FRITSCH
UMR Chrono-environnement
CNRS

Post-registration monitoring of the environmental impact of pesticides ?

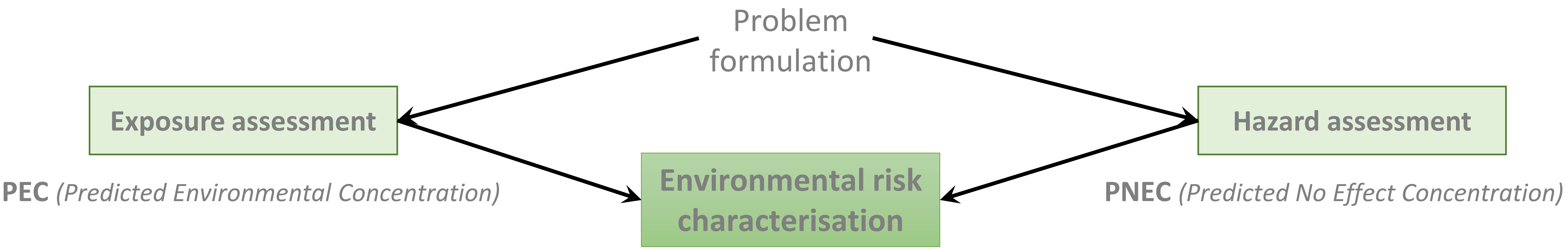
The purpose of registration is to ensure that pesticides, when used according to directions for use, will be effective for their intended purpose, while **not posing unacceptable risks** to users, consumers of treated food, and **wildlife or other non-target organisms**.



Beronius, A., et al. (2020). Methodology for health risk assessment of combined exposures to multiple chemicals. Food and Chemical Toxicology, 143, 111520.

Post-registration monitoring of the environmental impact of pesticides ?

The purpose of registration is to ensure that pesticides, when used according to directions for use, will be effective for their intended purpose, while **not posing unacceptable risks** to users, consumers of treated food, and **wildlife or other non-target organisms**.



Post-registration activities provide a means of measuring the validity of predictions based on registration data regarding environmental effects

If results of field surveillance raise doubts → further studies may be required or appropriate regulatory sanctions imposed

Surveillance in real agricultural fields / landscapes

Vijver, M. G. et al. (2017). Postregistration monitoring of pesticides is urgently required to protect ecosystems. Environmental Toxicology and Chemistry, 36(4), 860-865.

Post-registration monitoring of the environmental impact of pesticides ?

The purpose of registration is to ensure that pesticides, when used according to directions for use, will be effective for their intended purpose, while **not posing unacceptable risks** to users, consumers of treated food, and **wildlife or other non-target organisms**.

Problem formulation

Exposure assessment

Hazard assessment

Environmental risk characterisation

PEC *(Predicted Environmental Concentration)*

PNEC *(Predicted No Effect Concentration)*

Post-registration activities provide a means of measuring the validity of predictions based on registration data regarding environmental effects

If results of field surveillance raise doubts → further studies may be required or appropriate regulatory sanctions imposed

Surveillance in real agricultural fields / landscapes

Evaluate environmental contamination (air, water, soil) and non-target organisms exposure

(Bio)indicators of exposure ??

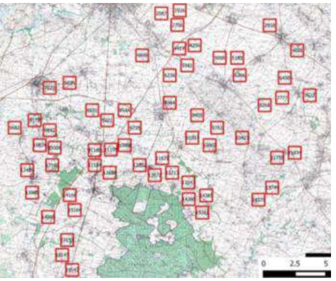
Evaluate the impacts on non-target organisms (individuals, populations, communities, food webs)

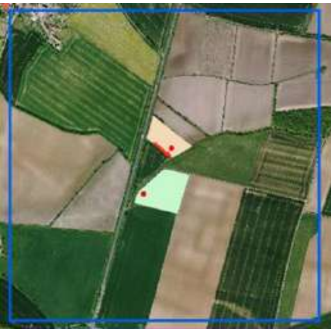
(Bio)indicators of effects ??

Measuring concentrations in water, air and soils

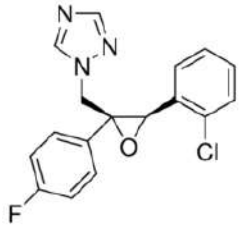
The actual risk that multiple plant protection products residues might pose to non-target species is difficult to assess due to the lack of clear evidence of their actual concentrations

Measuring concentrations in water, air and soils



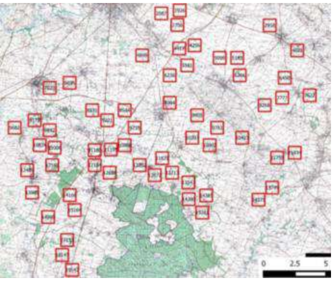


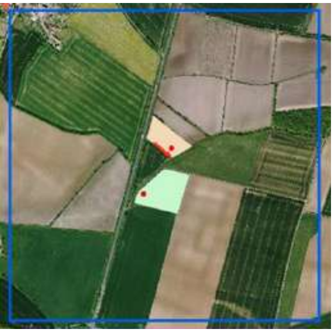
Epoxiconazole



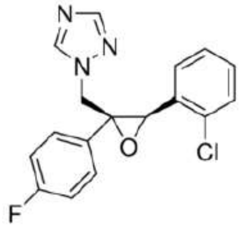
Pelosi, C. et al. (2021). Residues of currently used pesticides in soils and earthworms: A silent threat?. Agriculture, Ecosystems & Environment, 305, 107167.

Measuring concentrations in water, air and soils



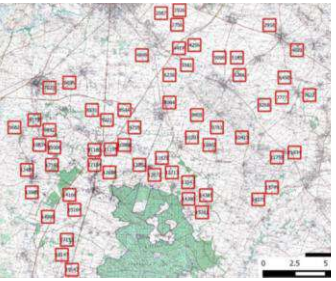


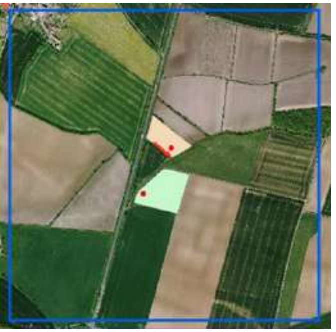
Epoxiconazole detected in 81% of the samples (145 / 180)
Concentration mean : 28 ng/g
Concentration max : 283 ng/g



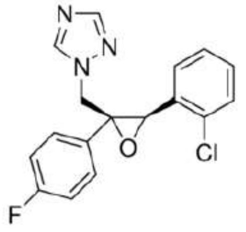
Pelosi, C. et al. (2021). Residues of currently used pesticides in soils and earthworms: A silent threat?. Agriculture, Ecosystems & Environment, 305, 107167.

Measuring concentrations in water, air and soils





Epoxiconazole detected in 81% of the samples (145 / 180)
Concentration mean : 28 ng/g
Concentration max : 283 ng/g



Class	Pesticide	Recommended dose (ng/g)	**PEC_{soil} initial (ng/g)**	LC50 acute earthworm (ng/g)	**NOEC reproduction earthworm (ng/g)**
Fungicide	Epoxiconazole	153	**128**	> 62500	**84**

MEC > PEC
for 8 soil samples

7 cereal fields ; 1 hedgerow

TER earthworms (NOEC / MEC)
≤5 for 52 soil samples

38 cereal fields (1 OF) ; 6 hedgerows ; 8 grasslands

Pelosi, C. et al. (2021). Residues of currently used pesticides in soils and earthworms: A silent threat?. Agriculture, Ecosystems & Environment, 305, 107167.

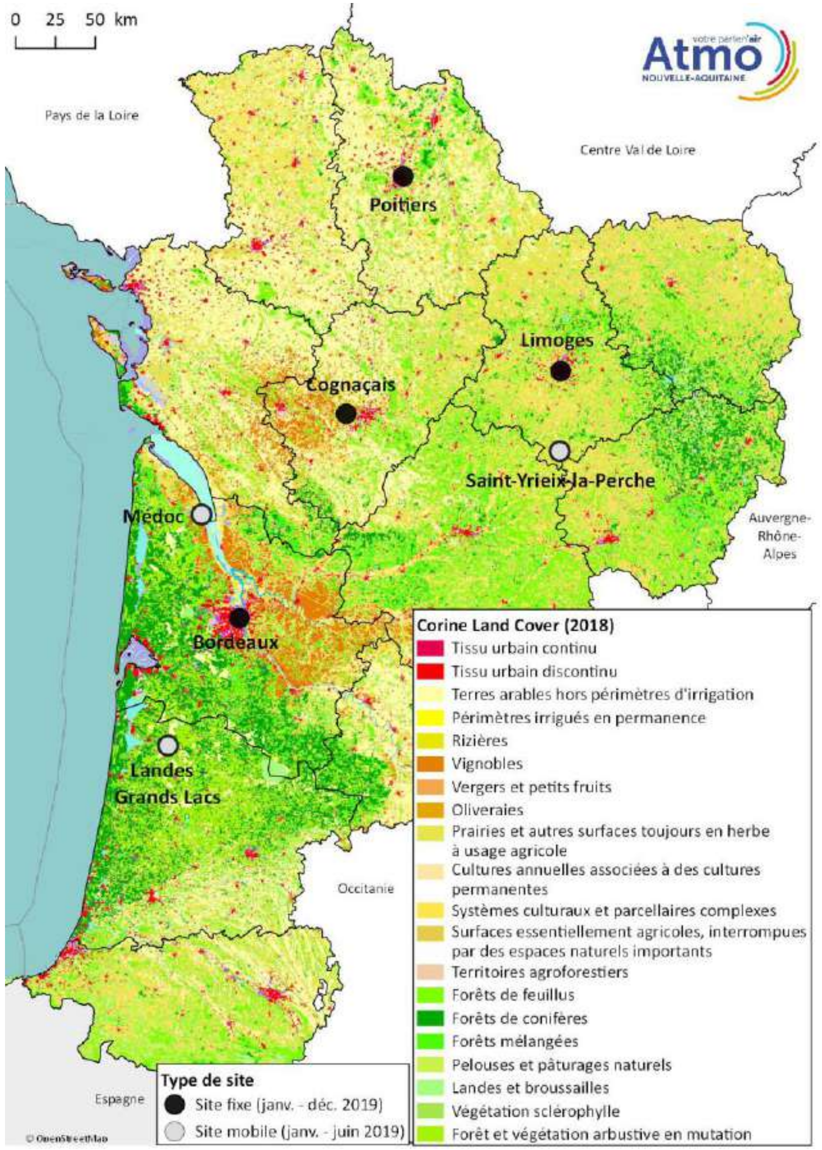
Measuring concentrations in water, air and soils

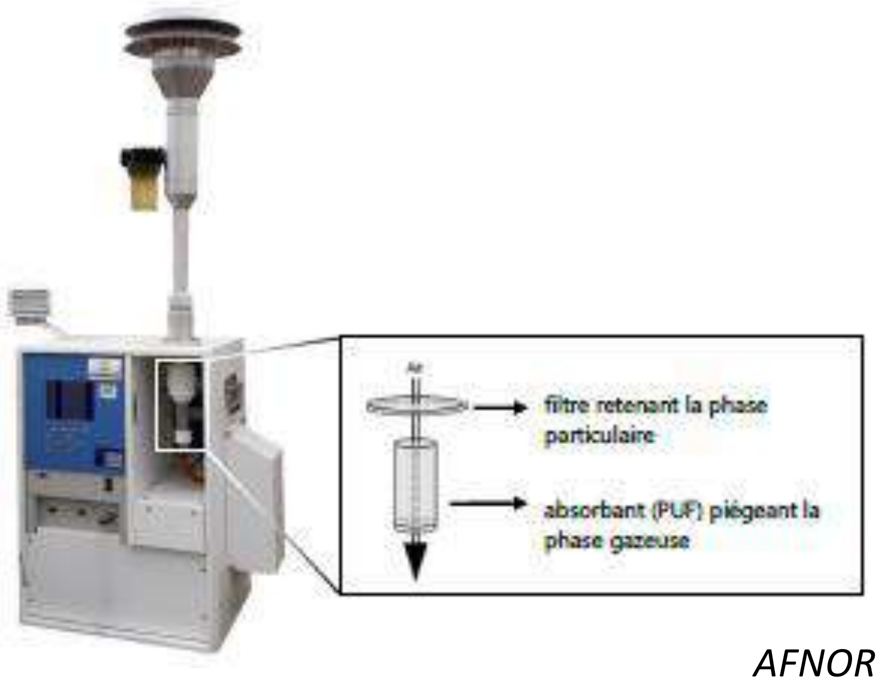
REAL ASSESSMENT OF THE ENVIRONMENTAL CONTAMINATION ?

→ Challenging due to the large number of potential contaminants

Fédération des associations de surveillance de la qualité de l'air
Atmo France

Measuring concentrations in water, air and soils





39 Herbicides
31 Fungicides
34 Insecticides

AFNOR XPX 43-059 standard
gas chromatography or liquid chromatography + tandem mass spectrometry

Measuring concentrations in water, air and soils

Fédération des associations de surveillance de la qualité de l'air

Atmo France

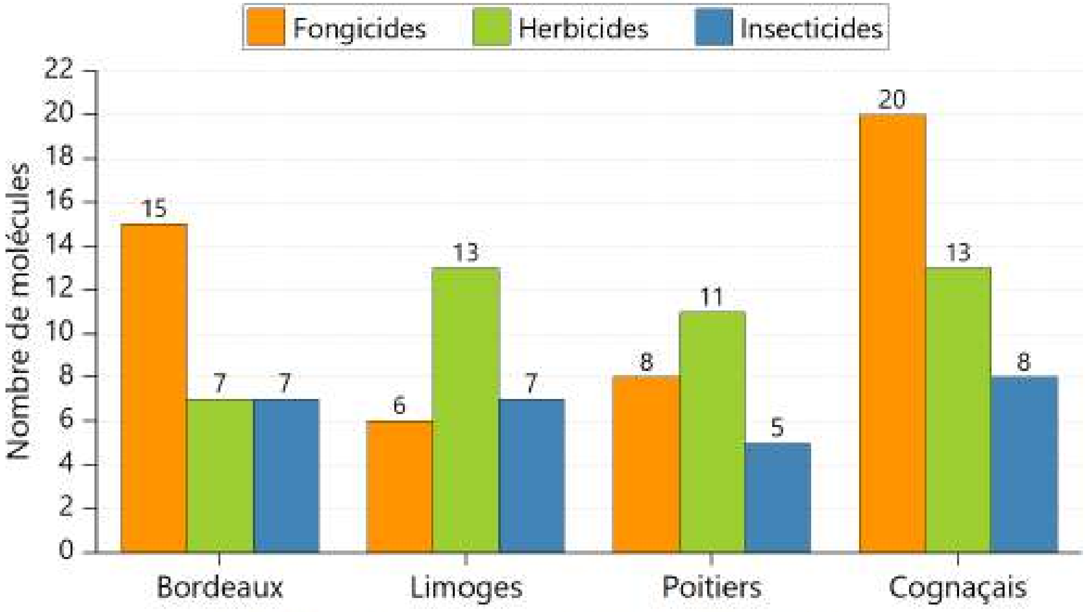


Figure 10 : Nombre de molécules détectées en 2019

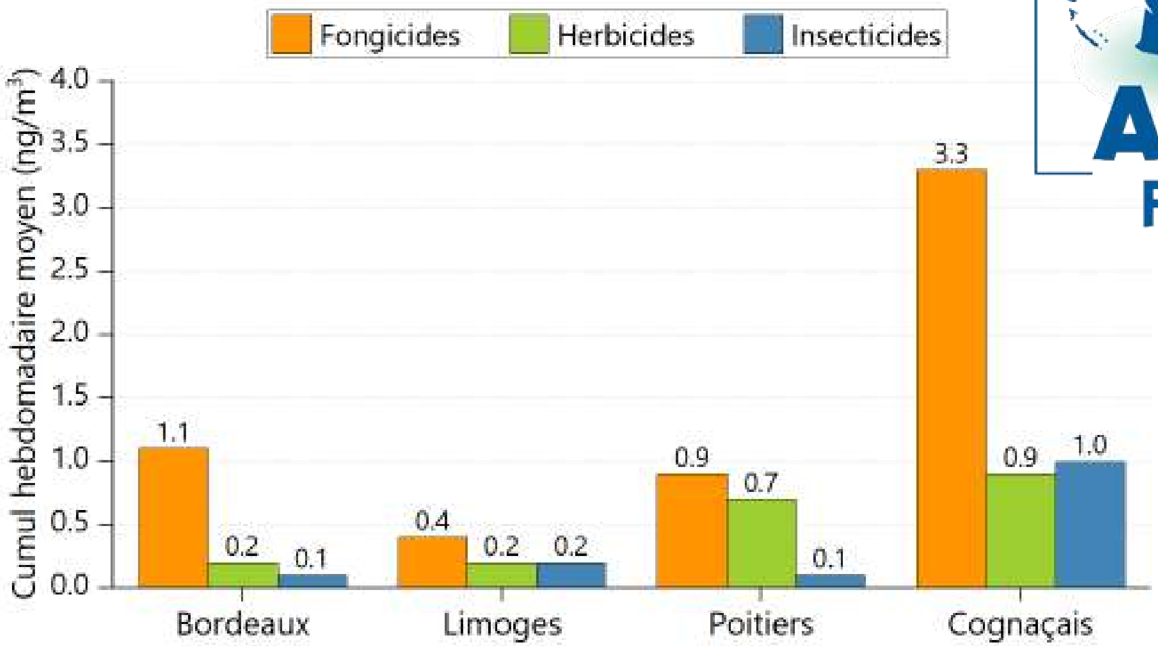


Figure 12 : Cumuls hebdomadaires moyens des concentrations en 2019

REAL ASSESSMENT OF THE ENVIRONMENTAL CONTAMINATION ?

→ Challenging due to the large number of potential contaminants

→ Most scientific studies and routine monitoring programs only include a "limited" number of pesticides

→ Metabolites??

→ But promising new analytical methods → Large pesticide multiresidue screening methods

https://www.atmo-nouvelleaquitaine.org/fiche-bilan/les-pesticides-dans-lair-bilan-annuel-2019

Measuring concentrations in water, air and soils

→ **Pesticide multiresidues in the environment (water + air + soil)… what to do with this data??**

→ Lack of reference of the mixtures (and concentrations) of pesticides that can be found in different agropedoclimatic contexts

→ How to compare environments where the mixtures found are not the same?

→ Difficulty in estimating the risk of mixtures to biodiversity
the combined exposure to multiple chemicals can trigger stronger (or occasionally weaker) (eco)toxicological effects than exposure to individual chemicals alone

$$RQ_i = MEC / PNEC \rightarrow RQ_{mix} = \sum RQ_i$$

no risk (RQ < 0.01), lower risk (0.01 ≤ RQ < 0.1), moderate risk (0.1 ≤ RQ < 1) and higher risk (RQ ≥ 1)

Need to be able to test the effects of mixtures under real exposure conditions

OECD (2018), Considerations for Assessing the Risks of Combined Exposure to Multiple Chemicals, Series on Testing and Assessment No. 296

Measuring concentrations in biological matrices

→ **REAL ASSESSMENT OF BIODIVERSITY EXPOSURE ?**

Take into account exposure by ingestion

Measuring concentrations in biological matrices

→ **REAL ASSESSMENT OF BIODIVERSITY EXPOSURE ?**

Take into account exposure by ingestion

Pollen ; Nectar ; Honey

Zioga, E. et al. (2020). Plant protection product residues in plant pollen and nectar: A review of current knowledge. Environmental research, 109873.

Measuring concentrations in biological matrices

→ **REAL ASSESSMENT OF BIODIVERSITY EXPOSURE ?**

Take into account exposure by ingestion

Pollen ; Nectar ; Honey

Same locks as mentioned above
Lack of reference of the mixtures, difficult to compare environments with different mixtures, difficulty in estimating the risk of mixtures to biodiversity

+

How to integrate different exposure routes (contact / ingestion / inhalation) ?
whose contribution is different according to the organisms considered

Zioga, E. et al. (2020). Plant protection product residues in plant pollen and nectar: A review of current knowledge. Environmental research, 109873.

Measuring concentrations in biological matrices

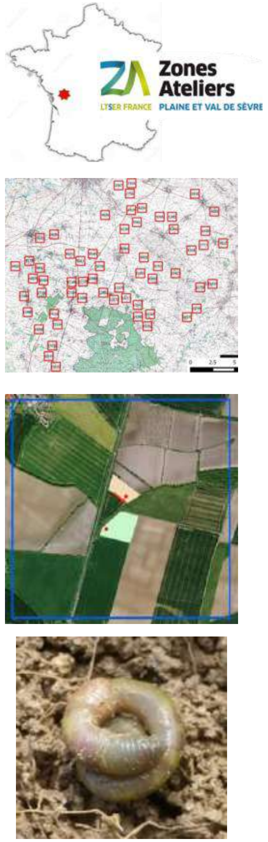
→ **REAL ASSESSMENT OF BIODIVERSITY EXPOSURE ?**

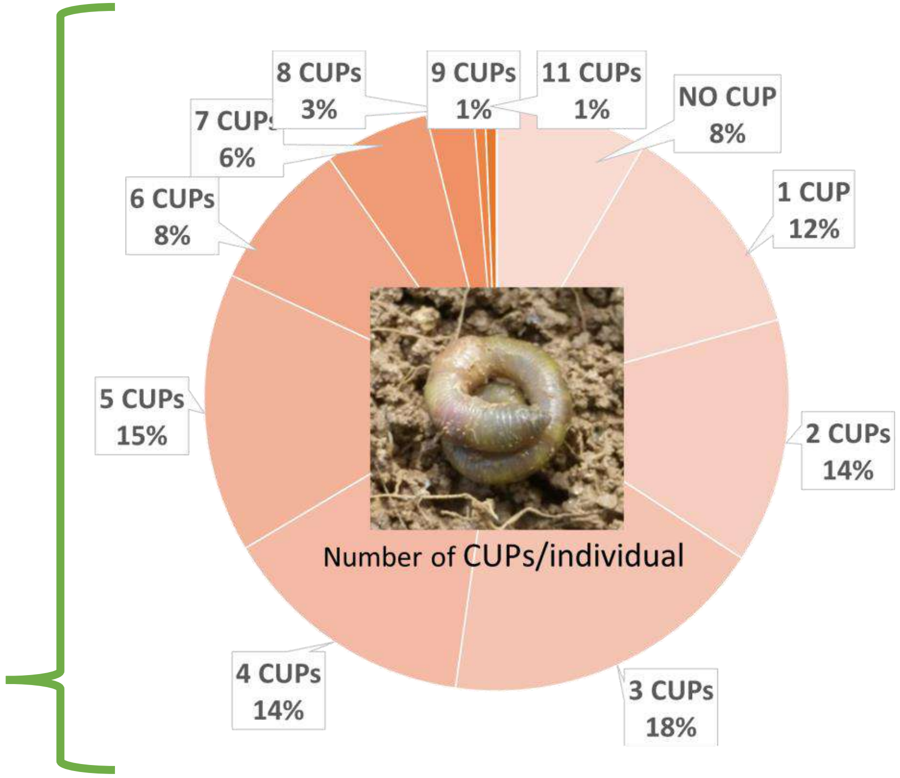
→ Biomonitoring data can be used to quantitatively estimate internal dose or absorbed dose from all exposure routes and can be useful to provide information on co-exposure.

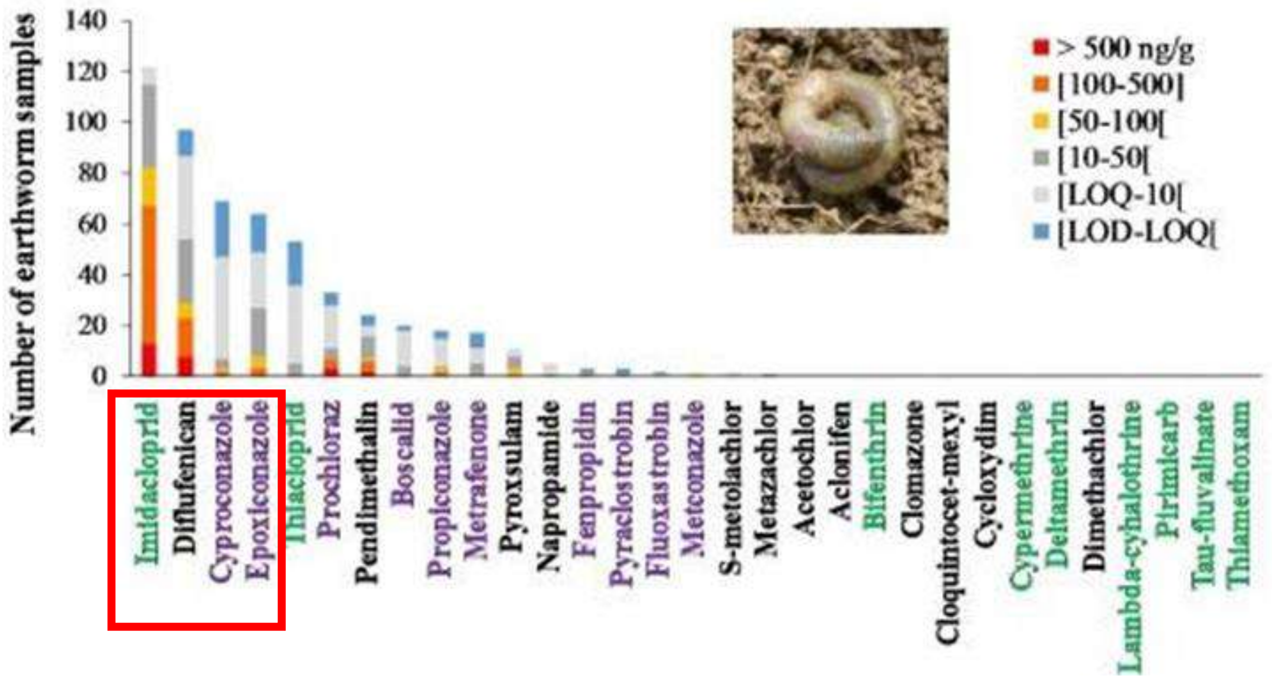
Measuring concentrations in biological matrices

→ **REAL ASSESSMENT OF BIODIVERSITY EXPOSURE ?**

→ Biomonitoring data can be used to quantitatively estimate internal dose or absorbed dose from all exposure routes and can be useful to provide information on co-exposure.







Measuring concentrations in biological matrices

→ **REAL ASSESSMENT OF BIODIVERSITY EXPOSURE ?**

→ Biomonitoring data can be used to quantitatively estimate internal dose or absorbed dose from all exposure routes and can be useful to provide information on co-exposure.

→ **… what to do with this data??**

→ The estimation of actual exposure from biomonitoring data requires an understanding of the compound’s toxicokinetics information

Need to be able to interpret this data => Link it with toxicological information

→ comparer les concentrations internes mesurées avec des valeurs de référence?

Besoin de disposer de « Toxicity reference values (TRVs) »

The 2 extremes of (regulatory) studies on effects

Laboratory Tests

Genes
Cells
Organs
Individuals

Assessment of EFFECTS of pesticides

***In situ* Biomonitoring**

Individuals
Populations
Communities
Functions

The 2 extremes of (regulatory) studies on effects

In vivo assays

Laboratory Tests

Genes
Cells
Organs
Individuals

In vitro assays

European Food Safety Authority; Guidance Document on Risk Assessment for Birds & Mammals on request from EFSA. EFSA Journal 2009; 7(12):1438. doi:10.2903/j.efsa.2009.1438.

The 2 extremes of (regulatory) studies on effects

In vivo assays

Laboratory Tests

In vitro assays

- Toxicology, Toxicokinetics / toxicodynamics, Mechanisms of effects
- **Indicators:**
  - **Biomarkers**
    - *genotoxicity, disorders in physiology or metabolism, endocrine disruption, teratotoxicity, pathogenicity, embryotoxicity, carcinogenitiicty, etc*
  - **Toxicological thresholds**
    - *LC50/LD50, NOAEC/NOAEL, LOAEC/LOAEL*

(Druart C., thesis, 2011; Augustyniak et al. Mutation research, 2016)

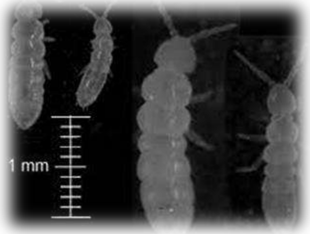
The 2 extremes of (regulatory) studies on effects

In vivo assays

Examples:
Standardized normalized
(ISO, OECD) tests

Eisenia fetida
Source : worm-farm.co.za

Honeybees
Source : OECD



Springtails
Source : OECD

Laboratory Tests

- Toxicology, Toxicokinetics / toxicodynamics, Mechanisms of effects
- **Indicators:**
  - **Biomarkers**
    - *genotoxicity, disorders in physiology or metabolism, endocrine disruption, teratotoxicity, pathogenicity, embryotoxicity, carcinogenitićty, etc*
  - **Toxicological thresholds**
    - *LC50/LD50, NOAEC/NOAEL, LOAEC/LOAEL*

In vitro assays

(Druart C., thesis, 2011; Augustyniak et al. Mutation research, 2016)

The 2 extremes of (regulatory) studies on effects

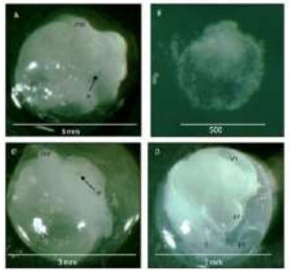
In vivo assays

Laboratory Tests

- Toxicology, Toxicokinetics / toxicodynamics, Mechanisms of effects
- **Indicators:**
  - **Biomarkers**
    - *genotoxicity, disorders in physiology or metabolism, endocrine disruption, teratotoxicity, pathogenicity, embryotoxicity, carcinogeniticty, etc*
  - **Toxicological thresholds**
    - *LC50/LD50, NOAEC/NOAEL, LOAEC/LOAEL*

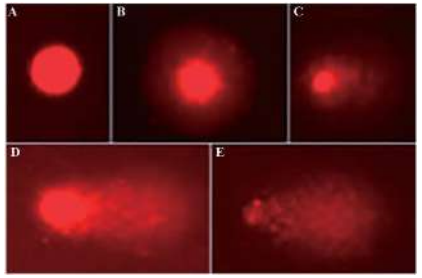
In vitro assays

Examples:
Standardized alternative bioassays



Embryotoxicity Terrestrial snails

Source : Druart C.



Comet Assay insects

Source : Bioone.org

(Druart C., thesis, 2011; Augustyniak et al. Mutation research, 2016, ISO, OECD guidelines)

The 2 extremes of (regulatory) studies on effects

Poisoning

In situ Biomonitoring

Passive Biomonitoring

Individuals
Populations
Communities
Functions

Biodiversity

European Food Safety Authority; Guidance Document on Risk Assessment for Birds & Mammals on request from EFSA. EFSA Journal 2009; 7(12):1438. doi:10.2903/j.efsa.2009.1438.

The 2 extremes of (regulatory) studies on effects

- **Indicators:**
  - **Mortality / Morbidity**
    - *Pathogenic status, health status, signs of intoxication (necropsy, residues of PPPs in tissues/GI tract), etc*

- Toxicovigilance, Epidemiosurveillance, Phytopharmacovigilance

Passive Biomonitoring

Poisoning

***In situ* Biomonitoring**

Biodiversity

(Geiger et al, Basic and Applied Ecology, 2010; Millot et al., Environ Sci Pollut Res, 2017)

The 2 extremes of (regulatory) studies on effects

- **Indicators:**
  - **Mortality / Morbidity**
    - ➢ *Pathogenic status, health status, signs of intoxication (necropsy, residues of PPPs in tissues/GI tract), etc*

Example: SAGIR Network (OFB)

- Toxicovigilance, Epidemiosurveillance, Phytopharmacovigilance

Passive Biomonitoring

Poisoning

***In situ* Biomonitoring**

Biodiversity

(Geiger et al, Basic and Applied Ecology, 2010; Millot et al., Environ Sci Pollut Res, 2017)

The 2 extremes of (regulatory) studies on effects

Poisoning

- **Indicators:**
  - **Mortality / Morbidity**
    - *Pathogenic status, health status, signs of intoxication (necropsy, residues of PPPs in tissues/GI tract), etc*

In situ Biomonitoring

- Toxicovigilance, Epidemiosurveillance, Phytopharmacovigilance

Passive Biomonitoring

- Biodiversity, biological conservation, ecosystem functioning/services

- **Indicators:**
  - **Biodiversity and ecosystem functioning**
    - *Occurrence, richness, adundance of 1 or several taxa, soil functioning, potential for biological pest control*
  - **Population dynamics**
    - *Temporal dynamics of some taxa population, reproduction outcomes, etc*

Biodiversity

(Geiger et al, Basic and Applied Ecology, 2010; Millot et al., Environ Sci Pollut Res, 2017)

The 2 extremes of (regulatory) studies on effects

- **Indicators:**
  - **Mortality / Morbidity**
    - *Pathogenic status, health status, signs of intoxication (necropsy, residues of PPPs in tissues/GI tract), etc*

Poisoning

- Toxicovigilance, Epidemiosurveillance, Phytopharmacovigilance

Passive Biomonitoring

In situ Biomonitoring

- Biodiversity, biological conservation, ecosystem functioning/services

- **Indicators:**
  - **Biodiversity and ecosystem functioning**
    - *Occurrence, richness, adundance of 1 or several taxa, soil functioning, potential for biological pest control*
  - **Population dynamics**
    - *Temporal dynamics of some taxa population, reproduction outcomes, etc*

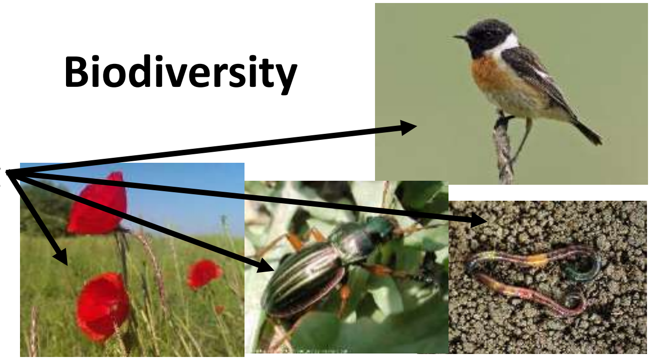
Example:
Survey of unintentional effects
(suivi ENI - ECOPHYTO plan)

FREDON FRANCE

aGRICULTURES & TERRITOIRES CHAMBRES D'AGRICULTURE

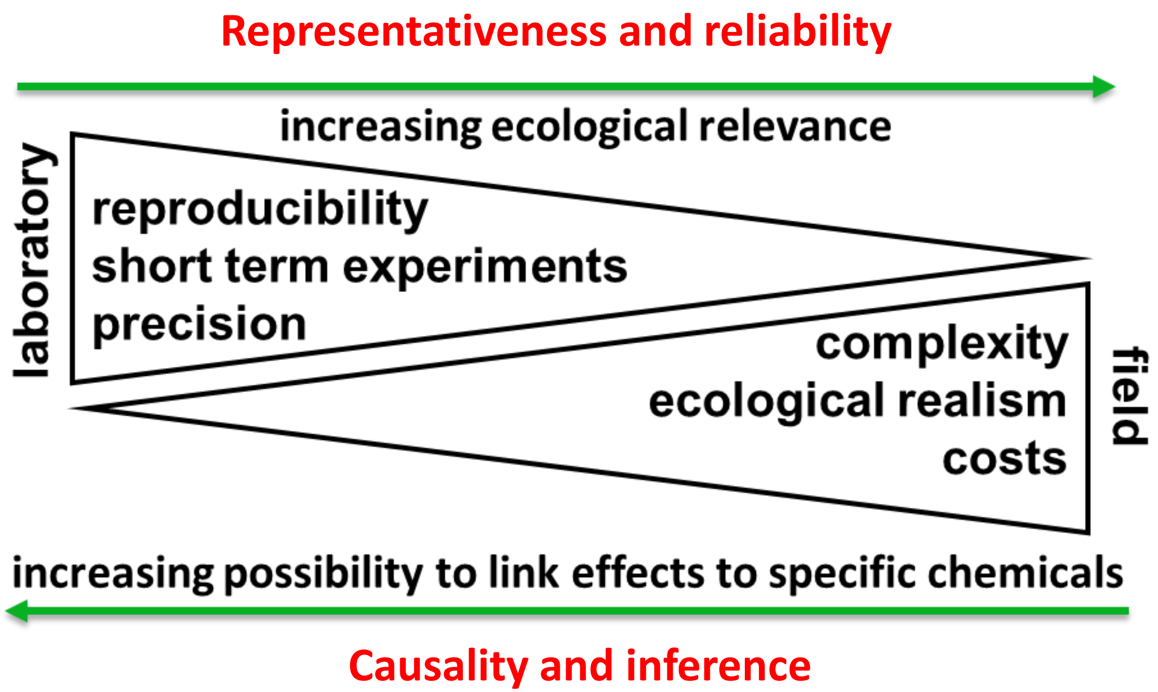
- Field monitoring of 4 taxa
- 500 plots at national scale

Biodiversity



(Geiger et al, Basic and Applied Ecology, 2010; Millot et al., Environ Sci Pollut Res, 2017)

The pros and cons of each approach



Kraak & Roessink, Community ecotoxicology. (2021, January 18). https://chem.libretexts.org/@go/page/294568

The pros and cons of each approach

Short duration

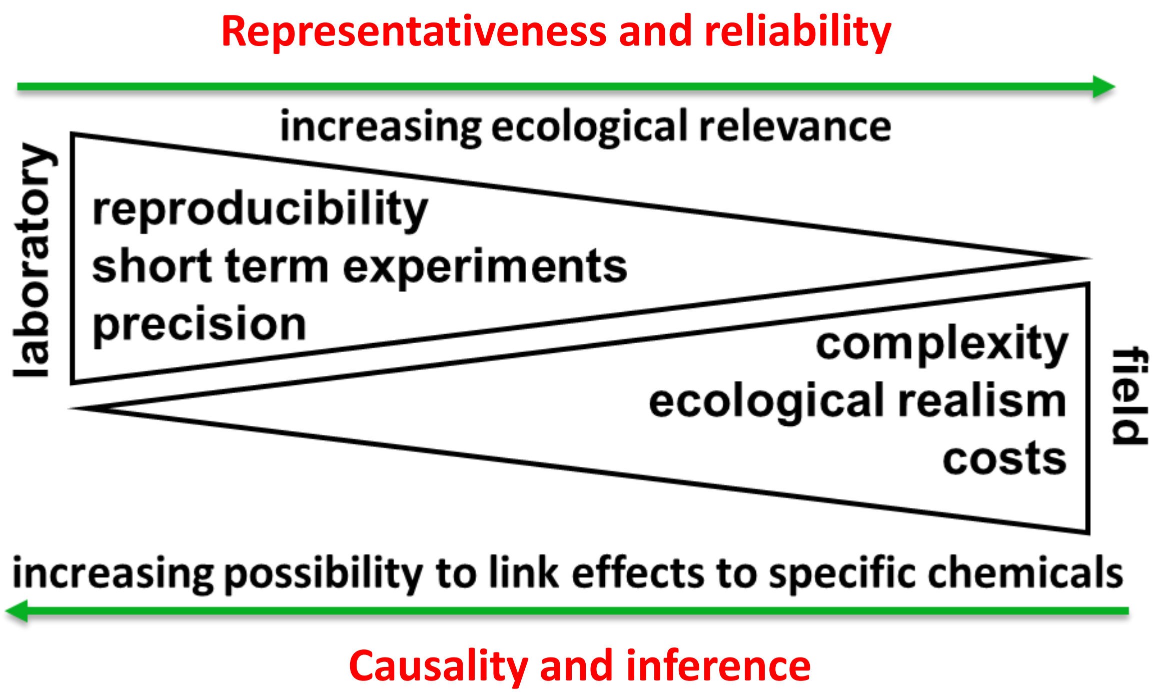
Single exposure

Acute/Repro toxicity

Full life cycle

Chronic / repeated exposure

Low to acute dose



The pros and cons of each approach

Short duration

Single exposure

Acute/Repro toxicity

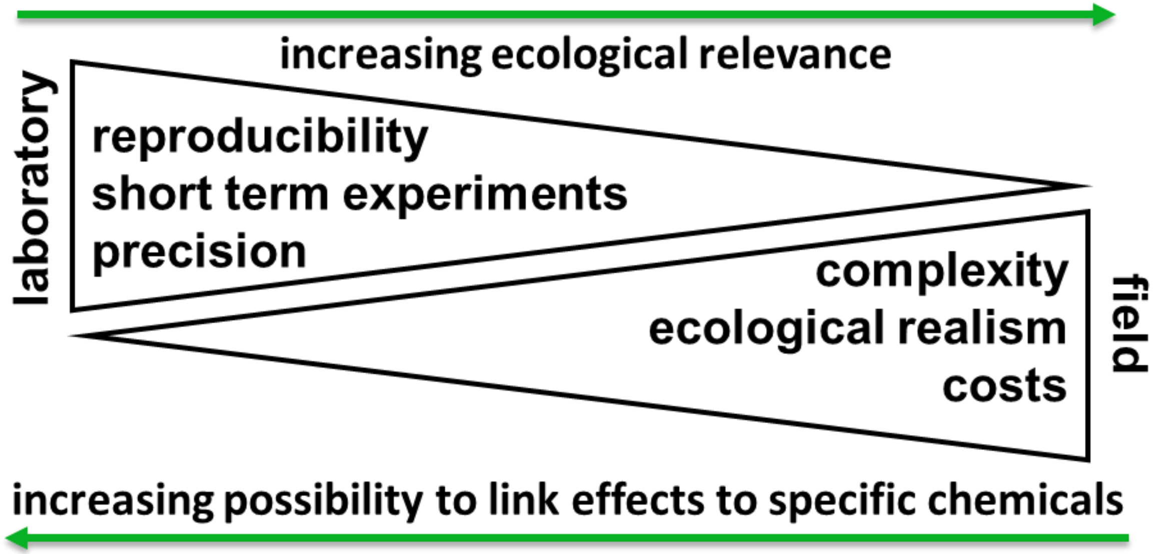
Mono-substance

Mono-source

Direct toxic effects

Experimental species
Cell lines

Representativeness and reliability



Causality and inference

Full life cycle

Chronic / repeated exposure

Low to acute dose

Multiple exposure (mixtures)

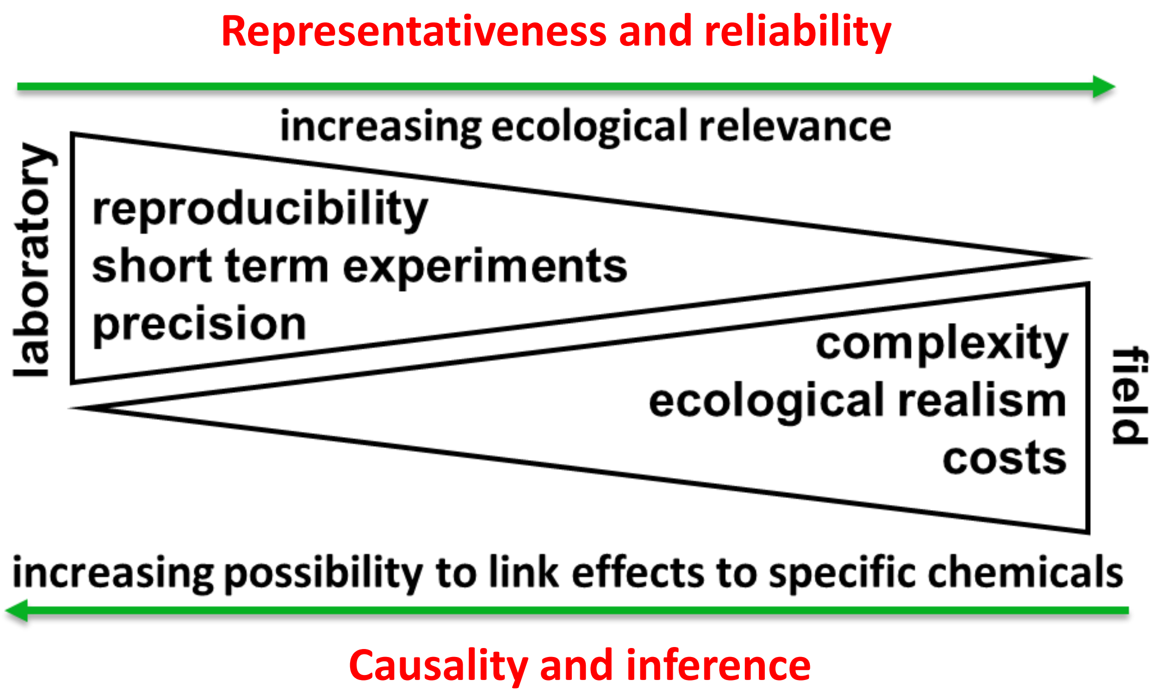
Multimedia exposure

Direct & indirect effects (e.g. trophic cascade)

Free-ranging species
(sensitivity/vulnerability, traits, conservation issues)

Kraak & Roessink, Community ecotoxicology. (2021, January 18). https://chem.libretexts.org/@go/page/294568

The pros and cons of each approach



Short duration	Full life cycle
Single exposure	Chronic / repeated exposure
Acute/Repro toxicity	Low to acute dose
Mono-substance	Multiple exposure (mixtures)
Mono-source	Multimedia exposure
Direct toxic effects	Direct & indirect effects (e.g. trophic cascade)
Experimental species Cell lines	Free-ranging species (sensitivity/vulnerability, traits, conservation issues)
Standardized experimental space	Farming practices (e.g. fertilizers, chemicals, tillage)
Optimal & controlled environmental conditions	Multi-stress (land use, climate, food resources, predation, competition, pathogens anthropogenic disturbances (light, noise, chemical pollution)

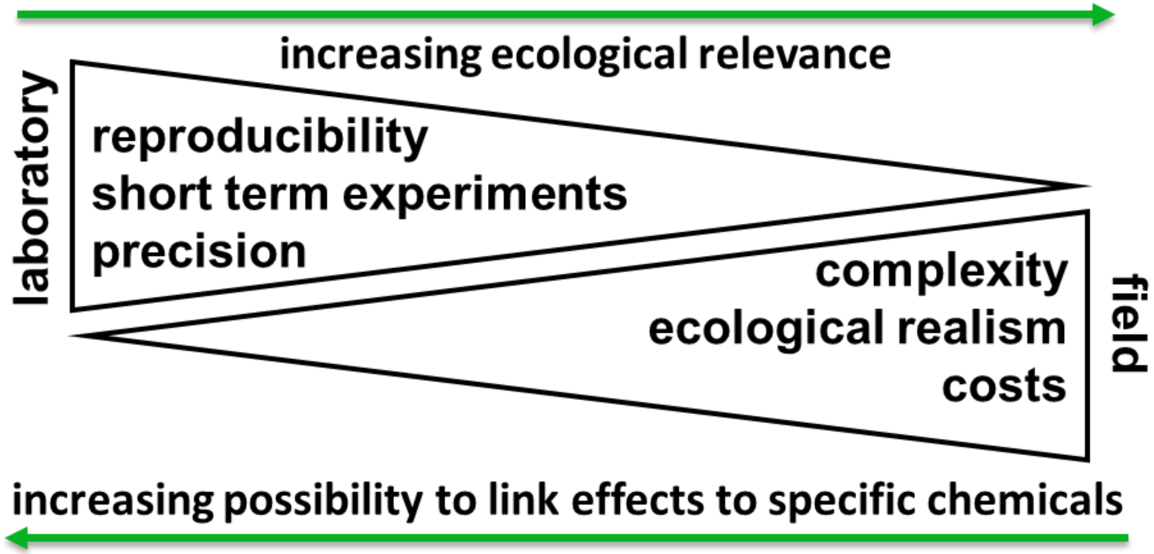
Kraak & Roessink, Community ecotoxicology. (2021, January 18). https://chem.libretexts.org/@go/pa

The pros and cons of each approach

MISMATCH WITH
REALITY OF USE

ACTUAL EXPOSURE
AND IMPACTS

Representativeness and reliability



Causality and inference

SIGNIFICANCE OF
DOSE-RESPONSE

CONFOUNDING FACTORS
WORSENING FACTORS

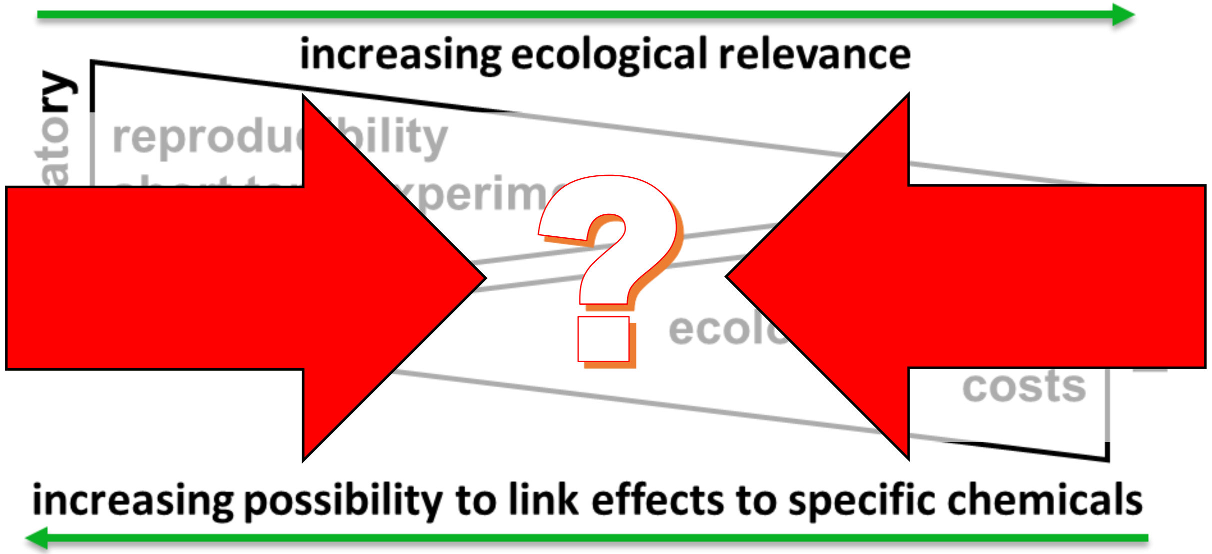
Kraak & Roessink, Community ecotoxicology. (2021, January 18). https://chem.libretexts.org/@go/page/294568

Bridge the gap: Scientific issues and Needs to support survey, management and regulation

MISMATCH WITH
REALITY OF USE

ACTUAL EXPOSURE
AND IMPACTS

Representativeness and reliability



Causality and inference

SIGNIFICANCE OF
DOSE-RESPONSE

CONFOUNDING FACTORS
WORSENING FACTORS

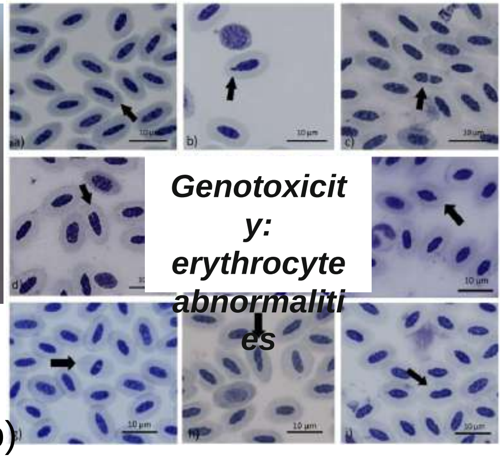
Kraak & Roessink, Community ecotoxicology. (2021, January 18). https://chem.libretexts.org/@go/page/294568

Lab Biomarkers in field studies/field species in the lab

Examples:
Genotoxicity, body condition, plasma biochemistry, oxidative stress

American kestrel
Falco sparverius

Agricultural area (Mexico)



Genotoxicity: erythrocyte abnormalities

Genotox varied with ***season****,* ***size/health****,*
and ***coverage of native vegetation*** *around capture site.*
Genotox observed coincide with the ***time when agrochemicals are applied*** *in the area"*

Frixione & Rodríguez-Estrella, 2020; Elmeros et al, 2011; Lopez-Antia et al, 2015)

Lab Biomarkers in field studies/field species in the lab

Examples:
Genotoxicity, body condition, plasma biochemistry, oxidative stress

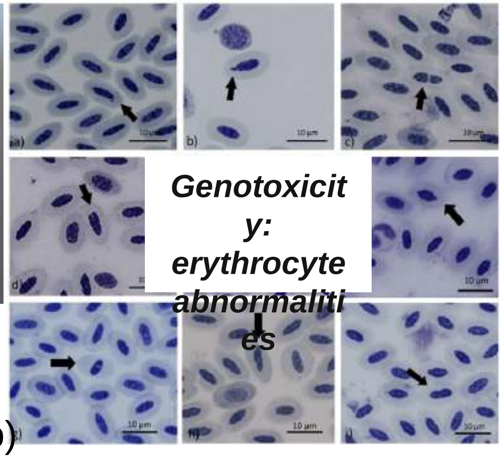
Small mustelids

Denmark

Decrease of body condition in individuals exposed to anticoagulant rodenticides

American kestrel
Falco sparverius

Agricultural area (Mexico)



Genotoxicity: erythrocyte abnormalities

Genotox varied with ***season**, **size/health**,* *and **coverage of native vegetation** around capture site.*
*Genotox observed coincide with the **time when agrochemicals are applied** in the area"*

Frixione & Rodríguez-Estrella, 2020; Elmeros et al, 2011; Lopez-Antia et al, 2015)

Lab Biomarkers in field studies/field species in the lab

Examples:
Genotoxicity, body condition, plasma biochemistry, oxidative stress

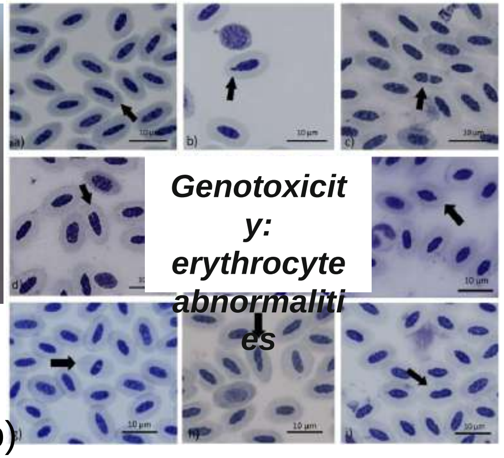
Small mustelids

Denmark

Decrease of body condition in individuals exposed to anticoagulant rodenticides

American kestrel
Falco sparverius

Agricultural area (Mexico)



Genotox varied with ***season, size/health,*** *and* ***coverage of native vegetation*** *around capture site.*
Genotox observed coincide with the ***time when agrochemicals are applied*** *in the area"*

Imidacloprid-treated seeds

Repeated exposure

Red-legged partridges *Alectoris rufa*

Changes in plasma biochemistry

Changes in markers of oxidative stress

Various effects according to timing

Frixione & Rodríguez-Estrella, 2020; Elmeros et al, 2011; Lopez-Antia et al, 2015)

Lab Biomarkers in field studies/field species in the lab

Examples:
Genotoxicity, body condition, plasma biochemistry, oxidative stress

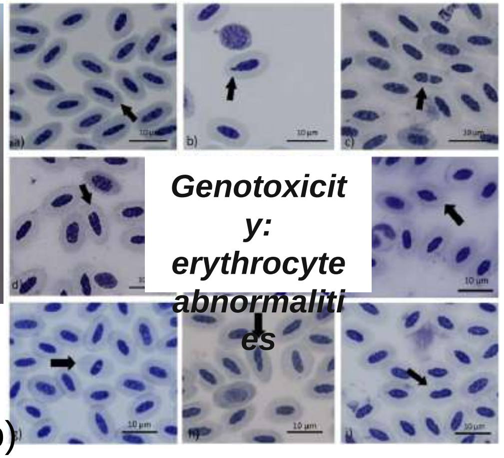
Small mustelids

Denmark

Decrease of body condition in individuals exposed to anticoagulant rodenticides

American kestrel
Falco sparverius

Agricultural area (Mexico)



Genotoxicity: erythrocyte abnormalities

Genotox varied with ***season, size/health,*** *and* ***coverage of native vegetation*** *around capture site.*
Genotox observed coincide with the ***time when agrochemicals are applied*** *in the area"*

Red-legged partridges *Alectoris rufa*

Imidacloprid-treated seeds

Repeated exposure

Changes in plasma biochemistry

Changes in markers of oxidative stress

Various effects according to timing

These markers are knwon to vary with various toxicants/stressors:

- Various pesticides, other xenobiotics (e.g. organic pollutants, metals)
- Radiations
- Pathogens/parasites
- Various stressors (e.g. food depletion, reproduction investment, climatic constraints)

Frixione & Rodríguez-Estrella, 2020; Elmeros et al, 2011; Lopez-Antia et al, 2015)

Lab Biomarkers in field studies/field species in the lab

Examples:
Genotoxicity, body condition, plasma biochemistry, oxidative stress

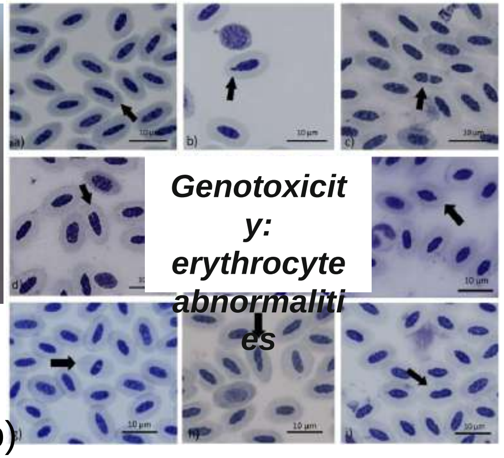
Small mustelids

Denmark

Decrease of body condition in individuals exposed to anticoagulant rodenticides

American kestrel
Falco sparverius

Agricultural area (Mexico)



Genotox varied with ***season, size/health,*** *and* ***coverage of native vegetation*** *around capture site.*
Genotox observed coincide with the ***time when agrochemicals are applied*** *in the area"*

Red-legged partridges *Alectoris rufa*

Imidacloprid-treated seeds

Repeated exposure

Changes in plasma biochemistry

Changes in markers of oxidative stress

Various effects according to timing

These markers are knwon to vary with various toxicants/stressors:

- Various pesticides, other xenobiotics (e.g. organic pollutants, metals)
- Radiations
- Pathogens/parasites
- Various stressors (e.g. food depletion, reproduction investment, climatic constraints)

→ Reflect actual health status of animals

→ Lack of specificity: difficult to interpret variations (pesticides?)

→ Difficulty to link to effects at population / community level

Frixione & Rodríguez-Estrella, 2020; Elmeros et al, 2011; Lopez-Antia et al, 2015)

Lab reaching field, field reaching lab?

Apply management tools
Support decision-making

→ Challenges

- Gain representativeness in controlled experiments
- Gain inference on specific pesticide role from field surveys

Druart et al. STOTEN, 2011; Vyas et al. Environ Monit Assess, 2007)

Lab reaching field, field reaching lab?

Active biomonitoring

Examples:
Semi-field experiments
(Experimental stations)

"La Cage"

INRAE

Druart et al. STOTEN, 2011; Vyas et al. Environ Monit Assess, 2007)

Lab reaching field, field reaching lab?

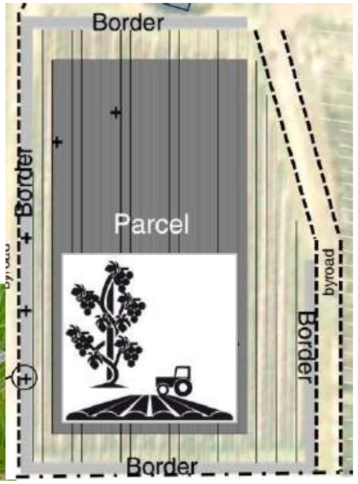
Active biomonitoring

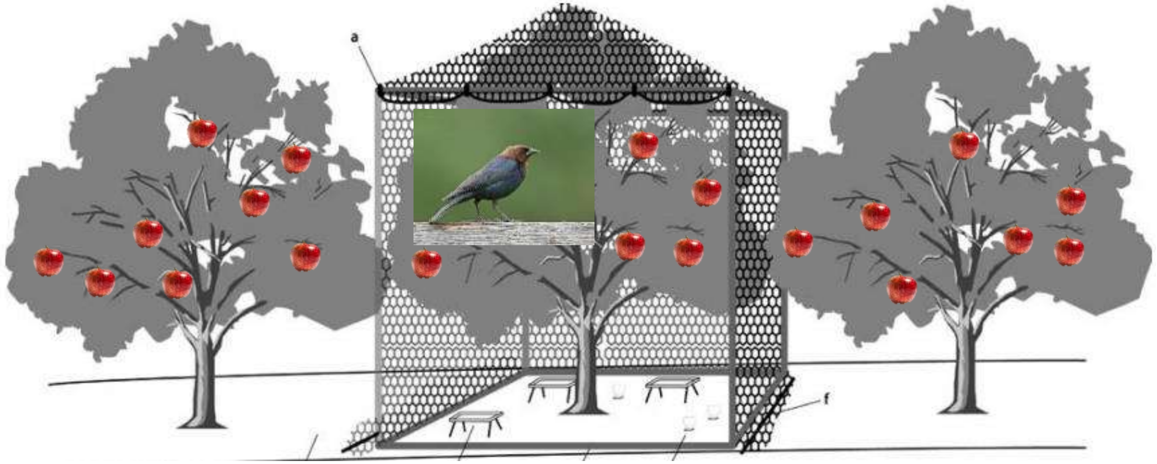
Examples:
Semi-field experiments
(Experimental stations)

"La Cage"

INRAE

Examples:
Snail caging, bird enclosure





- **Indicators:**
  - Exposure
  - Individual markers *(e.g. genotox, physiology, etc)*
  - Population parameters *(e.g. survival, reproduction, abundance, etc)*
  - Interactions *(e.g. trophic interactions)*

Druart et al. STOTEN, 2011; Vyas et al. Environ Monit Assess, 2007)

Lab reaching field, field reaching lab?

Active biomonitoring

- **Indicators:**
  - Exposure
  - Individual markers *(e.g. genotox, physiology, etc)*
  - Population parameters *(e.g. survival, reproduction, abundance, etc)*
  - Interactions *(e.g. trophic interactions)*

Examples:
Semi-field experiments
(Experimental stations)

"La Cage"

INRAE

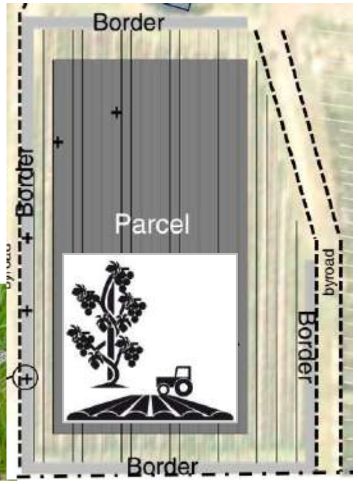
→ Semi-field experiments:

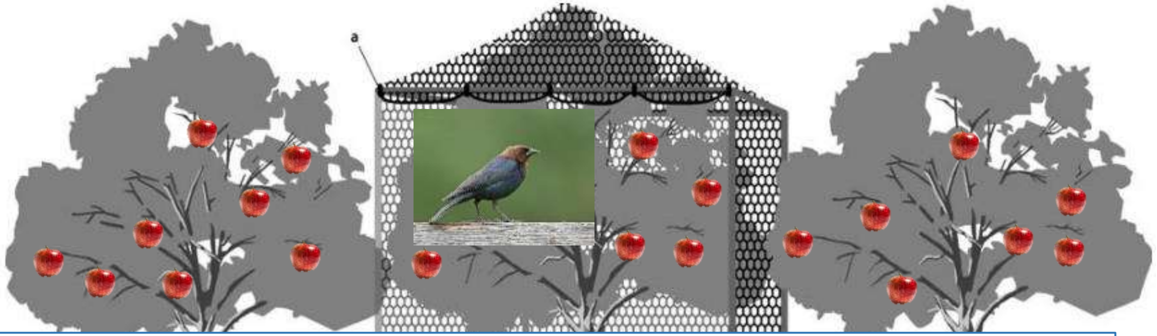
bias such as edge effects, size-effects, density-effects

Examples:
Snail caging, bird enclosure

→ Active biomonitoring:

not fully ecologically representative (e.g. life-cycle and carry-over effects, multi-stress)





→ Better ecological relevance than in lab

(real doses and practices, multiple sources, multiple exposure, actual environmental conditions)

→ Better link to specific pesticide causality than passive biomonitoring

(enclosure: movements, predation, competition, etc. are controlled; climate, practices, land use, etc. known and can be taken into account)

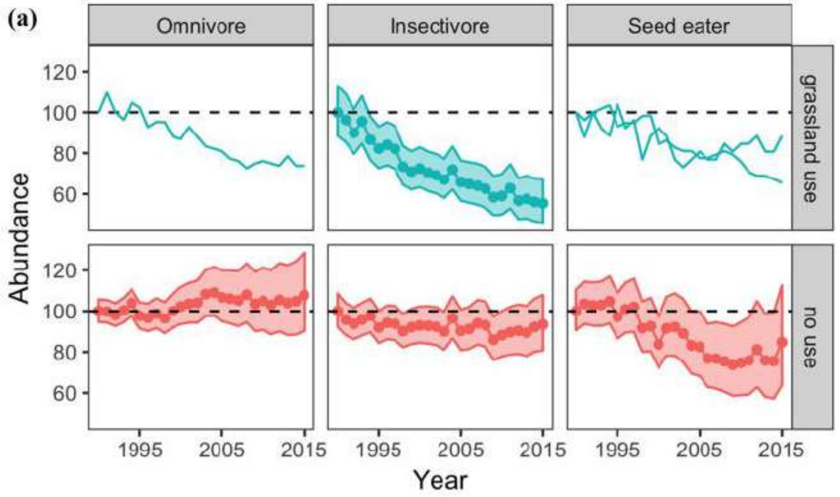
Lab reaching field, field reaching lab?

Long-term large-scale surveys
Epidemiological approaches

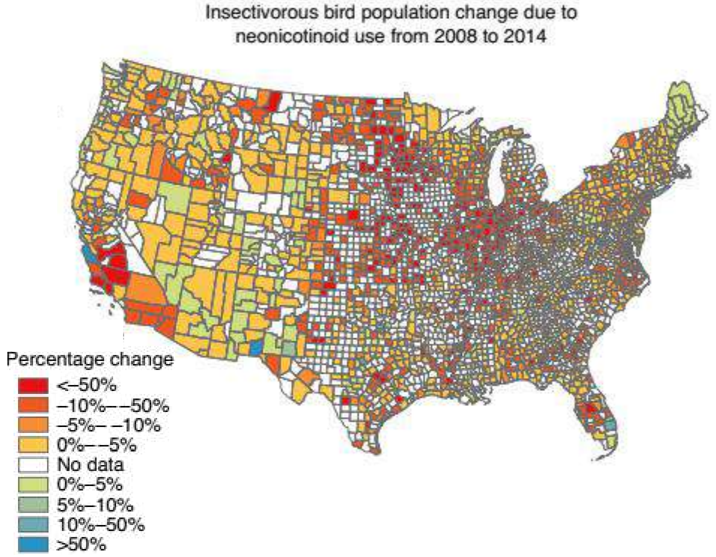
- **Indicators:**
- Trends populations/ communities *(dynamics, biological traits, etc)*
- Trends use of pesticides *(specific chemical families, specific uses, etc)*
- Links with other concomitant spatial/temporal changes (*climate, land use, etc)*
- Links with other taxa *(spatial/temporal trends, potential interactions, etc)*

Examples: National Bird Census

EU: Bird population changes according to grassland use and diet



USA: Bird population changes according to neonicotinoid use



Denmark: declines of both insects and birds


Received: 8 January 2018 | Revised: 6 March 2019 | Accepted: 18 April 2019
DOI: 10.1002/ece3.5236
ORIGINAL RESEARCH
Ecology and Evolution WILEY
Parallel declines in abundance of insects and insectivorous birds in Denmark over 22 years
Anders Pape Møller[1,2]

Bowleret al, Conserv Biol, 2019; Li et al, Nature Sustainability, 2020; Møller, Ecol Evol, 2019)

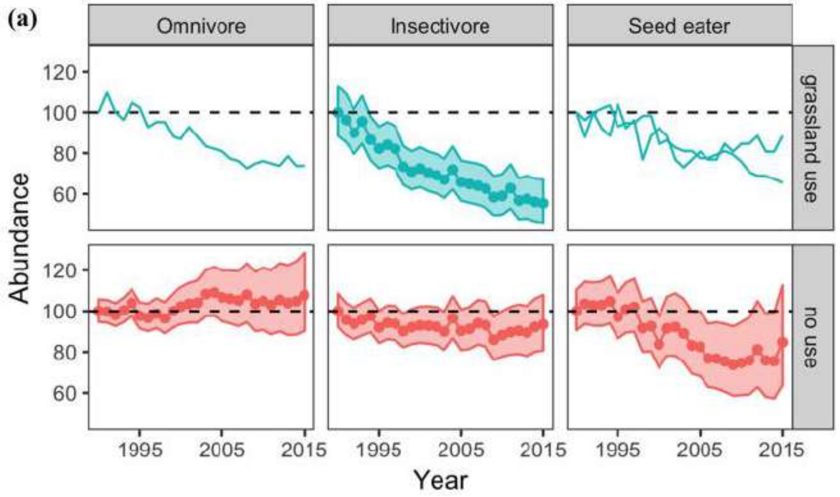
Lab reaching field, field reaching lab?

Long-term large-scale surveys
Epidemiological approaches

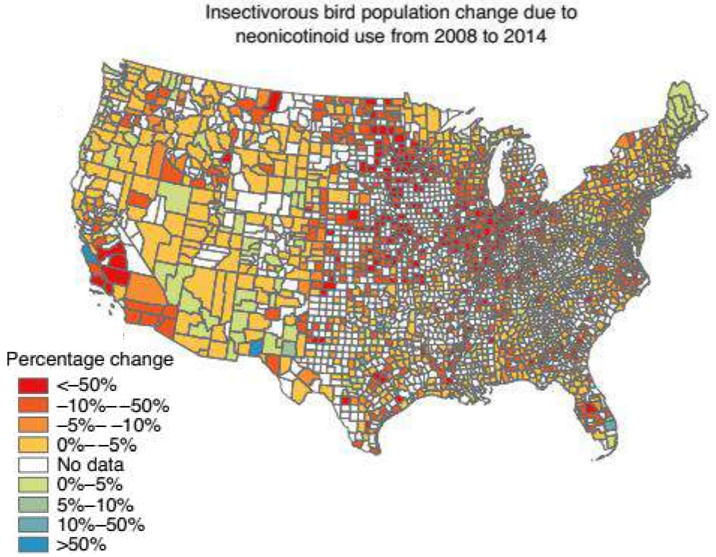
- **Indicators:**
- Trends populations/ communities *(dynamics, biological traits, etc)*
- Trends use of pesticides *(specific chemical families, specific uses, etc)*
- Links with other concomitant spatial/temporal changes *(climate, land use, etc)*
- Links with other taxa *(spatial/temporal trends, potential interactions, etc)*

Examples: National Bird Census

EU: Bird population changes according to grassland use and diet



USA: Bird population changes according to neonicotinoid use



Denmark: declines of both insects and birds


Received: 8 January 2018 | Revised: 6 March 2019 | Accepted: 18 April 2019
DOI: 10.1002/ece3.5236
ORIGINAL RESEARCH
Ecology and Evolution WILEY

Parallel declines in abundance of insects and insectivorous birds in Denmark over 22 years

Anders Pape Møller[1,2]

→ Real trends under multi-stress context & actual dynamics at relevant ecological scales
→ Independence from local/site-specific situations and temporary events
→ Statistics and meta-analyses help in disentangling/ranking the role of various factors

Bowleret al, Conserv Biol, 2019; Li et al, Nature Sustainability, 2020; Møller, Ecol Evol, 2019)

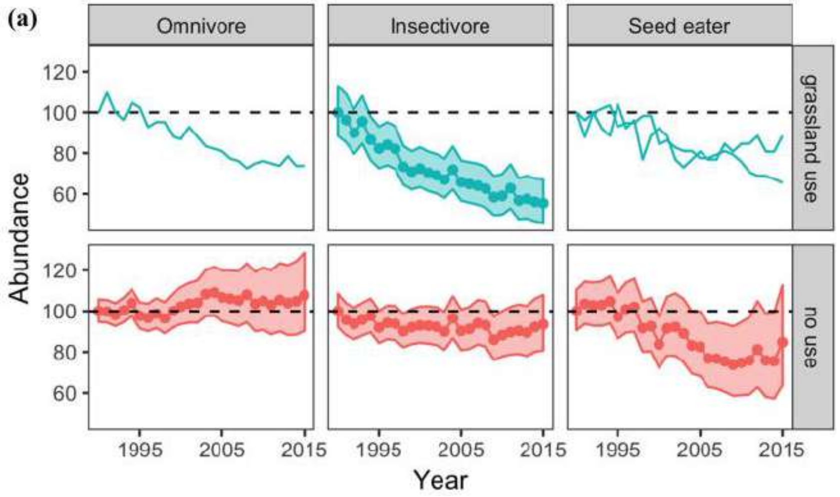
Lab reaching field, field reaching lab?

Long-term large-scale surveys
Epidemiological approaches

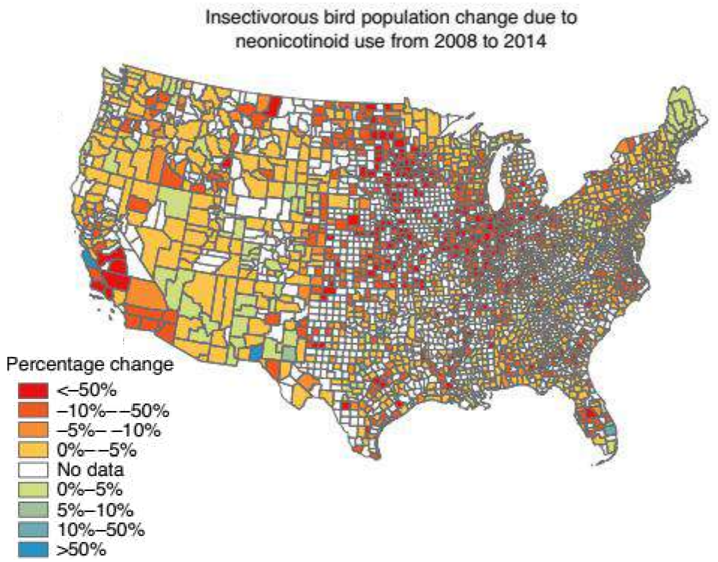
- **Indicators:**
- Trends populations/ communities
  (dynamics, biological traits, etc)
- Trends use of pesticides
  (specific chemical families, specific uses, etc)
- Links with other concomitant spatial/temporal changes
  (*climate, land use, etc)*
- Links with other taxa
  (spatial/temporal trends, potential interactions, etc)

Examples: National Bird Census

EU: Bird population changes according to grassland use and diet



USA: Bird population changes according to neonicotinoid use



Denmark: declines of both insects and birds


Received: 8 January 2018 | Revised: 6 March 2019 | Accepted: 18 April 2019

DOI: 10.1002/ece3.5236

ORIGINAL RESEARCH

Ecology and Evolution WILEY

Parallel declines in abundance of insects and insectivorous birds in Denmark over 22 years

Anders Pape Møller[1,2]

→ Real trends under multi-stress context & actual dynamics at relevant ecological scales

→ Independence from local/site-specific situations and temporary events

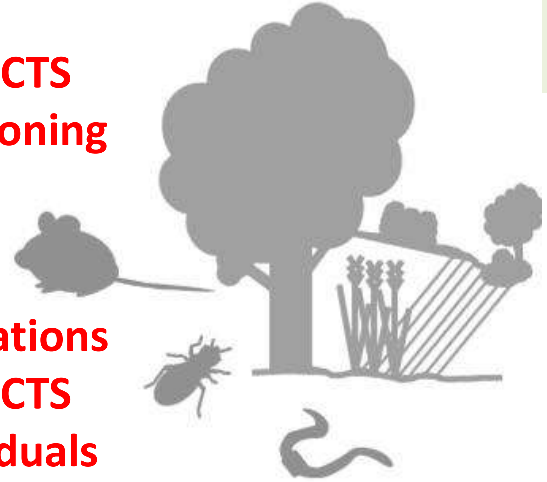
→ Statistics and meta-analyses help in disentangling/ranking the role of various factors

→ Still correlative, need for additional information (e.g. Hill's criteria)

→ Long-term trends: need for time and data accumulation before decision-making

→ Inherent issues of long-term large-scale comparisons and surveys (cf adaptive monitoring, costs)

Future directions



- Developp frameworks of complementary assessment of indicators in the field

  exposure/accumulation, individual health markers and population potential outcomes **at once**

  → link with functioning and apply on food webs

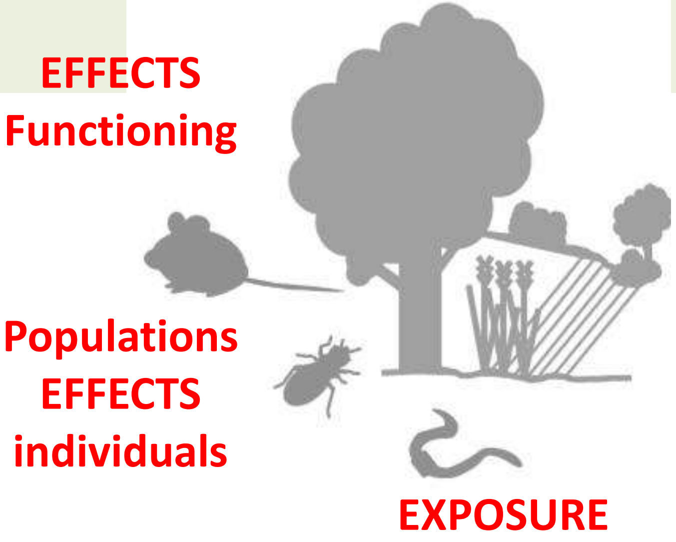
  → improve knowledge about mecanisms and understanding of impacts to allow prediction and support to management

- Create baselines and benchmarks for PPPs in environment (water, air, soil) and in organisms

  → detection molecules/practices/ecosystem at risk, survey temporal and spatial trends (regulation efficacy, hot-spot to be managed, etc.)

(Topping & Luttik Regul Tox Pharm, 2017)

Future directions



- Developp frameworks of complementary assessment of indicators in the field

  exposure/accumulation, individual health markers and population potential outcomes **at once**

  → link with functioning and apply on food webs

  → improve knowledge about mecanisms and understanding of impacts to allow prediction and support to management

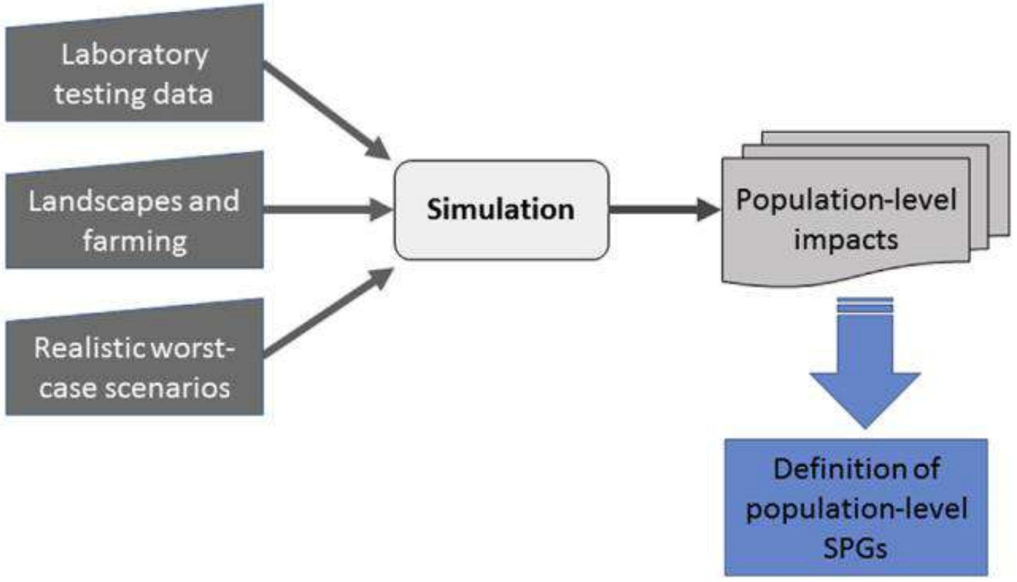
- Create baselines and benchmarks for PPPs in environment (water, air, soil) and in organisms

  → detection molecules/practices/ecosystem at risk, survey temporal and spatial trends (regulation efficacy, hot-spot to be managed, etc.)

- Use of modelling as a complement

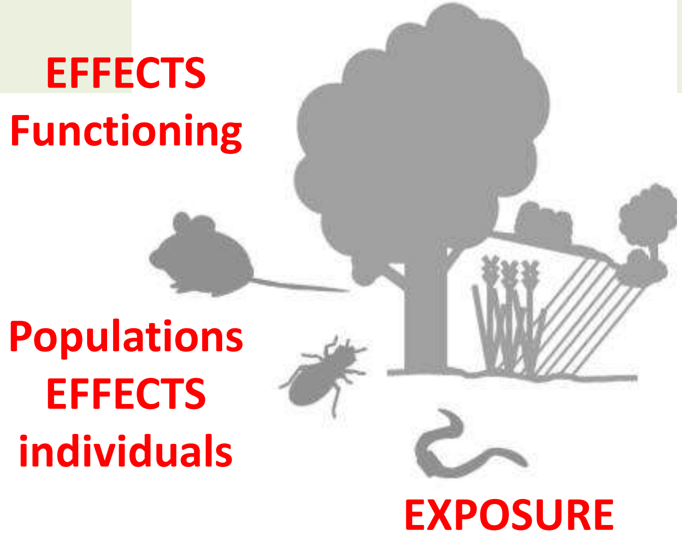
  → comprehensive and predictive approach of mechanisms (TK/TD, AOP),
  test of scenarii for spatial planning
  exploration of long-term expected trends

  → support for decision-making



(Topping & Luttik Regul Tox Pharm, 2017)

Future directions



- Developp frameworks of complementary assessment of indicators in the field

  exposure/accumulation, individual health markers and population potential outcomes **at once**

  → link with functioning and apply on food webs

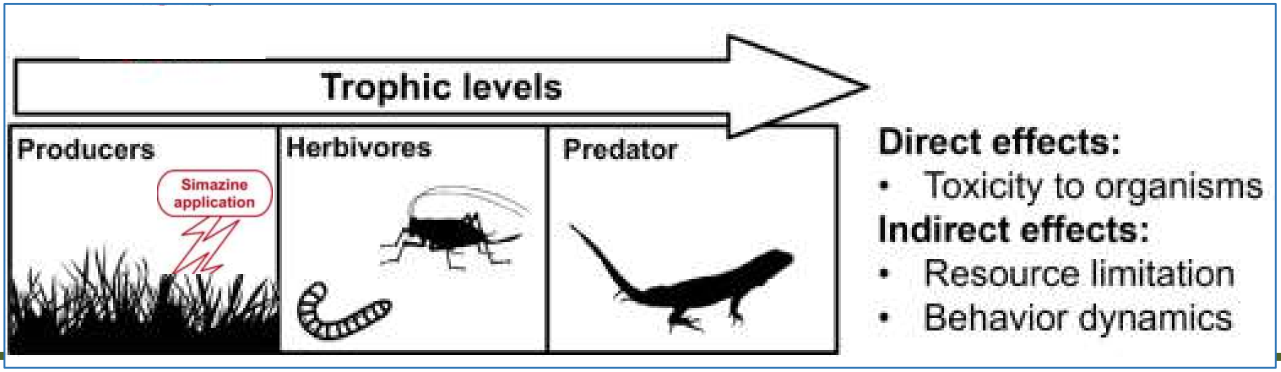
  → improve knowledge about mecanisms and understanding of impacts to allow prediction and support to management

- Enhance PNEC relevance and effect assessment to match ecological realism and adapt to 3R principles

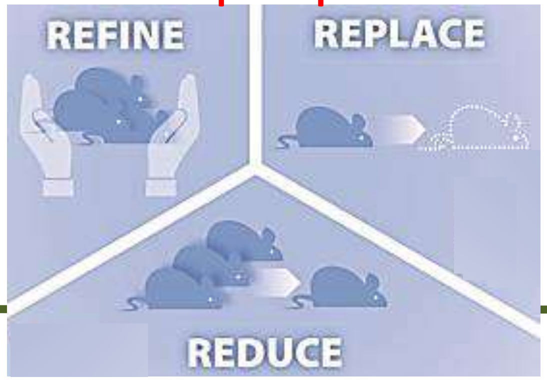
  → re-design laboratory tests to improve their representativness: natural soils, sequence of molecules and timing of exposure

  → re-think laboratory assay to link exposure to responses: assessment of bioaccumulation during tests of effects

  → improve ecological relevance direct & indirect effetcs: tri-trophic and multi-species tests

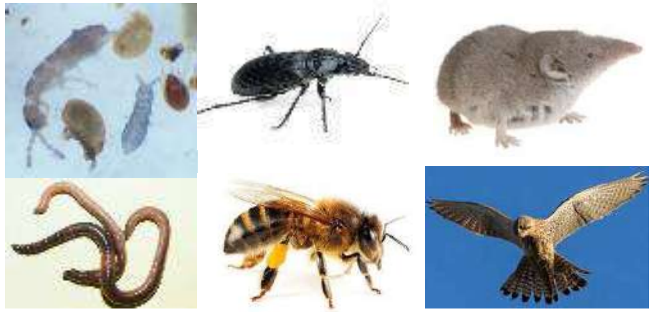


Use of animal models in scientific research
3R principles



(Arck, J Repro Immuno, 2019; Wang et al, STOTEN, 2021)

THANK YOU



Colette BERTRAND
Pôle Ecotoxicologie – UMR EcoSys
INRAe

Clémentine FRITSCH
UMR Chrono-environnement
CNRS