Using predatory birds to monitor long term trends of PBDEs in the UK

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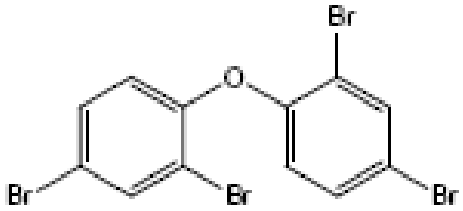
Overview

- PBDEs
  - What they are
  - Usage and consumption
  - Environmental occurrence
  - Why we should care



BDE47 (2,2',4,4'-)

- Environmental monitoring
- Using apex predators (birds and their eggs)
- Results from two UK birds
  - Spatial trends (marine, terrestrial)
  - Temporal trends
  - Toxicity

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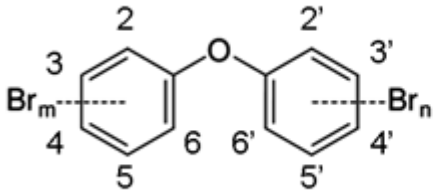
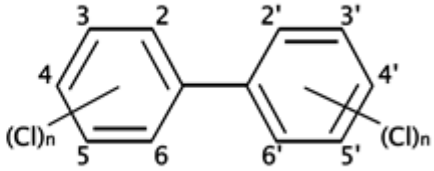
PBDEs

- Additive flame retardants
  - Not chemically bonded to host matrix
- Disrupt combustion
  - Dilute flammable gases
  - Scavenge free radicals
- Used in high impact plastics, textiles, furniture foam
- Release to environment from product manufacture, use, disposal
  - Continual release through normal usage

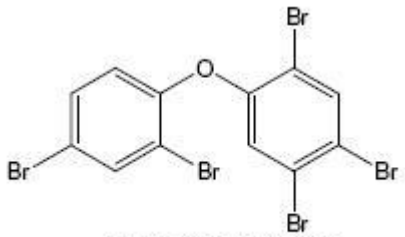
PBDEs

- Structurally and chemically analogous to PCBs





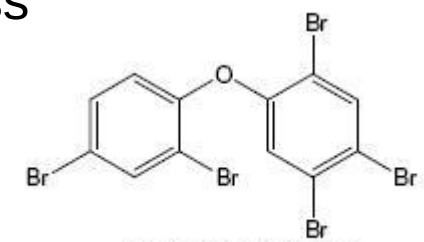
- 209 theoretical congeners
  - 28, **47**, **99**, **100**, **153**, **154**, **183**, 196,197, 201, 202, 203, **209**
- Technical products utilise a mixture of congeners
  - PeBDE (99,47), OBDE (183, 209), DeBDE (209)



BDE99 (2,2',4,4',5-)

Drivers for changes in PBDE usage

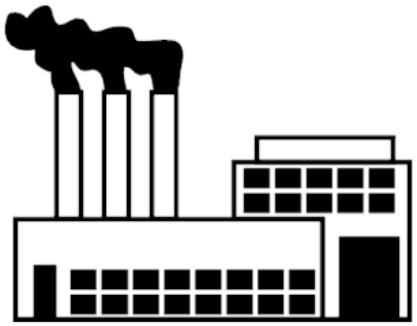
- Series of fire disasters in the UK and Ireland
  - Summerland 1973, Taunton train fire 1978, Woolworth's department store fire 1979, Stardust discotheque fire 1981, Bradford City football stadium fire 1985, King's Cross Underground fire 1987
  - Over 150 people died
  - Rapid spread of fire, production of toxic smoke



BDE99 (2,2',4,4',5-)

- Furniture and Furnishings Fire Safety Regulations (FFFSR), 1988
- RoHS, EEC Directive EEC793/93
- EEC proposes ban on penta- and octa-BDEs, 2001

PBDE consumption



Prevedouros et at., 2004

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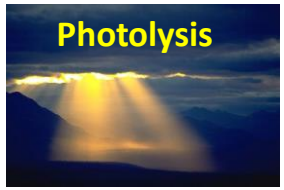
Cycling of PBDEs



Wet & dry Deposition

Agricultural Soils

Shipping / Drilling

Volatile/ particulate emissions/dust

Consumption & metabolism by plants & animals

Commercial products

Production /incorporation into consumables

Consumption and metabolism by humans

Water courses

Industrial effluents

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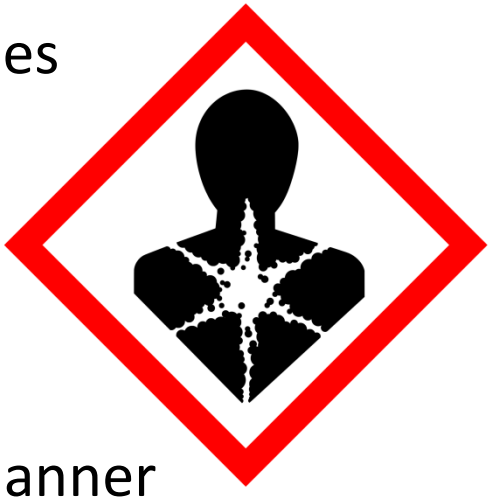
PBDEs are everywhere

- Persistent
- Subject to long range transport
- Lipophilic and bioaccumulative
- Are toxic

- Found in all environmental compartments
- Found in places where they have never been used
- Found in unborn children
- Growing evidence of toxicity

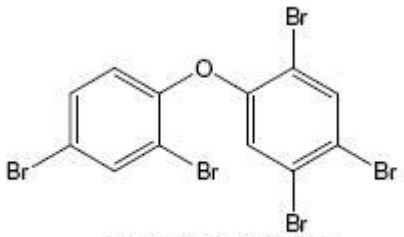
Examples of human toxicity

- Chromosomal damage and genotoxicity at low doses
  - (Barber at al., 2006; Llabjani et al., 2011)
- Cytotoxicity
  - (He et al., 2008)
- Apoptosis and genotoxicity in a dose dependant manner
  - (Song et al., 2009;
- Cellular changes in DNA/RNA reflecting a genotoxic mechanism – (Llabjani et al., 2011)
- Competitive binding with T4 to plasma thyroid hormone-transporter transthyretin (TTR)
  - (Athanasidou et al., 2008; Lacorte & Ikonomou, 2009; Ryden et al., 2012)



Specific examples in predatory birds

- Henny et al., (2009)
  - Osprey
  - Reduced productivity (concs >1ug/g wwt)

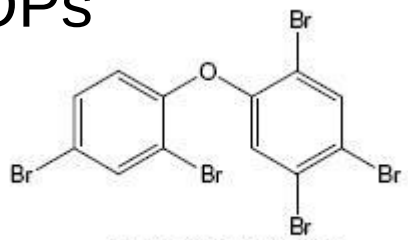


BDE99 (2,2',4,4',5-)

- McKernan et al., (2009)
  - American kestrel
  - Decreased pipping and hatching success (concs 10-20ug/g)
- Fernie et al., 2005, 2008, 2009 ; Marteinson et al., 2010
  - American kestrel - Concs 0.2 – 2.1 ug/g)
  - Delayed hatching, reduced pair bonding, shell thinning
- Llabjani et al., 2012
  - DNA/RNA effects
  - Low doses (10^{-9}, 10^{-12} M)

Legislation

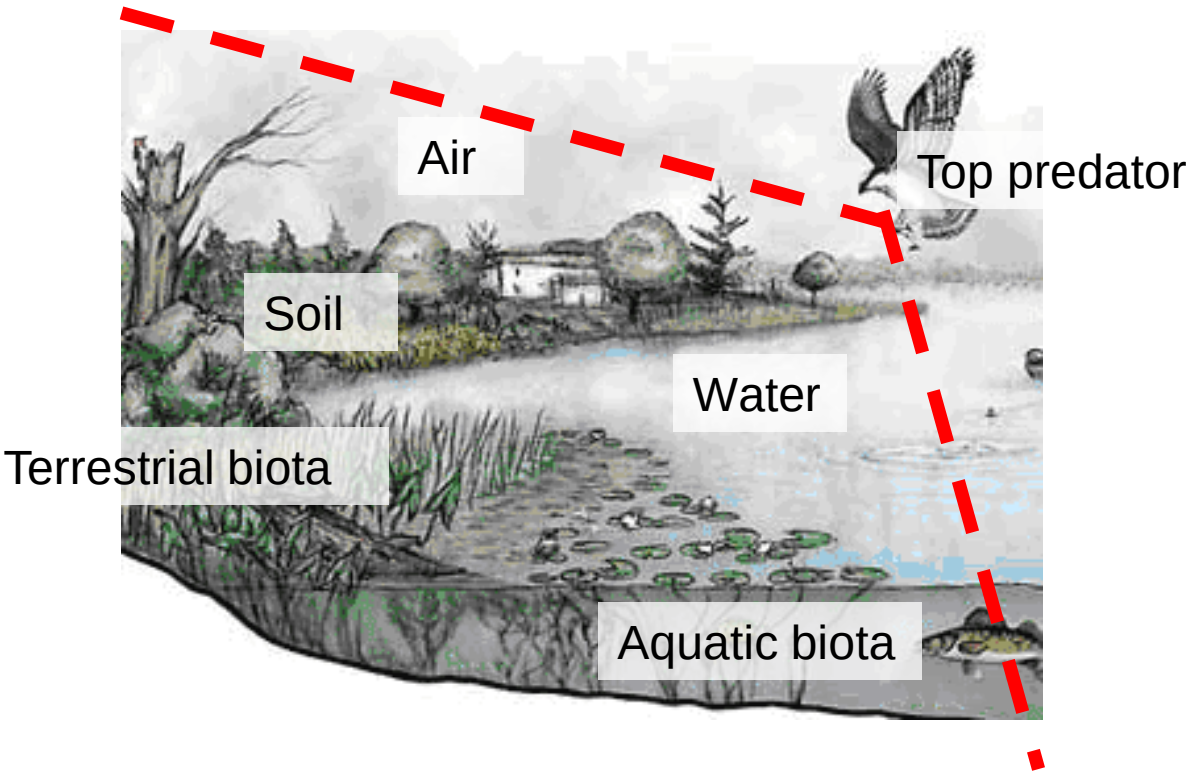
- Penta and Octa BDE mixtures now ‘banned’
- Inclusion into the Stockholm Convention on POPs
  - Tetra, Penta, Hexa, Hepta BDEs
  - Annex A (Elimination)
    - OC pesticides and PCBs



BDE99 (2,2',4,4',5-)

- Deca BDE now prohibited in EU in electrical goods
  - ~80% of usage
  - Subject to voluntary phase-outs in the US
- All formulations still in circulation in consumer goods
- Reoccurrence through recycled plastic?

Environmental sampling



- Occupy a high trophic position
  - Representative of a whole ecosystem

PBMS

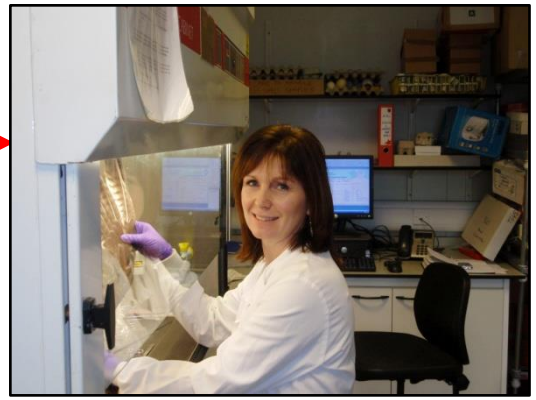
- Long term, national scale
- Funded by CEH, NE, EA, CRRU, RSPB
- Chemical surveillance and monitoring in *sentinel* species
- SGARs, POPs, Trace & toxic metals, PAHs

- Aims: identify hazards, assess risk, quantify environmental drivers, inform policy, evaluate mitigation, assess risks to high priority species
- Tissue and egg archive for monitoring and research

Predatory birds as Biomonitoring tools

- Why use predatory birds?
  - High trophic position
  - Integrated sentinel – more representative of the ecosystem as a whole
  - Sparrowhawks = terrestrial
  - Gannets = Marine
- Why use eggs?
  - Consistent media
  - Easy to collect
  - Long running archive ~1970-present
  - Good accumulators of lipophilic contaminants

How it works

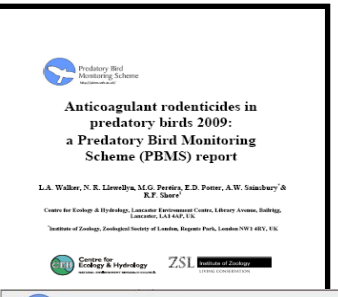


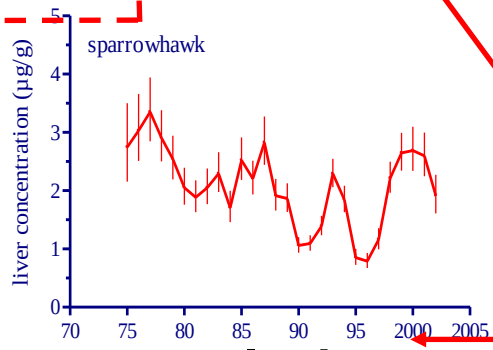
Volunteer submission

PM examination

Sample archive

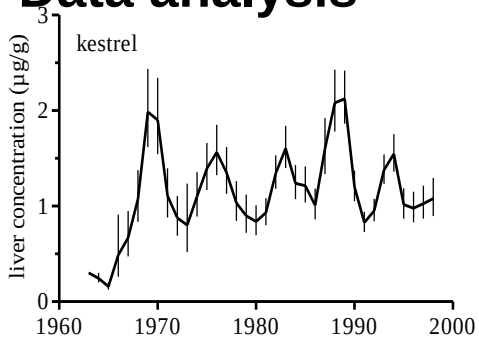
Publication





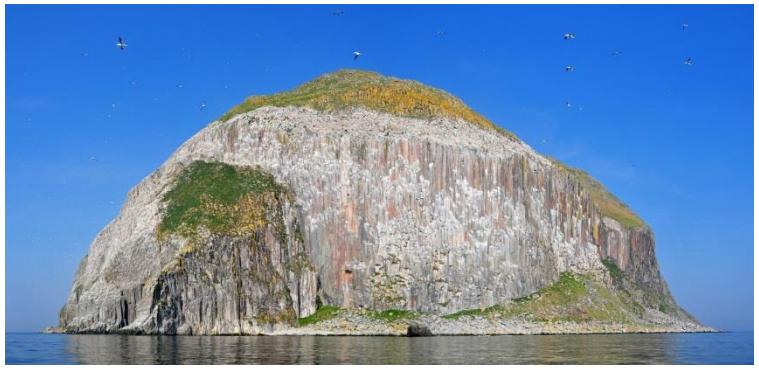
Chemical analysis

Data analysis



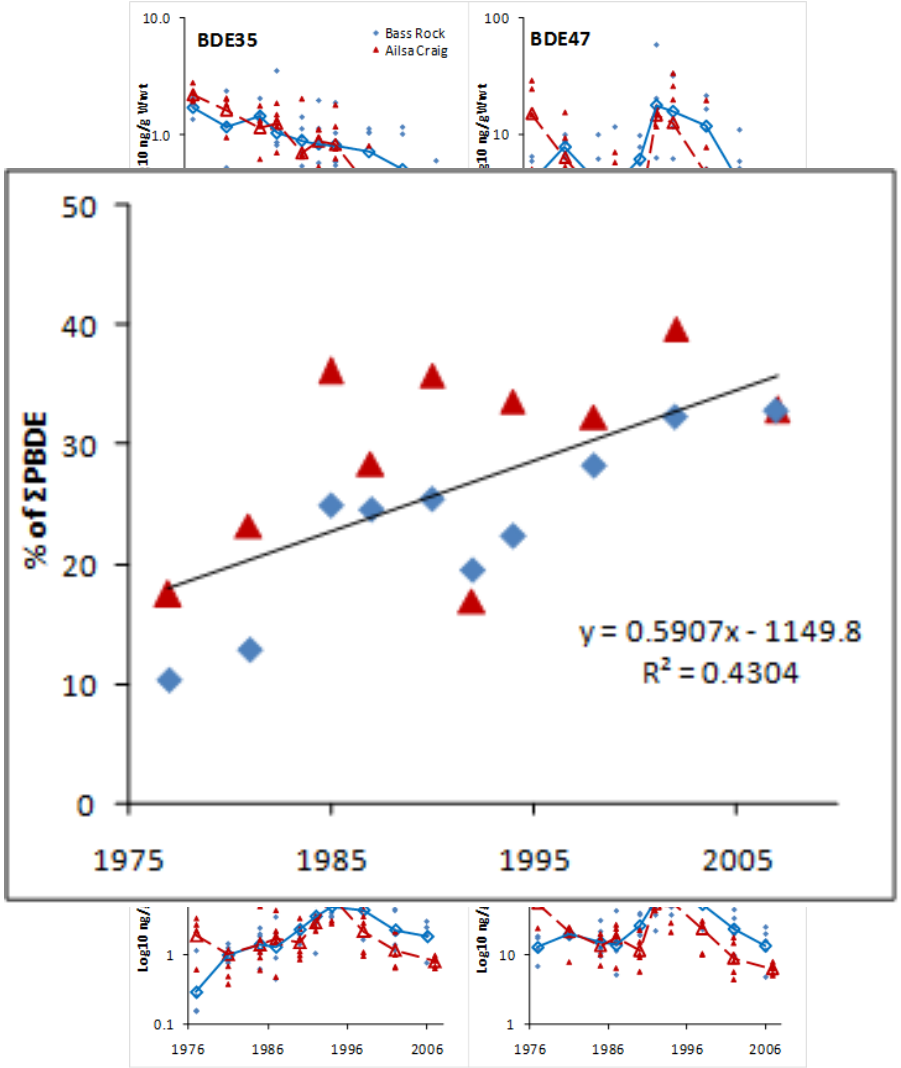
Study 1 - Gannets

- Marine sentinels
  - Two colonies; Bass Rock and Ailsa Craig
  - Historically contaminated waters
  - Eggs from 1977-2007
- Specific aims
  - Spatial differences
  - Temporal trends
    - PBDE concentration
    - PBDE congeners
    - BDE209 was not analysed as a 209 was not detected by Leslie et al., 2011 in a subsample of these eggs
- Toxicity
  - Shell thickness



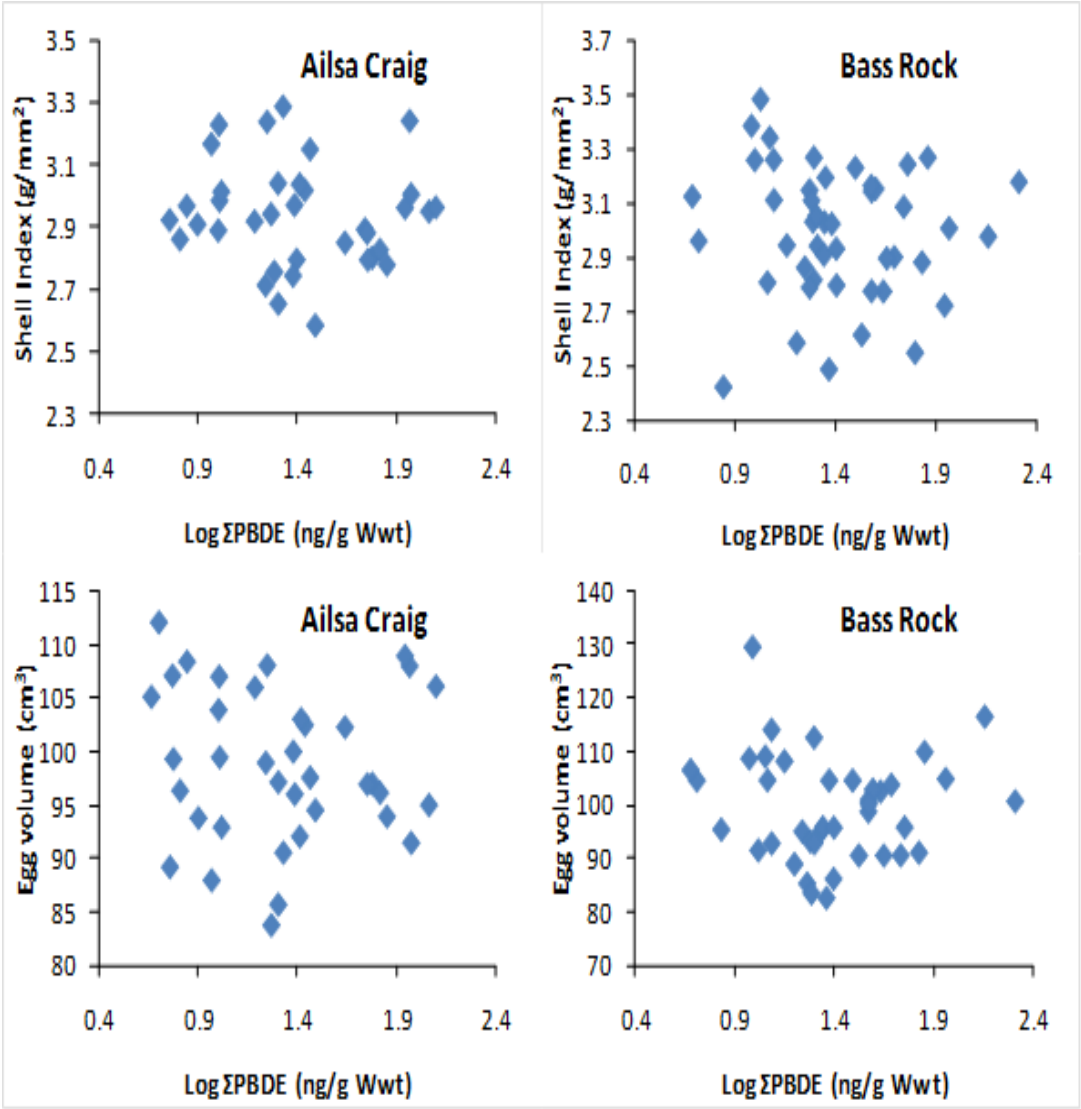
Study 1 - Results

- Congener profile
  - PeBDE dominated
- Spatial trends
  - No significant spatial trends
  - ΣPBDE or congeners
- Temporal trends
  - Significant temporal trends
  - Rapid increase from 1980s
  - Peak in 1994, before declining
  - Higher brominated congeners increase over time



Study 1 - Results

- Toxicity
  - Overall concentrations relatively low
  - 12.9 - 66.8 ng/g in eggs from Bass Rock
  - 6.3 to 60.8 ng/g in eggs from Ailsa Craig
  - No effect on eggshell thickness or volume



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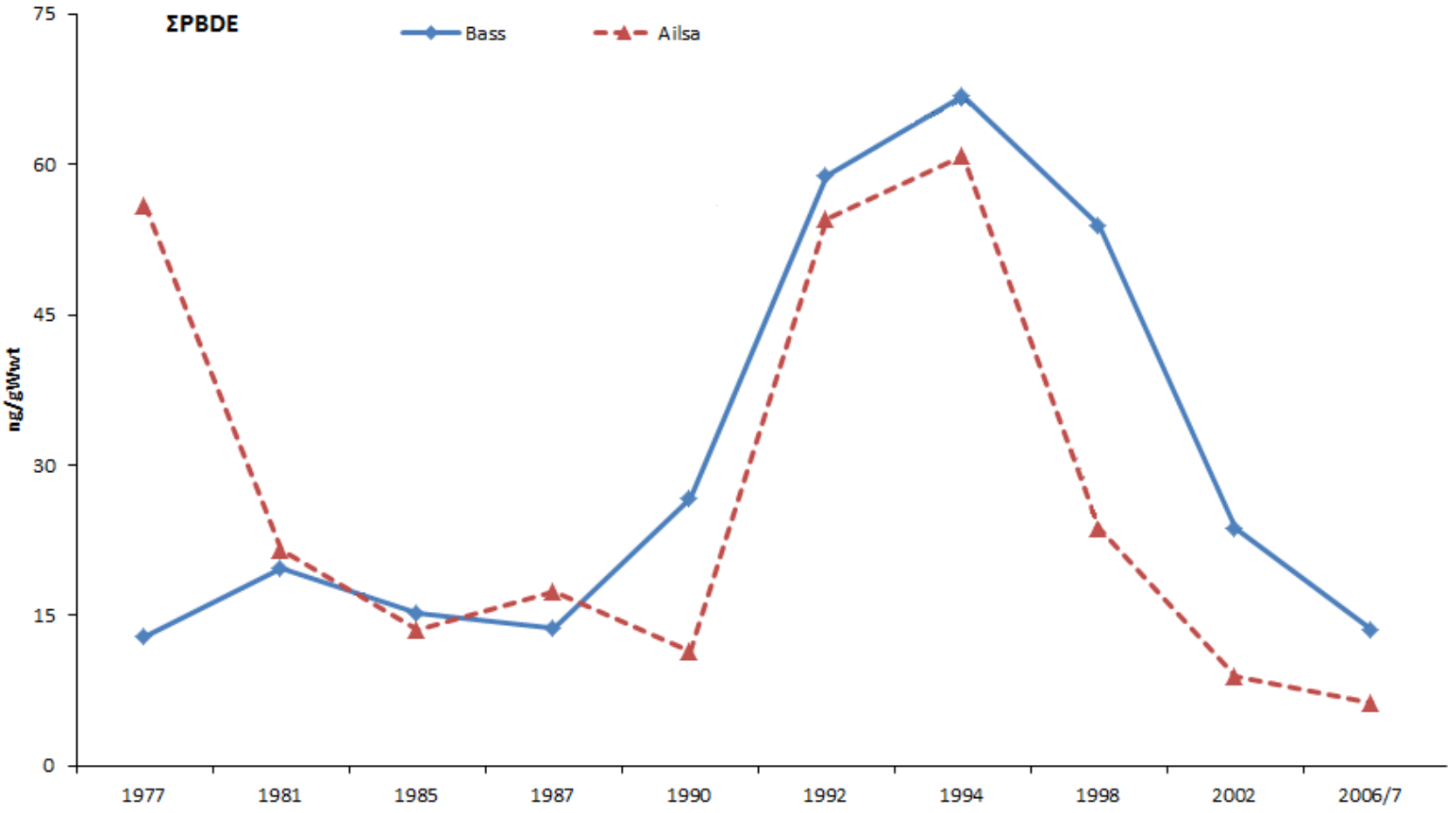
Study 1 - Results



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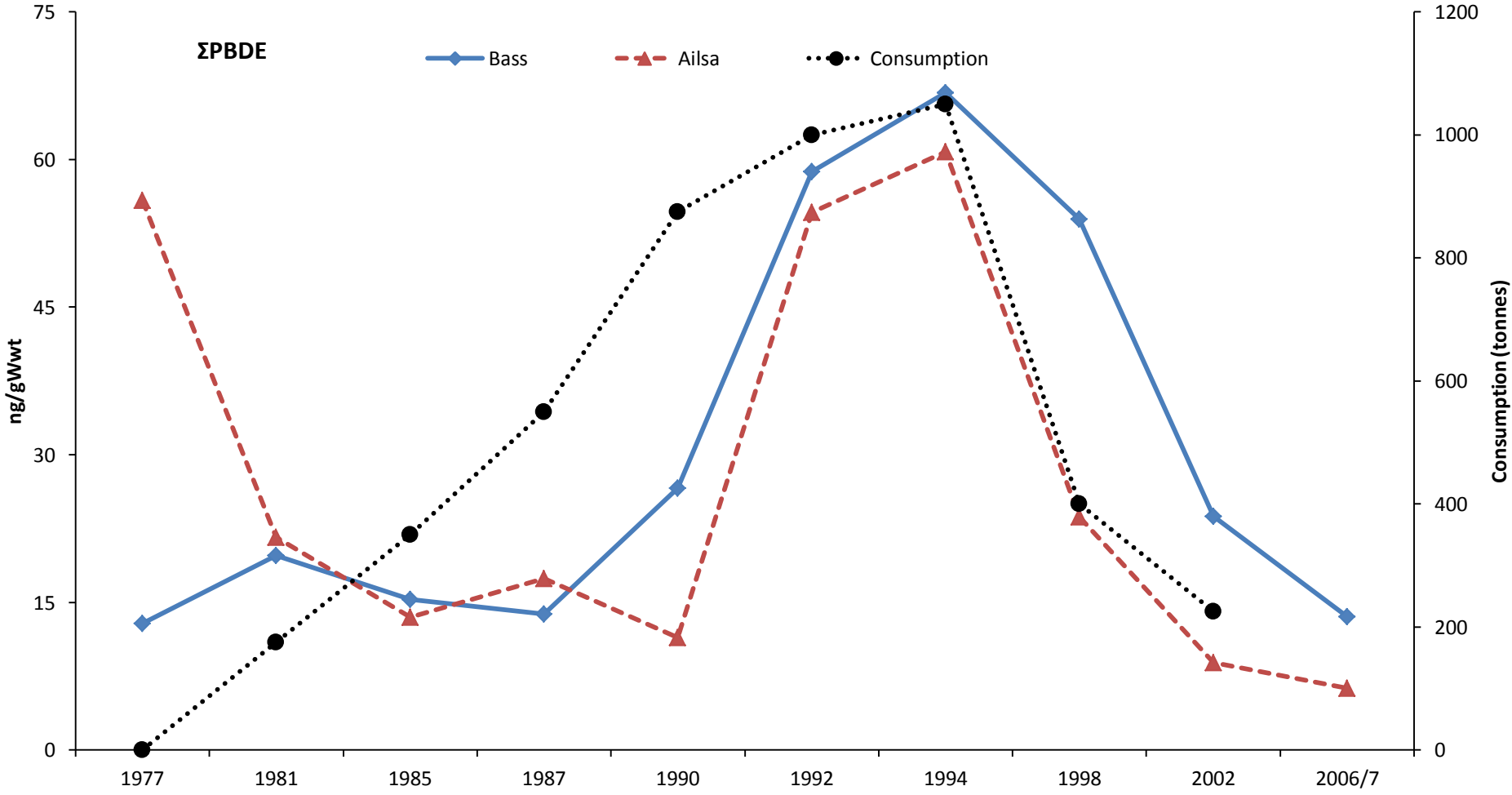
Study 1 - Results



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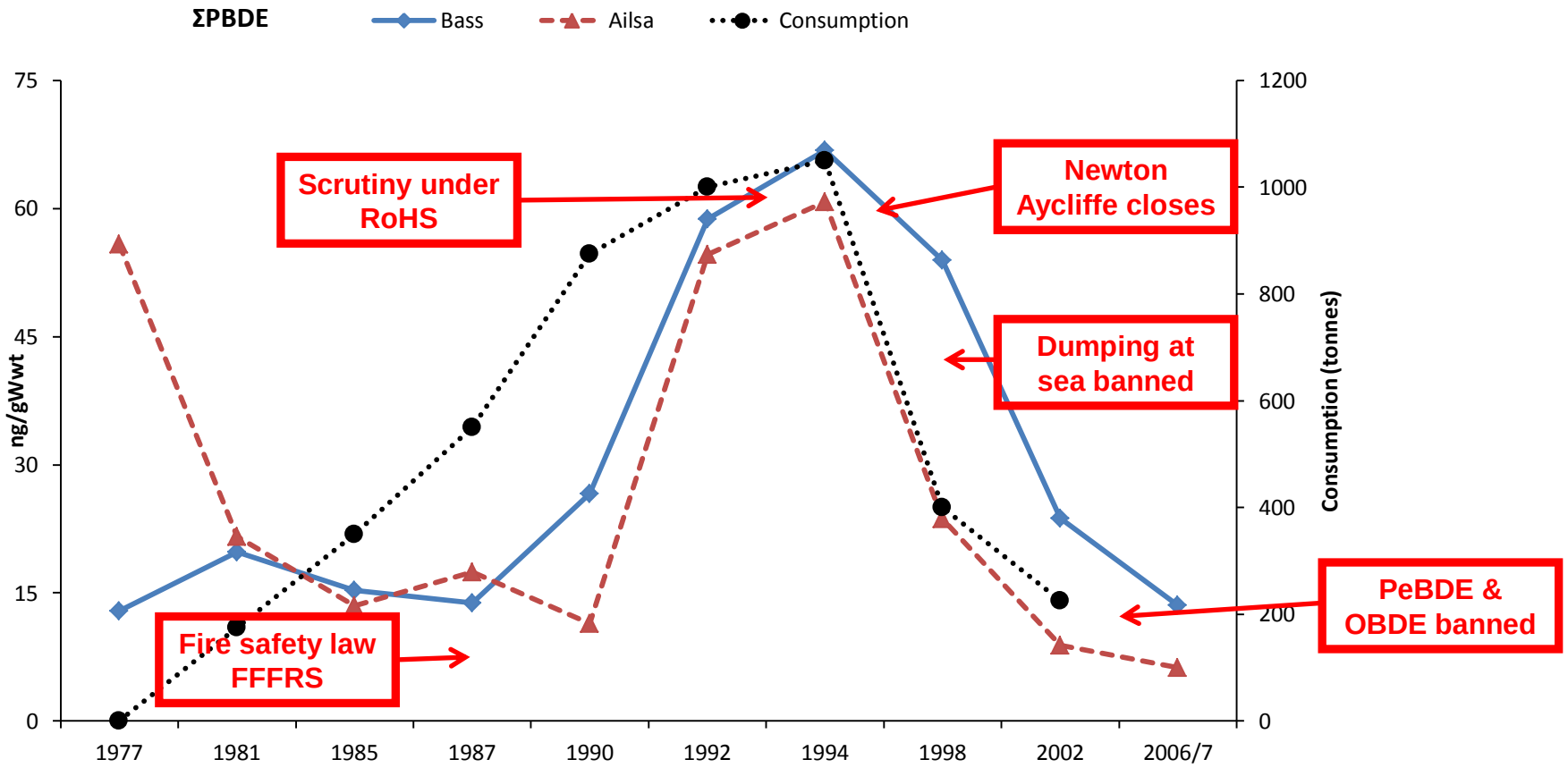
Factors affecting consumption in the UK

- Legislative drivers
  - For and against



- Environmental concentrations respond rapidly

Summary

- No spatial differences
  - North Sea and Irish Sea exhibit similar levels of contamination
- Congeners associated with PeBDE
  - BDE47 most dominant congener
- Temporal changes
  - Marine environmental concentrations respond rapidly to change
  - Increase in higher brominated congeners over time
- Toxicity
  - No significant effect on egg volume or shell thickness

Study 2 - sparrowhawks

- Terrestrial raptor
- Wide geographic distribution
- Long running archive
  - 1985 - 2007
- Specific aims
  - Temporal trends
    - PBDE concentration
    - PBDE congeners
    - BDE209 was not analysed for as this analysis was being conducted by Jacob de Boer's group (Leslie et al., 2011)
- Toxicity
  - Shell thickness

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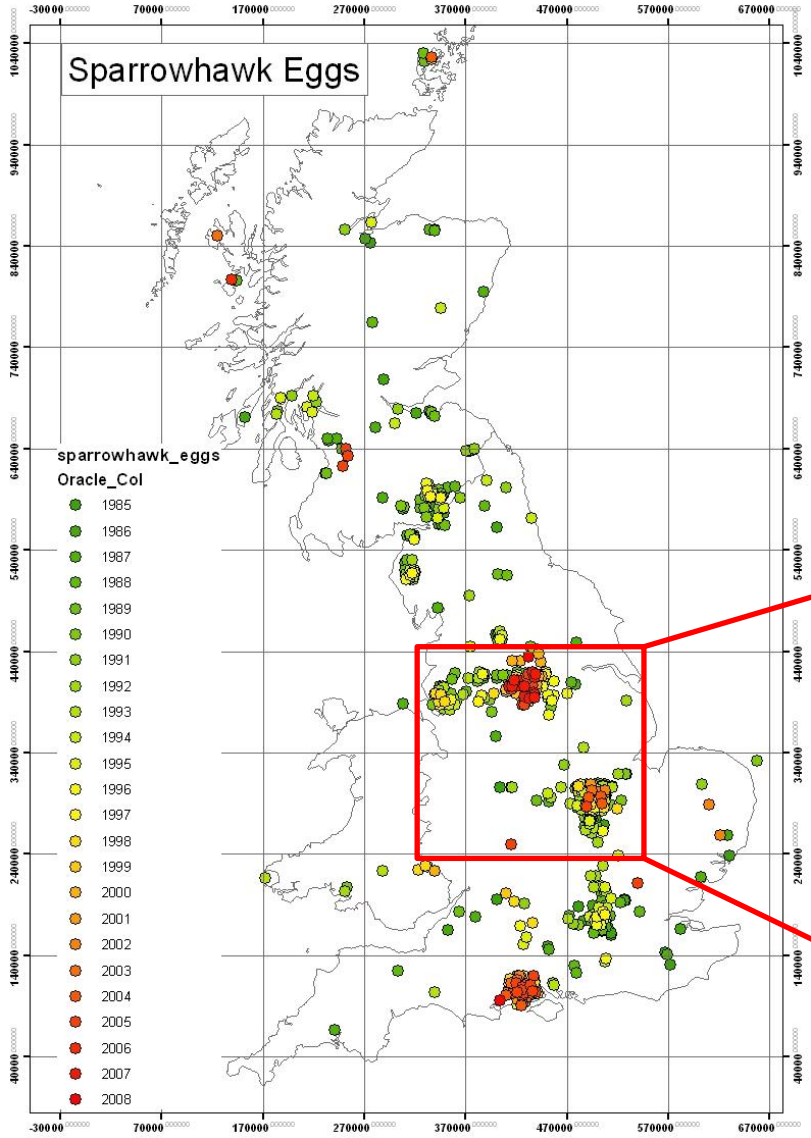
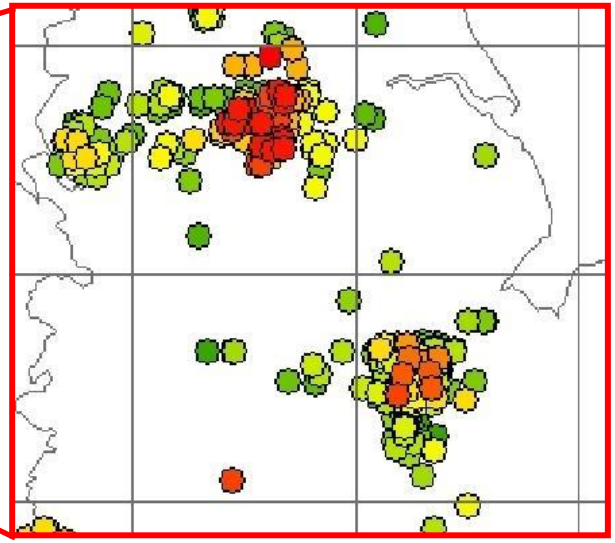
Sample selection



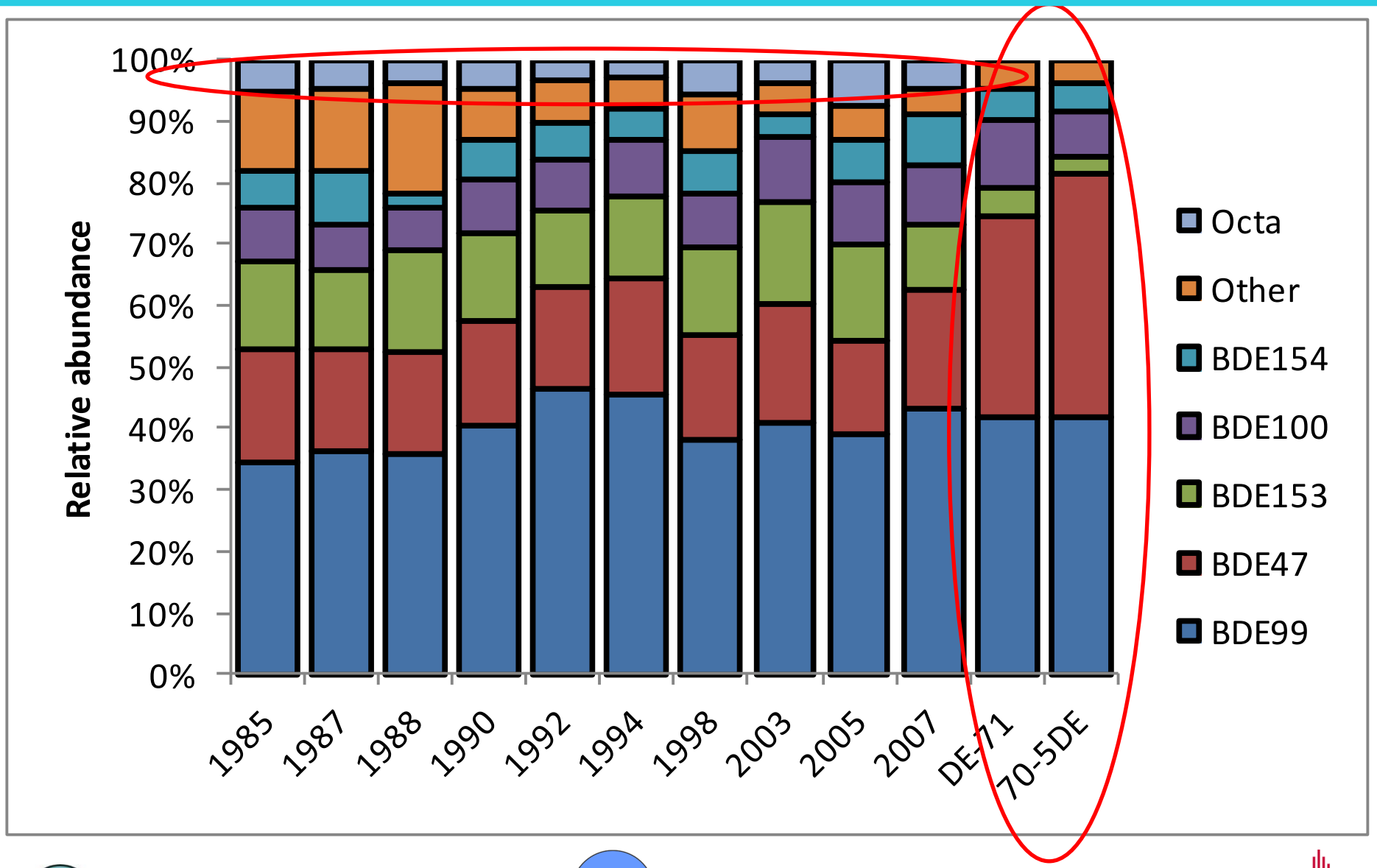
- Criteria 1
  - 1985-2007 (encompassing major legislation)
  - ~5 eggs per year
- Criteria 2
  - Smallest geographical area possible



Results

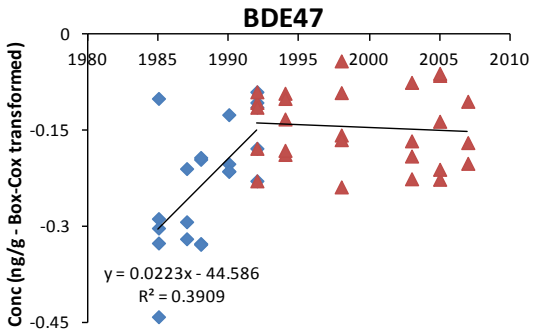
- Concentrations
  - 34 – 2281 ng/g wwt
  - Several orders of magnitude higher than the gannets
- Congener profile
  - BDE 99 dominant congener
  - BDEs 99>47>153>100>154 dominated the PBDE profile
    - Smaller contributions of BDEs 28, 85, 138
  - All congeners co-correlated with each other and with ΣPBDE concentrations ($p<0.001$)
  - Very similar to PeBDE mixture
  - Similar profile to that found in prey sp (Van den Steen et al., 2009)

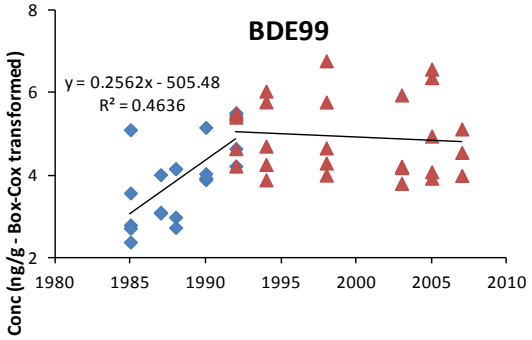
Results: Congener profile

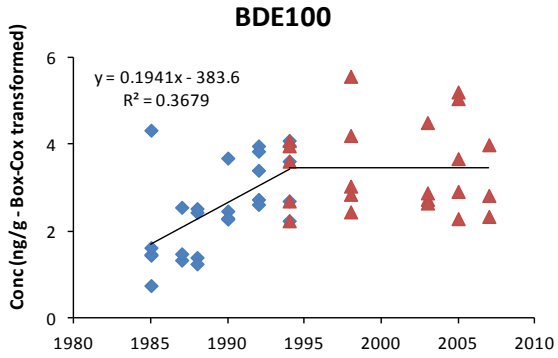


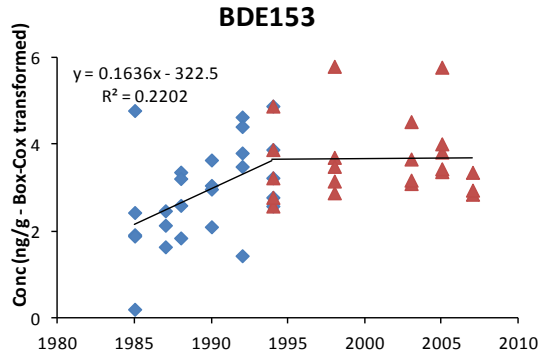
Temporal trends

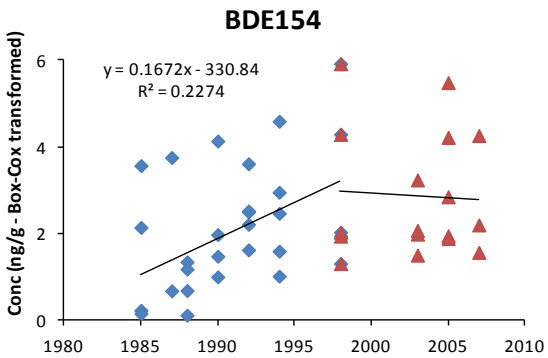
- Linear increase of ΣPBDE concentrations until mid 1990s (R^2=0.39, $F_{1,42}$=17.5, P<0.001)
  - Similar pattern for BDEs 47, 99, 100, 153, 154
  - BDE concentrations remained high from mid 1990s onwards
  - No significant decline

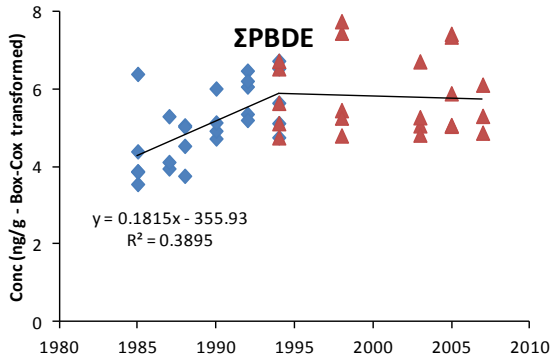












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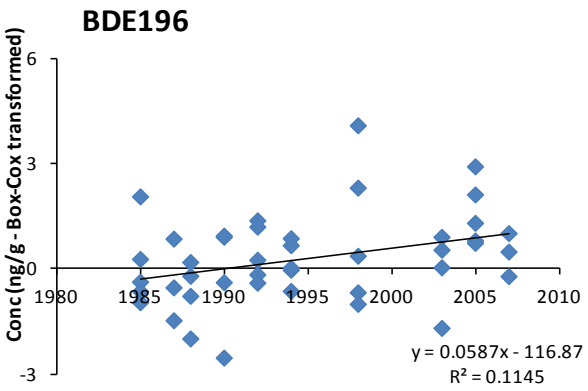
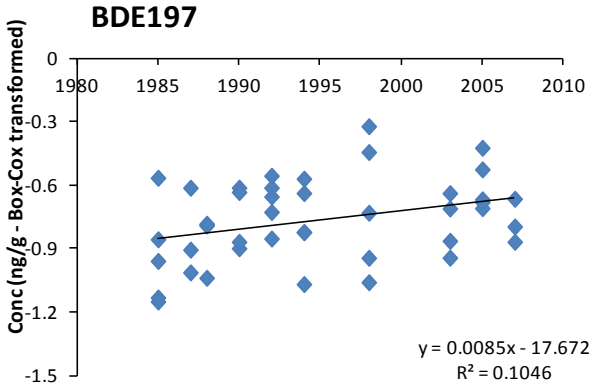
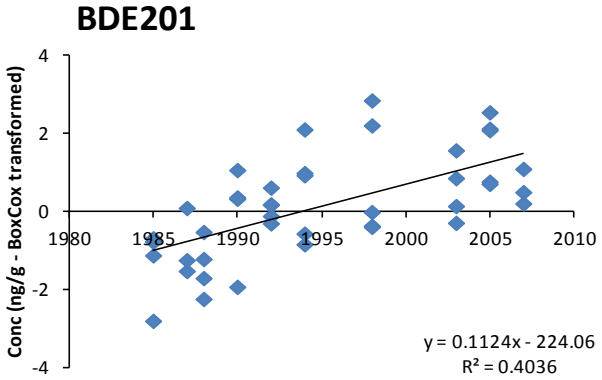
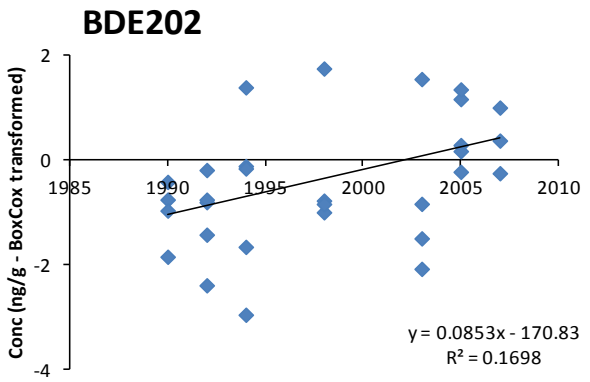
Temporal trends

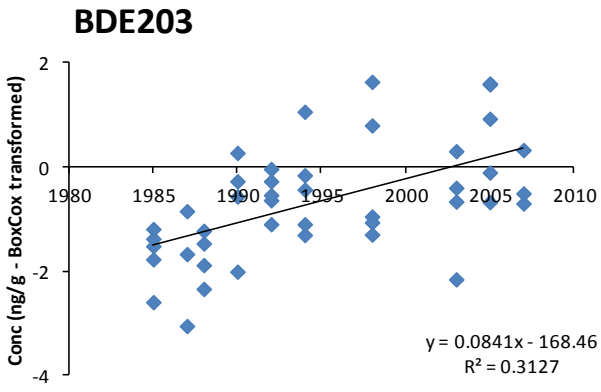
- OBDE-associated BDEs196, 197, 201, 202, 203 increased linearly over time ($R^2 \leq 0.40$, $F_{1,42} \leq 27.75$, $P<0.05$)











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Toxicity

- ΣPBDE in sparrowhawk eggs ranged from 0.34-2.28 ug/g wet weight (wwt)
  - 0.27-27.4 ug/g (lipid weight)
- Exceed the threshold for shell thinning and reproductive impairment found in other raptors (Fernie et al., 2009; Henny et al., 2009; Marteinson et al., 2010)
- No relationship between ΣPBDE nor individual congeners on sparrowhawk eggshell thickness ($p>0.05$)
  - Shell thickness increasing over time ($R^2=11.4$, $F_{1, 37}=5$, $P<0.05$)
- Eggs collected represent failed or abandoned eggs
  - May not be associated with PBDEs

Summary

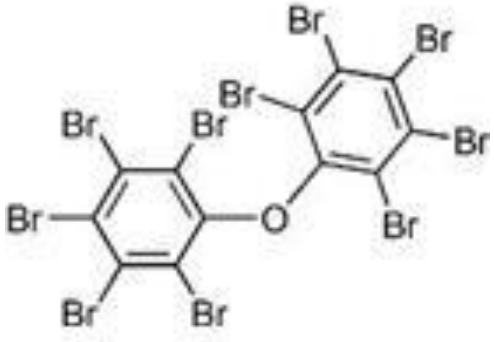
- Concentrations in sparrowhawk eggs represent environmental concentrations during the breeding season
- PBDE concentrations are not declining in sparrowhawk eggs
  - Slow clearance from the terrestrial system
  - Stark contrast to the marine system and other studies
- Dominated by PeBDE mix congeners
  - BDE99
  - Input from OBDE congeners
  - Slower clearance of these congeners
- Concentration of heavy BDEs increasing
  - BDE209 detected in a subsample of eggs
  - Debromination of labile BDE209

Summary (continued)

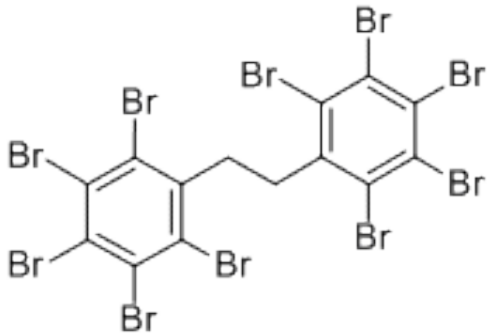
- Concentrations amongst the highest ever reported in bird eggs
  - Exceed threshold for shell thinning and impaired reproductive output
  - We did not find any effect of PBDEs on shell thinning
  - Difficult to relate cause and effect of PBDE concentrations on egg failures

What's next?

- DeBDE being phased out in US
  - UK following
  - New flame retardants already on the market
    - PBT, PBEB, HBB, DP, BTBPE, OBIND, TBPAE, TBECH, BATE, DBDPE
  - DecaBromoDiphenyl*Ethane*
  - Replacement for DecaBromoDiphenyl*Ether* (DeBDE)



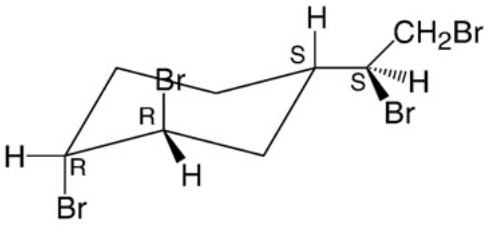
DeBDE (209)

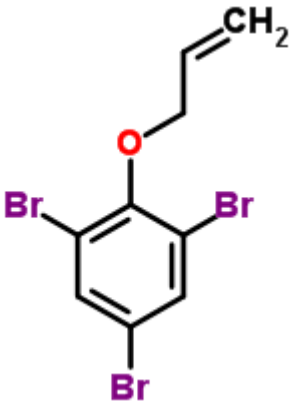


DBDPE

A long way from home…

TBECH





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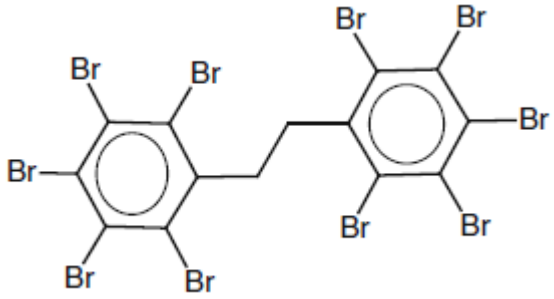

DBDPE

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Predatory Bird Monitoring Scheme
http://pbms.ceh.ac.uk/

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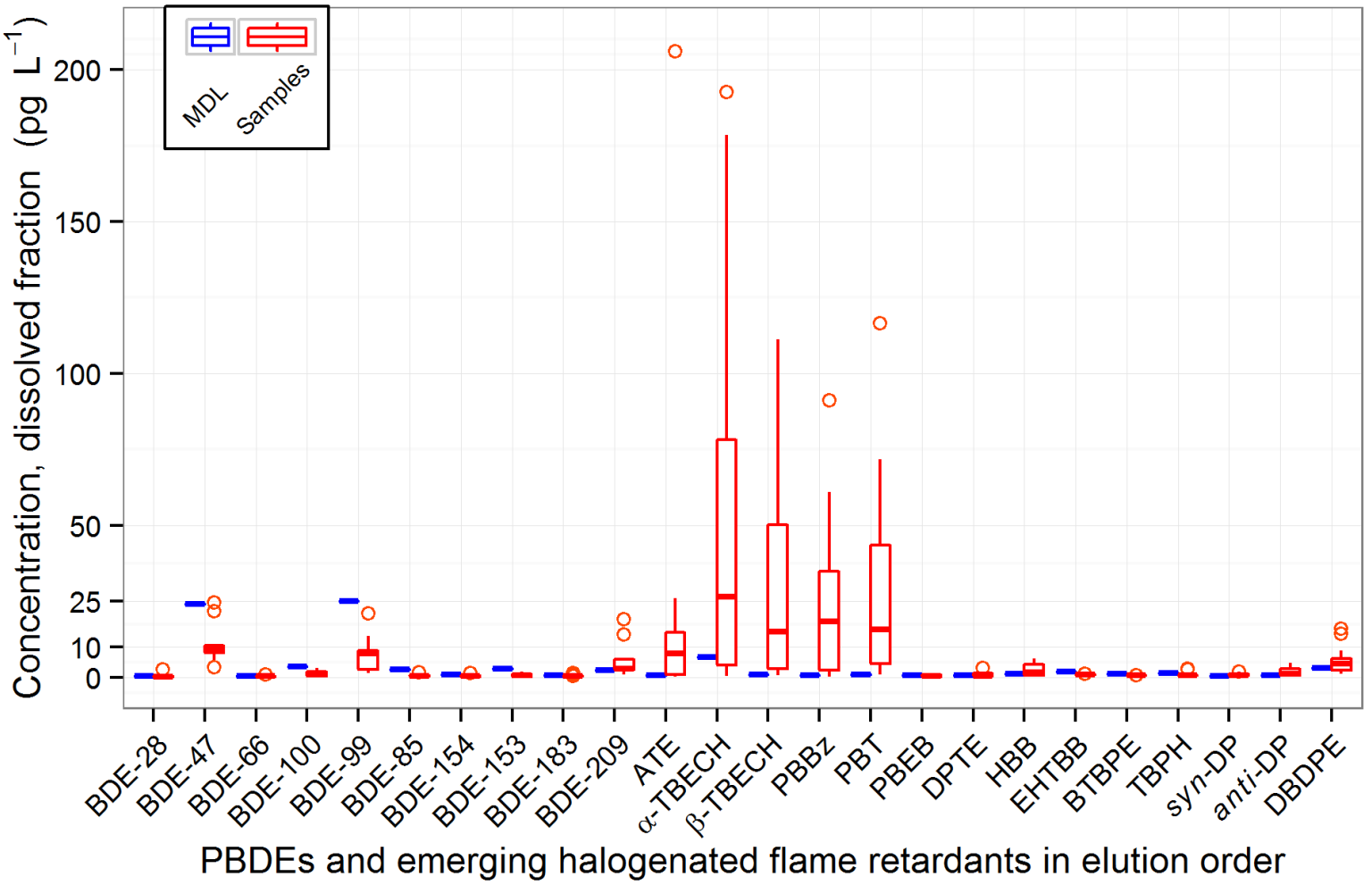

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  - Dr Gareth Thomas

NATURAL ENGLAND

RSPB
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Environment Agency

THINK WILDLIFE
Campaign for Responsible Rodenticide Use

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