Development of a UK Pesticide Load Indicator

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UK Pesticide Load Indicator: story so far

Started in 2019 as a research tool, funded by Defra, in partnership with the University of Hertfordshire

- Builds on Danish PLI
- Combine information on pesticide usage and pesticide properties
- Create indicators of various pesticide 'load' measures
- Assess trends in environmental effects
- Generate information to help track and understand policy impact

Lewis, K., Rainford, J., Tzilivakis, J. and Garthwaite, D. (2021) Application of the Danish Pesticide Load Indicator to UK arable agriculture. Journal of Environmental Quality, 50(5), 1110-1122. DOI: 10.1002/jeq2.20262

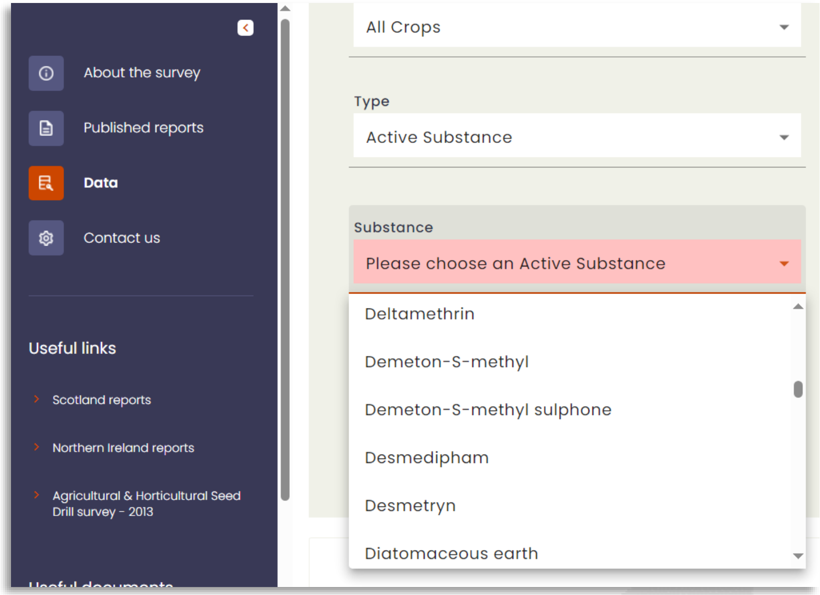
Pesticide Usage Survey

Original thinking... applied

https://pusstats.fera.co.uk/home

Provides representative sample of plant protection products applied in UK

- Used to estimate national and regional statistics (area treated, mass applied)
- Rolling program including arable, outdoor vegetables, soft fruit, top fruit, grassland and fodder
- For a given crop type and year, total usage is estimated from **stratified sampling by region and farm size** + June survey totals (or other sources for devolved authorities)



Results Export as CSV

Crops are not surveyed annually. To see which crops were surveyed in each year Click here .

Year	Survey	Region	Crop group	Active Substance	Total Area Treated (ha) 1	Total Weight Applied (kg)
2022	Arable crops	United Kingdom	All	Deltamethrin	14,604	64
2020	Arable crops	United Kingdom	All	Deltamethrin	25,492	145
2018	Arable crops	United Kingdom	All	Deltamethrin	54,112	327
2016	Arable crops	United Kingdom	All	Deltamethrin	41,846	260

Pesticide Properties Database

For each active substance, extracted 4 measures of fate

- persistence; surface and groundwater mobility; bioaccumulation

And 16 measures of ecotoxicity

- algae, aquatic plants, aquatic invertebrates, fish, birds, earthworms, bees, mammals, and other arthropods

ECOTOXICOLOGY

Terrestrial ecotoxicology

Property	Value	Source; quality score; and other information	Interpretation
Mammals - Acute oral LD_{50} ($mg\ kg^{-1}$)	> 2000	A5 Rat	Low
Mammals - Short term dietary NOEL ($mg\ kg^{-1}$)	-	-	-
Mammals - Short term dietary NOEL (ppm diet)	-		-
Mammals - Chronic 21d NOAEL ($mg\ kg^{-1}\ bw\ d^{-1}$)	≥ 939	A5 Rat Reproductive NOAEL	Low
Birds - Acute LD_{50} ($mg\ kg^{-1}$)	> 2000	A5 *Anas*	Low

Pesticide Properties Database

- **Fate metrics:**
  - Persistence (soil DT_{50})
  - Surface water mobility (Kfoc/Koc)
  - Groundwater mobility (GUS)
  - Bio-concentration factor (BCF)
- **Ecotoxicity metrics:**
  - Algae acute (EC_{50})
  - Aquatic plants acute (EC_{50})
  - Daphnia acute (EC_{50})
  - Daphnia chronic (NOEC)
  - Fish acute (EC_{50})
  - Fish chronic (NOEC)
  - Birds acute (LD_{50})
  - Birds chronic (NOEL)
  - Worms acute (LC_{50})
  - Worms chronic (NOEC)
  - Bees contact (LD_{50})
  - Bees oral (LD_{50})
  - Mammals acute (LD_{50})
  - Mammals chronic (NOAEL)
  - Parasitic wasps (LR_{50})
  - Predatory mites (LR_{50})

Data extracted from the Pesticide Properties Database (PPDB): http://sitem.herts.ac.uk/aeru/ppdb/en/
When data are missing for substance, a protocol exists to derive the data, including using data for related substances and/or using means for the respective 'chemical group'.

Creating the indicators

1. Scale each PPDB measure (0-1) to give a relative score

2. Use PUS to estimate pesticide use
   - nationally, regionally, by crop, and by pesticide type

3. Multiply the substance score by estimated pesticide use

4. Sum across all substances
   - But keep the intermediate information to visualise contribution of individual substances to the load

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Original thinking... applied

PLI visualisation tool – example for arable crops

Select two years to compare

Select the reference year to benchmark against: 2010

Select the target year for comparison: 2018

Select the target percentage: 10%

Relative Change in Load Metrics between 2010 & 2018
[All Arable crops; allregions; All Pesticides]

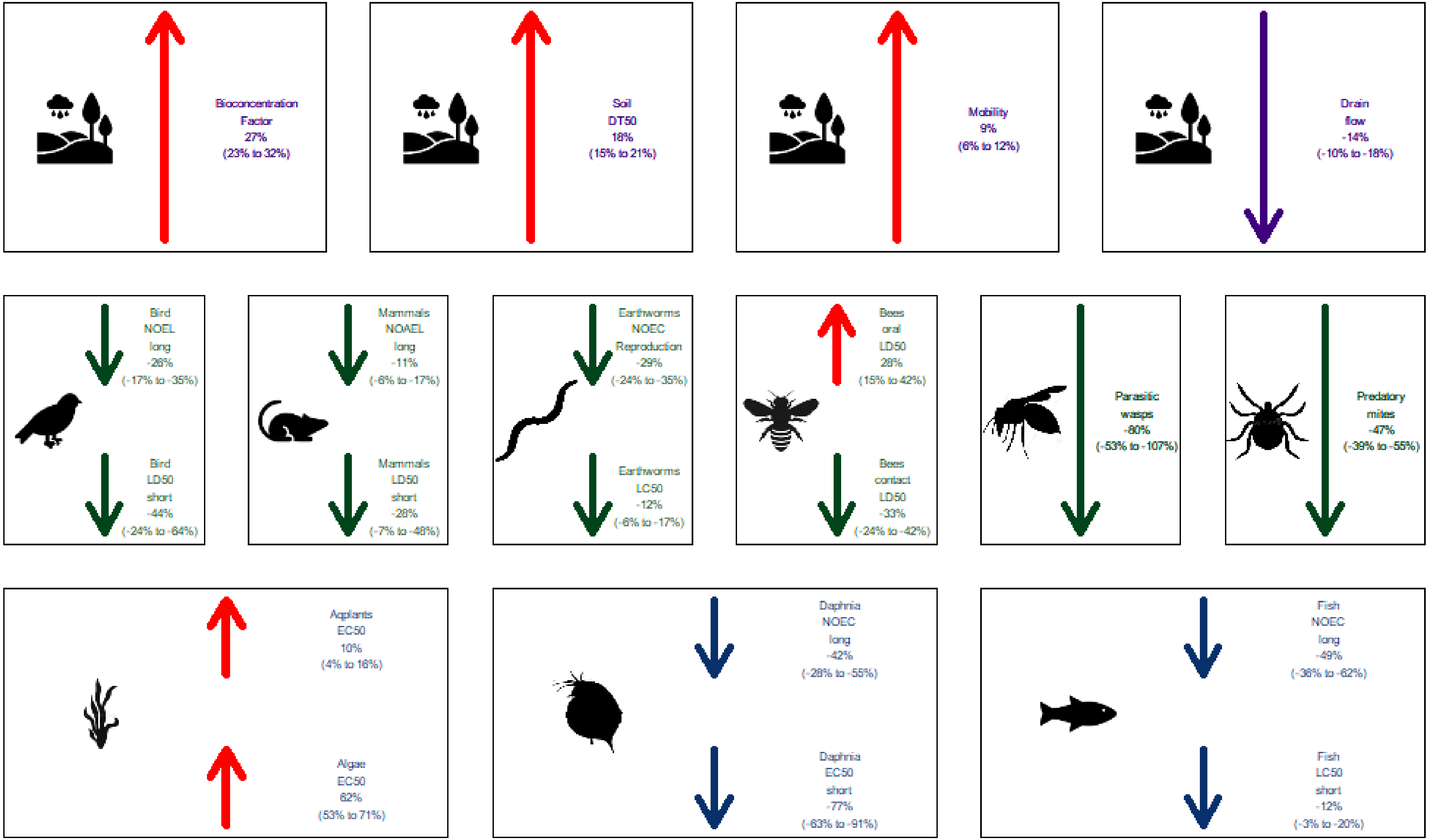
Load has reduced by at least 10%	Load reduced by less than 10% [lower interval]	Load has increased
Drain flow **Bird LD50 Actute Toxicity** **Bird NOEL Chronic Toxicity** **Earthworms NOEC Reproduction** **Bees contact LD50** **Parasitic wasps** **Predatory mites** **Fish NOEC Chronic Toxicity** **Daphnia EC50 Actute Toxicity** **Daphnia NOEC Chronic Toxicity**	**Mammals LD50 Actute Toxicity** **Mammals NOAEL Chronic Toxicity** **Earthworms LC50** **Fish LC50 Actute Toxicity**	**Bioconcentration Factor** **Soil DegT50** **Mobility** **Bees oral LD50** **Algae EC50** **Aqplants EC50**

PLI visualisation tool – example for arable crops

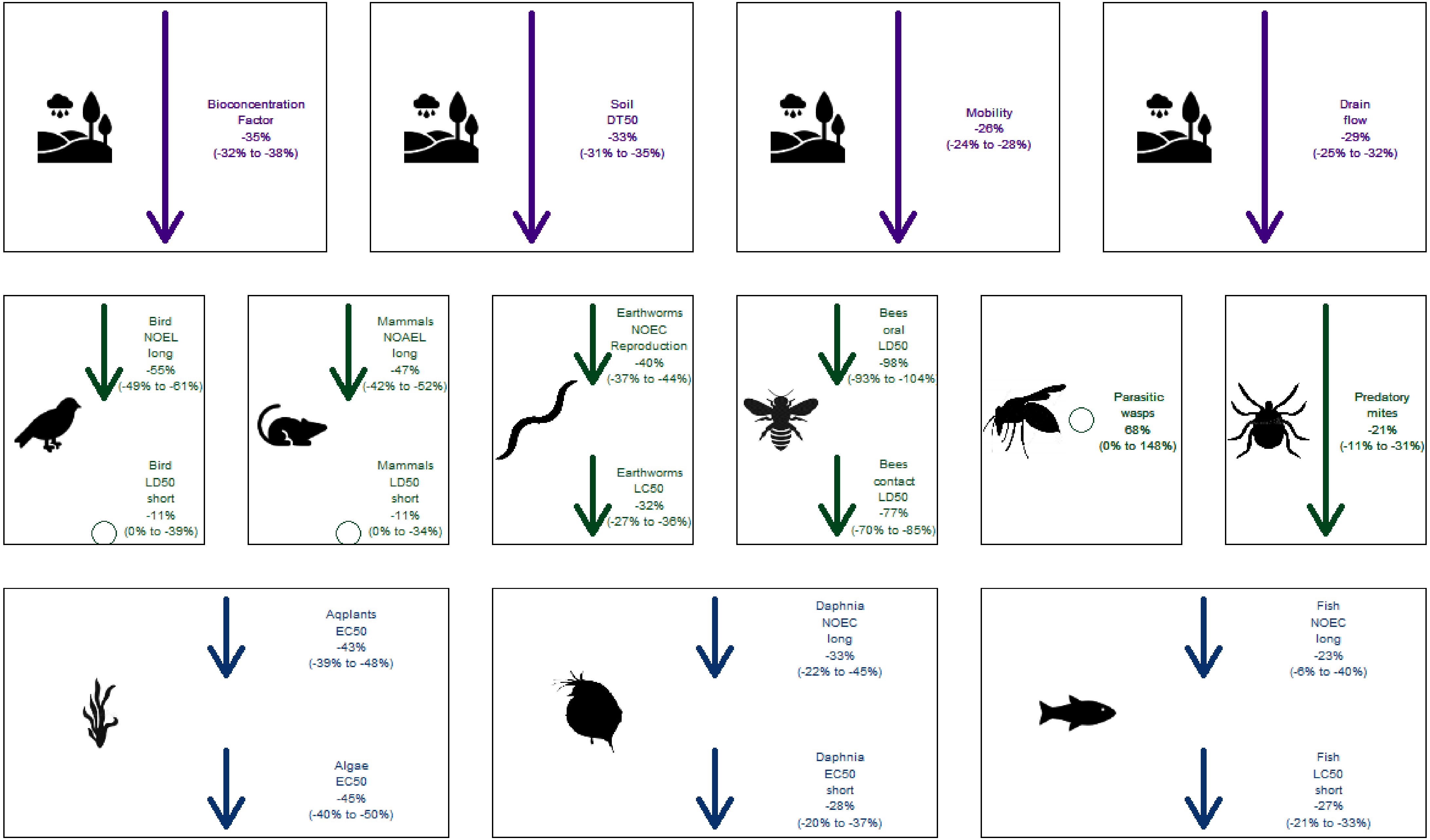
Original thinking... applied

Relative Change in Load Metrics between 2018 & 2020
[All Arable crops; allregions; All Pesticides]

Load has reduced by at least 10%	Load reduced by less than 10% [lower interval]	Limited net change in Load
Bioconcentration Factor Soil DegT50 Mobility Drain flow Bird NOEL Chronic Toxicity Mammals NOAEL Chronic Toxicity Earthworms LC50 Earthworms NOEC Reproduction Bees contact LD50 Bees oral LD50 Predatory mites Fish LC50 Actute Toxicity Daphnia EC50 Actute Toxicity Daphnia NOEC Chronic Toxicity Algae EC50 Aqplants EC50	Fish NOEC Chronic Toxicity	Bird LD50 Actute Toxicity Mammals LD50 Actute Toxicity Parasitic wasps



2010–2018 Changes (relative % increase or decrease)



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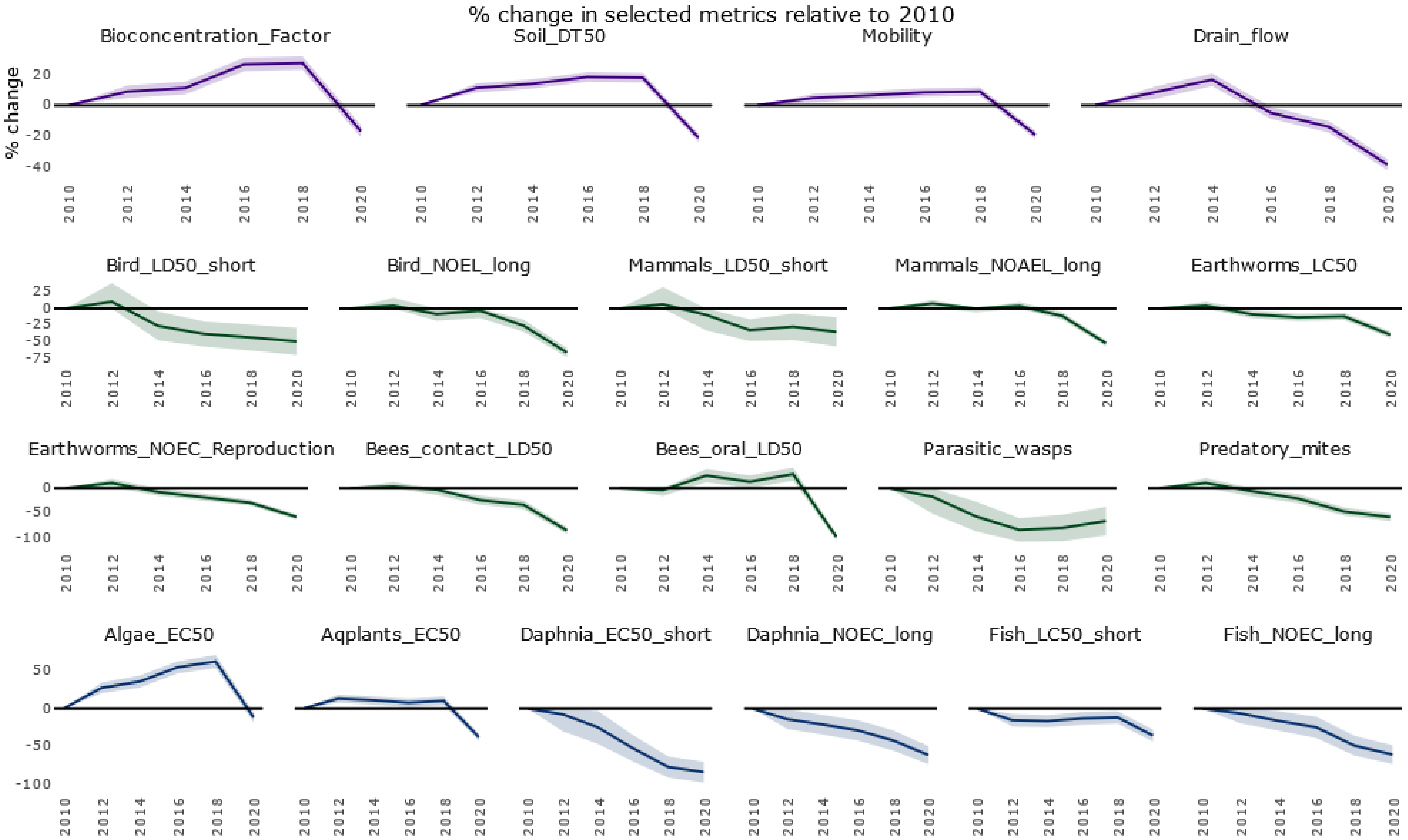
2018–2020 Changes (relative % increase or decrease)



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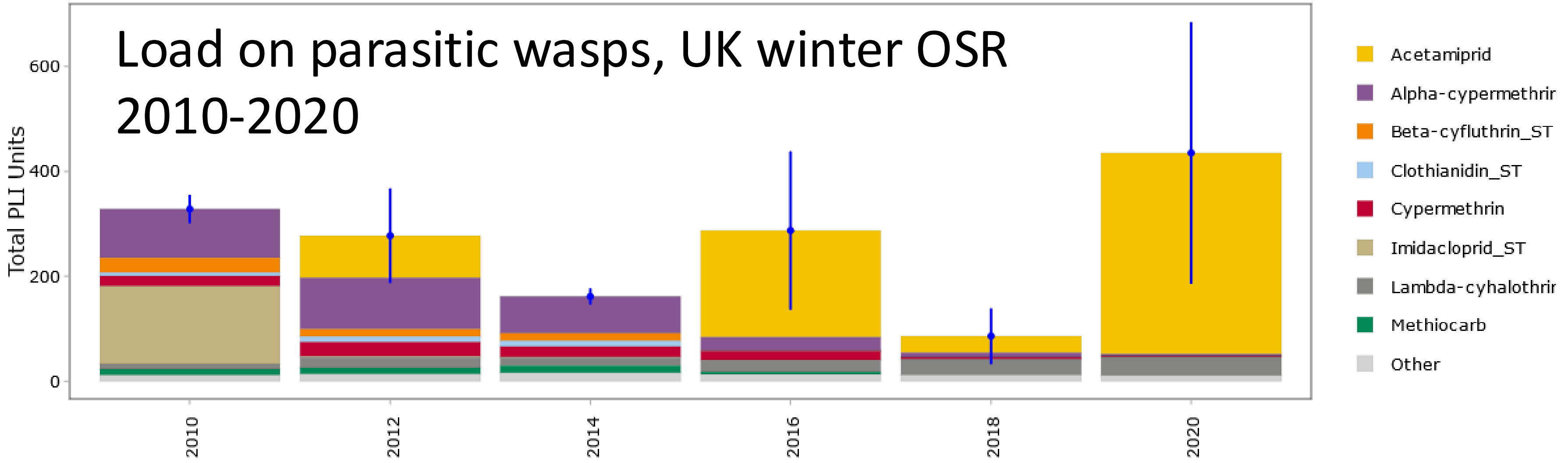
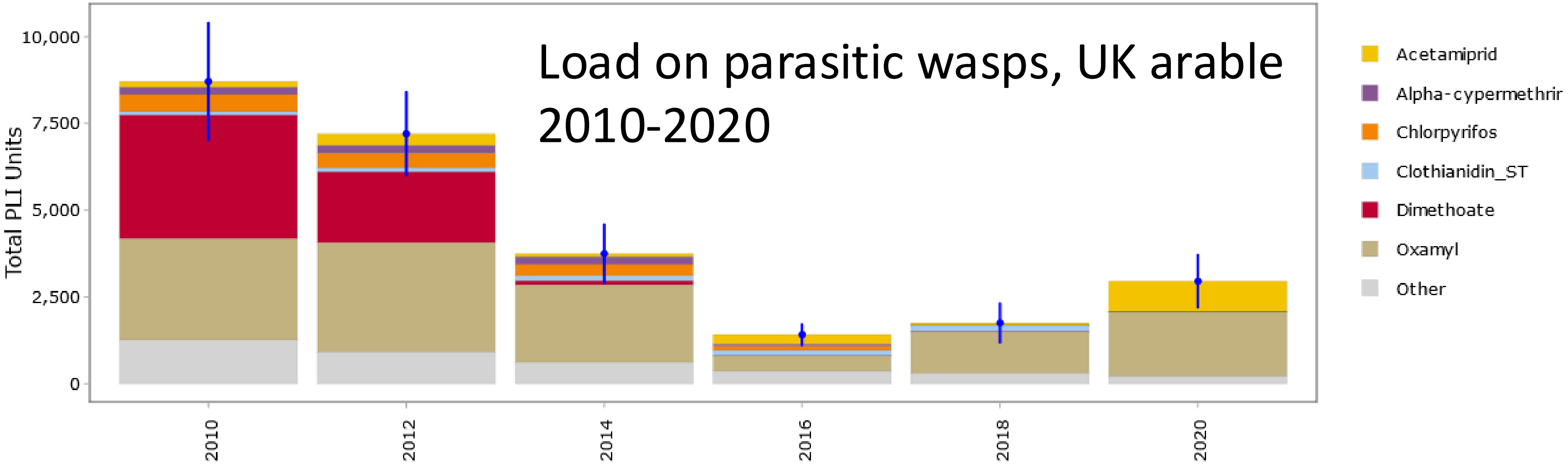
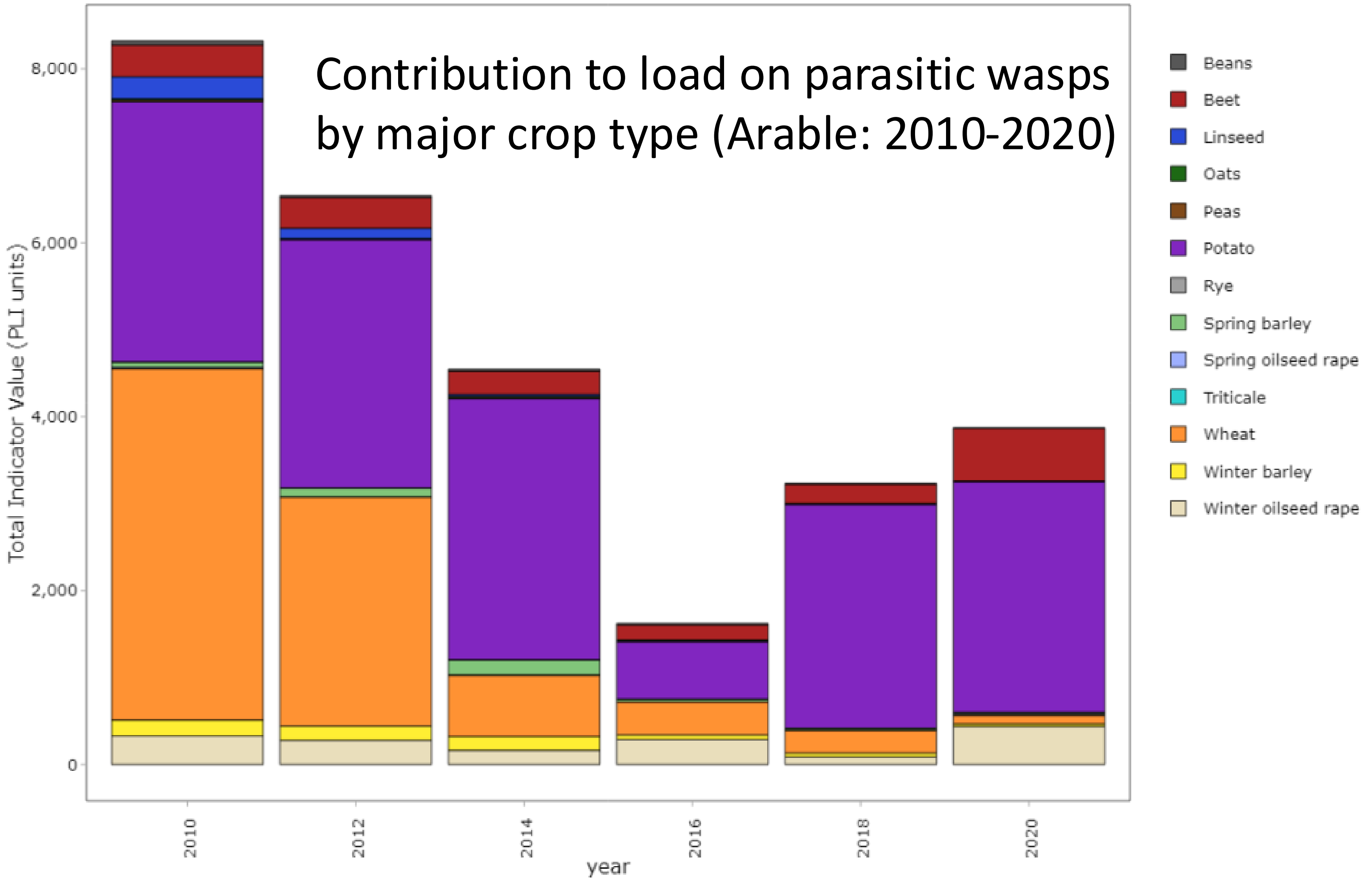
PLI visualisation tool - examples





PLI visualisation tool - examples



Limitations of the PLI

- Only an indicator. Doesn't represent real effects and has no units
  - Processes not modelled (bioaccumulation, exposure, mitigation)
- Yearly variations in usage may mask effects from policy interventions
  - 2020 good example, usage severely influenced by weather
- Doesn't include all possible hazards
  - Protocol developed to handle missing information and to decide which substances are out of scope
- Uncertainty calculations are less reliable for small samples (e.g. specific region/crop/pesticide combinations)

Comparisons with other pesticide indices

- Danish PLI
  - Developed by Danish government, used to support taxation of pesticide use
  - Aggregation across multiple measures (human, fate, ecotoxicity), weighted sum with weights assigned to each component – based on subjective judgement/importance
  - Includes metrics for human health (1), environmental fate (3) and ecotoxicity load (12)
  - Standardised scores from 0 (least toxic) to 1 (most toxic) are derived. UK PLI uses simpler linear scaling for ecotoxicity scores to prevent single extreme-case substances skewing the overall metric

Comparisons with other pesticide indices

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Original thinking… applied

- TAT – Total Applied Toxicity
  - Substances weighted according to regulatory threshold limits (RTL) rather than hazard limits for individual taxa. 'Worst case' study, rather than taxa- and method-specific study.
  - Factor (e.g. 10, 100) can be applied as weights to account for species sensitivity
  - Difference in usage data collection (e.g. sales versus applied amounts)
  - Slightly different versions applied in USA (Schulz et al, 2021) and Germany (Bub et al, 2023), attempt to align with relevant risk-assessment processes
  - Potentially simpler to apply in practice, but less transparency and difficult to properly account for missing values
  - Fate (persistence, mobility, bioaccumulation) not included

Plans for 2024/5 and beyond

- Phase 5 added 2022 survey data and some historical surveys
  - Identified need for further development – to be worked through in Phase 6
- More improvements to the user interface – user-friendly features and flexibility (including data download)
- Improve method for quantifying uncertainty

- Add new surveys as they become available – Up-to-date information on trends
- Defra to decide how PLI information can be made more widely available
  - Working with devolved authorities
  - Use in research projects – e.g. link with trends in biodiversity indicators and real environmental outcomes
  - Incorporate related international developments on indicators, for harmonisation