Modelling the costs of chemical impacts on wildlife populations

The case of peregrine falcons (Falco peregrinus) exposed to PBDEs

CADASTER Workshop
08-09 October 2012
Background

REACH

• Protection of human health and the environment

• Enhance innovation and competitiveness of the EU chemicals industry

→ risks versus benefits of chemicals
Background

• Cost–benefit analysis (CBA)

• External costs: costs not included in the market price

→ how to quantify costs of chemical impacts on non-market ecosystem properties?
Aim

Quantify the costs of chemical impacts on wildlife populations
Approach

- Matrix population model
- Year-to-year population dynamics based on a **transition matrix**
- Vital rates: growth, survival and fecundity per age/stage class
- Vital rates influenced by population density and exposure to chemicals

→ transition matrix as function of population density and exposure concentrations
Approach

- Dominant eigenvalue of the transition matrix is the population growth rate $\lambda$
- Right eigenvector of the matrix is the stable age or stable stage distribution

→ calculate equilibrium population per toxicant exposure concentration:
  solve the transition matrix for $\lambda = 1$

→ if equilibrium population < user-defined minimum:
  calculate number of individuals needed to restore the equilibrium population

→ replacement costs
Case study

Costs of PBDE impacts on a population of peregrine falcons

Why this case?

- Data availability
  - population parameters
  - exposure concentrations
  - toxicological data
  - replacement cost estimates

- High PBDE concentrations in eggs
Case study – transition matrix

- Three life stages: juveniles, non-breeding birds, breeders
- Fecundity modelled as function of exposure to PBDEs
Case study – transition matrix

- Density-dependence modelled as the probability of a non-breeding bird to acquire a breeding territory
Case study – transition matrix

Transition matrix

\[
A = \begin{bmatrix}
0 & S_{nb} F C P_b & S_b F C \\
S_j & S_{nb} (1 - P_b) & 0 \\
0 & S_{nb} P_b & S_b
\end{bmatrix}
\]

- *F*  fecundity
- *S*  survival
- *P_b*  probability of a non-breeder to acquire a breeding territory
- *j*  juvenile
- *nb*  non-breeding sub-adult
- *b*  breeding adult
Case study – model testing

• Simulate population from 1981 through 2007 and compare with observations

• Exposure concentrations:

![Graph showing the logarithmic concentrations of PBDEs in eggs from 1978 to 2006.](image)
Case study – model testing

• Population development as function of exposure to PBDEs:
Case study – model testing

- Population development as function of exposure to PBDEs and DDE:

![Graph showing population development over years with reference population size and observations.](image-url)
Case study – results

Equilibrium population size (breeders) in relation to PBDE exposure

- Stable population
- Growing population
- Declining population

PBDEs in eggs (µg·g^{-1} fresh wt)

Number of breeding adults
Case study – results

Number of young birds needed per year

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<th>Number of young birds per year</th>
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PBDEs in eggs ($\mu$g·g$^{-1}$ fresh wt)
Case study – results

Costs per year

PBDEs in eggs (μg·g⁻¹ fresh wt)

- Nb = 50
- Nb = 250
- Nb = 316

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Conclusions

• Quantitative approach to calculate replacement costs

• Results are population-specific:
  - population parameters (fecundity, survival, density-dependence)
  - concentration-response curve (EC50 and slope)
  - replacement costs per individual

• Density-dependence may mask toxicant impacts on wildlife populations

• Multi-stressor approach needed
Outlook

• Application to other species

• Application to other stressors (including interactions)
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