2020

afbi AGRI-FOOD & BIOSCIENCES INSTITUTE

Science Impacts 2020

Leading | Protecting | Enhancing







Contents

5 Introduction

6 AFBI - What we do

8 The key metrics for AFBI 2015 - 2020

9 SECTION 1 - Leading Improvements in the agri-food industry

13 Improving perennial ryegrass varieties for Northern Ireland
14 Replacing imported protein sources for dairy cows with locally grown field beans
15 Changing pig nutrition - good for the environment, pigs and your neighbours!
16 Building a farming workforce for the future - upskilling and lifelong learning
17 Extending shelf-life to tackle potential Brexit transport delays
18 Tailoring beef production to meet regional tastes
19 Potential Brexit Impacts on UK Farm Incomes
20 AFBI forecasting - helping mitigate the 2018 drought

23 SECTION 2 - Protecting animal, plant and human health

24 Leading the fight against viruses
26 Ground-breaking Campylobacter research benefitting agri-food sector
28 Internationally renowned research into bovine tuberculosis
30 Florfenicol non-compliance in milking cows
31 'Shedding light' on improving vitamin D content in popular foods
32 Safeguarding Plant Health
33 Illegal import testing reveals an unwelcome first for the UK
34 Making a 'mark' genetically to combat Bovine Respiratory Disease
36 Disease surveillance in frontline of safeguarding livestock

39 SECTION 3 - Enhancing the natural and marine environments

40 Can energy crops reduce wastewater pollution?
41 Follow that fish – acoustic tracking of migratory fish
42 Safeguarding our threatened peatlands and wetlands
43 Using the 'earth' to tackle climate change
44 Ecosystem Modelling key to sustainable aquaculture
46 No more 'hide & seek' for Irish Sea Cod

48 SECTION 4 - Ongoing AFBI science making an impact

57 SECTION 5 - Research highlights

59 SECTION 6 - Journal articles

Introduction

I am pleased to introduce the third in the series of AFBI Science Impacts in which we highlight some of our latest achievements and key outcomes.

As an arms-length body of DAERA, AFBI science plays a crucial role in providing the underpinning research and development, diagnostic and analytical testing, emergency response capability and expert scientific advice required to support the various work programmes of DAERA and the wider requirements of the agri-food industry.

We live in an era of significant global challenges which include issues which affect all of us such as climate change, food security, and the growing threat from antimicrobial resistance. As I write this introduction, the COVID-19 pandemic has sadly claimed many lives globally and is the most devastating example in recent times of the on-going threat posed by disease emergence, an issue for both human and animal populations.

At a local level, we are fortunate in Northern Ireland to have a wonderful natural environment which is enjoyed by wider society and tourists alike. However, the NI agri-food industry, as custodians of that environment, faces the on-going challenge of how to simultaneously balance environmental and economic sustainability; effectively how do we all ensure sustainable and profitable agri-food production delivered in harmony with a clean, healthy, and diverse environment.

Against that backdrop of global and local challenges, arguably the need for science has never been greater. AFBI is well placed to contribute to meeting these challenges through our work which centres on our three key themes of leading improvements in the agri-food industry, protecting animal, plant and human health and enhancing the natural and marine environments. The achievements noted in this booklet provide testament to these goals.

Science is increasingly multidisciplinary and frequently involves a range of organisations working together. To deliver many of the achievements within this booklet, AFBI has been delighted to work alongside industry, government and academic colleagues to ensure that the work we do has direct relevance and impact and to maximise our learnings from others.

This booklet reflects the excellence of our scientists through their ability to conduct highly relevant applied science, addressing local needs but also making a scientific impact nationally and internationally. We have included a number of examples in this booklet of AFBI's involvement in collaborative and far reaching initiatives which not only add value to Northern Ireland but also develop novel strategies and foster imaginations to ensure future success.

I trust you will enjoy reading about the successes of AFBI over the past 18 months.

Dr Stanley McDowell CEO

afbi

Who we are and what we do

AFBI'S VISION

Advancing the local and global agri-food sectors through scientific excellence.

AFBI'S MISSION

Enhancing industry innovation and informing government policy across the agri-food and rural sectors through excellence in scientific services, research and development & knowledge.


LEICA M420

Key metrics for AFBI 2015 - 2020

PROTECTING THE NI ECONOMY

AFBI have delivered on

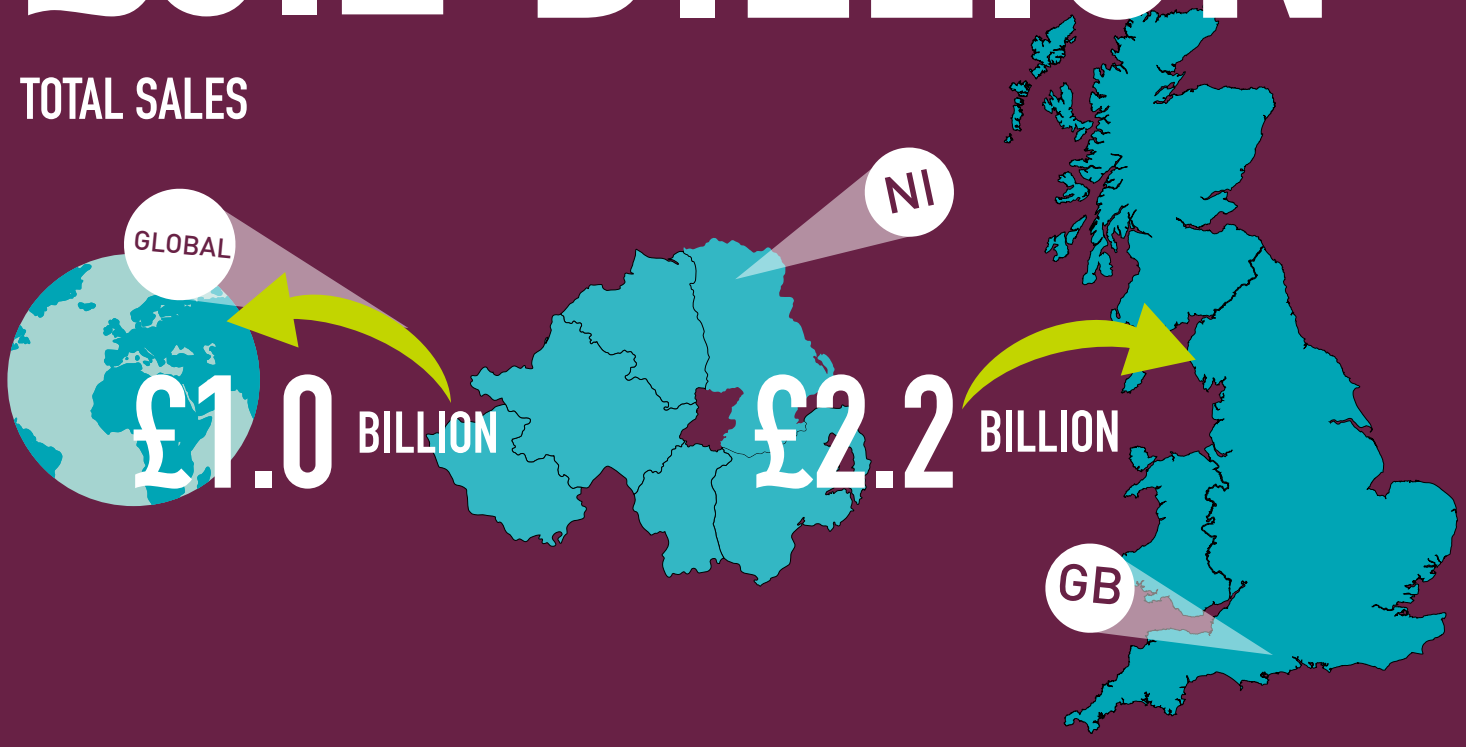
4 MILLION

ANIMAL, PLANT AND FOOD SAFETY TESTS

In support of sales from the agri-food industry to the value of:

£3.2 BILLION

TOTAL SALES



INFORMING POLICY

AFBI has delivered

91

EVIDENCE AND INNOVATION

Projects for DAERA

KNOWLEDGE TRANSFER

AFBI has delivered

2155

OUTREACH ACTIVITIES

Over The Past 5 Years

WORKING WITH OTHERS

AFBI works with partners across

35 COUNTRIES

AFBI have secured

£44 MILLION

OF EXTERNAL RESEARCH GRANTS AND CONTRACTS

EXCELLENCE IN SCIENCE

AFBI has delivered

399

SCIENTIFIC PAPERS

OVER THE PAST 5 YEARS

SECTION . 1

Leading Improvements in the agri-food industry


539
530
527

Improving perennial ryegrass varieties for Northern Ireland

Research lead: Dr Gillian Young

Northern Ireland continually needs new grass varieties to increase year-on-year efficiencies in production as measured by grass utilization and livestock output. Current grassland utilization on Northern Irish farms is approximately five to seven tonnes of dry matter per hectare per year. At AFBI's Loughgall site, however, our synthetics can produce over 20 tonnes of dry matter per hectare per year.

Advances in grass breeding research mean that AFBI's new varieties coming onto the market have improved yield and nutritional quality when compared to existing varieties.

As part of this work AFBI's highly successful grass breeding programme funded by DAERA and based in Loughgall launched its latest forage grass varieties, Gosford and Ballintoy, in 2018 and Callan in 2019. The varieties are marketed through AFBI's commercial partner, Barenbrug UK Ltd, and seed is now available. AFBI has also helped to set up a Barenbrug-funded field trial testing site in Clonakilty with the aim of further testing our varieties under more southern conditions.

The importance of genetic progress with regard to grass was highlighted in 'The Sustainable Agricultural Land Management Strategy report (2016)' which demonstrated the substantial gains that can be made on-farm if grass utilization is increased. For example, if the current average farm utilised just one extra tonne of good quality dry matter production (ie, by using improved varieties) of grass per ha, the net profit gain would be £137 per ha per year (assuming the beef price was 280p per kg). That's an increase of £22 per ha.

Reseeding with improved grasses increases both grass production and utilization, making a significant financial contribution to Northern Ireland's grassland-based agricultural industry. Assuming that the benefit of these sown varieties is maintained by good management for five years, the annual current net gain to local agriculture would be £3.1m.

Grass plots at new testing site in Clonakilty in 2018

Replacing imported protein sources for dairy cows with locally grown field beans

Research leads: Dr Conrad Ferris and Dr David Johnston

As the milk yield potential of dairy cows has increased, so too has the demand for concentrate feeds and the high quality 'protein' ingredients that they contain. Many protein ingredients, however, are imported from countries outside the EU, and this has left the dairy sector vulnerable to supply instability and price volatility, particularly as the outcome of Brexit is still to be determined. Consequently, there is considerable interest in using locally-grown protein crops, including field beans.

Field bean (Vicia Faba) is a grain legume with a moderate crude protein content (280 g/kg dry matter), and a relatively high starch content (400 g/kg dry matter). It might, therefore, be ideal in ruminant diets. The inclusion of field beans in ruminant diets, however, is normally restricted due to the perceived risk associated with 'anti-nutritional substances' that may reduce intakes and digestibility, and oestrogenic compounds that could adversely impact fertility.

Given these concerns, the potential of including field beans in dairy cow diets has been examined in a series of AFBI studies, with the beans used in these studies grown on farms in Northern Ireland. Inclusion levels in the diet ranged from zero to 8.4 kg per cow per day, with beans replacing all of the soya bean meal, rapeseed meal and maize gluten in the concentrate at the highest inclusion level.

Including field beans in the diet had no adverse effects on Dry Matter intake in any of these studies, while ration digestibility was largely unaffected by bean inclusion. These findings suggest that the 'anti-nutritional substances' present in beans do not have as large an impact on intakes and digestibility as previously thought.

While milk yields were also unaffected when field beans were offered, there was a trend for milk protein content to be reduced when intakes of beans were approximately 4.5 kg per day. There was a definite reduction in milk protein and milk fat content when the intake of beans was 8.4 kg per day. While the reduction in milk fat content can likely be attributed to the higher starch intake with high intakes of beans, the reduction in milk protein content is more likely to reflect a shortage of limiting amino acids in the diet. For example, field beans are known to contain much lower levels of methionine and lysine (both essential for milk protein synthesis) than either soya-bean meal or rapeseed meal. Thus, it may be possible to eliminate the fall in milk protein content by supplementing the diet with specific limiting amino acids.

From an environmental point of view, offering field beans did not affect enteric methane production. While there are concerns about the presence of some oestrogenic compounds in beans, the inclusion of beans in the diet had no effect on days to first oestrus. Very large numbers of cows, however, would be required to identify if beans had an effect on fertility outcomes. A further study has demonstrated that simple on-farm processing techniques (such as acid treatment) can be effective in preserving moist beans and that drying is not necessary.

Locally grown field beans provide an opportunity to partially replace conventional protein sources in dairy cow diets which are normally imported. Given the reductions in milk protein concentrations observed, however, it is recommended that field bean inclusion levels for dairy cows do not exceed 4.0 – 5.0 kg per cow per day, unless diets are balanced for essential amino acids. Commenting on the outcomes of the research programme, Jason Rankin from AgriSearch said

"Northern Ireland farmers are increasingly recognising the challenges of relying on imported protein feedstuffs and this research programme has demonstrated that locally grown field beans have the potential to partially replace conventional protein ingredients."

Jason Rankin, AgriSearch

Funding for the study was provided by DAERA and AgriSearch.

Changing pig nutrition - good for the environment, pigs and your neighbours!

Research leads: Dr Elizabeth Ball and Dr Ursula McCormack

Through its work with industry partners in a long-standing Pig Research Consortium, AFBI has shown that reducing the dietary crude protein (CP) content of finishing pig diets reduced water intake, ammonia emissions and slurry output. These findings will have a positive effect on the environment and will inform policy makers and regulators on potential dietary mitigation strategies.

Excess ammonia emitted to the environment has had a detrimental effect on sensitive habitats leading to a loss of biodiversity. This loss not only negatively changes the natural environment, it also reduces carbon sequestration which has wider implications for climate change.

Pig production is not a large contributor of ammonia when viewed from a Northern Ireland perspective, but units close to sensitive areas and large enterprises face particular scrutiny. In addition, odour emissions from pig units are problematic, can cause issues with neighbours and, if excessive, can hinder business expansion.

There are a number of ways to reduce ammonia and odour production, with most focus on altering diet. A reduction in the level of dietary CP results in less nitrogen excreted, and, therefore, a reduction in the potential for ammonia creation (provided CP and digestible amino acids are adequately supplied and the diet is formulated to ensure production performance is maintained). Some producers of finishing pigs have reduced dietary CP content in recent years, but it is not known what quantitative effect this reduction will have on ammonia, odour or slurry output.

As part of the study, pigs were housed in respiration chambers to allow accurate ammonia production assessment. A sample of air was also taken for dynamic olfactometry to assess odour offensiveness. Pigs were offered either a high protein diet (18% CP and 1.1% lysine), a medium protein diet (15% CP and 1.1% lysine) or a low protein diet (13% CP and 0.9% lysine) from 65-110kg. The diets were formulated by John Thompson and Sons Ltd. using 'Evolution Technology'.

Reducing dietary CP content significantly reduced ammonia emissions (by 49%), water intake (by 25%) and slurry output (by 38%) which has major environmental benefits. Although not statistically significant, odour offensiveness was numerically 19% less in pigs offered lower CP diets.

The relative differences between ammonia emissions, water intake and slurry output as a result of different dietary CP demonstrate environmental benefits of reduced CP diets. Performance trials are currently being conducted as it is important to ensure that production performance is maintained across the dietary CP levels. Further studies are also on-going specifically targeting the reduction of odour.

Funding was provided by DAERA, John Thompson and Sons Ltd., Devenish Nutrition and Preferred Capital Management.

"Having the ability through the research consortium, to produce scientifically and statistically robust information on the emissions from pigs fed commercially applicable diets is extremely valuable from John Thompsons / Devenish Nutrition point of view. First, it provides information which validates and proves that emissions can be reduced when a correctly formulated and target nutrition programme is used. Secondly it provides confidence for our pig farming customers that emissions can be reduced successfully without compromising on animal performance and without any additional cost. Thirdly it provides a robust information base that can be used to help meet the requirements for planning, IPPC or future legislation. Overall, this type of project provides the confidence to allow farmers to adopt these technologies and deliver the required environmental benefits."

Sam Smyth Business Development & Technical Manager, John Thompson and Sons Ltd
Violet Beattie, Research and Technical Services Manager, Devenish Nutrition

Building a farming workforce for the future - upskilling and lifelong learning

Research leads: Dr Claire Jack, Dr Austen Ashfield and Dr Conall Mullan

Farming is facing an ever changing environment - worldwide population growth, climate change, maintaining global food security and changing consumer demand to name just a few. As a result, the need to enhance farmers' skills has never been greater.

For a sector which is increasingly becoming more knowledge intensive, the adoption of new technologies and implementation of good farm management practices are even more critical to achieving profitability and sustainability - regardless of the size and scale of a farm business. Likewise, developing polices that foster skills and encourage positive approaches to lifelong learning is also essential.

AFBI Economics undertook a review of the provision of agricultural education and training in Northern Ireland. The research involved in-depth interviews with a wide range of key stakeholders and a survey of farmers who had previously undertaken agriculture training locally.

The study was funded by DAERA and its aim was to gain an understanding of the skills and training challenges currently facing the sector; obtain views on current provision and gain an understanding of the demand for future skills development. The study identified the main areas where there was a training need, the methods of training favoured by farmers, perceived barriers to training and current and potential future skills gaps within the sector.

"This research has provided sound underpinning evidence which will help to guide CAFRE in developing its portfolio of education and training courses to meet the needs of the agricultural industry".

James O'Boyle, Head of Education Service, CAFRE, College of Agriculture, Food and Rural Enterprise| Department of Agriculture, Environment and Rural Affairs.

An important theme emerging from the research is the need to embed key professional skills, (both business and technical) into the more practical aspects of farming through the development of a programme of continuous professional development that encourages and supports life-long learning. Moreover, the fast pace of change and the need for farmers to adopt new practices, innovations and technologies on-farm, requires greater partnership between key players in the sector. These include researchers, extension services, educators and the wider industry with the aim of ensuring a more timely transfer of science and innovation to foster best practice at farm level.

The study proposed nine key recommendations to provide a framework for strategic direction in the area of skills development and life-long learning for current agricultural education providers, policymakers and the wider industry. The research has been presented to CAFRE's Management Board and its wider industry College Advisory Group and has contributed to the evidence base underpinning CAFRE's strategic plan. It has also informed policy around DAERA's Knowledge Framework.

Extending shelf-life of food products

Research leads: Joan Tollerton and Dr David Farrell

As meat accounts for 50% of Northern Ireland's agricultural output, it's essential that the shelf life of refrigerated fresh meat is maximised. Shelf life, however, is currently limited to days, leading to substantial losses for both consumers and retailers. This is particularly relevant given potential future appointments for NI to market products to a more diverse range of markets. High Pressure Processing (HPP) may provide the answer.

HPP is a cold pasteurisation technique that subjects packaged foods to extremely high pressures in a water medium. HPP has been proven to extend product shelf life by inactivating the vegetative flora present in food.

Recent DAERA-funded research, carried out at AFBI, highlighted the potential of natural antimicrobial essential oils to restrict the growth of specific microorganisms (Figure 1). Cinnamon bark oil, clove bud oil and lemongrass oil were shown to restrict most of the microorganisms studied.

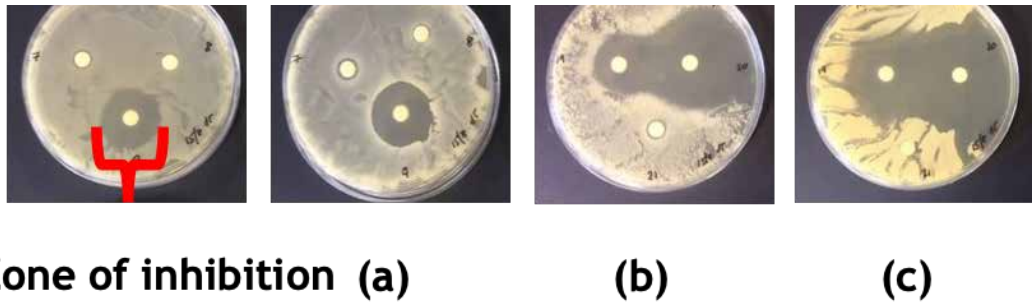


Figure 1. Example of a disk diffusion assay showing the effect of selected spice oils and untreated "control" on (a) Bacillus subtillis (lemongrass oil), (b) Brocothrix thermosphacta (clove bud and lemongrass oil) and (c) Micrococcus luteus (clove bud and lemongrass oil)

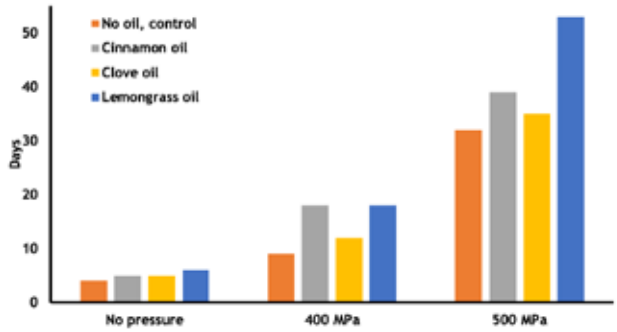


Figure 2. Effect of essential oil active packaging and HPP treatment on the time required to reach shelf life (107 cfu/g Total Viable Count).

Active packaging films prepared using cinnamon, clove and lemongrass oil extend the shelf life of raw minced beef purchased at retail by one to two days (Figure 2). Results also highlight synergistic effects between HPP (400 & 500 MPA) and active packaging which could extend the shelf life of raw minced beef by up to 40 days (Figure 2). AFBI-Food Research Branch is planning further research on these packaging and HPP solutions to extend shelf-life of commercial products.

An additional one to two days on the shelf-life of meat could prove valuable. Developing these technologies may have an important impact on the shelf-life and economics of Northern Ireland into the future.

Tailoring beef production to meet regional tastes

Research leads: Fui Shien Chong, Dr Terence Hagan and Dr Linda Farmer

Consumer panels at AFBI - Newforge Lane

Consumers from Great Britain, Northern Ireland and Republic of Ireland like the same steaks, but did you know that GB consumers give the highest scores in consumer trials?

Northern Ireland (NI) and the Republic of Ireland (ROI) supply beef to both their home markets and to Great Britain (GB). Consequently, the beef industry is keen to understand what, if any, regional differences exist between consumers in these islands.

Consumer panels were conducted in Belfast, Cork and Reading with 120 consumers from each region, following a standard protocol. Consumers assessed the same beef striploins for tenderness, juiciness, flavour liking and overall liking.

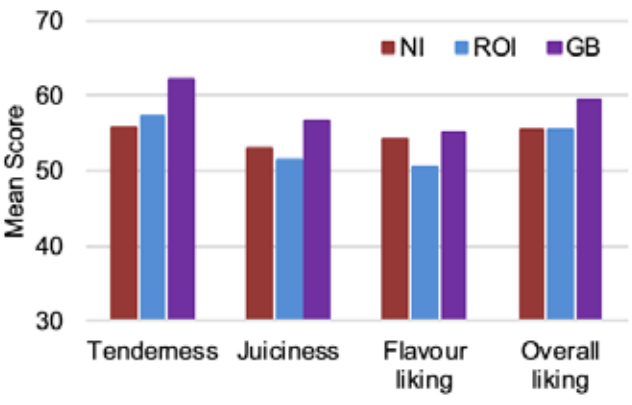


Figure 1. Mean sensory scores for Northern Ireland (NI), Republic of Ireland (ROI) and Great Britain (GB).

The panels found that region had significant effects on consumer sensory scores (Figure 1), including tenderness, juiciness, flavour liking and overall liking. GB consumers gave higher mean scores for the beef striploin samples, with the highest differences observed for tenderness and juiciness.

The differences between GB and ROI/NI consumers were not explained by sociodemographic factors, such as age, gender or income. Evidence suggests, however, that higher GB consumer scores may be due to their higher consumption of less tender cuts such as rump steak. Despite the difference in scores, GB consumers did not differ from their ROI/NI counterparts in the relative scores attributed to the steaks, and the same steaks were liked or disliked in all regions. This means that sensory panels conducted in NI or ROI will still provide valid results for exporters of beef to GB.

The data and information attained from such consumer trials provides both retailers and processers with a greater understanding of consumer preferences and enables more directed marketing of their products. AFBI- is now one of the few organisations in the UK and Ireland with extensive experience of conducting consumer panels at a range of locations.

The research was conducted in collaboration with Dr Maurice O'Sullivan and Professor Joseph Kerry of University College Cork, Dr Lisa Methven of University of Reading and was funded through the Sensory Food Network Ireland by the Department of Agriculture and Food's Food Institutional Research Measure (FIRM: 13 SN 401).

Potential Brexit Impacts on UK Farm Incomes

Research leads: Dr Myles Patton, Prof John Davis and Dr Siyi Feng

AFBI-Economics, in collaboration with Newcastle University, The Scottish Rural University College (SRUC) and University of Missouri, has estimated the impacts of possible Brexit trade and domestic policy scenarios on UK farm business. Economy-wide and farm sector projections (to 2026) were linked with a series of farm models to evaluate the impacts on farm businesses and households. The impacts were examined across heterogeneous farm populations and regionally across the UK.

Three possible Brexit trade scenarios were analysed:

- A bespoke free trade agreement with the EU - a 'soft Brexit' option
- A WTO Default scenario with high tariffs applied to trade between the UK and EU - a 'hard Brexit' option and
- An extreme Unilateral Trade Liberalisation (UTL) scenario with zero tariffs applied to imports to the UK – another 'hard Brexit' option.

In addition, two alternative domestic policy alternatives were considered:

- Pillar I direct payments retained as currently under the CAP and
- A phased elimination of Pillar I direct payments over a five-year period with Pillar 2 payments remaining at current levels.

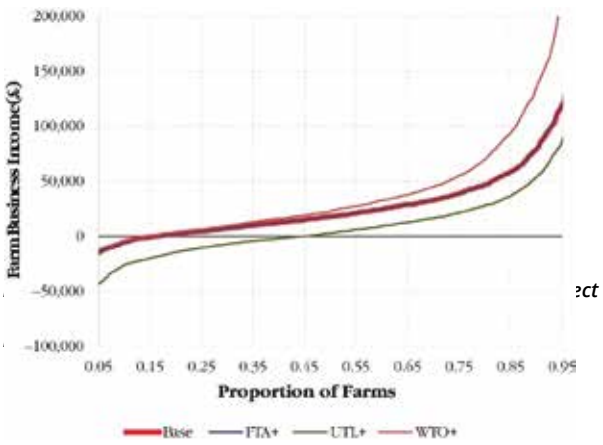
The UTL scenario shows significant negative impacts on producer prices, particularly in the UK beef and sheep sectors. Under this scenario, for example, it is estimated that there will be a large increase in imports to the UK beef sector from the rest of the world. This reflects the highly competitive nature of overseas suppliers (e.g. Brazil and Australia), and results in UK producer beef prices falling close to world levels. This decline in prices under UTL has marked negative impacts on farm incomes.

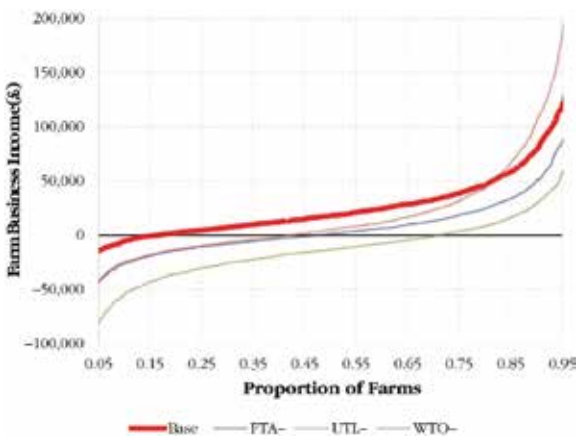
While 15-20% of farms did not make any money in the baseline case (Figure 1-red line), this rises to 45% under the UTL scenario with Pillar I direct payments still in place (Figure 1-green line). Given the dependence of many UK farms on direct payments, their removal predictably worsens the negative impacts on farm income. The elimination of Pillar I direct payments further increases the proportion of farms not making any money to 70% under UTL (Figure 2-green line).

The negative impact on farm incomes is greater in the devolved administrations than in England where farms are more diversified and less dependent on the beef and sheep sectors.

This analysis has been discussed extensively with policy makers and industry representatives across the UK. It has made a significant contribution to the body of evidence used by policy makers within the UK's four agriculture administrations to prepare a range of papers and briefings, and to inform policy positions on the potential impacts of alternative Brexit scenarios. The analysis has also been widely cited by industry bodies across the UK, including the NFU of England and Wales as part of its submission to the House of Lords' EU Select Committee inquiry 'Brexit: Deal or No Deal'.

Funding was provided by the Economic and Social Research Council (ESRC) through its 'UK in a Changing Europe' initiative, DEFRA and the Devolved Administrations.





Forecasting grass growth - helping mitigate the 2018 drought

Dr Debbie McConnell and Dr Francis Lively

GrassCheck, AFBI's long-running grass growth monitoring and forecasting project, provides essential scientific information to help local farmers produce more from grass in an increasingly unpredictable climate. AFBI was the first organisation in the world to develop and operate such a grass growth forecasting service and in 2018 its worth was proven beyond doubt.

The 2018 growing season created massive challenges due to low air and soil temperatures in spring followed by good growing conditions, but then acute drought conditions in June and July. This caused large fluctuations in grass growth on commercial livestock farms across the Province. With grassland occupying 91% of Northern Ireland's agricultural area, the impact on the industry of unexpected climatic variations can be severe, reducing forage feedstocks for animals and increasing farm costs.

GrassCheck provides seven and 14-day grass growth forecasts for farmers, published weekly in the agricultural press and online (www.agrisearch.org/grasscheck) throughout the growing season. In 2018 these forecasts provided early warnings of extreme reductions in grass growth, particularly during the drought by predicting falls in grass growth rates from a peak of 113 kg DM/ha/day to 18 kg DM/ha/day (Figure 1). This provided farmers with the opportunity to take early action to protect forage stores on farm, minimising the negative financial costs of this drop in grassland productivity.

These forecasts are supported by a network of 48 dairy, beef and sheep farmer co-researchers (figure 2) who provide key grass growth and quality information on a weekly basis from 50 sites across Northern Ireland. This information is paramount to understanding and predicting grass growth potential across the Province. During 2018 a difference in 2 t DM/ha was observed in grassland productivity across different areas of Northern Ireland.

This information was used as a key evidence base by both DAERA policy makers and farm advisors to provide farm support during the challenging season. The weekly alerts helped local farmers minimise the impact of the exceptional 2018 growing season and they continue to provide this support, keeping farmers well prepared to manage future surpluses and deficits as they occur.

In 2019 GrassCheck was developed further afield, with 50 dairy, beef and sheep farms from England, Scotland and Wales enrolling on the GrassCheck GB programme. This three-year programme of work, carried out in conjunction with CIEL and a range of industry partners, is seeking to improve grassland management on commercial farms in GB whilst developing forecasting models for farms in those areas.

Figure 2: Location of GrassCheck dairy, beef and sheep monitor farms for 2018 and 2019.

Paul Turley GrassCheck research Farmer said

"Measuring grass growth and quality through GrassCheck is essential to getting maximum value out of the grass that we grow. I know what is in front of the cattle and I can manage grass deficient or surpluses much better. Maximising the value of the grass I grow is critical for the profitability of my beef enterprise."

AFBI works closely with CAFRE on GrassCheck NI while funding is provided in NI by AgriSearch, DAERA and CIEL, and in GB by AHDB, QMS, HCC, Handley Enterprises, Waitrose, Germinal and Sciantec.

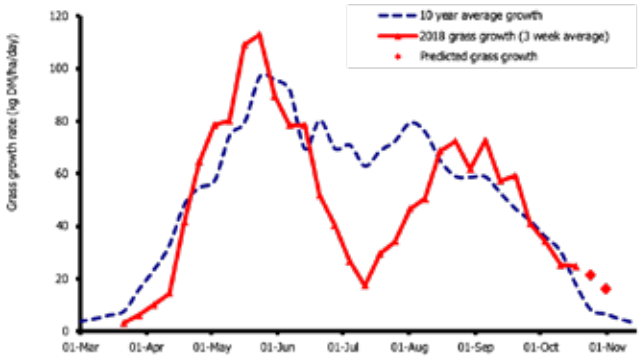


Figure 1: GrassCheck 2018 grass growth curve.

Protecting animal, plant and human health

Leading the fight against viruses

Research leads: Dr John McKillen and Dr PJ Collins

In the late 1990's post-weaning multi-systemic wasting syndrome (PMWS) emerged, almost simultaneously, in Canada and northern France before quickly spreading throughout the world. It's estimated that PMWS cost producers in EU Member States up to €900 million annually during the peak infection years. Vigilance against viruses is, therefore, essential.

Although PMWS is well documented, what is less well known is that AFBI, in collaboration with Queens University Belfast (QUB) and University of Saskatoon (USASK), helped identify the causal virus (porcine circovirus type II), leading to the development of a vaccine (PCV2) to manage it.

The team's collaboration with a major animal health company, to develop PCV2 was a great success story for the industry, providing considerable socio-economic benefits and improvements to animal health and welfare. As all pathogens evolve and change over time, however, AFBI's work in this area is ongoing.

In the last number of years two new types (genotypes) of PCV2 have been identified, PCV2d and PCV2e.

Some research groups have suggested that the presence of PCV2d has caused the failure of the PCV2 vaccine. The role of these new genotypes in vaccine failure, however, is unproven and experimental infection studies have shown that current commercial PCV2 vaccines are protective against these new genotypes. Vaccine failure is more likely to be due to other factors such as vaccinating too early, too late or vaccinating sick pigs.

PCV2 is also not the only circovirus circulating in pigs at the moment. In 2015 a new circovirus called porcine circovirus 3 (PCV3) was discovered in the USA in pigs between two to 10 weeks of age with pathology of the heart of undetermined cause. The virus is a distant relation to PCV2 and is less than 40% similar in terms of its genetic sequence.

PCV3 was also detected in sows with porcine dermatitis and nephropathy syndrome (PDNS), as well as in mummified foetuses aborted from these sows. The virus has been detected in a wide variety of tissue types including in the brain of stillbirth samples, lung, lymph node, tonsil, semen and serum. It has now been detected in a number of different countries and is expected to have a worldwide distribution.

AFBI's Veterinary Sciences Division has examined 240 tissue and faecal samples collected from pigs of varying ages in Northern Ireland from 2002 to the present. PCV3 was detected in 20% of samples from as far back as 2002. The virus was found in faeces, lymph nodes, tonsil and spleen, but not in colon, liver or lung tissues. We also examined 80 tissue samples from pigs of varying ages from England taken between 2001 and 2004. PCV3 was detected in 5% of the samples. When AFBI sequenced the virus genome it was found to be 98% similar to the viruses described in the USA.

Figure 1. Litter mates, the pig on the left has PMWS and the pig on the right is healthy.

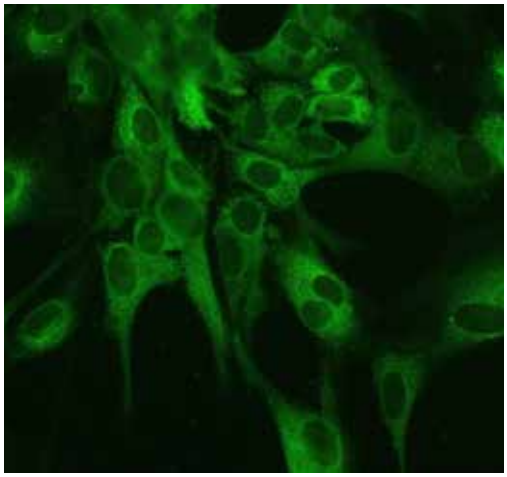
These results show for the first time, that PCV3 has been circulating in pigs in the UK for a number of years. While the role of the virus in disease has not been fully established, the presence of a novel circovirus and the apparent association of it with clinical disease similar to PCV2 warrants further investigation. More research is necessary to fully understand the role of the virus in abortion, PDNS cases and other pathologies.

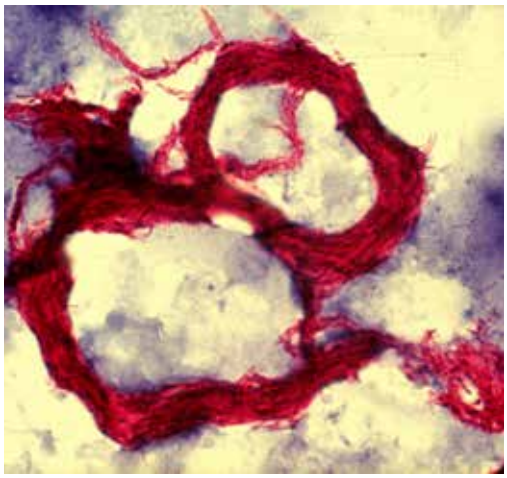
When PCV2 first emerged there were sporadic reports of the disease before it became one of the most devastating problems to afflict the industry. Close monitoring of the evolution of both PCV2 and PCV3 is important and surveillance needs to be maintained on an all-island basis to gather further information on the prevalence and genetic diversity of these viruses.

Recent advances in virus discovery have demonstrated that there are considerably more viruses circulating in animal populations than we were previously aware of. Even if not all of these are primary pathogens, they still have the potential to act as co-factors in disease, have subclinical effects or change and emerge as problem viruses in the way PCV2 did.

While vaccination is a crucial tool in preventing disease in pig herds, this new knowledge emphasises the need for good general biosecurity to help manage the entire infectious burden on any farm.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 659961.





Ground-breaking Campylobacter research benefitting the agri-food sector

Research lead: Prof Nicolae Corcionivoschi

One of the challenges in trying to achieve enhanced performance efficiency through the food chain is to achieve simultaneous reductions in bacteria which are potentially hazardous to humans. One such challenge is presented by the bacterium *Campylobacter* which causes bloody diarrhoea, fever and abdominal pains in humans. It can also cause post-infectious sequelae such as Guillain-Barré syndrome which is a potentially fatal paralytic autoimmune illness.

Campylobacter is the leading cause of bacterial food poisoning in the developed world. In developing counties, asymptomatic and occasionally persistent *Campylobacter* infections are common in children younger than one year. This correlates with stunted growth and, therefore, life-long physical and cognitive deficits. Approximately 80-90% of these infections are attributed to *C.jejuni*, with poultry being the most important source of human campylobacteriosis within industrialised countries. *C.jejuni* colonises the chicken cecum with relatively high numbers (109 CFU per gram). Traditionally it was considered a commensal of the chicken gut, but more recently it has been demonstrated to be pathogenic to the chicken (dependent on the genetics of the host and the strain of infection).

Five-years ago AFBI's Food Microbiology Unit began a novel programme of research to characterise the type and species of *Campylobacter* present within poultry flocks in Northern Ireland. The studies brought new thinking to the *Campylobacter* challenge and posed the question – are all *Campylobacter* strains equally

virulent or could selective pressures in production systems be favouring the persistence of particular virulence factors?

The research tested for the pathogenic potential of *C.jejuni* and *C. coli* isolates obtained from retail packs of raw chicken for the presence of the recently recognised virulence mechanism caused by a secretion system named T6SS. In *C.jejuni* T6SS is potentially associated with more severe forms of disease as it can confer cytotoxicity towards red blood cells. The team also developed rapid molecular qPCR methods for the individual detection and enumeration of *Campylobacter jejuni*, *Campylobacter coli* and *Campylobacter lari* in poultry faeces and intestinal contents. This novel testing platform is now being used to enumerate *Campylobacter* in commercial and scientific projects and has led to several high impact publications.

Controlling Campylobacter

AFBI Food Microbiology has also developed a significant research platform to find new ways of controlling *Campylobacter* spp. that goes beyond detection and enumeration studies and seeks to find new solutions.

New control strategies are being developed, based on novel approaches and technologies to address this public health priority.

This work is also aligned to the current trend to reduce the antibiotic usage in animal production, which imposes urgency in the identification of novel biocides. Work conducted by AFBI is investigating the role of plant extracts and innovative antimicrobial mixtures in reducing not only the presence of the bacterium, but also its virulence. Through a collaboration with the Irish-based Auranta Company we have shown that mixtures of natural antimicrobials, at sub-inhibitory concentrations, can reduce the ability of this pathogen to adhere and colonise animal and human intestinal cells.

AFBI has also published work on the effect of individual plant extracts (e.g. carvacrol) showing that this essential oil can delay *Campylobacter* spp. colonisation of chicken broilers, by inducing changes in gut microflora, demonstrating promise as an alternative to the use of antibiotics.

Furthermore ground-breaking research conducted by AFBI identified for the first time that *Campylobacter* can be detected in the chicken gut at day 16 of poultry production. This comes one day after the most substantial changes in metabolic profiles observed (Figure 1).

In addition, microbial variation over time is most likely influenced by the diet of the chickens and by changes in feed. This study was unique in comparison to other studies as the sampling was neither sporadic nor was the *Campylobacter* artificially introduced. The findings from this work will be useful for developing future intervention strategies and helping reduce the burden of *Campylobacter* within the food chain.

Undertaken by PhD students through AFBI, the work was funded by Moy Park, and in collaboration with the London School of Hygiene and Tropical Medicine and was published in Frontiers in Microbiology (2019).

This project has received funding from industry partners.

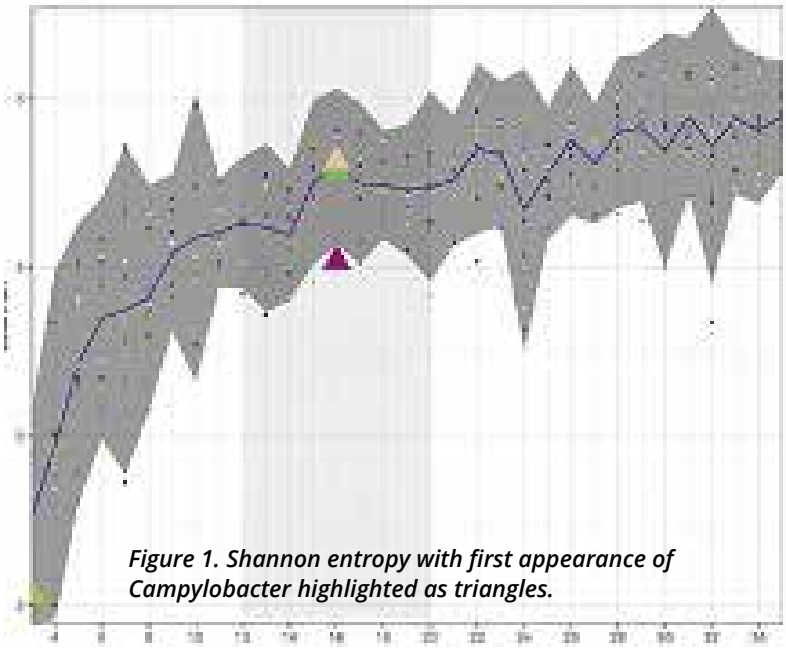


Figure 1. Shannon entropy with first appearance of Campylobacter highlighted as triangles.

Internationally renowned research into bovine tuberculosis

Research leads: Dr Adrain Allen, Dr Andrew Byrne and Dr Robin Skuce

Bovine tuberculosis (bTB) continues to blight cattle farming, with a heightened disease incidence in recent years in Northern Ireland.

AFBI is a nationally and internationally respected participant in research into the epidemiology of bTB in cattle and badger hosts. This work plays an important role in informing policy makers, stakeholders and the general public on risks and potential mitigation for this important disease. Our researchers continue to develop new knowledge through providing scientific support and innovation to the bTB control programme. We inform policy development through activities such as editing special editions of journals, producing leading hypothesis articles and undertaking analyses that help to inform bTB control.

Shaping opinions on bTB

Drs Adrian Allen and Andrew Byrne, alongside Dr Dan O'Brien of Michigan Department of Natural Resources, USA, and Professor Michele Miller of Stellenbosch University, RSA, recently co-edited a special issue of the prestigious online journal Frontiers in Veterinary Science, focusing on 'Bovine Tuberculosis – International Perspectives on Epidemiology and Management.' The publication represents a 'one-stop resource' on the current international knowledge on TB eradication. The issue included a total of 28 peer review articles were peer reviewed and published, with 151 authors from over 15 countries contributing to subjects including epidemiological modelling, host genetics, pathogen genetics, wildlife reservoirs, diagnostics and social aspects of disease control. As a measure of its impact the issue was viewed over 62,000 times.

Bovine TB in Britain and Ireland – A perfect storm?

Drs Byrne, Allen and Prof. Skuce also authored the lead Hypothesis and Theory article - 'Bovine Tuberculosis in Britain and Ireland – A Perfect Storm?. The article focuses on the ongoing problems of eradicating bTB in Britain and Ireland and asks why have these territories experienced such different outcomes in eradication success compared to continental European neighbours? Could a cocktail of unique epidemiological and ecological factors be hindering efforts? Suggested factors included the presence of a dense wildlife reservoir, differing diagnostic approaches, variation in pathogen genetics, co-infection, the structure and density of animal movement trade networks, and the potential for environmental persistence and a benign climate.

To date this article has achieved over 11,000 views, putting it in the top 6% of the most read articles across the whole Frontiers family of journals. In a little over a year it has also garnered 17 citations in the wider bovine TB literature and is further evidence of the impact and international standing of AFBI scientists researching bTB. It is also acting as a primer for addressing evidence gaps through current and future research. AFBI is, therefore, inspiring research efforts to address many of these potentially important factors around bTB through empirical, hypothesis led research.

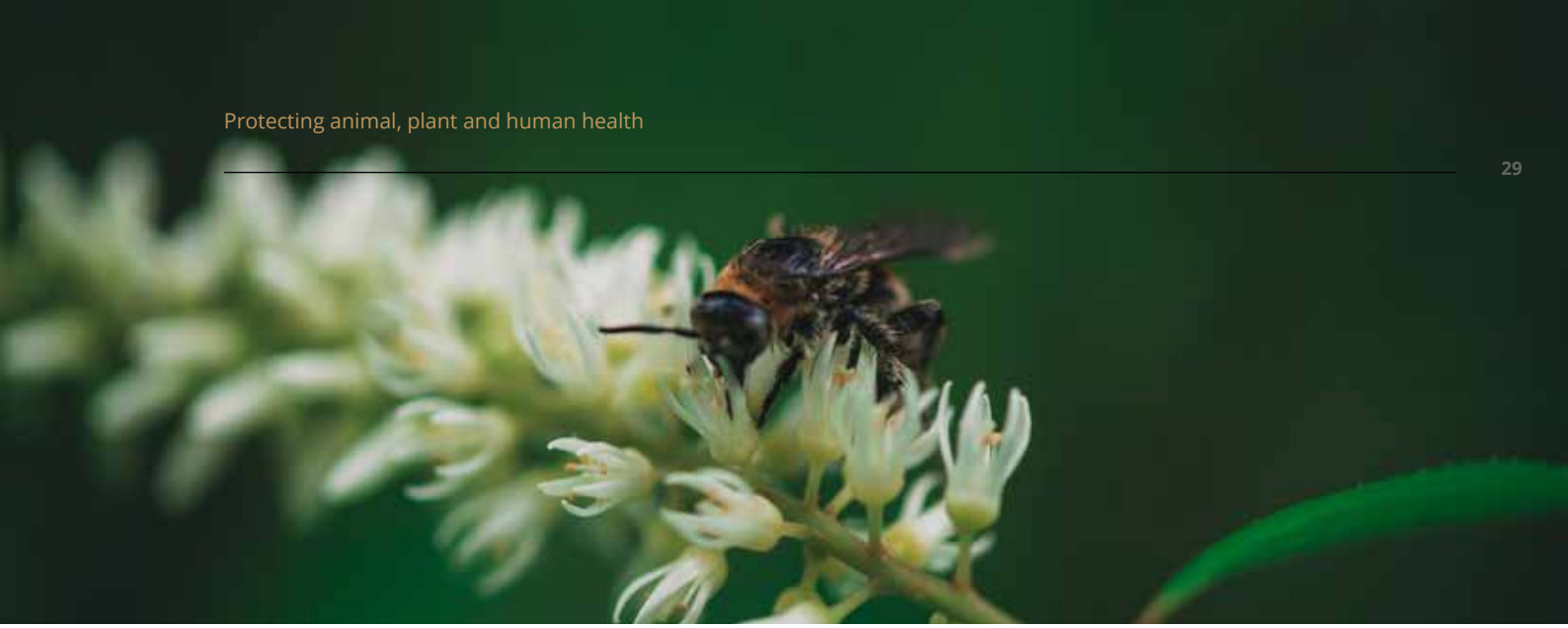
Understanding patterns of Bovine TB infection in Northern Ireland.

Epidemiology is a principal strength within AFBI which involves the study of patterns of prevalence and distribution of infection across our landscape. By knowing more about the key drivers of infection, better eradication tools can be designed.

Dr Georgina Milne has led multiple, important epidemiological research projects dedicated to developing a better understanding of bTB in Northern Ireland. Her research investigated herds unaffected by bTB and found that they were limited to a few small geographical clusters, which limits the possibility to implement spatially targeted interventions. Dr Milne also demonstrated that these herds were associated with fewer animal movements compared to herds with prolonged bTB infection.

In a further analysis focussing on herds with chronic bTB infections, Dr Milne demonstrated that areas with chronic herds largely reflect areas with high bTB incidence, alluding to the effect of 'neighbourhood' in disease maintenance. Her work, however, also reveals a cluster of chronic infection in an area with less disease, suggesting spatial differentiation in epidemiological forces driving chronic infection.

To investigate further, Dr Milne interrogated AFBI's extensive biobank of genetically fingerprinted tuberculosis bacteria to better understand sources of infection. It was demonstrated that in the majority of bTB affected herds only one pathogen genetic type was present, suggesting local sources are particularly important. These included re-infection from other cattle within the herd, infected nearby herds and wildlife, or a contaminated environment.



Beef herds typically contained more genetic types of the bTB bacteria compared to dairy herds, which is likely due to different husbandry practices. Beef finishing herds tended to import more animals from over a wide geographic extent encompassing different bacterial genetic types, leading to greater strain diversity on farm. Critically, this work shows bTB transmission dynamics are ultimately related to production type and that future interventions must take account of different animal husbandry practices.

Refining implementation of diagnostic tools for Bovine TB

The diagnostic tests for bTB are known to have limitations, especially when it comes to correctly identifying all infected animals. Knowing these limitations means that their performance can be optimised across differing infection scenarios to ensure they are used as effectively as possible to remove diseased animals.

Drs Lahuerta-Marin and Milne looked at the performance of the skin test and interferon gamma blood test in herds experiencing chronic infection. They showed limited sensitivity of the skin test for animals in herds with chronic bTB reinforcing the utility of the interferon gamma blood test. Additionally, the skin test is associated with poorer performance in dairy settings compared to beef settings, possibly related to different animal husbandry practices between both production types.

Wildlife ecology

The European badger (Meles meles) is an important host for bTB, with several lines of evidence pointing towards their role in transmitting infection to cattle. Learning more about badger ecology can lead to better understanding bTB transmission risks. Badger behaviour is likely to influence direct and indirect interactions with cattle, thereby facilitating disease spread between the species.

AFBI's Dr Adrian Allen and international collaborator Dr Jimena Guerrero, used an island-wide genetic survey of c.500 Irish badgers to demonstrate that the primary driver in badger genetic differentiation across Ireland was physical distance. In addition, it appeared that different land-cover types (forest / urban / arable / pasture / Shannon river system) were not major barriers to gene-flow across the Irish landscape. Given that small numbers of Irish badgers have been observed dispersing up to 21km from their home ranges, the implication is that there may be few barriers to an infected animal spreading disease over a wider area.

This paper was the culmination of an international collaboration between AFBI, DAERA and colleagues in the Republic of Ireland's Department of Agriculture Food and the Marine, the University of Glasgow and the Centre d'Ecologie Functionelle et Evolutive, France.

Figure 1 – Global demographic viewing metrics for the Frontiers in Veterinary Science special issue, 'Bovine tuberculosis – International perspective on epidemiology and management.

Figure 2 – Global demographic viewing metrics for the article 'Bovine tuberculosis: A Perfect Storm? From www.frontiersin.org

Florfenicol non-compliance in milking cows

Research lead: Dermot Faulkner

Florfenicol, which belongs to the amphenicol family of antimicrobials, is frequently used for the treatment of bovine respiratory disease (BRD). Although the drug is banned for use in milking cows, evidence appeared in early 2017 via the veterinary drug residue testing programme, suggesting that there was unauthorised use in dairy cows.

In collaboration with DAERA, AFBI developed a process to extend the testing for florfenicol to include milk samples. A total of fifteen non-compliant milk samples were then found across the residue testing schemes to the end of 2017.

During this time AFBI scientists undertook two separate experimental investigations related to the high incidence of florfenicol non-compliance. The first study followed the elimination of florfenicol from the milk of lactating animals which had been given a therapeutic dose of the drug. It was discovered that it took 65 days before the concentration of florfenicol in the milk was at an acceptably low level.

The second study was designed to assess the possibility that florfenicol non-compliance may arise as a result of cross-contamination between animals. Each of three untreated cows (housed with treated animals) produced only one milk sample, from seven days of twice daily sampling, that was found to be non-compliant, but with concentrations much lower than in the treated animals. It was, therefore, concluded that cross-contamination with the drug via treated animals was unlikely and that treatment of animals is much more probably the cause of non-compliance.

DAERA, FSA and Dairy UK have now acted on this new knowledge and advice to ensure the safety of milk for human consumption. Analytical services were also provided to industry to assist them in identifying potential problems. As a result of the analytical testing, experimental investigations and the subsequent dissemination of the accrued data, the number of non-compliant florfenicol milk samples detected in Northern Ireland fell from fifteen in 2017 (3%) to just one in 2018 (0.2%).

‘Shedding light’ on improving vitamin D content in popular foods

Research leads: Dr Colin McRoberts, Ruth Loy and Dr Conrad Ferris

Several studies have concluded that a significant proportion of the EU’s population is vitamin D deficient with figures ranging from c.13% to 40%. This is concerning as Vitamin D is important for regulating the amount of calcium and phosphate in the body, and keeping bones, teeth and muscles healthy.

Vitamin D is produced by the action of sunlight (specifically UV-B wavelengths) on the skin and is also obtained through the diet, although foods naturally high in vitamin D (such as oily fish and eggs) are generally not popular with consumers. Consequently, there is interest in increasing the Vitamin D content of commonly consumed foods such as milk and meat and AFBI is helping shed ‘light’ on the subject.

Initial studies found that the concentration of vitamin D in milk from cows grazed outdoors in summer was up to 10 times higher than from housed cows, illustrating the impact of sunlight. This difference was reduced in winter when UV levels were lower. Subsequently, exposure to UV-B from special lighting installed in a dairy house was shown to increase the vitamin D content of milk and improve the vitamin D status of livestock. Similar studies with pigs resulted in pork meat with increased vitamin D content.

A principle partner in this project, Devenish Nutrition Ltd., believes that the use of UV-B lighting has significant potential to address seasonal vitamin D variation in milk and dairy products, and would allow industry to produce a range of added-value dairy and pork products with increased vitamin D content.

This innovative approach may also improve the vitamin D status of livestock, resulting in both beneficial health impacts for the animal and the end consumer.

The study was co-funded by the Agri-Food Quest Competence Centre (AFQCC) and carried out in partnership with Devenish Nutrition, AFBI, Thompsons, Dale Farm, Karro, CAFRE and NICHE, Ulster University.

Safeguarding Plant Health

Research leads: Dr Colin Fleming and Dr Richard O'Hanlon

A team from AFBI has undertaken a review of the UK Plant Health Risk Register (UKPHRR) and assessed its potential as an effective Plant Health tool. The work supports a risk-based approach to managing plant health which is now regarded as the most effective way to identify priority plant health risks and direct plant health planning and surveillance resources. The team concluded that developing a local Northern Ireland plant health risk register (NIPHRR) would be of immediate and practical use to DAERA Plant Health Policy, Plant Health Inspectorate, industry and the general public.

The UK Risk Register comprises over 1,000 viruses, bacteria, fungi, oomycetes, insects and nematodes. During AFBI's analysis, potential pests and pathogens with a particular relevance to Northern Ireland were re-prioritized or added. This regional reprioritisation of the Risk Register was based on factors such as local prevalence and climate, routes of entry into Northern Ireland and significance of local crops/ hosts (e.g. grass, cereals, apples). It also considered the influence of our land border and trade with the Republic of Ireland and the absence of pests in Northern Ireland which occur in GB.

Jim Crummie, DAERA Forest Service Plant Health Director said: "The Northern Ireland Plant Health Risk Register is an important tool in efforts to protect Northern Ireland's high plant health status from the most threatening pest risks. The web-based register which is open to everyone also enables Forest Service to prioritise its resources based on solid science and risk assessment."

He added: "DAERA Forest Service plant health professional staff and AFBI Plant Health expert scientists through regular conversations and working together aim to ensure that the register is regularly updated, includes the most up-to-date science-based evidence on plant pests worldwide and also informs inspection surveillance priorities.

"Working in collaboration Plant Health Directorate as part of the UK Plant Health Service and AFBI will continue to cooperate to ensure we strive to stay one step ahead of global plant pests."

Following AFBI/DAERA collaboration to develop the NIPHRR, colleagues in the Republic of Ireland's Department of Agriculture, Food and the Marine is currently engaged with AFBI to discuss the development of a Republic of Ireland Plant Health Risk Register. This is particularly significant given the general acceptance that Ireland is a single epidemiological unit for plant health and the forthcoming implications of Brexit.

The project is supported by DAERA funding.

Testing of Illegal food imports to protect the pig industry

Research leads: Prof Louise Cosby, Dr PJ Collins

AFBI Virology Branch staff have undertaken testing to detect African Swine Fever (ASFV) nucleic acids in illegally imported food products coming into Northern Ireland.

ASFV is currently spreading across the world with notable outbreaks in China, the wider south east Asia region and Belgium. The mortality rate in domestic swine often approaches 100% and ASFV can remain viable for long periods in uncooked or undercooked pork products.

In July 2019 over 180 separate seizures of illegally imported food products were made at Northern Irish ports of entry. These seizures comprised multiple food items from 32 countries across five continents. DAERA requested investigation into the possible ASFV threat to Northern Ireland and other viruses entering the ports in these illegal food products.

AFSV nucleic acid was detected in two of 13 products examined by AFBI's Virology Branch. This is the first ever detection of ASFV nucleic acid in an import to the UK. While this does not indicate that infectious virus has entered the country it flags up the need for continuous and more widespread testing of illegal food products entering our ports to prevent infection of livestock.

Making a 'mark' genetically to combat Bovine Respiratory Disease

Research lead: Prof Louise Cosby

Bovine Respiratory Disease Complex (BRDC), also known as pneumonia, is the largest cause of mortality (40%-50%) in calves aged one to five months old. Consequently, BRD is one of the most economically important diseases for the agri-food industry worldwide with the costs involved accentuated by increased morbidity (70-80%) and high treatment costs. There are also 'hidden' costs such as weight loss, reduced reproductive performance and low milk yields or carcass blemish – all of which can reduce market prices.

By any measure BRDC is a major issue, not least because its treatment has also called public health concerns into question – the massive use of antibiotics to treat secondary bacterial infections has increased the possibility of selecting antibiotic resistant bacteria.

Studies have found that neither immunization nor antimicrobial therapies have significantly reduced the prevalence or severity of BRDC. The ability, therefore, to identify genetic markers of resistance to virus infection is crucial for future animal selection.

In collaboration with TEAGASC and the University of Missouri, AFBI Virology Branch is starting to map these genetic markers.

The first results for one of the major virus pathogens, bovine respiratory syncytial virus (BRSV) have already been obtained. 934 differentially expressed genes were found, mainly relating to the immune response between BRSV infected and non-infected animals.

This information will allow a more detailed analysis of these genes (most of which are involved in the immune response) in individual animals to select DNA markers which are associated with the best response to infection. These markers can also be used to inform future breeding programmes.

The findings will be integrated into the national genomics selection breeding programme, ultimately reducing the incidence of BRDC both in Ireland and globally.

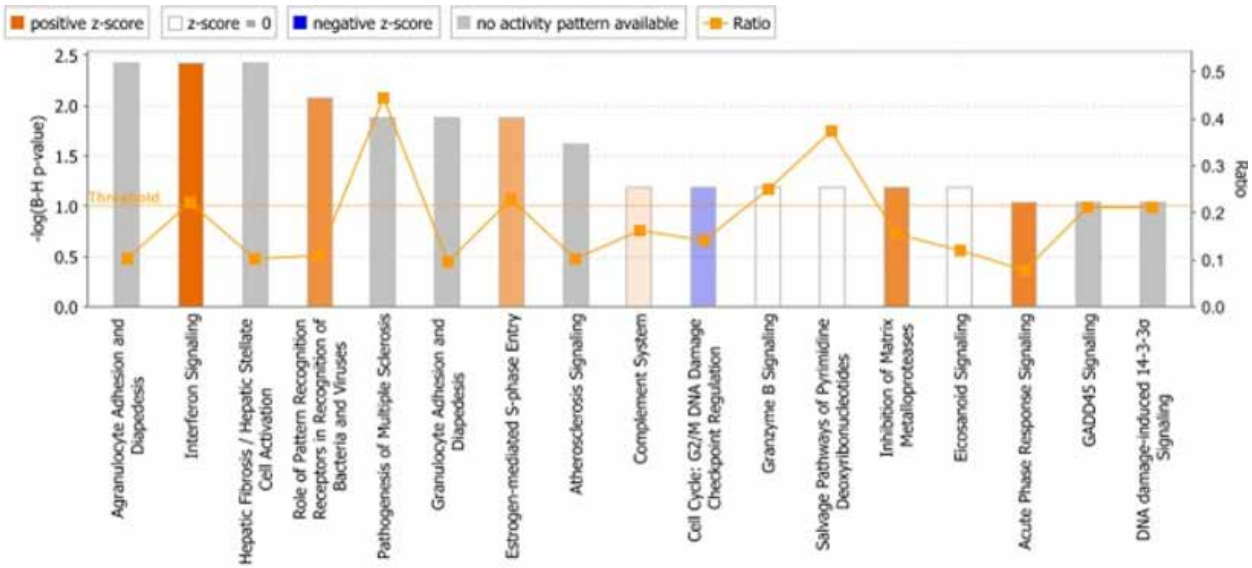
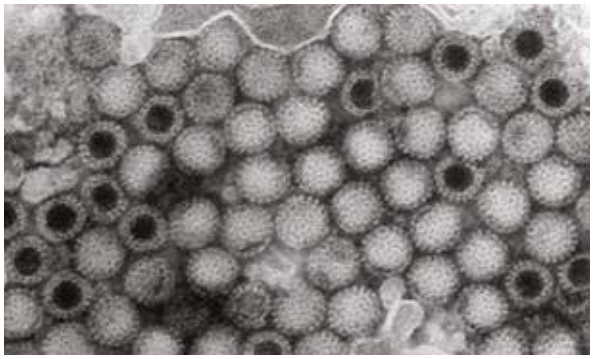


Figure 1: Ingenuity pathway analysis showed that seventeen canonical pathways were enriched (P < 0.05, FDR <0.1). Four of these pathways were predicted to be upregulated (Interferon Signaling, Role of Pattern Recognition Receptors in Recognition of Bacteria and Viruses, Inhibition of Matrix Metalloproteases and Acute Phase Response Signaling) (Z-score >2). (reproduced from Johnston et al. 2019).



Bluetongue detected in French import

Research lead: Dr Michael McMenamy

AFBI plays a central role in ensuring that diseases such as Bluetongue are prevented from becoming established in Northern Ireland.

Northern Ireland is currently Bluetongue free and DAERA maintains stringent import control measures to prevent the introduction of this economically devastating disease. Bluetongue is a notifiable disease of ruminants and camelids caused by Bluetongue Virus (BTV) and is spread by the Culicoides species of midges.

The Veterinary Science Division (VSD) undertakes post-import screening of all susceptible species imported into Northern Ireland using a combination of serology and molecular based assays (to detect BTV antibodies and virus respectively).

France experienced major outbreaks of BTV serotype 4 and 8 (BTV4 and BTV8) in 2018 and in December of that year, VSD detected BTV8 in a cow imported from France. DAERA was notified immediately and appropriate control measures were put in place. In the following days VSD tested all animals transported alongside the positive animal and worked closely with DAERA, The Pirbright Institute and other UK authorities to co-ordinate confirmatory testing and sample transport, as well as provide expert advice to stakeholders.

Understanding Avian Orthoreovirus

Research lead: Dr Victoria Smyth

Avian orthoreoviruses are rapidly evolving RNA viruses which are widespread in poultry flocks, causing growth problems and lameness in chickens. Although most strains (c.80%) don't cause disease there is currently no way to distinguish pathogenic strains from non-pathogenic strains. There are also other causes of lameness, including bacterial infection and mechanical injury, which further complicate diagnosis.

To improve the diagnosis of lameness caused by reovirus, scientists and vets at VSD have been working together to develop an informed testing approach which relies on observing a particular histopathological pattern that is indicative of inflammation from a reovirus infection in leg tendons.

Reovirus is then isolated from affected tendon samples through cell culture techniques and the reovirus isolate is typed using DNA sequencing and bioinformatics analysis. A large library of disease-associated reovirus strains from clinical cases is now in place and is being investigated with the aim of identifying molecular markers or genetic signatures of pathogenicity that will aid future diagnosis.

A further objective is this programme of work is to investigate the effectiveness of the reovirus vaccine against the diverse strains circulating that cause lameness and stunting in flocks. Electron micrograph of a cluster of avian orthoreovirus particles isolated from a clinical case.

Disease surveillance in frontline of safeguarding livestock

Research lead: Dr Barry McInerney

AFBI's Disease Surveillance and Investigation Branch (DSIB) carries out a comprehensive range of tests to assist in the surveillance and diagnosis of animal diseases and provide detailed information on the health status of herds and flocks.

The purpose of farm animal disease surveillance is to provide intelligence on animal health and welfare to enable farmers, the veterinary profession and governments to take decisions which can improve animal health, animal welfare, productivity and public health.

A robust surveillance system is crucial in assuring exports of animals and agri-food products, which is essential for the sustainability of agriculture and farming in a small country like Northern Ireland.

DSIB provides scanning (diagnostic) surveillance for epizootic, notifiable, zoonotic and emerging diseases. Quarterly reports on disease surveillance findings are submitted to DAERA and are also published in the 'Veterinary Record' (the weekly journal of the British Veterinary Association) to contribute to wider national and international surveillance information. This activity provides DAERA with a programme of animal disease surveillance by monitoring for epizootic diseases, new or emerging diseases and changes in patterns of endemic diseases.

As part of this surveillance work, high volumes of carcasses and samples from cattle, sheep, pigs, poultry and fish are submitted to AFBI's Veterinary Services Division (VSD) annually. Each year DSIB receives approximately 2,700 post-mortem cases and carries out a further 460,000 tests on samples received from post mortem carcases or samples provided from farmers, vets and research samples.

A wide range of examinations and diagnostic tests are carried out on carcases and various clinical samples (blood, swabs, faeces, urine etc). The veterinary diagnostic facilities provided by VSD are also highly valued by veterinary practitioners and farmers.

The results from post-mortem examinations carried out by DSIB's Pathology Units at Stormont and Omagh are further supplemented, when deemed necessary, by a highly qualified and experienced team of veterinary research officers and pathologists using a range of techniques - histopathological (microscopic pathology) examination, diagnostic bacteriology, diagnostic virology, parasitology and biochemistry. These results allow vets - in discussion with the farmer - to make knowledge-based decisions on treatment and disease prevention that improve animal and herd health and farm productivity.

The correct diagnosis of disease improves treatment and control decisions, protocols and outcomes on farms. With the emerging global threat of Antimicrobial Resistance (AMR) and the increasing drive to reduce the use of antibiotics in agriculture, AFBI's role in disease surveillance has never been more vital.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SECTION 3

Enhancing the natural and marine environments

Can energy crops reduce wastewater pollution?

Research lead: Chris Johnston

Although the treatment of waste water in modern waste water treatment plants (WWTPs) is highly effective, the discharge from older or overloaded WWTP can contain nutrients or other contaminants that may contribute to the pollution of surface waters. Across Europe there are numerous small rural WWTPs often serving small populations which are too impractical or expensive to upgrade. Such WWTPs, however, often discharge potentially highly polluting effluent into streams and rivers.

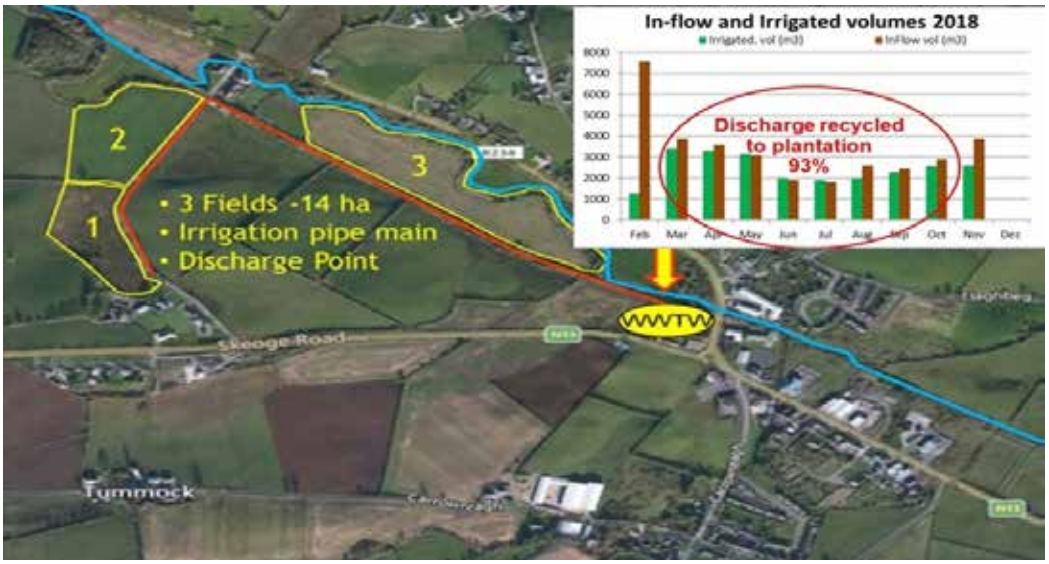
This is emphasised in the second River Basin Management Plans published by the EU which found that only 38% of EU surface water bodies were in good or better chemical status. It also highlighted that a significant pollution pressure on surface water bodies came from point source discharges such as WWTPs. Solutions, however, are available. Short Rotation Coppice (SRC) willow, for example, can be the ideal crop for the bioremediation of a variety of effluents and other wastewater streams and the growing biomass also contributes to a developing local bio-economy.

As part of the AFBI-led, EU funded (INTERREG IVA) ANSWER project (Agricultural Need for Sustainable Willow Effluent Recycling), a 14 ha Proof of Concept irrigation scheme was established by Donegal County Council. Jointly monitored, the scheme was planted in spring 2013 and has been irrigated with municipal effluent since June 2014.

Since then, significant quantities of waste water has been recycled to the coppice plantation rather than being discharged into the environment. In total an estimated 4,000 kg of nitrogen and 190 kg of phosphorus has been recycled to the plantation.

Most notably, during 2018, a particularly dry year, although low flow rates in receiving streams made them much more vulnerable to the negative effects of polluting discharges, excellent recycling rates were achieved. Between March and October 2018, only 7% of the waste water entering the treatment works was discharged to the stream while the remaining 93% was irrigated to the willow planation (Fig 1). SRC willow systems, therefore, not only provide valuable bioenergy, but can also significantly mitigate the negative impacts of municipal effluent on fresh water ecosystems.

Fig 1. Irrigated Willow plantation at Bridgend Co, Donegal.



Follow that fish – acoustic tracking of migratory fish

Research lead: Dr Robert Rosell

Timing of migration, routes taken and the range of habitat used by fish has for most of history been a matter of conjecture, with information available only from where fish are caught or seen. Increasing pressure to conserve populations of migratory species such as salmon and eel, however, has created a need to know when and where in the lifecycle critical impacts occur. Such knowledge will help direct targeted conservation action.

Advances in acoustic tracking technology are providing vital new information. It is now possible to attach or implant small electronic tags in fish and record their movements in great detail, removing guesswork, filling in knowledge gaps and providing a detailed record of the travels of individual fish.

AFBI has invested significantly in acoustic tracking systems for fish, particularly salmon, sea trout and eel. Networks of underwater listening stations are deployed where fish pass, in rivers, lakes and even open coastal water. Any tagged fish passing within range will be individually identified and recorded, leaving a trail throughout the network of receivers.

Results from recent AFBI fish tracking have dramatically increased our understanding in key scenarios. We have documented the migration speed of emigrating juvenile salmon to the open sea from their starting point upstream in Northern Ireland rivers (Bush, Lough Neagh tributaries and Bann). This shows major variation in survival between wet springs when migration is fast and much lower success rates under low flow dry conditions. Adult salmon returning from the sea have been tracked moving upstream in the Bann/Lough Neagh system, allowing us to split the total counted run to identify how many enter each tributary used for spawning.

The downstream movement of eel has also been followed through the Bann/Neagh and Erne systems, confirming the efficiency of commercial and conservation (trap and transport) fisheries, and escapement to sea. Silver eel tagged in the river Bann have been detected heading out to the open ocean, moving westwards past the mouth of the Foyle.

The latest deployment has moved even further into marine waters. Through the AFBI-led and EU-INTERREG funded International COMPASS project, AFBI and its partners have completed a first pilot year, tagging and following sea trout from rivers to the coastal waters of counties Down and Louth. This tagging is already indicating use of marine areas shared between fish from multiple rivers. It is important to understand these movements to ensure sustainable fishing across the Irish Sea is achieved.

COMPASS has deployed a full network of listening stations. A total of 402 sea trout and salmon were tagged in 2019.

Safeguarding our threatened peatlands and wetlands

Research lead: Mel Flexen

Peatlands and wetlands are an integral part of our environment which have come under pressure in recent years. AFBI scientists are working in collaboration with partners to help safeguard these sensitive and important areas.

As part of the CANN project (Collaborative Action for the Natura Network) AFBI is seeking to improve the conservation status of priority habitats and species on peatlands and wetlands in Northern Ireland, the Border Region of Ireland and Scotland, by addressing key threats.

The main project outputs will be to support 3,650 hectares of habitats attain improved conservation status and to produce 27 Conservation Action Plans or Special Areas of Conservation (SACs). AFBI is leading a project work package ('Mapping, monitoring and evaluation') and is responsible for the following activities:

- Development of methodologies and best practice for mapping and monitoring of habitats/vegetation, invasive plant species and features of designated SACs
- Terrestrial habitat mapping, including use of remote sensing techniques and technologies, including trialling the use of Unmanned Aerial vehicles (UAVs) and stereo colour infrared (sCIR) imagery

Photograph: Conducting an assessment of peatland vegetation

- Scientific monitoring of terrestrial vegetation to assess the impacts of management actions
- Investigation into how aquatic vegetation of marl lakes is linked to water quality and hydrology and
- Provision of spatial maps and data to inform the Conservation Action Plans for the Northern Ireland SACs and cross-border sites.

CANN is a cross-border environment project which will help the region meet key EU Biodiversity targets under the Habitats and Birds Directives, and ensure the future of these internationally important habitats and species.

Partners/industry contributions:

This project is being carried out by AFBI in partnership with **Newry, Mourne and Down District Council** (Lead Partner); **Argyll & The Isles Coast and Countryside Trust**; **Armagh, Banbridge and Craigavon Council**; **East Border Region; Golden Eagle Trust; Institute of Technology Sligo; Monaghan County Council; Scottish Natural Heritage; Ulster University and Ulster Wildlife**. Staff from **Northern Ireland Environment Agency** and **National Parks & Wildlife Service** provide technical guidance on the project.

Sources of funding

CANN is supported by the EU's INTERREG VA Programme, managed by the Special EU Programmes Body (SEUPB). Match funding in Northern Ireland is being provided by DAERA. Total funding for the project is €9.4 million.

Using the 'earth' to tackle climate change

Research lead: Dr Dario Fornara

Over the next few years we can expect to hear much more about how soil can help tackle climate change. That's because global soil carbon stocks are approximately three times larger than the stocks in vegetation and twice those in the atmosphere. Small changes in soil carbon stocks can, therefore, have significant impacts on the atmosphere and climate change.

Given that soils can help offset greenhouse gas (GHG) emissions from agriculture, soil sequestration is now high on both the scientific and political agenda. As a result, there has been an increasing number of international initiatives to assess soil organic carbon sequestration potential across different agro-ecosystems.

AFBI is working in this area through an international initiative promoted by the Food and Agricultural Organization of United Nations (FAO). The aim is to produce new guidelines on how to measure soil carbon stocks and predict soil carbon stock changes in livestock-based production systems across the world. The guidelines are a product of the Livestock Environmental Assessment and Performance (LEAP) Partnership, a multi-stakeholder initiative whose goal is to improve the environmental sustainability of the livestock sector through better methods, metrics and data.

The intended uses of this document are wide due to the range of objectives and scales for soil organic carbon (SOC) stock change studies. The guidelines have practical implications for policy, industry and science in Northern Ireland. These include:

- Measuring GHG emissions and removals from the land sector as a component of climate change accounting
- Monitoring, reporting and verification obligations for the United Nations Framework Convention on Climate Change
- Analysis of the climate change impact of livestock products
- Evaluation of the environmental impacts of grazing land management for animal agriculture
- Assessment of the mitigation potential of agricultural practices at an industry, region or farm scale
- Implementing mitigation options in emissions trading or other market mechanisms where SOC sequestration payments depend on accurate and verifiable quantification and
- Research into soil and biological processes affecting SOC stocks and dynamics

Three groups contributed to the development of the guidelines, an ad hoc Technical Advisory Group (TAG), the LEAP Secretariat and the LEAP Steering Committee. The soil carbon stock changes in rangelands and grasslands TAG carried out the background research and developed the core technical content of the guidelines. AFBI scientist Dr Dario Fornara was one of 38 international scientists involved with the TAG.

AFBI research using a long-term permanent grassland experiment shows how sequestration rates can vary between 0.35 and 0.86 tonnes of carbon per hectare per year depending on nutrient fertilisation regime.

AFBI's research is funded through DAERA-funded projects including Project 7001 'Long term Effects of Slurry on Grassland' and project 15/4/03 'Evaluation of the potential for changing land use practices to encourage soil and grass carbon sequestration'.

Livestock-based grassland production systems and soil carbon sequestration. Soil profile indicates significant amount of organic matter stored in grassland soils.

Ecosystem modelling - key to sustainable aquaculture

Research leads: Dr. Heather Moore, Dr. Matthew Service

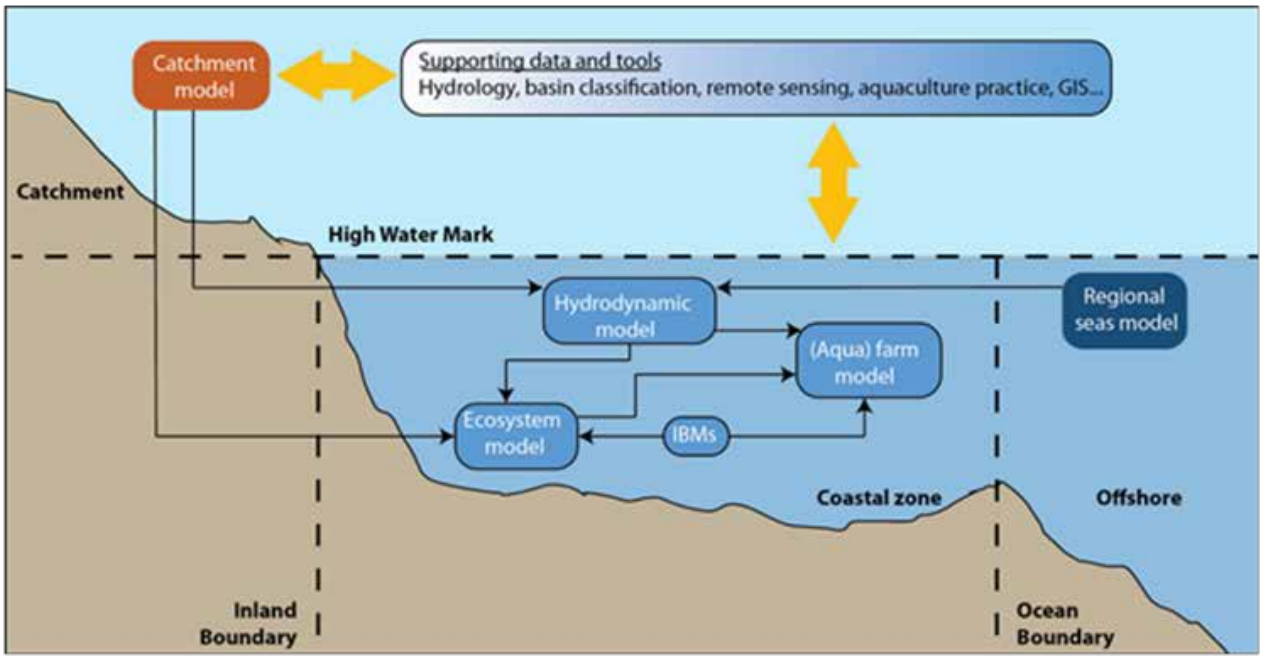
The sustainable expansion of aquaculture is a key aspect in the development of marine resources in Northern Ireland. To achieve this AFBI is undertaking ecosystem modelling to examine the interaction between provisioning services as well as regulatory and support services at a catchment level. Funding from a variety of sources was obtained during 2018 to further develop the catchment interactions in coastal water bodies.

This work also provides an opportunity to include additional components such as integrated catchment management and local-scale simulation of shellfish culture. This will support the development of an integrated coastal zone management framework that brings together catchment pressures, aquaculture activities in the loughs, offshore exchanges and a more accurate representation of the role of wild species. Such a framework enables managers to address relevant issues arsing from the Water Framework Directive and the Habitats Directive, and potentially also the Marine Strategy Framework Directive at the system and shellfish farm-scale.

Models have been developed using the SUCCESS (System for Understanding Carrying Capacity, Ecological, and Social Sustainability) Framework (Figure1). This integrates SWAT catchment models including diffuse and point source discharges, hydrodyanamic process models for the receiving waters and individual biological models into a single ecosystem model. This model is capabable of:

- Providing a tool to simulate the biogeochemical cycles within a coastal system, fully integrating the relevant water column and diagenetic processes
- Simulating primary production (both pelagic and benthic, as required), taking into account both bottom-up and top-down control
- Explicitly describing the role of ecosystem components on the environment. These impacts are both positive (e.g. top-down control of eutrophication) and negative (e.g. release of dissolved nutrients to the water column)
- Providing water and aquatic resource managers with a tool to evaluate ecological and production carrying capacity and
- Simulating human interaction including the effect on water bodies of changes to land-based nutrient loading.

General framework for ecosystem modelling



SUCCESS (System for Understanding Carrying Capacity, Ecological, and Social Sustainability) Framework.

Impact on Shellfish Aquaculture

Shellfish Aquaculture in Northern Ireland has expanded rapidly over the last 16 years with mussels and Pacific oysters being the main shellfish cultivated. The environmental benefits of mussel and oyster culture include providing habitat for other species, enhancing biodiversity and reducing phytoplankton concentrations. The reduction of phytoplankton concentrations provides positive environmental externalities by increasing: transparency, and, therefore, indirectly promoting oxygenation of bottom waters; and 'short-circuiting' the organic decomposition - cyclephytoplankton is removed before the cells die naturally, curtailing the second stage of eutrophication.

The application of catchment models suggests that nutrient loading into Lough Foyle is mostly associated with agricultural activities such as pasture and unimproved grassland. Consequently, the implementation of source control measures to deal with potential non-compliance of the lough under the Water Framework Directive should focus on both changes to land use and discharge control.

Controls of diffuse inputs are difficult, expensive and, if they affect the established way of life of human populations, may have significant social consequences. The holistic management of potential eutrophication symptoms by including a burgeoning shellfish industry in the lough allows traditional catchment activities to flourish whilst taking advantage of the full range of ecosystem services supplied by bivalve filter-feeders. Research is also studying the wider quantification of shellfish ecosystem services, particularly with respect to nutrient regulation. In the Foyle watershed where 98% of nitrogen loading comes from diffuse sources there are no easy solutions to reduce chlorophyll in Lough Foyle apart from top-down control. For the Foyle, a reduction of 1 mg L-1 for chlorophyll P90 costs at least 30.57 M€ y-1 in terms of source control, and the cost ratio of symptom value (chlorophyll) / causative factor value (N) varies between 5.8 and 13.7.

Models can make an important contribution to evaluating the role of shellfish in potential nutrient credit trading frameworks (these are incipient in Europe and Canada, but are already well-developed in the United States).

The key regulatory ecosystem service is not nutrient removal, but mitigation of eutrophication symptoms. There are few options to analyse this other than by ecosystem model frameworks.

AFBI's work in this area is now actively being applied to manage the sustainable development of aquaculture and the SUCCESS framework has been adopted as core to the revitalisation of Waste Water Management for Greater Belfast and its catchments.

No more 'hide & seek' for Irish Sea Cod

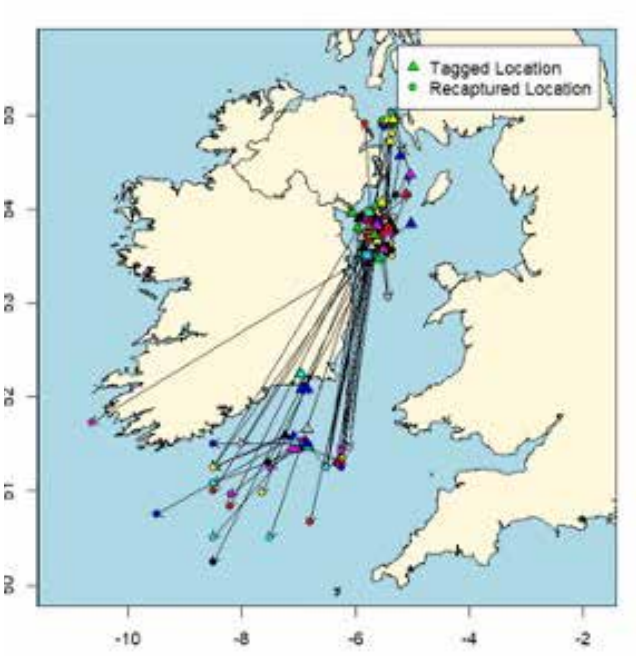
Research lead: Dr Mathieu Lundy

An internationally coordinated tagging programme, led by AFBI and funded by the European Commission, has been carried out on Irish Sea cod over the last three years. By recapturing tagged cod in the Irish Sea scientists can map movement, analyse growth and stock status and, ultimately, understand causes of mortality.

Irish Sea cod is a commercially valuable stock which has suffered a notable decline caused by exploitation in the 1980's and 1990's. The Cod Recovery Plan initiated by the International Council for the Exploration of the Sea (ICES) in 2000 has aided stock recovery, but not to the extent expected and a steep age decline in cod remains unexplained. Natural mortality and fishing pressure alone can't answer questions about Irish Sea cod mortality, but tagging may hold the answer.

Fish were tagged in the Irish Sea and adjoining areas in the North Channel and Northern Celtic Sea. Scientists tagged fish on commercial fishing vessels, scientific research surveys on AFBI's RV Corystes and at recreational angling events. When a fisherman or angler catches a tagged cod, the fish is returned to project staff along with recapture date and location. These recaptured fish provide a wealth of information, including geographic movement, time at 'liberty', growth, age, sexual maturity and feeding habits.

Recaptured cod have so far predominantly stayed in the Irish Sea, however, a significant number of cod have moved from the Irish Sea to the Celtic Sea. It is possible that post spawning, adult cod are migrating, posing a question for stock management as Irish Sea and Celtic Sea cod are currently treated as two separate stocks.



Movement patterns of tagged fish and both fisheries dependant and independent information gathered by AFBI provides invaluable insight into what is happening with this species. This informs assessment and management approaches for maintaining long-term viability of Irish Sea cod stock.

Appreciating that Irish Sea and Celtic Sea cod mix helps manage the fishery and improves our understanding of sustainable fishing levels for Irish Sea cod. Documenting movements and understanding the environmental drivers for these is crucial as stocks that exhibit significant mixing post spawning could be subject to high levels of exploitation if spatial ecology, migration and home range are not considered.

Commenting on AFBI's work, Harry Wick, CEO, Northern Ireland Fish Producers Organisation, said

"NIFPO is fully committed to fishing responsibly. We fully support the work of AFBI and the ongoing cod tagging project. This project, alongside other research, has a key role in ensuring we get the best possible scientific advice allowing us to fish at sustainable levels and guarantees the stock for the future."

Harry Wick, CEO, Northern Ireland Fish Producers Organisation

SECTION · 4

Ongoing AFBI science making an impact

Marine Protected Area Management and Monitoring: MarPAMM

Research lead: Dr Matt Service

Summary

The MarPAMM project will deliver four new models to support the conservation of habitats and species that underpin Marine Protected Area (MPA) designations within the cross-border region of the West of Scotland, Northern Ireland the border counties of the Republic of Ireland. These models, along with other models being developed by sister INTERREG VA projects and existing data, will be used to develop six new MPA management plans, including four regional management plans and two site-specific plans. The models include a seabirds model (with climate change scenarios), benthic habitat and species model, marine mammals/underwater noise model and coastal processes model (with climate change scenarios). The models seek to fulfil existing evidence gaps that hinder effective management of the MPA network in a cross-border region.

Policy/industry impact:

To achieve their defined conservation objectives, MPAs require management plans/schemes to be developed and implemented. Some MPAs in the region have such plans developed, many do not, and as the designated sites in the eligible area are connected by the wide habitat use of mobile species (e.g. seabirds, cetaceans and seals) and pelagic life stages of benthic species (e.g. horse mussels), effective management must be informed by knowledge of such connectivity and the cumulative pressures from a regional, cross-border context. MarPAMM will provide a co-ordinated approach delivering surveys and models to ensure management plans are developed within this context. Close liaison with policy-makers and stakeholders will ensure plans can be implemented. Effective MPA management will result in wider positive impacts on the status of the marine environment and the delivery of ecosystem services that industries rely upon.

Our partners and funders

This project brings together a strong interdisciplinary collaboration between scientists in AFBI, Marine Scotland Science, Scottish Natural Heritage, Scottish Association for Marine Science, Ulster University, University College Cork and BirdWatch Ireland.

This project is funded by the INTERREG VA programme, managed by the Special EU Programmes Body (SEUPB).

MarPAMM

Interreg
Northern Ireland - Ireland - Scotland

Special EU Programmes Body
Foras Um Chláir Speisialta An AE
Boord O Owre Ocht UE Projecks

Insects as a novel protein source in animal feed

Research leads: Prof. Nicolae Corcionivoschi, Dr. Elizabeth Ball, Dr. John McKillen

Project Team: Dr. Katerina Theodoridou, Prof. Nicolae Corcionivoschi, Dr. Alexandros Stratakos, Mr. Mark Linton, Dr. Elizabeth Ball and Dr. John McKillen

Summary

Food security is a global challenge and as overall demand for food increases, there is an urgent need to increase the protein supply protein from sustainable sources. Insects are a potential protein source which could contribute to freeing up land to grow crops for direct consumption by the human populace and lead to a concomitant increase in food security. The current legislation is moving forwards and taking into account edible insects as a novel feed/food. Insect protein is highly digestible (77-98 %), with an excellent level of essential amino acids (46-96 %). Insects could be used without any detrimental effects on the animals' performance, health or the quality of final product.

Policy/industry impact:

At present, 20% of livestock feed used in Northern Ireland is imported from outside the EU. Since the demand outweighs supply, insects have the potential to fill the current market gap and provide a suitable and sustainable animal feedstock. Two important factors - the recognition of the potential value of insects a complementary feed source for animals and demand for new sources of protein for animal feed - are driving commercial development. As NI is currently reliant on imported goods to sustain its livestock sector, thus reducing the sustainability of the local economy, the project will not only help develop insect farming in NI but also help improve the sustainability of the economy. This project has the potential to benefit the NI animal and food industry by increasing animal productivity and enabling the production of food products superior to competitors in terms of safety and quality thus strengthening industry competitiveness and contributing to its further growth and job creation.

Our partners and funders

This project brings together a strong interdisciplinary collaboration between researchers in AFBI and QUB accross in animal nutrition, microbiology, infection biology and animal science. The industry partners in this project are: Lynn's Country Foods Ltd T/A Finnebrogue Artisan Ltd., Moy Park and Cranswick.

This project is funded by the Agri-Food Quest Competence Centre.

RePhokus - Phosphorus Vulnerability Assessment of the UK Food System

Research leads: Dr Donnacha Doody, Dr Myles Patton, Dr Erin Sherry, Dr Siyi Feng

Summary

Sustainable management of phosphorus (P) is vital for the resilience and security of the UK food system, and the delivery of valued ecosystem services (ES) such as clean water and biodiversity. P is a key nutrient required for crop and livestock production, but the global reserves of phosphate rock (PR) from which fertilisers and feeds are derived are a finite critical resource. The UK has no PR and UK agriculture is entirely dependent on P imports in fertilisers, feeds and foods (>100 kt-P yr-1), which are becoming increasingly volatile in cost.

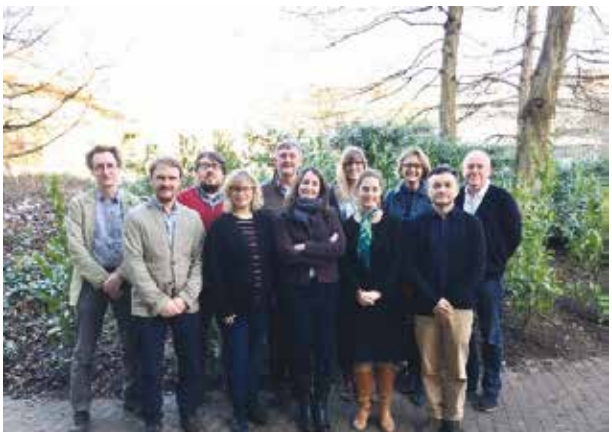
Policy/industry impact:

While fertiliser use in Northern Ireland (NI) has reduced significantly in recent years, the use of feed concentrates has steadily increased. Future global shortages of P, or fluctuating costs of P imports (P shocks) would therefore threaten the security of the agri-food industry here and in the rest of the UK. This 3-year project will undertake the first P vulnerability assessment of the UK food system at catchment and national scale, examining how the agri-food industry would be impacted and adapt to P shortages and/or increase in prices. The Upper Bann catchment in NI will be one of three UK catchment case studies in the project and in addition a phosphorus substance flow analysis of NI will be carried out to identify the sinks and sources of P within the NI food system. This analysis will provide the agri-food industry with an understanding of the potential to develop alternative sources of P and reduce our dependence on imported feeds and fertilisers.

Our partners and funders

This project brings together a strong interdisciplinary collaboration between researchers in global phosphorus (P) sustainability science, food system vulnerability, catchment science, environmental engineering, adaptive capacity and economic modelling. Other institutes involved in the project are Lancaster University (LU), University of Leeds (UL), Centre for Ecology and Hydrology (CEH) and University of Technology Sydney (UTS).

This project is co-funded by the UK research council (BBSRC, ESRC & NERC) and the Scottish Government. Rephokus Project Website (http://wp.lancs.ac.uk/rephokus/).



MASTER: Microbiome Applications for Sustainable food systems through Technologies and Enterprise

Research lead: Dr Steven Morrison

Summary

Although microorganisms dominate almost every ecological niche in our planet, it has only been during the past 10-15 years that we have begun to gain insights into the composition and function of microbial communities (microbiomes) as a consequence of major advances in High Throughput DNA sequencing (HTS) technologies. These approaches have allowed a comprehensive analysis of microbiomes for the first time. Following initial curiosity-driven investigations of microbiomes using HTS technologies, the field has evolved to harness the insights provided, leading to the development of a new multibillion euro industry focused on characterisation and modulation of microbiomes. The vast majority of this investment has been in the clinical space. In contrast, far less is known about microbiomes across complex food chains, making it difficult to harness food-chain microbiome data for the development of more sustainable food systems and to yield innovative products and applications. This is despite the evident importance of microbes throughout the food chain. MASTER will take a global approach to the development of concrete microbiome products, foods/feeds, services or processes with high commercial potential, which will benefit society through improving the quantity, quality and safety of food, across multiple food chains, to include marine, plant, soil, rumen, meat, brewing, vegetable waste, and fermented foods. This will be achieved through mining microbiome data relating to the food chain, developing big data management tools to identify inter-relations between microbiomes across food chains, and generating applications which promote sustainability, circularity and contribute to waste management and climate change mitigation. We will harness microbiome knowledge to significantly enhance the health and resilience of fish, plants, soil, animals and humans, improve professional skills and competencies, and support the creation of new jobs in the food sector and bioeconomy.

Policy/industry impact:

MASTER is a transdisciplinary, multi-actor consortium comprising world leaders with diverse and complementary expertise in the application of the microbiome for sustainable food systems through technology and enterprise across multiple food chains. The results of the project will allow markets to access high-impact microbiome derived products such as strains and consortia of strains; food, feeds and ingredients; services and processes; molecular analytical tools and assays; and databases and pipelines with high commercial value. A pan-European initiative, such as MASTER, addresses food sustainability across multiple food chains, and will achieve its desired impact by obtaining visibility through targeted and thoroughly planned dissemination, communication, and exploitation measures, and also through integration of RRI, gender issues and SSH perspectives throughout the innovation process. A transdisciplinary scientific and industry Advisory Board member group along with the Project Management Board and a Multi-Actor Knowledge Exchange (MAKE) Group, will input into the Plan for the dissemination and exploitation (PDE) and project outputs, ensuring that SSH and end-user perspectives, are brought to bear on the innovation process. These perspectives will greatly increase the long-lasting use, uptake and impact of MASTER products, processes and services and will be valuable in informing the targeting of communication, dissemination and exploitation strategies all along the MASTER project. Furthermore, the vast networks of transdisciplinary MASTER partners will be strategically used for communication, dissemination and exploitation, identifying intermediaries and knowledge brokers as advocates and amplifiers for MASTER innovations.

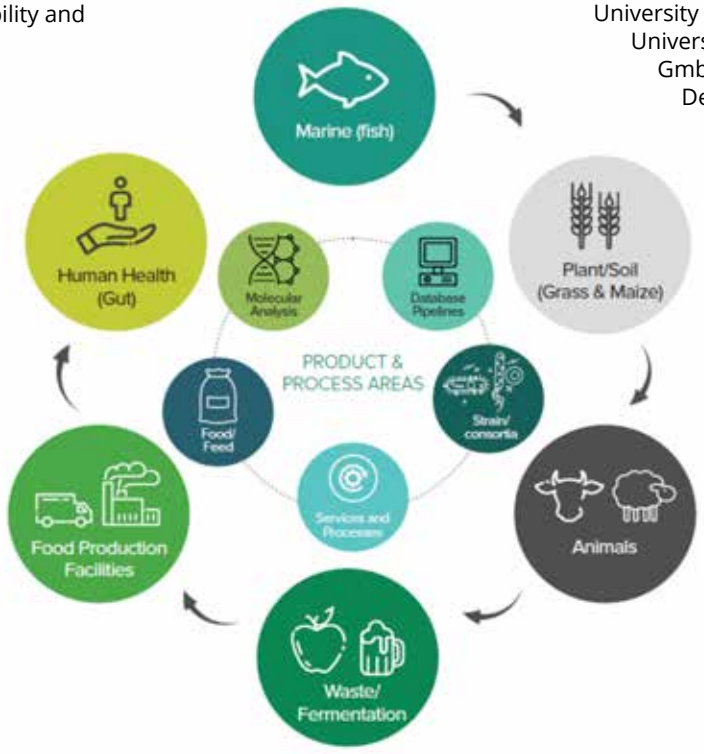
Key outputs:

Raise awareness of the potential behind microbiomes from terrestrial and aquatic environments in transforming and future-proofing our food system"

Bring to market new and cost-effective commercial applications to assist different stages and processes throughout the food chains, by 2025

Improve overall knowledge of microbiomes from land and seas towards the market needs in areas where applicability and readiness is not visible

Improve overall sustainability, including climate change mitigation, and innovation capacity of the food system through the use of microbiome applications and knowledge"



Our partners and funders are:

The project involves collaboration with partners from Teagasc, Agenica Estatal Consejo Superior Deinvestigaciones Cientificas, Luonnonvarakeskus, FFoQSI GmbH, Universita Degli Studi Di Napoli Federico II, Universidad de Leon, The Circa Group Europe Limited, Queen's University of Belfast, AIT Austrian Institute of Technology GMBH, Qiagen GMBH, Tritecc SRL, Institut National de la Recherche Agronomique, Novolyze, Matis OHF, AB-Inbev NV, Oxford Nanopore Technologies Ltd, Wageningen University, University College Cork – National University of Ireland Cork, INOQ GmbH, Devenish Research Development and Innovation Limited, 4D Pharma Cork Limited, CHR. Hansen A/S.

Horizon 2020

Food Futures - SMART Sustainable Agri-Food Production

Research lead: Dr Steven Morrison

Summary

The Agrifood sector lacks a methodology/tool box which measures the "sustainability" of food production in Northern Ireland. It is essential that this is addressed to (1) support the sustainability credentials of food produced in Northern Ireland, (2) support current and future markets, (3) support behavioural change to improve sustainability footprint, (4) identify areas for knowledge exchange and (5) identify knowledge gaps which may inform future Research and Development priorities for each supply chain, sector and the wider industry.

The Food Futures project will adopt a unique participatory approach to enhance the sustainability credentials of Northern Ireland Agri-Food section. The objective is to develop a holistic Sustainability Platform including a reporting tool for the agri-food supply chains. The new industry wide tool will be formed by three core pillars - Economic, Environmental and Social. Thirty ambassador farms, from multiple supply chains, will provide narrative case studies of the journey to evidence sustainability and will provide valuable input into the development of the Sustainability toolbox.

Policy/industry impact:

With increasing pressure on land, labour and nutrients and growing concern on the impact of farming and food sector on water, soil and air quality how we deliver more food in a sustainable manner will be key challenge. Policy makers, retailers and ultimately consumers want to know more about how food is produced, the impact on the planet and assurance it was produced ethically in terms of animal welfare/health and producer work/life balance and standard of living.

The Food Futures project will provide and essential toolbox to quantify and evidence the sustainability footprint of the agri-food sector in Northern Ireland. This will deliver major benefits to supply actors from producers to processors and will also underpin the future marketing of food produced in Northern Ireland. This is essential to support our existing markets and to compete for new global markets, which will require this degree of wide Sustainability evidence.

Key Outputs

1) Provide a robust, science-based platform for driving behavioural change relating to the sustainability credentials of our livestock products including efficiency of production. This will therefore help protect and enhance the agri-food sector for current and future generations.
2) Create a platform from which to capture and credit components that will enhance the sustainability credentials of Northern Ireland Agri-food such as enhanced product quality, reduced supply chain waste, etc.
3) Provide a unique, defendable, evidence base to assist in the marketing of the Northern Ireland livestock products locally, nationally and globally
4) Enhance consumer confidence in the sustainability claims of Northern Ireland food and the **Food Futures** platform will inform and enhance sustainability of the land and food based sector and help create an additional unique selling point for AgriFood sector in Northern Ireland. The project is a vital to support the AgriFood sector in Northern Ireland in ***producing high quality, safe, nutritious and sustainable food.***

Our partners and funders are:

This project involves collaboration with partners in Queen's University, Northern Ireland Agricultural and Research Council (AgriSearch), ABP UK, Dale Farm Ltd., Devenish Nutrition Ltd, Dunbia Ltd, Lynn's Country Foods Ltd T/A Finnebrogue Artisan Ltd, Foyle Food Group Ltd, LacPatrick Dairies (NI) Ltd, Lakeland Dairies (NI) Ltd, Linden Foods Ltd, WD Meats, Hewitt Meats, C&J Meats.

The project is funded through the Agri-Food Quest Competence Centre.

SUPER G : Developing SUstainable PERmanent Grassland systems and policies

Research leads: Dr Francis Lively, Dr Debbie Mc Connell and Dr Aurelie Aubry.

Summary

The existence and management of permanent grasslands (PG) is key to the delivery of multiple ecosystem services (ES) across Europe. However, PG maintenance and functions are under threat from sub-optimal management of inputs, cultivation in higher output farming systems and abandonment in remote and marginal areas. The overall objective of the SUPER-G project is to co-develop sustainable PG systems and policies with farmers and policy makers that will be effective in optimising productivity, whilst supporting biodiversity and delivering a number of other ES.

Policy/industry impact:

SUPER-G will apply a multi-actor approach, working with farmers; land owners/managers and their advisers; third sector and civil society groups; non-governmental organisations (NGOs) and researchers, policy and business communities to achieve: 1) better understanding of the importance and functioning of PG; 2) benchmarking of PG performance across Europe; 3) co-development of integrated approaches for profitable and sustainable PG management; and 4) co-development of tools and policy mechanisms, which are inclusive of stakeholder and citizen priorities, to support the maintenance and sustainable management of PG. The project will last five years to allow time for the establishment of farm networks for data gathering and analysis; and the development of good grassland practices, innovative techniques and farm-level and policy support tools. Using a responsible research and innovation (RRI) approach, the project will develop a comprehensive European grassland typology and a shared conceptual model of how PG can deliver in terms of productivity, biodiversity and other ES such as climate regulation, water quality, mediation of water flows and erosion control. The potential of PG to deliver multiple ES will be informed by benchmarking and testing, involving a network of farms and experimental platforms in 14 countries covering the Mediterranean, Atlantic, Continental, Alpine, Pannonian and Boreal regions.

Our partners and funders are:

This project brings together a strong multi-disciplinary collaboration between researchers working in the permanent grassland field. In total the project involves 20 partners from 14 countries. Full details of partners is available on www.super-g.eu

This project is funded by Horizon 2020

SUPER-G
SUSTAINABLE PERMANENT GRASSLAND

The Living With Water Programme (LWWP) Ecosystem Modelling

Research lead: Dr Matt Service

Summary

AFBI are developing a system-scale ecological model, operated in a three-dimensional formulation. It is applied to simulate extended periods of time, ranging from one year to decadal scales. The main objectives of the EcoWin model are:

1. To simulate primary production (both pelagic and benthic, as required), taking into account both bottom-up and top-down control;
2. To explicitly simulate human interaction including the effect on aquaculture yields of changes to land-based nutrient loading—a model chain derived from SWAT and waste water modelling can be used to examine the consequential changes to primary production and ecosystem functioning;

Policy/industry impact:

The Living With Water Programme (LWWP) is tasked with developing a Strategic Drainage Infrastructure Plan (SDIP) for Belfast to ensure compliance with EU Water Framework Directive (WFD), Urban Waste Water Treatment Directive (UWWTD) and European Floods Directive (EFD) requirements. A Scoping Study carried out to investigate potential delivery options recommended the development of an ecosystem model, to inform and facilitate implementation of measures to achieve the EU Water Framework Directive (WFD) objective of Good status, but can also be adopted to demonstrate compliance with a wide range of other EU environmental legislation. This detailed, evidence based modelling approach facilitates implementation of optimised, sustainable solutions and provides the means to demonstrate value for money in line with the WFD requirement for Cost Effectiveness Analysis (CEA) through identification of the best combination of measures to achieve the objectives at lowest cost.

Our partners and funders are:

This project brings together a strong interdisciplinary collaboration between ecosystem modellers, waste water engineers and environmental regulators.

This Project is funded by Northern Ireland Water

Living With Water Programme
Strategic Drainage Infrastructure Plan

SECTION 5

Research highlights

Research highlights

Dr Adrian Allen

Tsairidou, S., Allen, A., Pong-Wong, R., McBride, S., Wright, D., Matika, O., Pooley, C., McDowell, S.W.J., Glass, E., Skuce, R.A., Bishop, S., Woolliams, J. (2018). An analysis of effects of heterozygosity in dairy cattle for bovine tuberculosis resistance. **Animal Genetics, 49(2): 103-109.**

AFBI is involved in ongoing collaborative efforts with the University of Edinburgh's Roslin Institute, to determine the genetic basis of cattle susceptibility to infection with bovine tuberculosis.

In this paper, using an existing well characterised genetic dataset of affected cases and unaffected controls, we applied analytical tools designed to search for dominance effects and heterozygote advantage potentially associated with TB susceptibility – focusing on genomic regions that other studies have suggested such effects are observed in.

One genetic variant on chromosome 6, in a pseudogene related to a gene involved in cattle immune function, was found to associate with the TB phenotype, exhibiting a dominance effect. Interestingly, unaffected control animals exhibited reduced heterozygosity at this locus compared to affected cases. This is intriguing because disease resistance has in the past been associated with balancing selection and heterozygote advantage.

Further validation of these data in larger studies will be of interest to researchers seeking to gain a better mechanistic idea of how TB resistance works in cattle. These efforts are part of ongoing programmes of work to enhance breeding schemes to produce a more TB resistant national herd.

Dr Nicolae Corcionivoschi

Ijaz, U., Sivaloganathan, L., McKenna, A., Richmond, A., Kelly, C., Linton, M., Stratakos, A., Lavery, U., Elmi, A., Wren, B.W., Dorrell, N., Corcionivoschi, N. and Gundogdu, O. (2018) Comprehensive Longitudinal Microbiome Analysis of the Chicken Cecum Reveals a Shift From Competitive to Environmental Drivers and a Window of Opportunity for Campylobacter. **Frontiers Microbiolology, 9: 2452.**

Industry has endeavored to reduce the burden of Campylobacter within chicken production lines with supplements often administered with the aim of performance enhancing and/or reducing bacteria such as Campylobacter, typically post day 25. In this study we have performed a comprehensive analysis of the chicken cecal microbiome from days 3 to 35, with 12 replicates per day (final n = 379), correlating additional metadata such as chicken weight and feed conversion rates with Campylobacter detection in a natural environmental setting. The relative stability of the chicken cecal microbiota at this time point may explain the efficacy of such products, however the identification of a window of opportunity for bacteria such as Campylobacter may call for intervention strategies between days 12 and 20, or even earlier. This study can act as a baseline for the future.

Dr Dario Fornara

Egan, G., Zhou, X., Wan, D., Jia, Z., Crawley, M., Fornara, D. (2018). Long-term grassland management strongly influences soil biology: implications for ecosystem service delivery. **Biogeochemistry, 141: 213-228.**

The first objective of this study was to address how common agricultural practices including grazing, fertilization and liming might affect soil biology in permanent grassland. The second objective was to address how changes in soil biology (i.e. microbial abundance) might be related to changes in soil carbon sequestration. It was found that liming had the most significant effects on soil microbes increasing bacterial and archaeal groups and decreasing fungal abundance. Changes in soil microbial abundance were not related to changes in soil carbon stocks. A practical implications of this study is that liming had positive effects on soil pH and grass yields without negatively affecting soils' ability to sequester carbon in the long-term. Thus the application of agricultural lime could support the delivery of multiple ecosystem services including grass production, carbon sequestration and a better use of nitrogen and phosphorus nutrients within the soil-microbe-plant system.

Dr Adewale Adenuga

Adenuga, A., Davis, J., Hutchinson, G., Donnellan, T., Patton, M. (2018). Modelling regional environmental efficiency differentials of dairy farms on the island of Ireland. **Ecological Indicators, 95(1):851-861**

This economic research is aimed at nitrogen and phosphorus as critical indicators of agri-environmental sustainability in dairy production systems on the island of Ireland. Employing a novel economic modelling technique (Data Envelopment Analysis (DEA)), we estimated the environmental and technical efficiency of dairy farms in four regions of Ireland (North and South) consistent with public policy goals that seek to simultaneously reduce pollution and increase milk production. Our results showed that there is potential to simultaneously increase milk output and reduce environmental pollution in the regions. Another interesting finding from our study was a positive and significant relationship between technical and environmental efficiency; providing empirical evidence that the adoption of best production management practices also contributes to improvements in the environmental performance of dairy farms. We identified that dairy production can be both environmentally sustainable and profitable. At a time when the UK is leaving the EU, this research is expected to inform future dairy system management practices and impact on agri-environmental policy debates.

Dr Donnacha Doody

Macintosh, K.A., Doody, D., Withers, P.J.A., McDowell, R.W. (2018). Transforming soil phosphorus fertility management strategies to support the delivery of multiple ecosystem services from agricultural systems. **Science of the Total Environment, 649(2019):90-98**

Current nutrient advice to farmers focuses almost exclusively on agricultural production. This limits our ability to address national and international strategies for the delivery of multiple ecosystem services (ES) impacted on by P (e.g food production, water quality, biodiversity, waste recycling). Currently there is no method in place to manage soil P fertility for multiple ES delivery and to identify the potential on agronomic production if crop yield is sacrificing for other ESs. This study presents a approach by which this can be achieved so that cost of trade-offs between different ES can be quantified at farm-scale.

Dr Conrad Ferris

Little, M., Wylie, A., O'Connell, N., Welsh, M., Grelet, C., Bell, M., Gordon, A.W., Ferris, C.P. (2018). Immunological effects of altering the concentrate inclusion level in a grass silage based diet for early lactation Holstein Friesian cows. **Animal, 13(4): 799-809.**

While the impact of changes in concentrate level on dairy cow performance is well known, its impact on immune function is less well understood. The objective of this study was to evaluate the effect of concentrate inclusion level in a grass silage based mixed ration on immune function. Diets comprised a mixture of concentrates and grass silage, with concentrates comprising either a low (30%, LC), medium (50%, MC) or high (70%, HC) proportion of the diet on a DM basis. Increasing concentrate feed level resulted in a higher total DM intake, milk yield, fat + protein yield, mean body weight and mean daily energy balance. At week 3 postpartum, cows on HC tended to have a higher percentage of oxidative burst positive neutrophils than cows on LC, although at all other times concentrate inclusion level in the total mixed ration had no effect on neutrophil phagocytic or oxidative burst characteristics, or on interferon gamma production. Consequently this study provides little evidence that dairy cow immunity can be improved by increasing concentrate feed level when a good quality forage is available.

Dr Linda Farmer

Farmer, L.J., Farrell, D.T., (2018) Beef Eating Quality – A European Journey. **Animal, 12 (11): 2424-2433.**

Beef Eating Quality: a European journey
Consumers want beef that is safe, nutritious and of predictable eating quality. A recent paper by Linda Farmer and David Farrell, AFBI Food Research Branch, reviewed methods for predicting beef quality. This paper, "Beef eating quality: a European journey", described a range of instrumental and grading approaches with potential implications for the European beef industry. Instrumental and spectroscopic techniques have the potential to be implemented on the processing line to non-destructively measure muscle pH, colour, fat and moisture content. Attempts have been developed to use similar approaches to predict eating quality and fatty composition of beef, but the prediction still needs to be improved. Grading systems such as the USDA and other national systems, as well as those implemented by individual retailers, attempt to predict the eating quality of carcasses based on animal traits and measurements of pH, colour and marbling. However, consumers buy and eat individual cuts and not raw carcasses. The Meat Standards Australia (MSA) grading scheme predicts eating quality for each "cut x cooking method" combination to better satisfy consumers. A new European grading scheme, based on the same principles as the MSA system, could be used to predict beef eating quality in Europe and hence underpin commercial brands and official quality labels. This system would need to be flexible to adapt to developing needs and simple at the point of operation. Ultimately, beef production is funded by consumers and meeting their expectations is essential for the future of the European beef industry.

Dr Pia Schuchert

Schuchert, P., Kregting, L., Prittchard, D., Savidge, G., Elsäßer, B. (2018) Using coupled hydrodynamic biogeochemical models to predict the effects of tidal turbine assays on phytosplankton dynamics. **Journal of Marine Science & Engineering, 6(2): 58.**

The effects of large scale tidal energy device (TED) arrays on phytoplankton processes owing to the changes in hydrodynamic flows are unknown. Coupled two-dimensional biogeochemical and hydrodynamic models offer the opportunity to predict potential effects of large scale TED arrays on the local and regional phytoplankton dynamics in coastal and inshore environments. Using MIKE 21 Software by DHI (https://www.dhigroup.com), coupled two-dimensional biogeochemical and hydrodynamic models were developed with simulations including no turbines or an array of 55 turbines with four solar radiation scenarios to assess the temporal and spatial changes of phytoplankton dynamics in an idealised domain. Results suggest that the effect of TEDs on phytoplankton dynamics accounted for up to 25% of the variability in phytoplankton concentrations, most likely associated with an increased residence time in an inshore basin. However, natural variation, such as the intensity of photosynthetically active radiation, had a larger effect on phytoplankton dynamics than an array of TEDs. The paper also suggest that 2D models are a powerful tool in predicting the changes of primary production with regard to the introduction of marine renewable energy structures such as tidal or wave energy turbines.

SECTION 6

Journal articles

Journal Articles *1st January 2018 to 31st December 2019*

Aboagye, G. and Rowe, M. T. (2018) 'Optimisation of decontamination method and influence of culture media on the recovery of Mycobacterium avium subspecies paratuberculosis from spiked water sediments', **Journal of Microbiological Methods, 150, pp. 24-28.**

Adenuga, A. H., Davis, J., Hutchinson, G., Donnellan, T. and Patton, M. (2019) 'Environmental Efficiency and Pollution Costs of Nitrogen Surplus in Dairy Farms: A Parametric Hyperbolic Technology Distance Function Approach', **Environmental & Resource Economics, 74(3), pp. 1273-1298.**

Amoroso, R. O., Pitcher, C. R., Rijnsdorp, A. D., McConnaughey, R. A., Parma, A. M., Suuronen, P., Eigaard, O. R., Bastardie, F., Hintzen, N. T., Althaus, F., Baird, S. J., Black, J., Buhl-Mortensen, L., Campbell, A. B., Catarino, R., Collie, J., Cowan, J. H., Durholtz, D., Engstrom, N., Fairweather, T. P., Fock, H. O., Ford, R., Galvez, P. A., Gerritsen, H., Gongora, M. E., Gonzalez, J. A., Hiddink, J. G., Hughes, K. M., Intelmann, S. S., Jenkins, C., Jonsson, P., Kainge, P., Kangas, M., Kathena, J. N., Kavadas, S., Leslie, R. W., Lewis, S. G., Lundy, M., Makin, D., Martin, J., Mazor, T., Gonzalez-Mirelis, G., Newman, S. J., Papadopoulou, N., Posen, P. E., Rochester, W., Russo, T., Sala, A., Semmens, J. M., Silva, C., Tsolos, A., Vanelslander, B., Wakefield, C. B., Wood, B. A., Hilborn, R., Kaiser, M. J. and Jennings, S. (2018) 'Bottom trawl fishing footprints on the world's continental shelves', **Proceedings of the National Academy of Sciences of the United States of America, 115(43), pp. E10275-E10282.**

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Angioloni, S., Wu, Z. and Sherry, E. (2018) 'Welfare distribution of collective in-kind transfers in education: an application to the extended schools programme', **Applied Economics Letters, 25(20), pp. 1411-1415.**

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Bonny, S. P. F., Hocquette, J. F., Pethick, D. W., Legrand, I., Wierzbicki, J., Allen, P., Farmer, L. J., Polkinghorne, R. J. and Gardner, G. E. (2018) 'Review: The variability of the eating quality of beef can be reduced by predicting consumer satisfaction', **Animal, 12(11), pp. 2434-2442.**

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use efficiency and nitrous oxide emissions from five UK fertilised grasslands', **Science of the Total Environment, 661, pp. 696-710.**

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