Ammonia N2K

Improving Environmental Assessments for Atmospheric Ammonia

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AmmoniaN2K

- A UCD/UWE project Funded by STRIVE, as administered by the Irish Environmental Protection Agency (EPA)

- Outputs;

  - PhD Thesis

  - EPA Final Report

  - Five peer-reviewed publications

- Received additional support & guidance from;

  - National Parks and Wildlife Service

  - Centre for Environmental Data & Recording

  - Centre for Ecology and Hydrology

  - Joint Nature Conservation Committee

  - University of Trent

- Focus on Ammonia (NH_3) emissions from Irish pig & poultry farms

- Impacts on Irish Natura 2000 (N2K) Sites
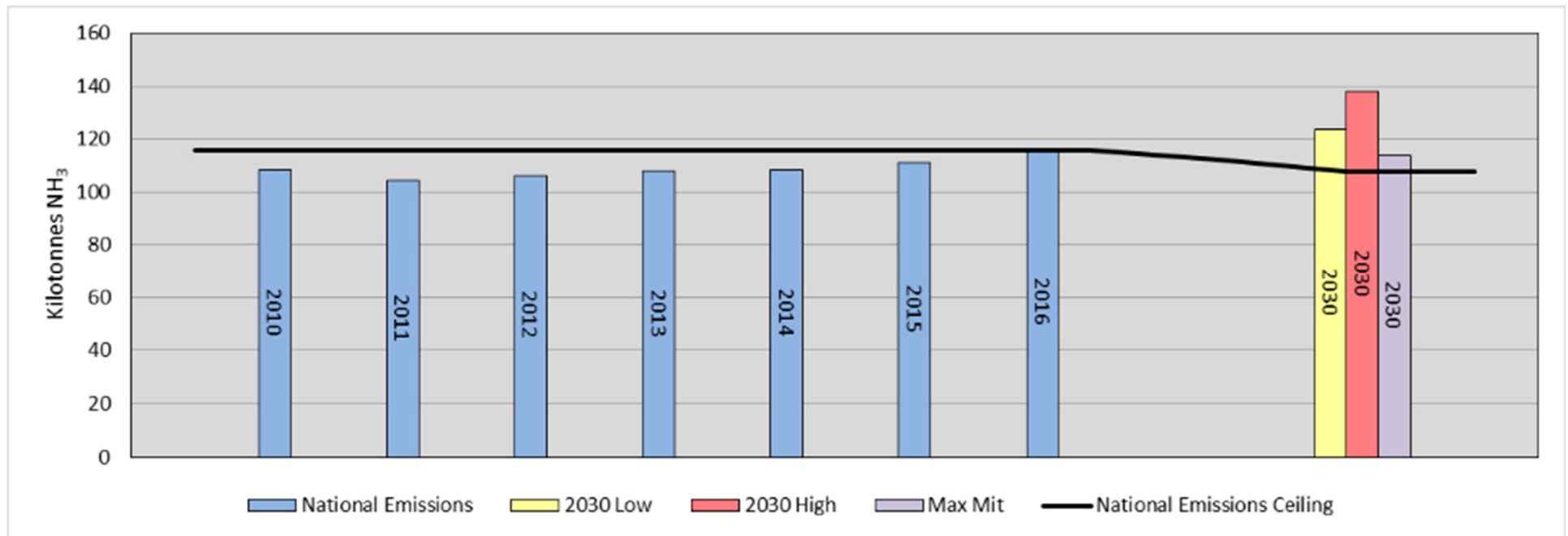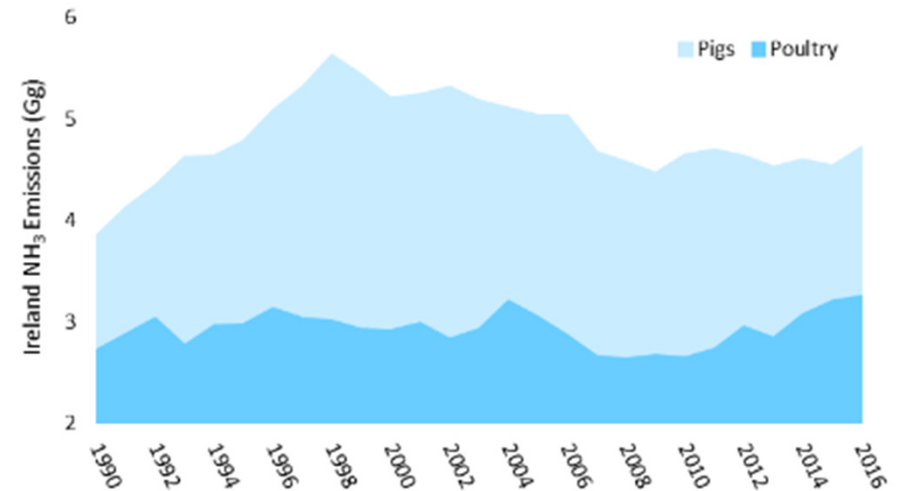
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Introduction

- Since 2016 Ireland has exceeded it's National Emissions Ceilings Directive limit for ammonia

- With government led agricultural expansions (Food Wise 2025) it will be difficult for Ireland not only to meet targets required by the NECD Directive
  - But also comply with the EU Habitats Directive – protect against environmental impacts on sensitive sites

- More important than National Ceilings
  - Site specific exceedance of critical levels and loads
  - Important to understand;
    - Locations of sources
    - Respective emission rates
    - Contribution to local concentration & dry deposition
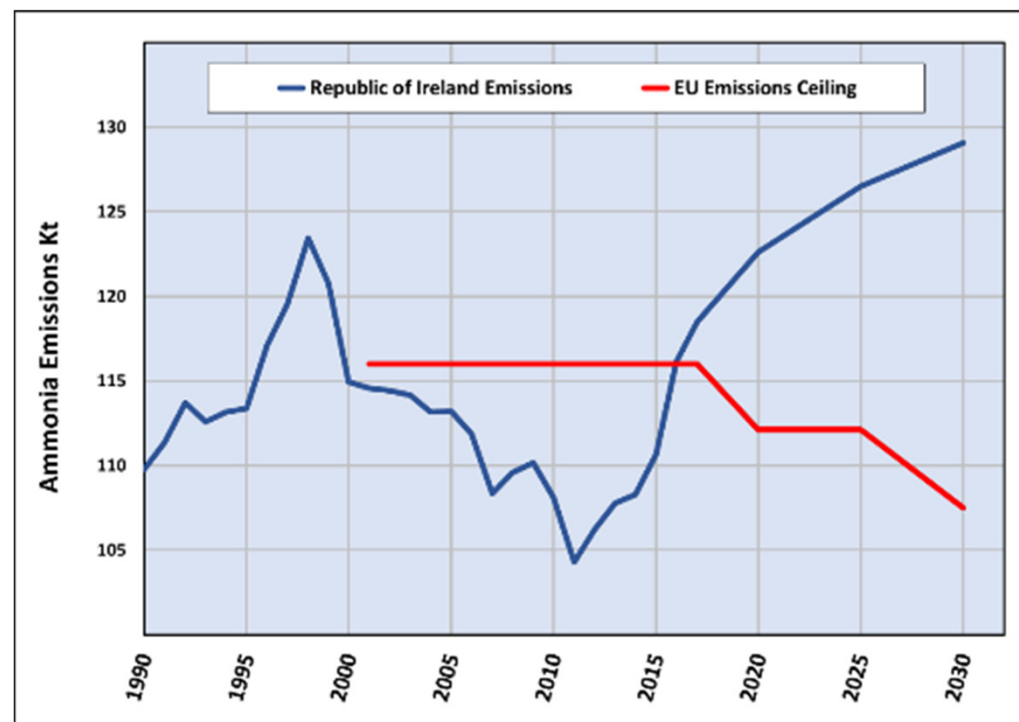
Predictions without additional abatement

- Though slight recent increases in pig and poultry populations

- Current exceedance primarily due to increased dairy herd

- Even with mitigation scenarios it will be extremely difficult for Ireland to meet current and future committed emission reductions

Ecological Effects Observed

- Raheenmore Bog SAC receiving impacts from local dairy production

- Designated for Annex I priority habitats
    - Active Raised Bogs [7110]

- 130.5 ha of uncut high bog

- One of 12 Natura 2000 Sites monitored by AmmoniaN2K

- Evidence of ecological impacts at concentrations of c. 2.2 μg NH_3 m^{-3}

- Patches of decaying *Sphagnum sp.*
- Pink *Cladonia portentosa*
- *Ramalina* & other lichen sp. encroached by green algae
- Abundance of green algae on trees & dead heather
- *Xanthoria sp.* (indicator of nitrogen pollution)

Left: Decayed sphagnum

Right: Healthy sphagnum

Source of Impacts

- Contributions from cattle and slurry spreading can cause ecological effects
    - e.g. decaying sphagnum on Irish bog (right)

- Highest contributions expected from intensive hotspot sources
    - e.g. Pig and Poultry farms

- Monitoring conducted in UK indicated areas with pig & poultry farms had highest concentrations (*Tang et al., 2018*)

Unlicensed Pig & Poultry Houses

- The Irish EPA has access to the locations of Industrial Emission Directive licensed farms

  - > 40,000 birds

  - > 2000 finisher pigs or > 750 sows

- c. 225 pig & poultry farms licensed

- The EPA do not have access to locations of below threshold farms

  - Contribute to cumulative impact of ammonia

- Conducted systematic review of local authority planning applications

  - Plotted approx. locations using addresses

  - Validated by satellite imagery

- Identified additional 760 pig & poultry houses across Republic of Ireland
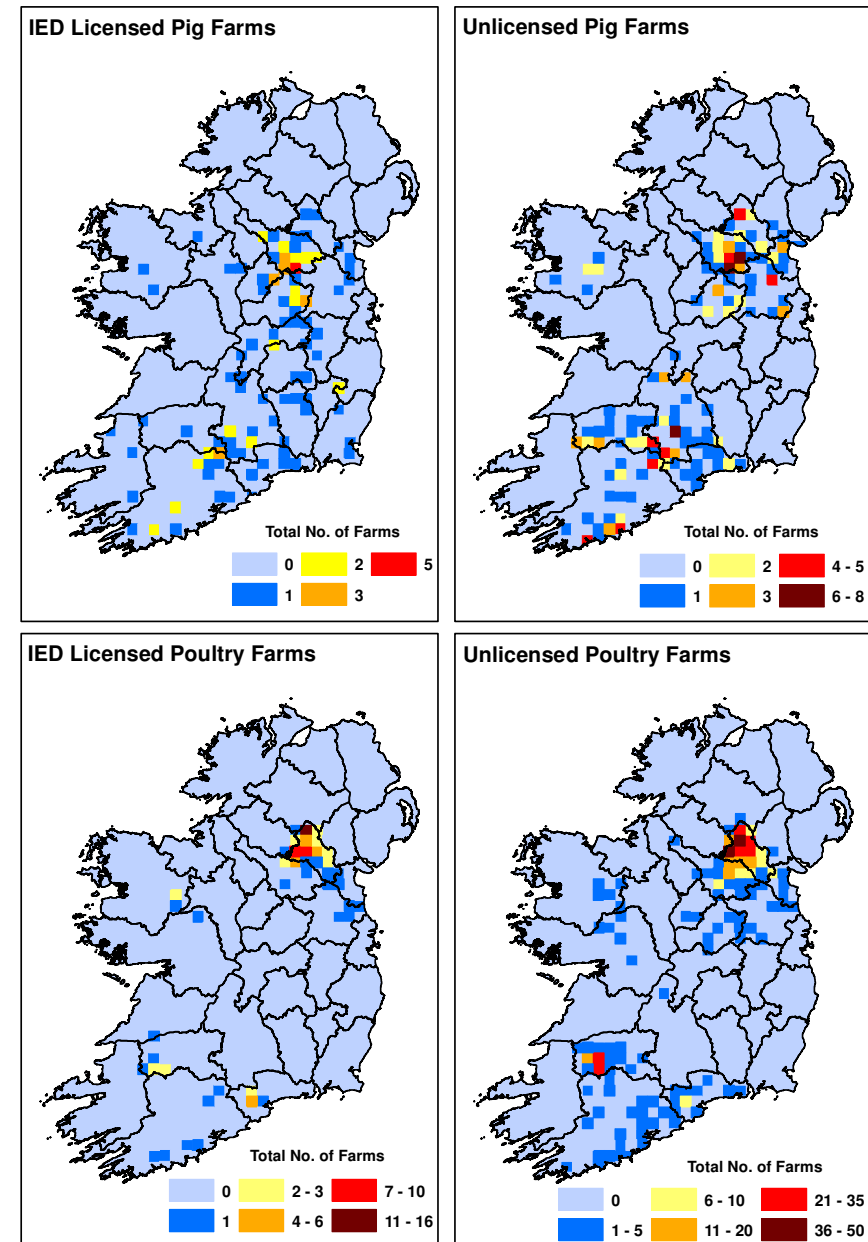
Potential Cumulative Impacts

- Overlapping 10 km buffers from all licensed and unlicensed pig
    - A – Pigs
    - B – Poultry
    - C – Both
    - D – Number of overlapping 10 km pig and poultry farm buffers within the Natura 2000 network of designated sites

- 33% of Irish Natura 2000 sites are within 10 km of a pig or poultry farm

- With 10% proximal to > 5 pig or poultry farms
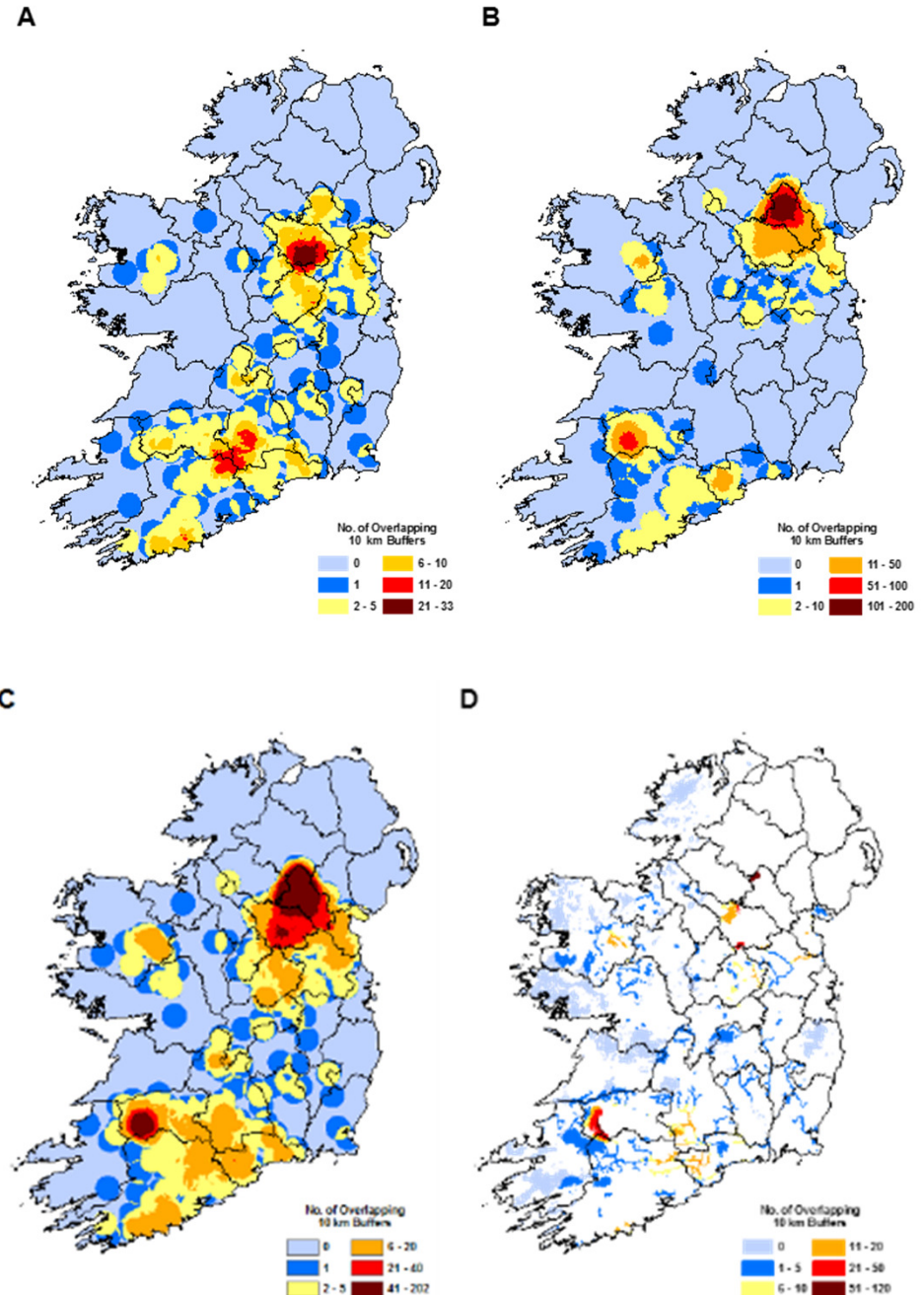
Emission Monitoring

- Monitored NH_3 emission rates from 17 intensive animal production houses
  - On 5 farms

- Mechanically ventilated
  - Exception dry / pregnant sow house 1 and 2

- Layers – Enhanced cages with conveyor belt manure removal

- Broilers – fully littered floors

- Pigs – fully slatted floors

Finisher House 1

- Newest finisher house on farm
  - Built c. 2000's
- Predominantly mechanically ventilated
  - Features additional natural ventilation
- Highest ventilation rate
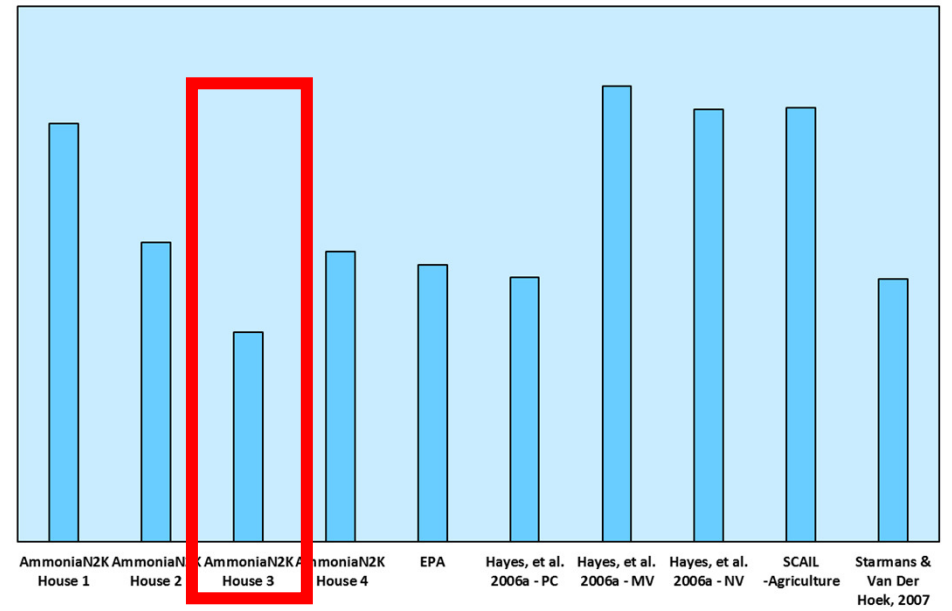- Highest emission rate
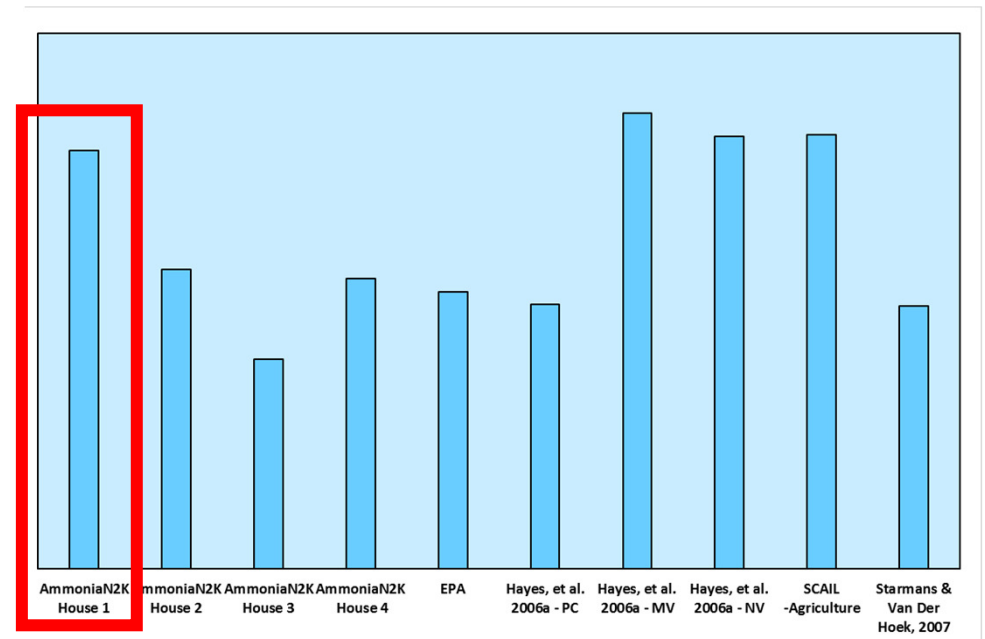
Finisher House 2

- Intermediate aged finisher house on farm
  - Built c. 1990's
- Mechanical ventilation system
- Intermediate ventilation rate
- Intermediate emission rate
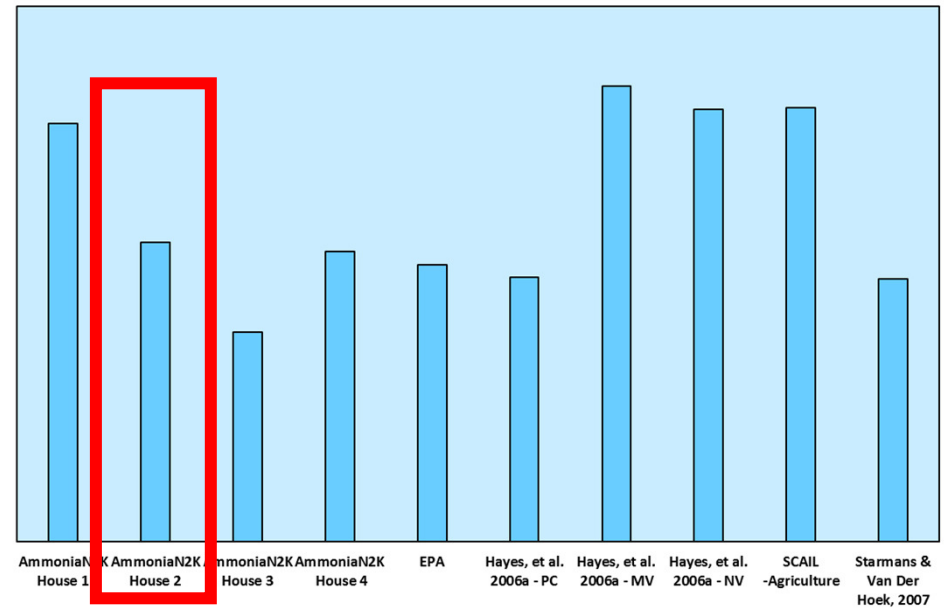
Finisher House 3

- Oldest finisher house on farm
  - Built c. 1960's

- Punch ceiling ventilation system

- Lowest ventilation rate

- Lowest emission rate

- **If house appears "cleaner" with no obvious mitigation measures, may mean;**
  - **Likely high ventilation rate**
 - **With higher emission rate**

Seasonal variation in Emissions

- Emission rates are typically higher during warm weather

- Due to combination of
  - Higher ventilation rate
 - Increased volatilisation of NH_3
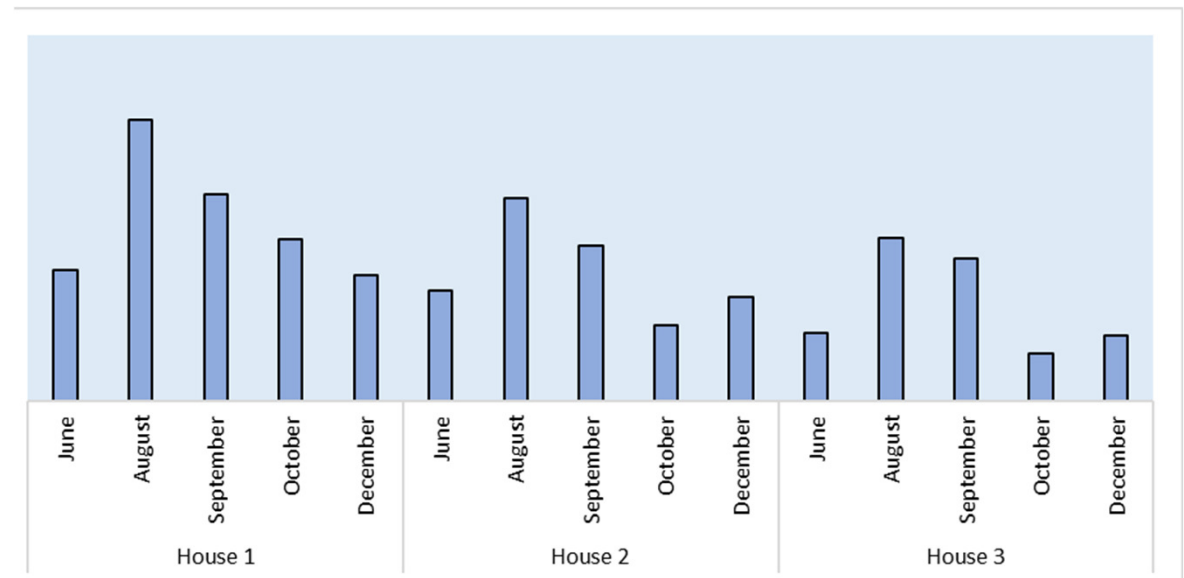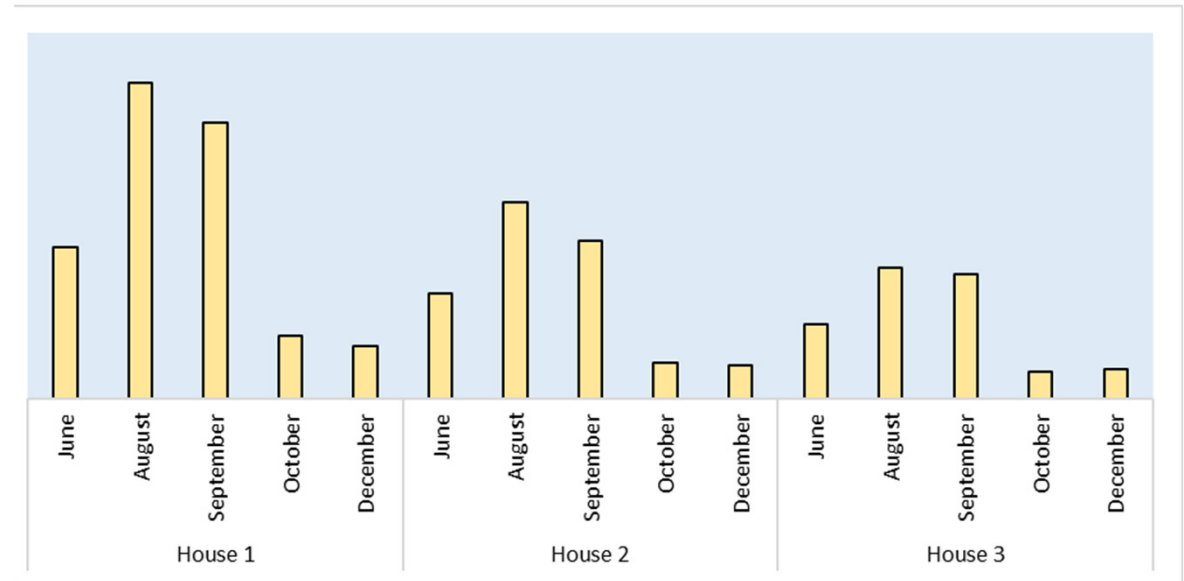
Production cycle variations

- Type of production cycle
- Broilers – typically 30 to 37 days
  - Increasing emissions as birds grow & manure accumulates
- Layers – though annual production cycle
  - Emissions vary throughout week
  - As manure accumulates & is removed

Broiler Daily Average Emissions

Layer Emission Rates

Layer daily Average Emissions
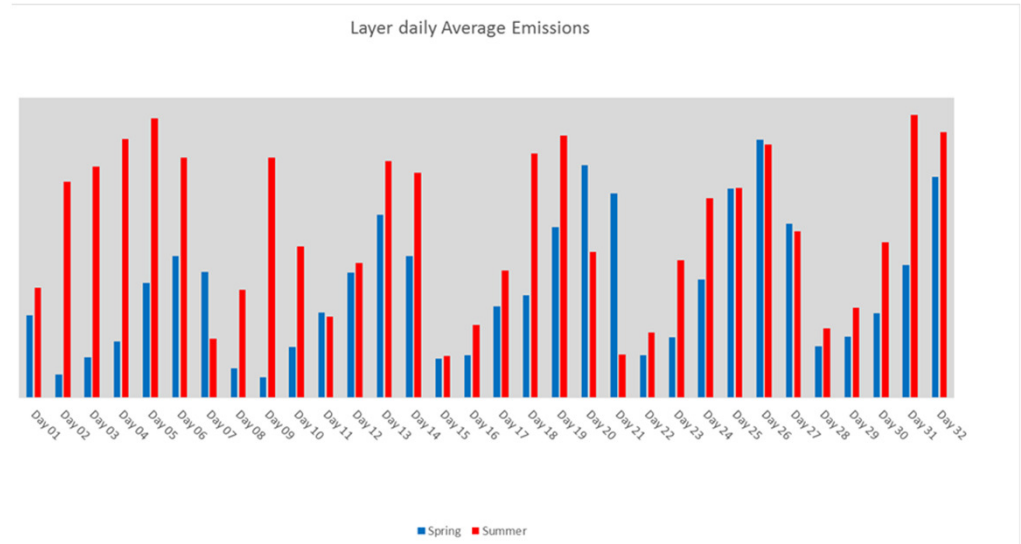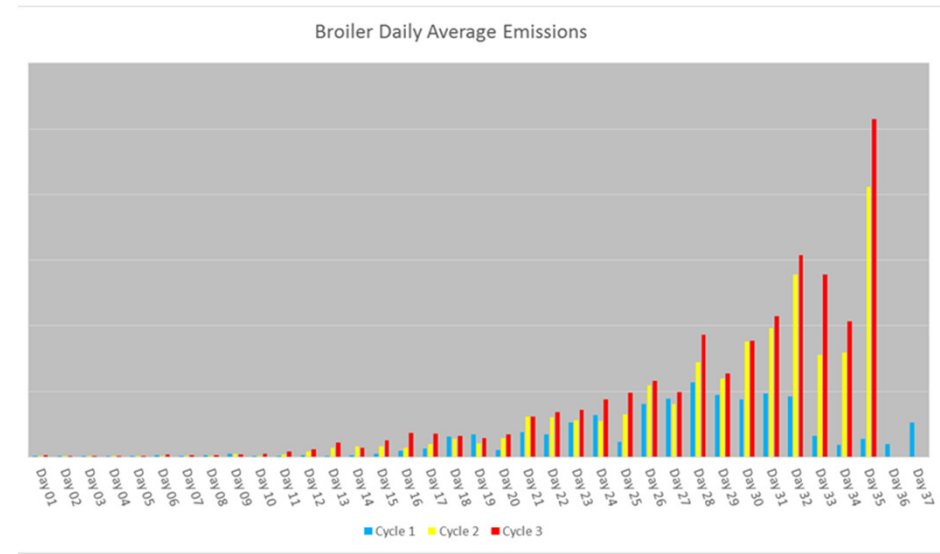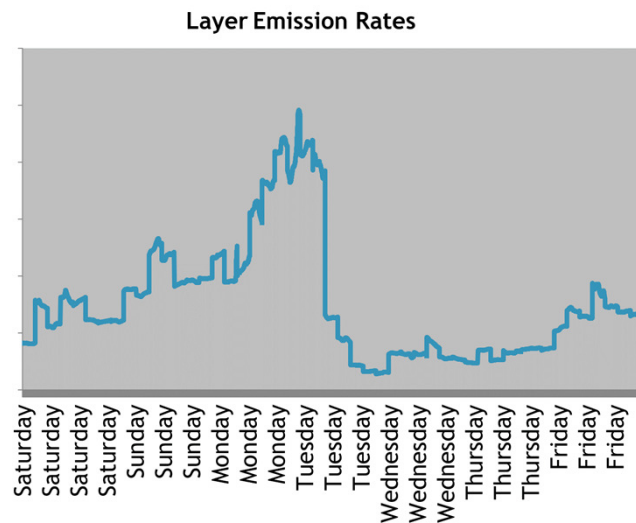
# Dispersion Modelling

- For four farms Monitored

- Generated atmospheric dispersion models

- Using Lakes © AERMOD

- Using updated;
    - emission rates
    - ventilation rates

- Used to estimate contribution to concentrations & dry deposition
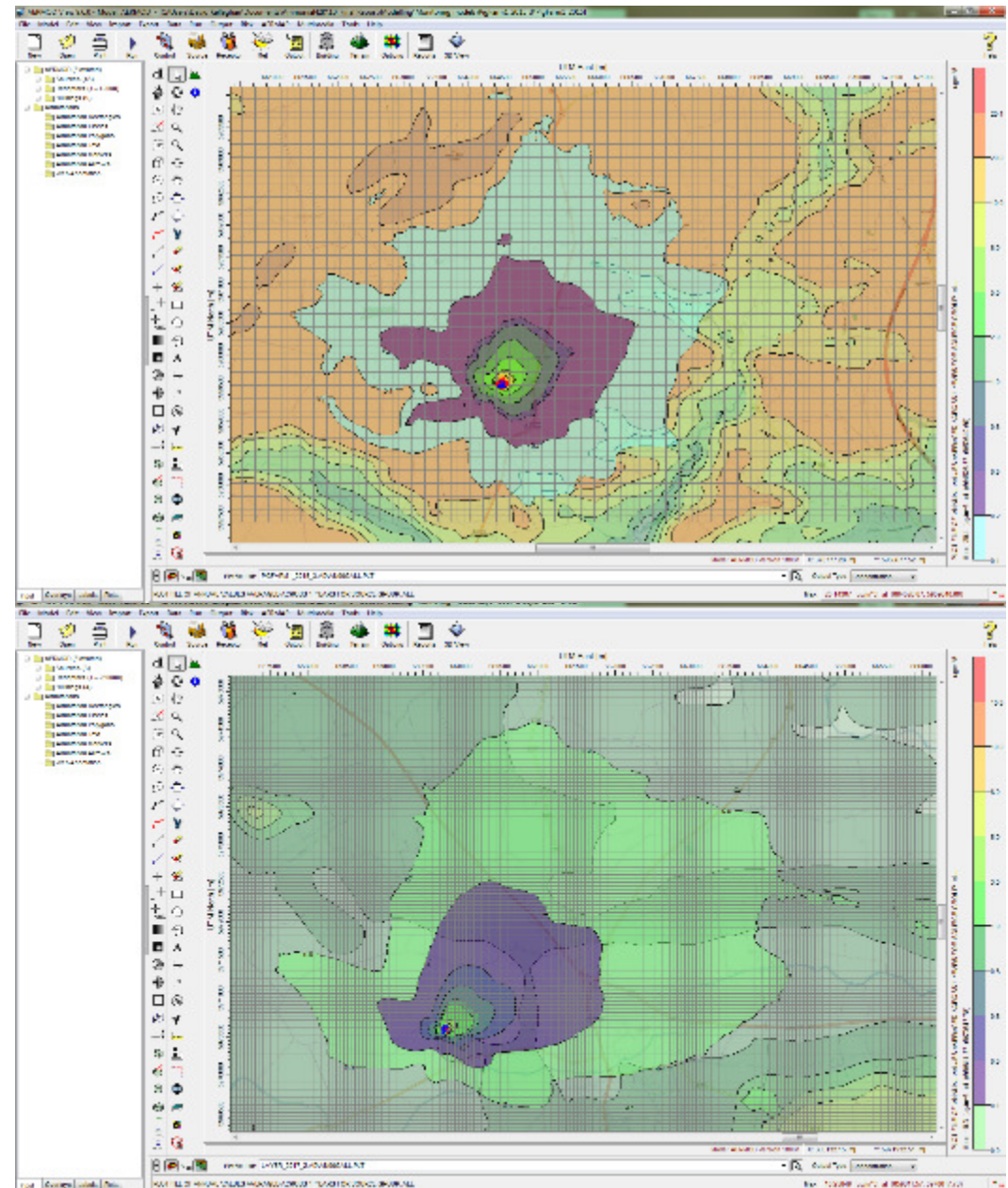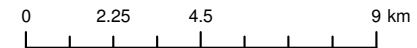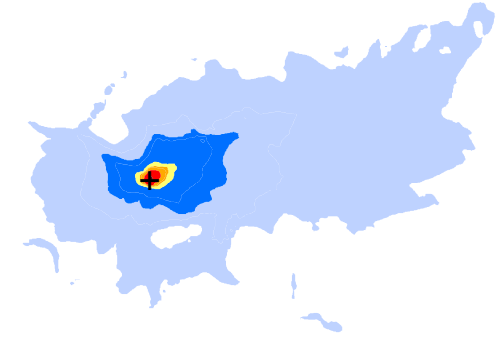
Annual Variation

- Annual variation in dispersion extents

- Due to meteorological data

- Model dispersion with entire year of Met Data
  - Account for seasonal variation

- Dispersion extent of 5 most recent years
  - 2017 greatest
  - 2015 lowest

2015

0   2.25   4.5   9 km

2017

0   2.25   4.5   9 km
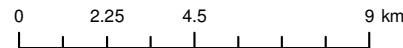
Dry Deposition Modelling

- Presuming high deposition velocity
  - 0.03 cm s^{-1}

- Contributions from farm exceed 0.8 kg ha^{-1} year^{-1} within 10 km of site

- Empirical Critical loads typically
  - $5 - 30$ kg N ha^{-1} year^{-1}

- Excludes ambient concentration
  - $0.18 - 3.21$ µg NH$_3$ m^{-3}

- Excludes other forms of Nitrogen
  - Wet Deposition of NH$_4$
  - NO$_x$

- Environmental Assessments need to consider deposition from all sources of Nitrogen
  - Total Nitrogen Deposition

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2015
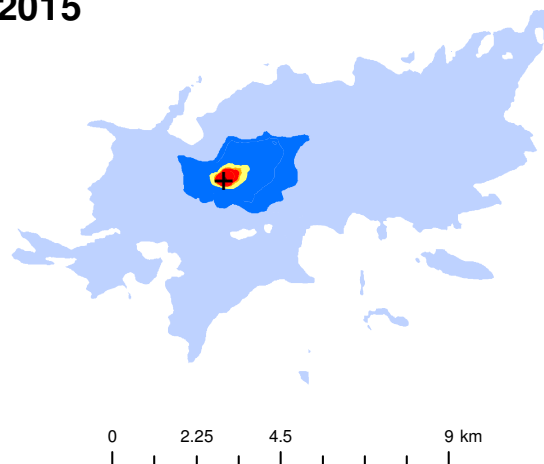
2017
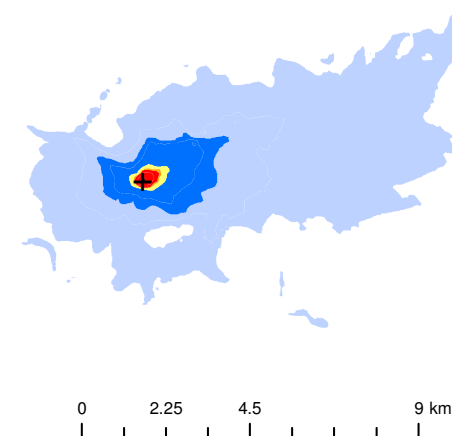
Estimate Baseline Concentration

- Before presuming baseline concentration provided by National Model is accurate on a local level

- Consider local variation that may not be represented by the national model

- For example, contribution of licensed broiler houses in Co. Monaghan below

  - provisional modelling

- The highest "baseline" concentration monitored in Ireland was 3.2 μg NH$_3$ m^{-3} in 1999 (de Kluizenaar and Farrell, 2000)

NH$_3$
Concentration
μg m^{-3}

2.1 - 2.6
2.7 - 3.0
3.1 - 4.0
4.1 - 7.0
7.1 - 22.3

Below Threshold Poultry Farms
• Unlicensed Poultry
Below Threshold Farm Size
High : 53,000

Low : 2000
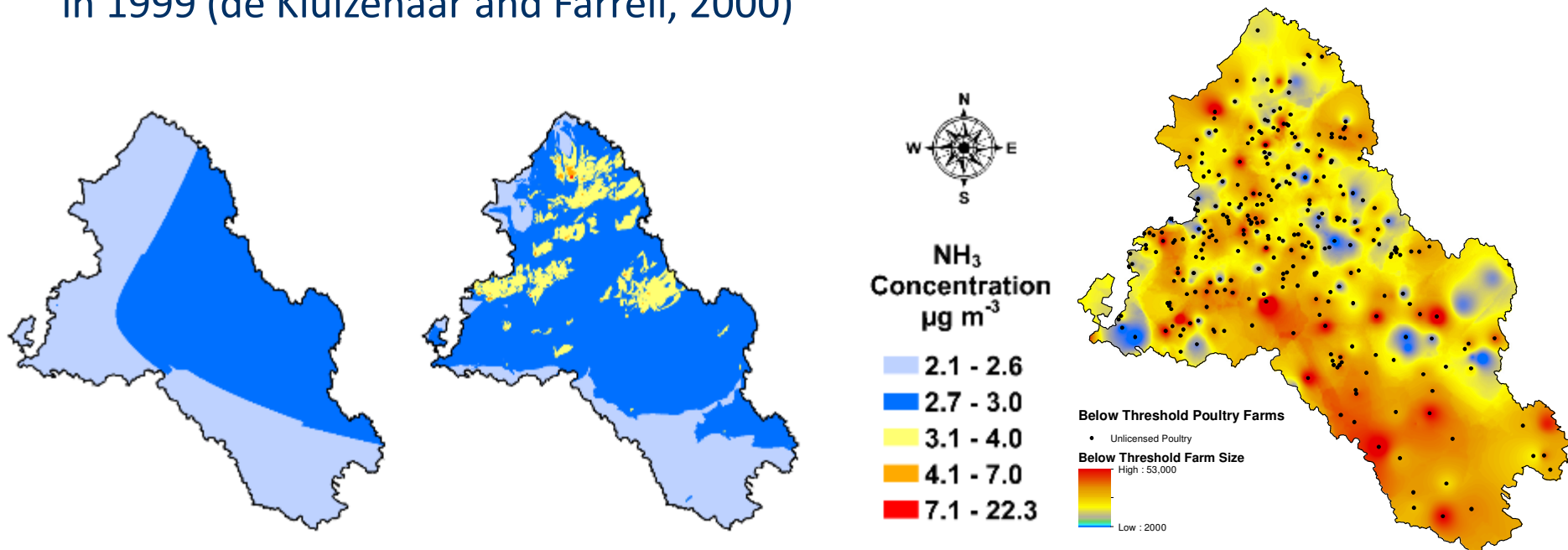
Seasonal Variation of Ambient Concentrations

- Ambient concentrations of NH_3 will vary seasonally

- Typically dependent on agricultural activity

- If monitoring in order to establish baseline concentrations

- Need to consider this seasonal variation

- Critical levels based on exceedance of annual average concentrations

Monthly Profile of Ammonia Concentration on Ballynahone Bog

— 2016   — 2017

Tang, S.; Stephens, A.; Crory, A. (2018). Ammonia measurements from passive samplers at Ballynahone Bog field site (2014-2017). NERC Environmental Information Data Centre
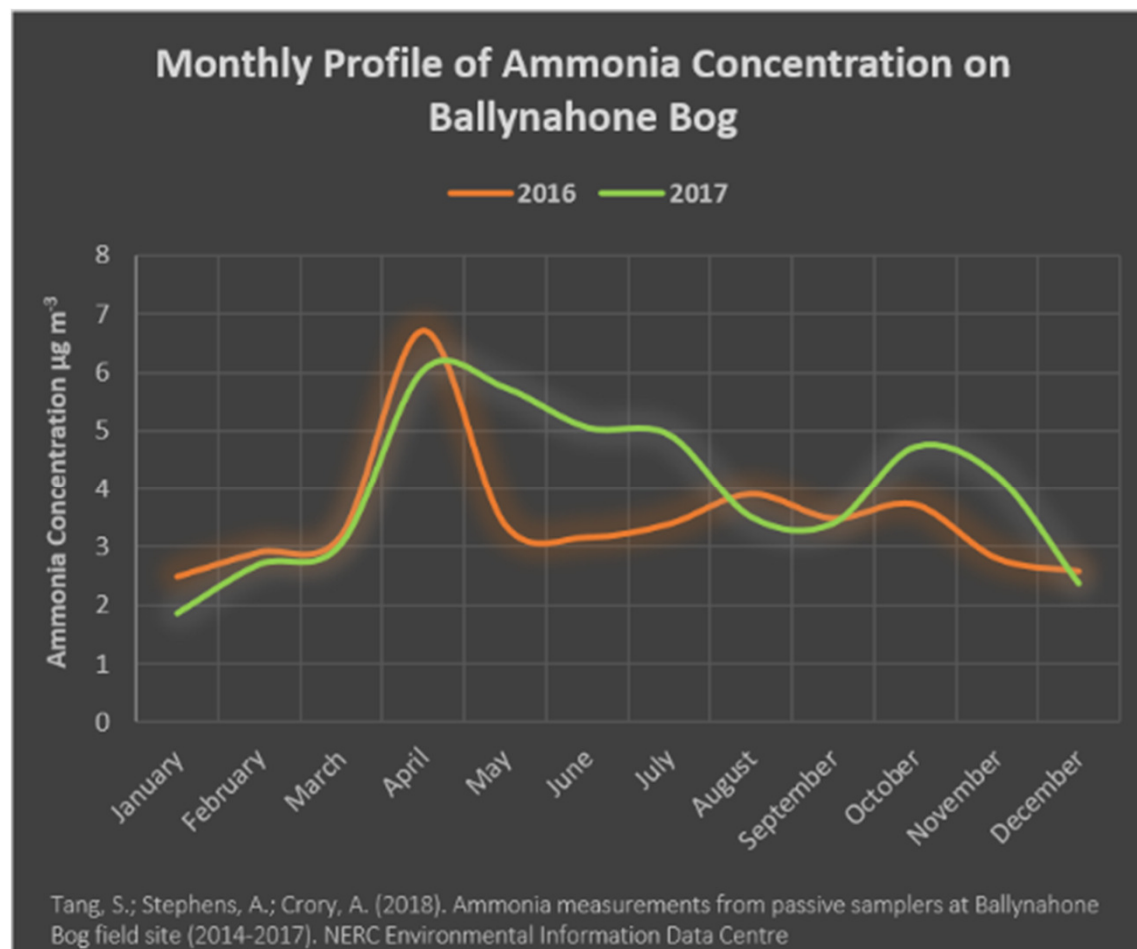
Mapping ammonia risk on sensitive habitats in Ireland

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- Mapping Ammonia Risk on Sensitive Habitats (MARSH) published in the Science of the Total Environment (Kelleghan et al., 2019)

- Used Geographical Information Systems to develop a risk based approach as required by the NECD directive

- Ireland does not have FRAME concentration model or APIS

- Site specific risk data generated for all Irish Natura 2000 sites intended to assist with compliance with both
  - National Emissions Ceilings Directive (NECD)
  - Habitats Directive

- NECD requires a risk based approach to identifying sites for inclusion in its National Ecosystem Monitoring Network

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Highlights

- A GIS risk-based approach gauges atmospheric NH_3 impacts in Ireland

- Integrates best available agricultural data to identify "at-risk" areas in Ireland

- Provides stakeholders with an atmospheric ammonia risk map for Ireland

- 80.7% of Natura 2000 sites likely to exceed critical level of 1 $\mu g/m^3$

- 5.9% of Natura 2000 sites likely to exceed critical level of 3 $\mu g/m^3$

Abstract

The aim of this study was to provide a simple, cost-effective, risk-based map of terrestrial areas in Ireland where environmental quality may be at risk from atmospheric ammonia. This risk-based approach identifies Natura 2000 sites in Ireland at risk from agricultural atmospheric ammonia, collating best available data using Geographical Information Systems (GIS). In mapping ammonia risk on sensitive habitats (MARSH), the method identifies sources of ammonia, classifying them on a scale of risk from 0 to 5. These sources are subsequently summed based on a weighting determined by their contribution to national emissions divided by their potentially impacted area. A Pearson's correlation coefficient of 0.72 allows for concentrations from United Kingdom's FRAME modelling to be applied to the MARSH model, which are corrected based on recent monitoring. Applying Designation Weighted Indicators (DWI), the MARSH model predicts that 80.7, 34.3 and 5.9% of Natura 2000 sites in Ireland may exceed ambient concentrations of 1, 2, and 3 $\mu g/m^3$, respectively. A Nitroindex map of Ireland based on available lichen records was also developed and is presented as part of this study. This Nitroindex was used to identify areas where impacts have already been recorded, thus informing the classification of sites "at-risk". The combination of both the MARSH and Nitroindex models ascertains which Natura 2000 sites are most at risk, thereby providing valuable data to relevant authorities. The MARSH model acts as a first step towards screening and assessing Natura 2000 sites most at risk from atmospheric ammonia, providing a tool to demonstrate compliance with the National Emissions Ceilings Directive.
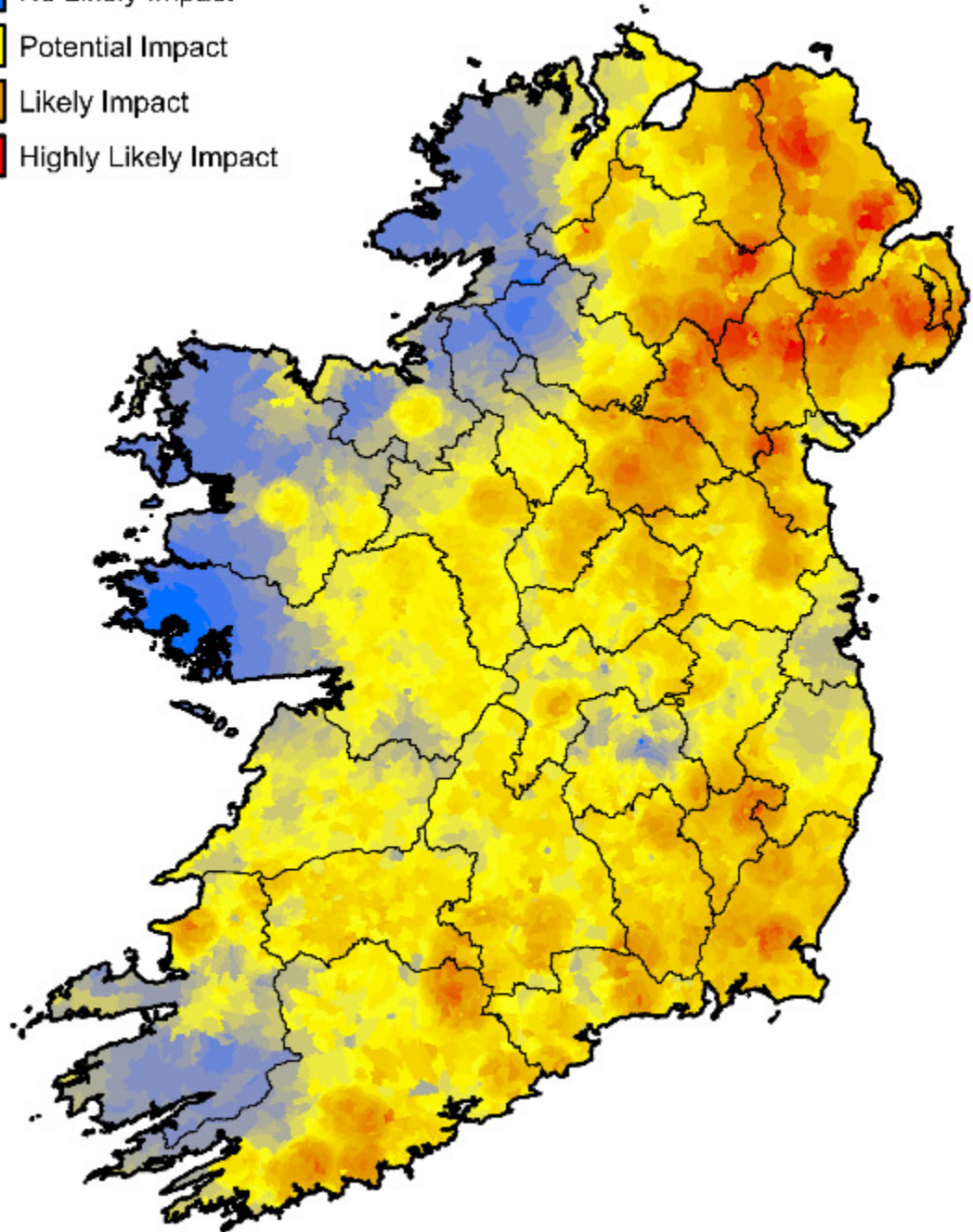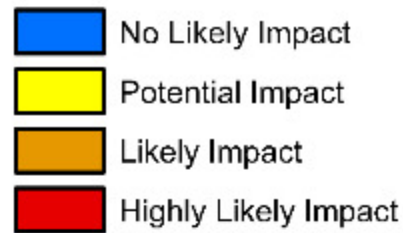
MARSH Components

- Identified contributing sources to atmospheric NH$_3$

- Ranked each sector on scale of 1 – 5 based on instensity

- Estimate contribution to likely impact based on;

- $\dfrac{total\ national\ emissions}{area\ occupied}$
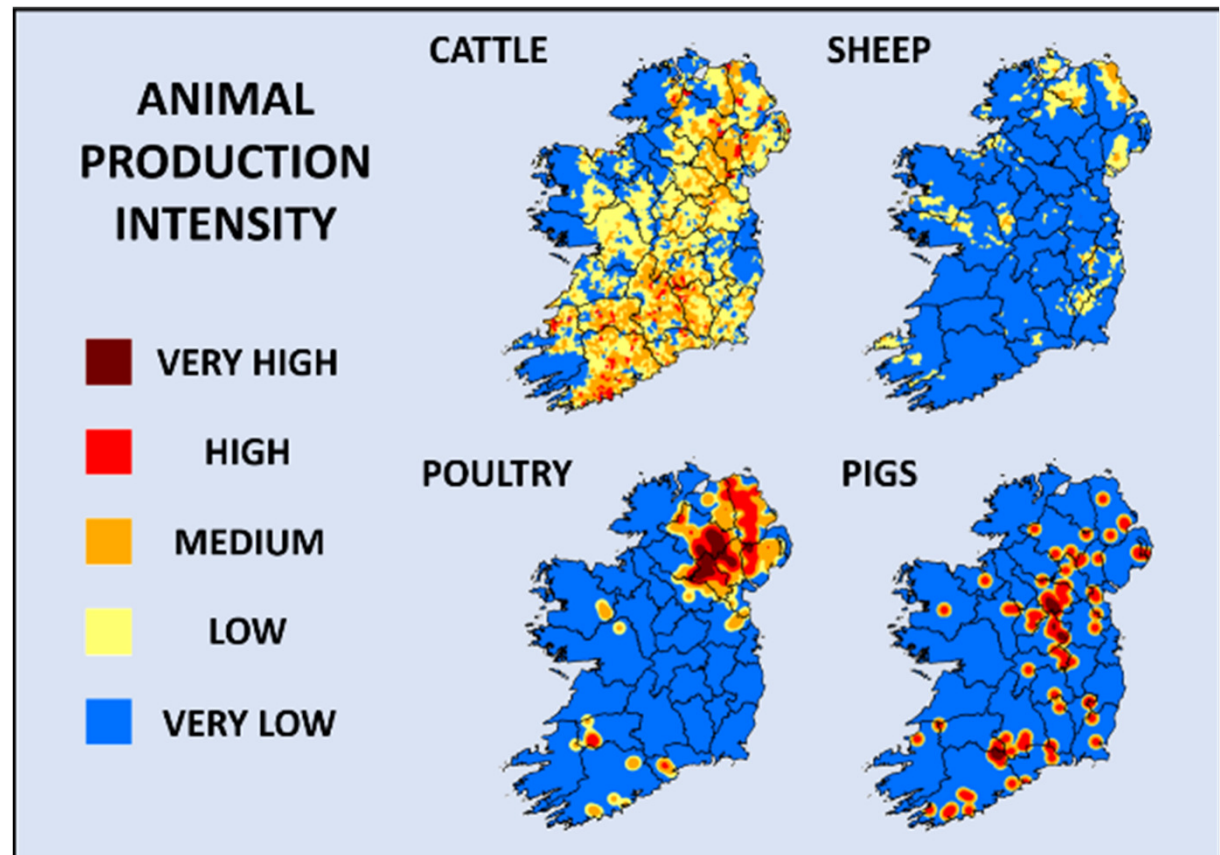
MARSH Risk Map

- Based on likely concentrations

- Derived from;
  - Animal production intensity
  - FRAME model in Northern Ireland
  - Ambient monitoring

Nitroindex

- Nitrogen sensitive lichen species between 2000 – 2014
  - Provided by CEDaR
- Used Nitroindex presented in Rihm et al., 2009
  - Within 10 km grids
- Interpolated using Inverse Distance Weighted (IDW)
  - Deterministic interpolation method
- Generated scale of + 1 to – 1
  - + 1 = Nitrogen tolerant (Impacted)
  - - 1 = Nitrogen sensitive (Unimpacted)

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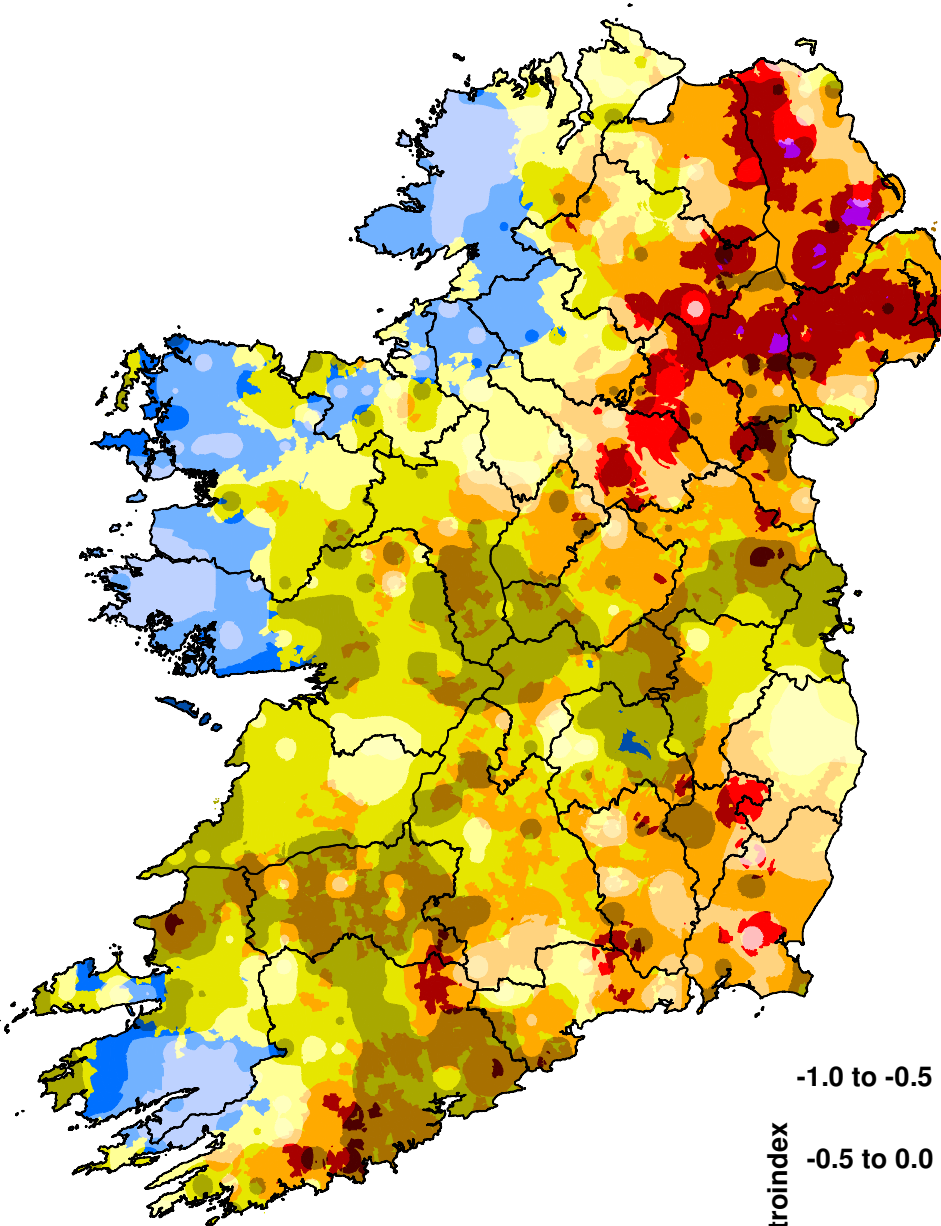+ 1

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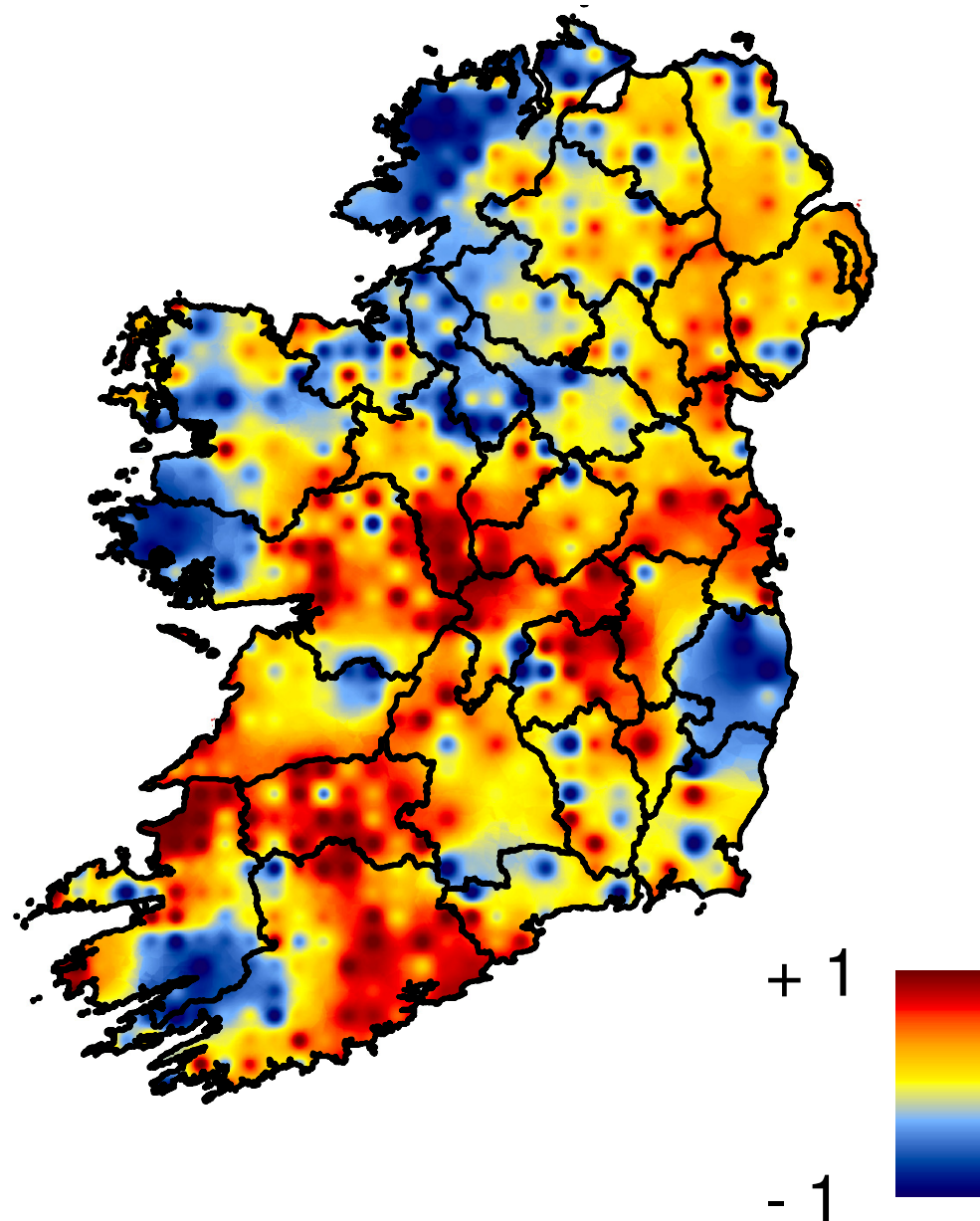
- Combining MARSH & Nitroindex to produce bivariate risk map
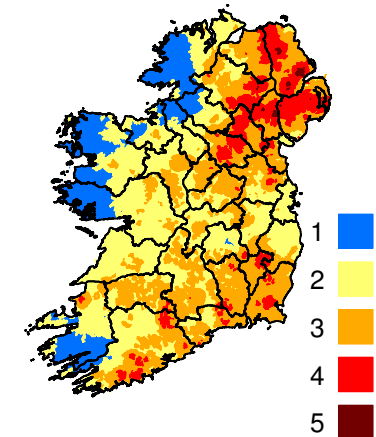   - Predicted concentrations (MARSH)
    - Recorded impacts (Lichen species – Nitroindex)

MARSH predicts;

- 80% > 1 µg NH_3 m^{-3}
- 35% > 2 µg NH_3 m^{-3}
- 6% > 3 µg NH_3 m^{-3}

MARSH

	1
	2
	3
	4
	5

Nitroindex

+ 1
- 1

MARSH Risk Category

| | 1 | 2 | 3 | 4 | 5 |

Nitroindex

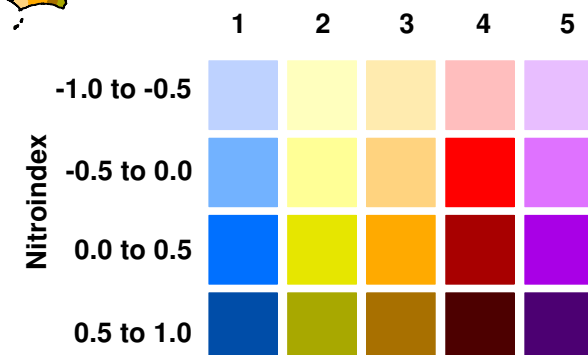| -1.0 to -0.5 |
| -0.5 to 0.0 |
| 0.0 to 0.5 |
| 0.5 to 1.0 |
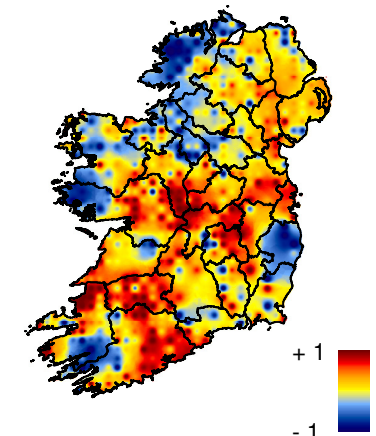
Validation of MARSH

- Conducted concentration monitoring on 12 sites

- Monitored concentrations

- MARSH appropriately predicts relative risk
  - Though tends to underestimate concentrations

- MARSH underestimated concentration on 9 out of 12

- Over predicted on 2

$y = 0.5102x + 0.4273$
$R^2 = 0.6029$

MARSH predicted NH_3 μg m^{-3}

Monitored NH_3 μg m^{-3}
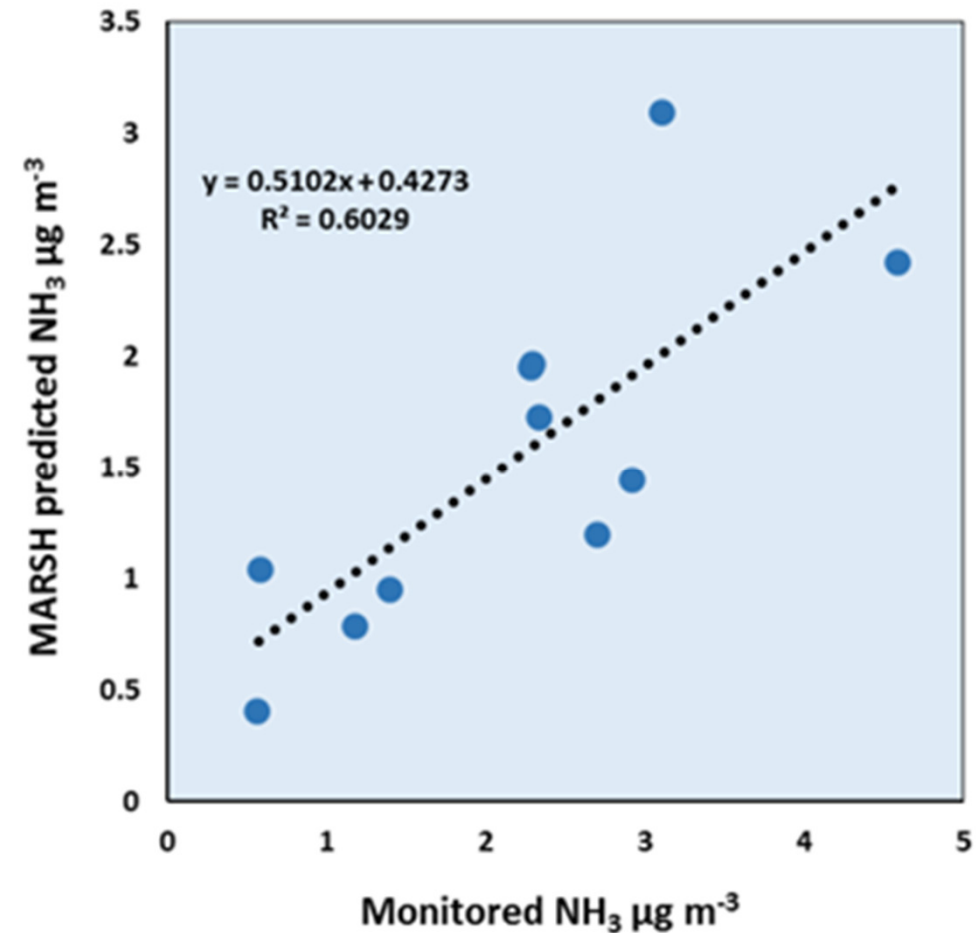
Pearson Correlation coefficient of 0.8 between

MARSH & monitored

Conclusions

- Habitats Regulations Assessments necessary for cattle & slurry spreading

- Below IED threshold pig and poultry farms need to be considered for cumulative impacts

- Precautionary principle should be applied when modelling impacts on Natura 2000 sites
    - Use highest emission rate possible if no site specific information is available

- Ventilation rate has an influence both on the emission rate and extent of the dispersion plume
    - Applying the precautionary principle here should consider lowest possible ventilation rate
    - Highest ventilation rate can underestimate concentrations locally

- Ventilation rate highly important in determining house specific emission factors
    - High ventilation rates may mask higher emission rates during site inspection

- Emission & Ventilation rates vary seasonally

Conclusions cont.

- Annual variation in dispersion extents
  - Due primarily to meteorological data

- Consider additional local contributions to air quality impacts when classifying baseline

- Environmental Assessments need to consider contribution of all types of Nitrogen inc. wet deposition & NOx's

- Ambient/Baseline concentrations vary seasonally – need to be considered for baseline monitoring

- If any doubt over baseline concentration due to number of proximal sources, should consider modelling contributions from existing sources or carrying out baseline monitoring

- MARSH model effectively acts as map of areas at risk from atmospheric NH_3
  - Underestimates concentrations
  - Detailed source apportioned concentration model required

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Website:

http://www.ucd.ie/
ammonian2k/