ARIES DOCTORAL TRAINING PARTNERSHIP

# ARIES CASE and Collaborative Studentship ideas from Sandpit Events (12th December 2017, Cambridge & 21st March 2018, Norwich)

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NERC SCIENCE OF THE ENVIRONMENT

Blue Ltd.

## Introduction

ARIES is the *Advanced Research and Innovation in Environmental Sciences* Doctoral Training Partnership (DTP). Funding is being sought from the Natural Environment Research Council (NERC) for 8 years of funding for PhD students starting their studies beginning in October 2019. The outcome of this bid will be known in September/October 2018, with recruitment of students beginning immediately thereafter (student application deadline in early January 2019).

ARIES is an evolution of the highly successful NERC-funded EnvEast DTP that takes its last intake of PhD candidates in October 2018. Current EnvEast PhD students would be able to begin internships with interested partners even before the start of ARIES, using existing EnvEast funds. For more on our current PINES internship scheme see enveast.ac.uk/professional-internships.

## The ARIES vision

The ARIES mission is '*to train postgraduate research students (PGRs) with excellent potential from across society, equipping them with the necessary skills to become 21st Century Scientists: leaders in the science and sustainable business of the natural environment*.'

## Co-designed and co-delivered studentships

ARIES encourages the active co-design of PhD studentships that address the interests of both academic and non-academic partners, whilst also meeting the expectations of PhD students to undertake high quality independent research at the core of their doctoral training.

The following are some of the ideas formed during two Sandpit Events led by the forerunner of ARIES (EnvEast) with representatives from across the ARIES consortium (see bit.ly/aries_partners). These ideas may form the starting points of discussions between University investigators, research organisations, and end users from commercial, policy making and third sector organisations.

ARIES is committed to a target of **70% of all PhD studentships** to be collaborative between academic and non-academic partners. Overlapping with this, it has a target of **35% of studentships to be formal CASE awards**. Further details of these are given at bit.ly/aries_collab.

## ARIES research themes

ARIES has defined five major research themes:

**1.** Ecology and Biodiversity

**2.** Marine, Atmospheric and Climate Science

**3.** Geosciences, Resources and Environmental Risk

**4.** Environmental Genomics and Microbiology

**5.** Agri-Environments and Water

These are further elaborated at bit.ly/aries_res. Within these, certain Priority Research Topics have been drawn out for immediate consideration, along with exemplar projects that might form the basis of actual studentship ideas. These are all described here, and may also be consulted for potential project ideas.

The following are research ideas that have arisen in consultation with end users, categorised according to primary research theme. They are not in any way meant to be exclusive.

## Theme 1. Ecology and Biodiversity

'HOT' TOPICS

- Information on bird distribution in space and time (at least seasonality) with associated habitat usage e.g., rafting, moulting or nesting. This should include both designated and UK BAP priority bird species.
- Emerging technologies such as GIS and Lidar techniques in assessing habitat and conservation status
- Coastal ecosystem biodiversity: Understanding the factors that determine biodiversity - pressures, threats, ecosystem response and resilience to climate change.
- What emissions reduction pathways lead to the best outcomes for biodiversity? (i.e. what temperature rise should we target)?
- Ecosystem Services: - What do the people in England want in their environment? What can any given parcel of land offer (e.g. interest, return to business, health)

Technology Use in Conservation: Acoustic monitoring and video monitoring are large areas for growth, but we need to find ways to store and analyse the data. There are also ethical questions around the use of technology e.g. drones? We also need to question is integrating new technology cost effective for the data that is being collected? Technology only goes so far - we also need to ask the right questions and do the right research.

- We need to measure the impact and actual effectiveness of conservation interventions.
- Interest in further exploring the connection between human health and conservation.

Ecosystems vs. individual species: Little research has been carried out into trophic levels and social impacts.

Data Analysis: There is potential for machine learning to analyse existing and new datasets to find new conclusions and links. Should we feed big data and analysed data (currently sitting in a database) into a central database to preserve it for future analyses when time and technology is good enough to do it? Social outcomes of conservation data to be integrated into environmental data. Large datasets are needed to draw social conclusions.

## Theme 2. Marine, Atmospheric and Climate Science

'HOT' TOPICS

- To improve identification of potential aquaculture development sites nationally and assess potential for economic values of aquaculture at each site. Valuation techniques should incorporate emerging products and culture techniques.
- Ocean fluxes: Understanding how marine organisms drive major biogeochemical processes - calcification, silicification, carbon and nutrient cycling.
- Plastic pollution: discreet, ubiquitous and how to monitor? Plastics as a vector for oil pollution? Plastics absorb toxins, how much worse does plastic make other existing pollutants? Bioaccumulation in tissues? How does oil interact with microplastics? Use existing long-term datasets, base lines and plug into models.

- To identify areas of fringing habitat and transitional communities at risk from coastal erosion and identify sites potentially suitable for managed mitigation or habitat creation in response to coastal squeeze impacts.

Pathways – how is marine pollution getting there and what is the longevity?

How to better understand impacts on the environment and impacts of remedial technologies (drivers for the oil & gas industry)

- Reliable information
- Quick access
- Reacting to an event
- Long term monitoring/surveying important
- Technology available to react to an event
- Impacts of dispersal (technology vs. pollution)
- Good practices
- Appropriate for environment type
- Always looking to improve knowledge to develop management of pollution events

Impact of pollution on polar regions
There is increased shipping in polar regions and therefore increased likelihood of pollution. What are the impacts? What is affected? Will it recover?

Plastics: discreet, ubiquitous how to monitor? Cumulative, slow acting and persistent. Plastics as a vector for oil pollution? Food chains? Plastics absorb toxins, how much worse does plastic make other existing pollutants? Bioaccumulation in tissues? How does oil interact with microplastics? Use existing long-term datasets, base lines and plug into models.

Impact of plastic on birds: there is a lot of existing research but still room for improvement. Recovery rates? Does it matter? Impact at a population level (e.g. long term impacts in breeding etc.). Scaling up – challenging to get this type of data before vs. after. Lack of studies on growth rates, ecotoxicology, physiology response, model organism build up to population scale.

Climate Change and Business Impacts: The Oil & Gas sector needs research in order to undertake assessments of severity of climate change and its long-term business impacts. Can we as an industry continue to exist? Requires knowledge of Carbon Capture and Storage and other technologies.

Predictability: Knowledge regarding predictability is important and how we can improve it – seasonal / decadal.

Data: There are huge volumes of data being dealt with; new and innovative methods to crunch through this are important. How do we use data, how do we define and use mathematical relationships? We will have so much data that radically different approaches will be needed to understand and manipulate the data. Lots of measurements, but so much 'noise' and natural variability. Another example is, is the Ozone hole recovering?

Models: Work with the latest generation of climate models is important for the next generation of IPCC reporting. Analytical abilities will be needed, including the ability to analyse within time frames? Further there are a range of complex mechanisms, which need to be parameterised in models, often with limited observational data to constrain them. For example, there are limitations on number of chemical species and reactions we can put into models. A major challenge is being able to separate the signal from the noise, including uncertainties.  Understanding uncertainties in all of these things. Trying to model a system for which there are so many degrees of freedom.  Use the latest computational science.

Urban air quality monitoring:  Translating model results into policy. Some problems have simple scientific solutions, but require behavioural changes. For example, in many developing countries the air quality could be improved considerably if people did not use solid-fuel for cooking, but the solution requires affordable technology and behavioural change.

Specific research area 1: *New monitoring methods and analytical techniques to detect and predict microplastic pollution*
We have limited comprehensive datasets on microplastic abundance in the sea. It is likely that the spatial and temporal distribution of microplastics is affected by source-sink gradients from point sources (various industries including sewage treatment works) and oceanographic structures that lead to local particle accumulation with potentially harmful consequences for the environment. It is further likely that coastal areas are more susceptible to microplastic pollution and receive the largest inputs. No simple, reliable and affordable instrumentation for the monitoring of microplastic abundance exists and remote/optical/acoustic detection of plastics from various platforms including ocean gliders, drones or satellites is in the very early stages of development. This project utilises the significant expertise among ARIES partners in shelf-sea processes, ocean circulation and modelling, the application of autonomous platforms to address:

a. Where, how and when do microplastics enter the marine environment?
b. Can we identify substantial point sources that warrant concerted efforts to minimise microplastic effluents?
c. The lack of data that would be needed to inform the legal framework for discharge consent limits.

Specific research area 2: *Mechanisms for aggregation and resulting mass transport of microplastics*
Once in the marine environment, the fate of microplastics of various types (chemical composition, size, shape) is poorly understood. Biological processes including the formation of biofilms and resulting production of extracellular polymeric substances (EPS) alter the characteristics of microplastic surfaces. This profoundly affects their size, abundance and bioavailability, their uptake and transfer through marine food webs, the processes related to the physical aggregation and export from the neritic and pelagic zones, and the half-life of particle-associated contaminants (e.g. oil-related hydrocarbons, pesticides). This project uses laboratory incubations and field experimentation in tidal flats to investigate:

a. The ageing process of pristine microplastics and resulting microbial diversity on their surfaces.
b. The (biogeo)chemistry of microplastics in relation to primary productivity and respiration of organic material.
c. The dynamics of aggregation and flocculation that lead to increased particle sizes and down-ward transport.
d. The fate of microplastics in intertidal and subtidal sediments.

Specific research area 3: *New technologies for the removal of microplastics in waste streams*
Building on knowledge generated in research areas 1 and 2, this area aims to develop new technologies to minimise the release of microplastic-rich effluents into coastal seas. Existing small-scale approaches (staining, detection and removal via flow-cytometric sorting) will be assessed and explored for their suitability for upscaling. Particular emphasis will be on engagement with industry partners (e.g. washing machine manufacturers) to develop suitable strategies for the reduction and/or removal of microplastics in local waste streams. Specific objectives include:

a. Explore the properties of biofilms for the optical detection and removal of microplastics from wastewater.
b. Assess the effect of biofilms on surface charge and the potential for electrostatic removal of microplastics.
c. Investigate the possibility to integrate optical and/or electrostatic removal technology into existing waste streams from washing machines and sewage treatment works.

Specific research area 4: *Seasonal-to-Decadal changes to arctic sea ice and shipping routes.* Forecasting changes in sea ice on decadal time scales, impacts of meteorological and oceanographic processes on sea ice cover in the arctic. End users might be the shipping and oil & gas sectors. Collaboration with economic sciences for business economic impacts (although this may not be publishable, because it may contain sensitive information). Interesting geopolitical questions about governance of shipping routes and claims to oil resources.

Specific research area 5: *Future changes in storminess in southern ocean.* Use climate model output to investigate processes that lead to changes in storms and evaluate confidence. Collaborate with economists to investigate the economic impact of these changes to tourism, fishing, oil & gas, shipping etc.

Other potential topics of interest include:
- Climate change impacts on business - CCS to compensate emissions.
- Climate change impact on global monsoons
- Climate change & climate hazards/extreme events
- Extreme event impacts on Polar Regions, including polar research stations, risk to shipping from sea ice, and risk of melting ice shelves.
- Engineering challenges around ocean and marine surface atmosphere observation
- Sea level rise impacts for the UK
- Observations of sediment transport using autonomous platforms
- Observations of the impact of undersea volcanic eruptions on sediment and ocean temperature using autonomous platforms.
- Links to social science? Impacts on biodiversity of oil spills? Social perspectives of risks and hazards? Social acceptability of arctic exploitation?

## Theme 3. Geosciences, Resources and Environmental Risk

'HOT' TOPICS

- Physical models to improve understanding of sediment transport routes.
- Some dredged material can be used for beneficial purposes. MMO would like to better understand the barriers to the reuse of dredged materials and where it could be used.
- Fracking and associated monitoring: Legislation in relation to fracking is poor so it could become a big business, therefore a good research opportunity
- The Oil & Gas sector needs research in order to undertake assessments of severity of climate change and its long-term business impacts. Can we as an industry continue to exist? Requires knowledge of Carbon Capture and Storage and other technologies.

Coastal Erosion: large interested end-user communities in Norfolk, Suffolk, Southwest. Large volumes of data held by e.g. county councils. LIDAR – recently digitised.

Fracking and associated monitoring: There is a big gap in scientific knowledge/methods and this is very relevant over the next five years for DTP2. Legislation in relation to fracking is poor so it could become a big business, therefore a good research opportunity.

Using Fibre Optics to Monitor Vibrations: Using fibre optics to monitor vibrations from e.g. shifting sand dunes. Cables are very cheap so low cost once they are set up.

Climate Change: Influence of many natural hazards (flooding, avalanches etc.). Opportunities to tap in to climate data. Sensor equipment/data for researchers (coastal erosion, LIDAR, models etc.). Interreg funds climate change (significant funding area).

**Specific research area 1:** Cascading events and processes within a physical-socio-economic system. This project takes as its system a relatively large watershed or catchment that contains a rural population, mixed but changing land-use of agriculture, light industry, urban areas and, at the lower end, a significant city (or megacity). This system consists of dynamically coupled components of environmental and human processes. The project is about understanding the strength of the couplings in this system, which can be examined by following the cascade of events that follow one or more significant disasters within the selected catchment. (An exemplar of this system is the Red River – Hanoi catchment, but there are others in SE Asia and India that might be chosen.) For example: a dam failure or a significant landslide might be the initiating event, large enough to trigger a variety of socio-economic and physical events that cascade through the system. These events (initial and triggered) do not happen in a vacuum, and they happen (most likely) in the context of similar events that have occurred throughout the region's history. The events can also include policies (developed in response to one or more of the earlier events). The student can decide how to approach an investigation of this system. It might be focused on the evolution of behavioural norms (at individual or institutional scales) informed by social sciences, or via behavioural economics. Or it might be computationally focused, by incorporating irrational behaviour within agent-based models.

**Specific research area 2:** Sand-engine geoengineering along the northern Norfolk coast.
A sand-engine is planned as part of a significant coastal protection scheme adjacent to the Bacton Gas plant in north Norfolk. This project would examine the actual and potential evolution of the large-scale sand-engine in the face of a changing climate and human forcings and within the site-specific conditions (including lithology, near and offshore bathymetry, etc.)

**Specific research area 3:** Coastal change as a coupled function of human and natural processes. Coastal change is typically examined as a physical problem and as a function of wave energy coupled to the resilience of beach and cliff material. However, it is now recognized that a significant driver of coastal change can be the human process, where that process comes in the form of market values of housing along the coast and of sand required for beach nourishment, availability of funds, coastal management policies, etc. The role of the human process, however, has not been explored fully nor in many environments. This proposal plans to tackle the role of the human process (as defined and refined by the PhD candidate) in the evolution of coasts over human time-scales.

## Theme 4. Environmental Genomics and Microbiology

'HOT' TOPICS

- Environmental genomic and Microbiology" :"Vertebrate and plant adaptation to a changing environment

- Evidence on whether, or to what extent, acclimatisation occurs (in the marine environment), whether acclimation is species dependant and the conditions under which acclimation occurs such as in interaction with other pressures.
- Mechanisms of plant immunity
- Pathogen adaptation and specialisation
- Marine microbes, phytoplankton, fungi and viruses: Controlling factors, interactions, variability and adaptation to change.

<u>Adaptation/mechanistic understanding</u>
<u>Genome-to-landscape (ecosystem) underpinning all other themes.</u>

Adaptation to environmental change and multiple stressors

- Scale: local to global
- Life-stage-specific effects

Inter-species adaptation, co-evolution and trade-offs
Remediation/regeneration of degraded contaminated environments
Mechanistic understanding of X

- Poorly understood organisms
- Molecular markers for X
- Functions and Resistance
- Biodiscovery

## Theme 5. Agri-Environments and Water

'HOT' TOPICS

- How to attribute changes in the level of hazardous chemicals, metals, etc. to ecosystem service provision – particularly when there is not a detailed mapped baseline or where there may be chemical interactions within the environment.
- What is the amount of land required to feed the population and mitigate climate change to 1.5°C and where is it (taking into account water constraints)?
- What combination of social, political and technical conditions are needed to ensure that these land and water requirements are compatible with preserving biodiversity and how do we achieve those conditions?
- How can we better promote sustainable development in wildlife corridors?

What are the small steps to address to the big questions? Partners are looking at broad questions.

<u>Short term water diversity (farming):</u> Ecology and hydrology measures.

<u>Ecosystem services and natural capital</u> – how do we implement the pure science?

- Nutrient and biomass flows from farms (hydrology).
- What do the people in England want in their environment? What can any given parcel of land offer (e.g. interest, return to business, health)
- What are the components of the marine system (modelling, maps, trade-offs)? What are the values they provide (is this too big for a studentship)?
- Link the pure science to social and economic science and policy.

Ecology Networks: How do we build resilient ecology networks? Fen ecology and biodiversity.

Broad research questions

There are lots of overlapping questions/interests. Someone needs to help work through these and bring in appropriate academics or be clear if you do not have the appropriate expertise.

- How to attribute changes in the level of hazardous chemicals, metals, etc. to ecosystem service provision – particularly when there is not a detailed mapped baseline or where there may be chemical interactions within the environment (Risk & Policy Analysts).

- Use of an ecosystem services framework to consider the impacts of chemicals on the environment.

Cross cutting themes:

- Environment and Biodiversity
- Resources and Environment
- Water Cycle → Marine
- International and Water
- Global water availability, scarcity and management
- Community based adaptation
- Water resources and international trade consumption/behaviour

Industry Drivers:

- Marine plastics – water quality
- Agri-environmental schemes
- Emerging contaminants
- Yield and sustainable increases
- Drought/flooding → climate and resilience →Day 0 →water resources (e.g. population change)
- Natural capital and ecosystem services
- Managing rural and urban water quality and quantity.

Global vision

- Agriculture and offsetting carbon due to soil quality
- Health implications of sludges to soil.

21st Century Soils – ARIES will nurture research concerned with the holistic understanding of soil and the ecosystem services it supports. We are mindful of the extensive manipulation, linked to agricultural interventions, across landscapes, and that now, in the 21st Century, there are possibilities to geoengineering soils to enhance delivery of soil ecosystem services (increase yields, increase carbon storage, regulate greenhouse gas emissions & water flows and mitigate pollution). However, these manipulation generate trade-offs where improved provision of one service might be at the detriment of others. Within the Nexus of linked issues underpinned by soil (food, energy and water) there is a need to understand the processes and to contextualise them within a valuation framework. Here there are roles for the next generation of environmental scientist to undertake discovery science, to influence environmental regulation and policy and to engage with agri/water industries to deliver societal impact.

**Biodiversity and Agri-environmental schemes.** Markets/dry year options/transfers and effective learning transferred overseas. Farm to fork: soils/consumer/supermarket. Environmental mitigation – linking of landscapes, consider benefits.

**Ground water and Ground water recharge.** Public perception of subsurface water e.g usage/fracking/CCS. Risks of flood and drought, flood mitigation. New tools and markets with novel approaches. Future visioning of communities e.g. food/water resources. Changes in land use and impacts on the water use and pollution. Valuing subsurface in natural captical/ecosystem services. Flood water re-use. 'Subsurface sponge' and public.

- Automation
- Smart technology
- Remote sensing
- Machine Learning
- Tech future

**Others:** Non-themes priorities identified by research-users not in the above

Other priority areas raised:

- AI (Artificial Intelligence) and Computing Science.
- Links to Industrial strategy
- Energy supply and alternative energy
- Mineral resources e.g. rare elements for mobile phones?
- Remediation of land sites
- Modelling e.g. satellite data needed in many areas.
- Machine learning
- What is the commercial potential in all these areas?
- Despite suggesting these as 'other' areas, companies can see areas to engage with the main themes above

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