Livestock Vaccination

Guideline for dairy, beef, and sheep sectors

Go

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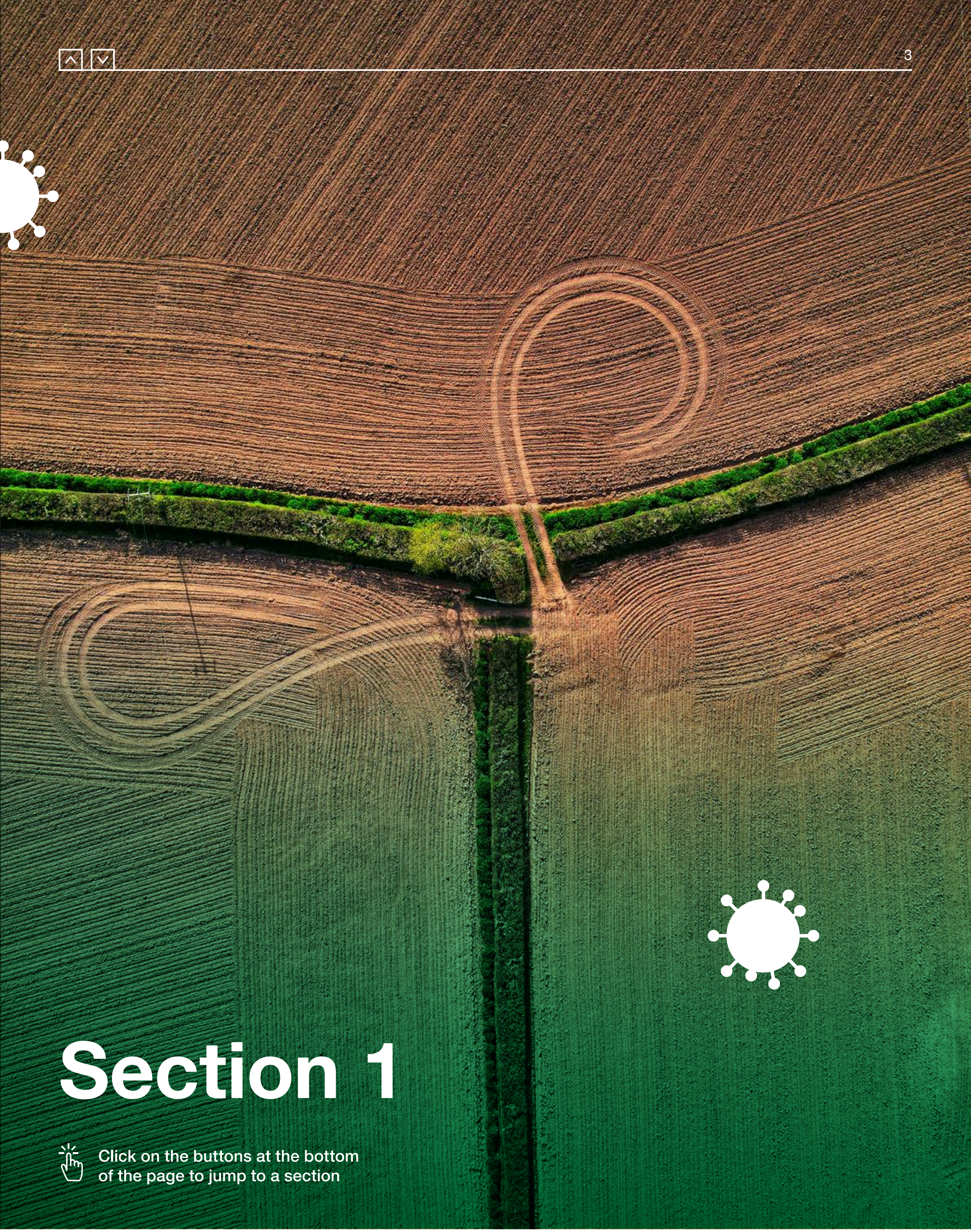

Section 1

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Foreword

Agriculture and livestock farming in the UK is undergoing a series of major changes that will have significant impact on its future.

This is an exciting time for English farming. The introduction of a new system that rewards farmers and land managers while delivering additional public goods that improve the environment gives us an opportunity to help make farming more productive, competitive and sustainable. These changes provide positive opportunities to evolve, to ensure livestock farming is fit for the future that lies ahead.

Despite the unpredictability of livestock farming, there is potential for the sector to evolve with a renewed focus and prioritisation on protecting the health and welfare of livestock, whilst delivering substantial valued public goods, including environmental and welfare benefits.

We recognise how important it is that policies and new programmes are implemented in a way whereby farmers and the wider industry have the tools to adapt and thrive. This is why we are working closely with industry to co-design solutions that improve resilience to threats and ensure opportunities can be realised. The support that is part of the forthcoming Animal Health and Welfare Pathway is a good example of what industry and government can achieve when working together.

Vaccination is a key tool in disease reduction, prevention and control. By encouraging a progressive livestock vaccination strategy across the UK, as part of a wider set of co-ordinated measures to improve the health status of the national herd and flock, we can support and further improve UK animal health and welfare standards. At the same time, we can contribute positively to One Health, including Antimicrobial Resistance (AMR), to sustainable livestock farming, environmental management, and food security.

A vibrant agricultural sector – built on resilience – produces safe, high-quality and nutritious food that helps to secure sustainable food production, bolsters national food security, and enhances economic growth. At the very centre of this is a step change towards a truly preventative health model that places a renewed emphasis on population risk, whilst realising the clear benefits of implementing national improvements.

The Livestock Vaccination Guideline sets out a vision and a blueprint for how vets, SQPs/RAMAs, farmers and policy makers can be supported through guidelines for priority diseases, where vaccination plays a key role in reduction, prevention and control.

The objective at the very core of this strategy is to challenge the status quo with a forward-thinking framework that can stimulate meaningful progress in the form of greater farm resilience, and sustainable improvements in efficiency and productivity across the UK.

Vaccination has an important role to play, along with good management, husbandry, nutrition and biosecurity. It can play a fundamental role in catalysing the change needed to support farm businesses and position the UK as an international brand for excellence in animal health and welfare, as well as sustainable food production.

The Veterinary Medicines Directorate works closely with NOAH and the pharmaceutical industry on the regulation of veterinary medicines to ensure availability of good quality, safe and efficacious vaccines on the UK market.

Livestock vaccination plays a crucial part in the future of UK farming and as Minister for Rural Affairs, Access to Nature and Biosecurity, I fully support our excellent, innovative, and world-leading animal health industry as they drive forward this important livestock vaccination initiative.

Lord Benyon

Minister for Rural Affairs, Access to Nature and Biosecurity

Highlights

The dairy, beef and sheep sections of this report set out in detail the background and rationale for vaccination. A categorisation tool to prioritise and review vaccination strategies is proposed and illustrated in **Table 1**. This applies across a range of priority diseases and conditions and can be used to review current vaccination strategies on farm to enable effective decision making. **Table 2** provides an overview of the Category One, highest priority vaccinations for the dairy, beef and sheep sectors.

The aim is to help deliver maximum benefit on farm that translates to benefits for animal health and welfare and sustainable farming across the UK.

Table 1: Livestock vaccination categorisation

Livestock Vaccinations	
1	**Category One** These are highest priority vaccinations and are considered highly important in flocks and herds. It should be considered that flocks or herds are vaccinated as a default unless appropriate justifications have been clearly identified by the vet and farmer working together. These justifications should be regularly reviewed.
2	**Category Two** These vaccinations are usually recommended as best practice with flexibility to apply their use depending on farmer and vet review and discussion.

TIP
You can click on abbreviations

Table 2: Category One vaccinations for dairy, beef and sheep

Dairy	Beef	Sheep
BVD IBR Leptospirosis BRD Calf scour	**Suckler cows** BVD Leptospirosis Clostridial diseases **Suckler calves** RSV Clostridial diseases **Growing and feeding cattle** Clostridial diseases IBR	Clostridial diseases Footrot Toxoplasmosis EAE Pasteurellosis

Vaccination is an integral part of progressive preventative herd and flock health management.

Introduction

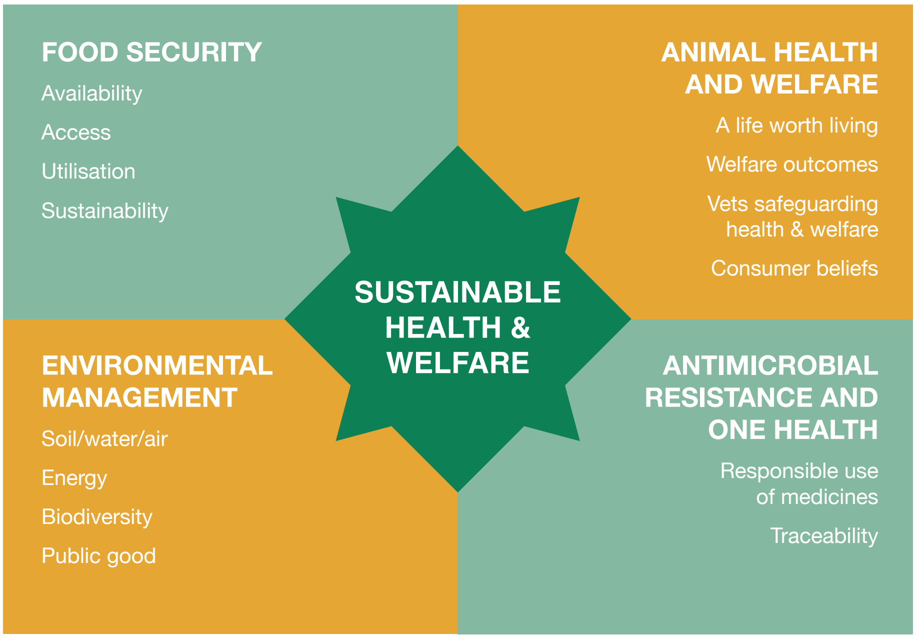
Vaccination is an integral part of progressive preventative herd and flock health management. It sits within a toolbox of measures, which include good biosecurity and nutrition, to effectively prevent or control disease on farm. This paper provides vaccination guidelines to support vets, Suitably Qualified Persons (SQPs)/Registered Animal Medicines Advisors (RAMAs) and farmers to manage the health and welfare of sheep and cattle.

The three sections in this report; namely dairy, beef, and sheep, can be read independently. Each provides a distillation of veterinary clinical experience and research to demonstrate current thinking on a proactive approach to vaccination. The overall aim of this report is to encourage best practice and discussion between vets and farmers to apply effective vaccinations strategies on farm.

The fundamentals of how vaccines work, and how to get the most from them, should be kept in mind. Vaccines help reduce the incidence of disease by stimulating the immune system to provide protection. The aim of any vaccination policy, in any species, is to challenge the individual with a "controlled" dose to stimulate an immune reaction that will prime the animal's immune system to respond quickly and effectively to any future field challenge. Thus, vaccination is designed to prevent/reduce future disease, clinical signs or impact on production; it will not necessarily prevent future infection. Additionally, the immune system is highly complex and its ability to function to its full potential can be compromised in several ways. Certain viruses, mycoplasmas, etc, can influence this response as can deficiencies in essential nutrients. The immune system of animals in poor body condition, lacking in essential micro-nutrients, or suffering from stress or concurrent disease rarely responds fully to exposure to a challenge, whether that is from an invading pathogen or to a vaccine.

Preventing and protecting livestock against harmful, production limiting, or zoonotic disease has obvious benefits. In addition, as shown in **Figure 1**, an effective and progressive vaccination strategy also contributes positively towards 'One Health' (an integrated, unifying approach that aims to sustainably balance and optimise the health of people, animals and ecosystems), including Antimicrobial Resistance (AMR), and to sustainable livestock farming, environmental management, and food security. An industry-wide strategic approach to vaccination can improve resilience and deliver these additional benefits on farm and across the UK.

Figure 1: the sustainable livestock health and welfare balance



One Health: vaccination and the responsible use of antibiotics

The most effective way to support responsible antibiotic use is to prevent disease, since healthy, protected animals do not require antibiotic treatment.

This is achieved through vaccination, improved animal breeding, good hygiene, optimising nutrition, improved animal accommodation and all aspects of animal husbandry through herd and flock proactive health planning and management for health, welfare and productivity. Vaccination plays an important role in 'One Health', a concept that encompasses animal health, human health and the environment. Several vaccines (for example those against salmonellosis, leptospirosis, ringworm) also act as a safeguard to protect human health by reducing the risk of zoonotic infection. This helps to ensure the health of those working with livestock by lowering disease levels. All those involved in the livestock industry, including vets and farmers, share responsibility for the health and welfare of food-producing animals, the quality and safety of the food they produce and protection of the environment.

The magnitude of One Health challenges are immense. It is estimated by the Food and Agriculture Organisation (FAO) that more than 70% additional animal protein will be needed to feed the world by 2050 and the World Organisation for Animal Health (OIE) estimates that more than 20% of animal production losses in the world are linked to animal diseases[1–3]. Alongside these headlines, it has been estimated that by 2050, the annual number of global human deaths due to antimicrobial resistance (AMR) could exceed 10 million and that drug-resistant infections will cost a cumulative 100 trillion USD of economic output[4].

The improvement of professional capacity and capability for effective infection prevention and control (IPC) and good antimicrobial stewardship in human medicine has been recognised as essential within the UK's five-year National Action Plan for tackling antimicrobial resistance[5]. The 2040 vision for AMR contained within this UK National Action Plan has nine ambitions for change which include the aim to minimise infection, to protect animal health and welfare, and to demonstrate appropriate use of antimicrobials. The plan also commits the UK to work with industry: to develop appropriate training, guidance and other communications; to assess prescribing practices; to develop evidence-based tools to guide these practices; and to explore business models that make better use of veterinary expertise in optimising antibiotic use.

The Responsible Use of Medicines in Agriculture Alliance (RUMA) Targets Task Force[6] has concentrated on developing specific targets to be delivered by each different agricultural sector. Huge progress has been made with respect to stewarding the use of antibiotics within UK agriculture e.g. a 52% reduction in antibiotic use from 2014 to 2020, which has been achieved through this voluntary multi-sector collaboration. Within a range of different management actions, these targets have consistently included measuring, monitoring and promoting vaccination uptake in the ruminant sectors. This new phase of work is helping to achieve the long-term sustainable and responsible use of antibiotics.

Key industry initiatives underway in the UK, such as Farm Vet Champions (FVC)[7] are based on the principle of 'Plan Prevent Protect'[8]: i.e. plan ahead to prevent disease and protect the flock or herd. These simple principles have appropriate vaccination protocols deeply embedded as key tools to achieve good animal health and responsible antimicrobial stewardship.

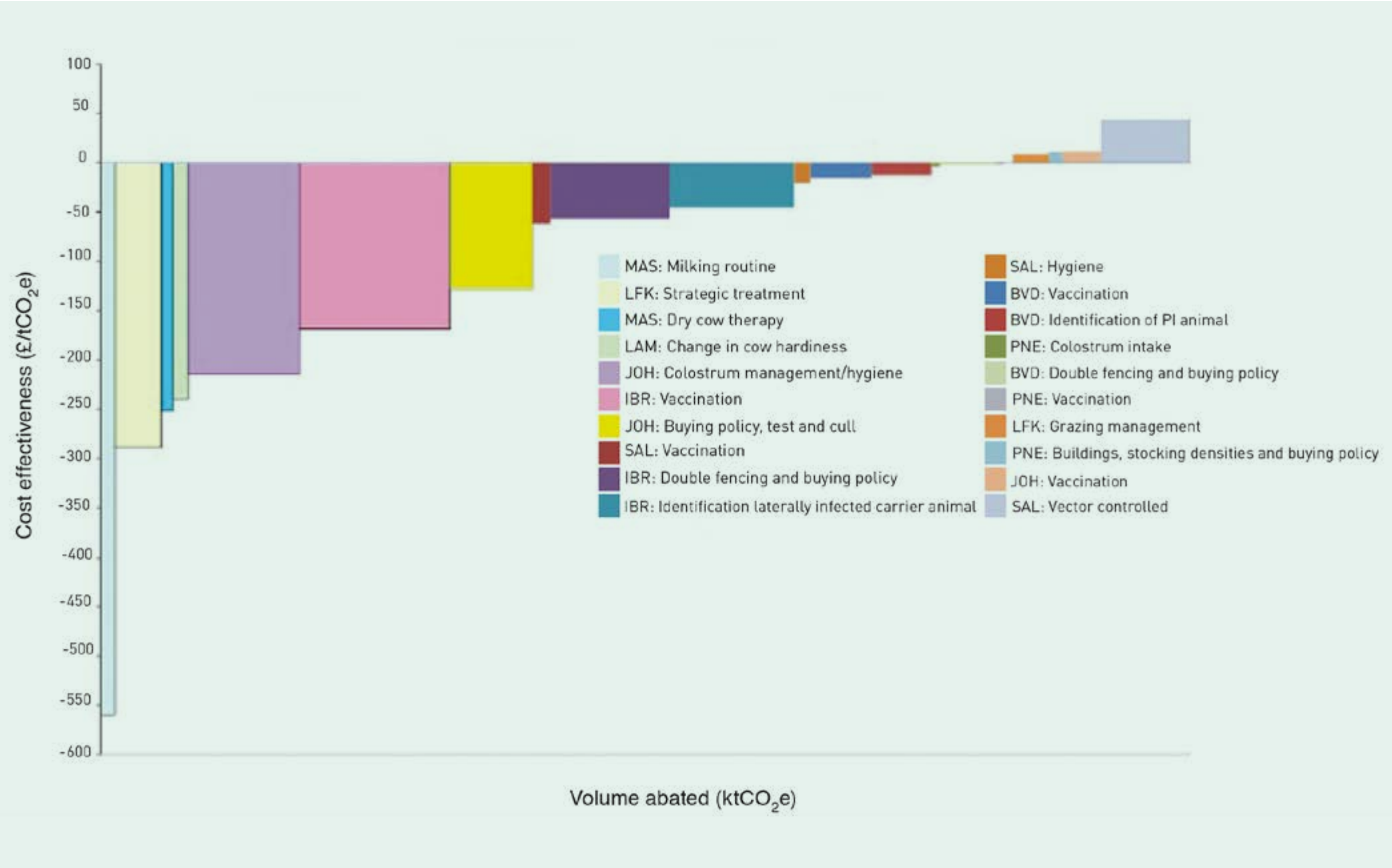
Sustainable livestock farming: environmental management and food security

Environmental Management

Livestock farming is under considerable scrutiny and pressure to contribute to the wider societal response to climate change. The livestock sector emerges as one of the top two or three most important influences on the environment, both at local and global levels[9]. However, raising livestock, with high standards of health, can be part of the solution. The UK Climate Change Committee reported that to deliver the UK Government's Net Zero greenhouse gas emissions target by 2050, a number of measures were needed, including encouraging low-carbon farming practices such as improving livestock health, which was identified as one of the most cost-effective measures from a mitigation perspective[10].

Marginal abatement cost is a measure of the cost of reducing a unit of pollution. Marginal Abatement Cost Curves (MACC) can identify the most economically efficient reductions in GHG emissions. Specific MACCs for endemic cattle disease control have been proposed as shown in **Figure 2**[11]. It should be noted that five of the measures in this prioritised list are vaccinations: for IBR, BVD, Salmonella, calf pneumonia and Johne's disease. A clear message is that many measures to improve cattle health, including vaccination against infectious diseases to improve cattle health are profitable in their own right, as well as reducing GHG emissions intensity.

Figure 2: Marginal Abatement Cost Curve for control of endemic disease in dairy cattle in the UK. Negative columns show how cost effective the GHG abatement is to the farmer. The width of each column gives the magnitude of GHG abatement for each HHM measure[11,12]



Case study example: dairy farming

For all dairy farming systems, in all countries, improved efficiency of milk production will have an impact to reduce the negative environmental effects of dairy farming. For any particular system, if fewer cows are required and there are fewer 'lost' litres of milk, then the environmental impacts per litre of milk sold or per animal on the unit will be reduced. 'Lost' milk includes milk that does not enter the food chain following animal treatment or a reduction in yield that occurs following clinical or subclinical disease or poor reproductive performance. A reduction in greenhouse gases (GHG), and in the use of non-renewable resources and chemicals, per litre of saleable milk, is an inevitable consequence of improved health and fertility because fewer cows at a given level of production, are required to produce the same quantity of milk. The difference in environmental impact between the best and poorest performing herds in terms of health and fertility is likely to be very large; in terms of fertility alone reductions in methane emissions of the order of 25% appear to be possible between the best and poorest performing herds[13].

Improving health and fertility to reduce the environmental impact of dairying has the substantial advantage that it is also beneficial for cow welfare and farm financial returns; it is a potential 'win-win' situation. This is clearly an area in which the veterinary profession can and should take a leading role. *Statham et al.*, (2020) published and presented work at COP25 United Nations Framework Convention on Climate Change (UNFCCC) setting out practical methods for establishing GHG emissions, what magnitudes of reduction may be expected with defined improvements in dairy cattle health – Animal health Improvement Measures (AHIM) and how these may be applied in national reporting to the UNFCCC through the Nationally Determined Contributions (NDC) and the necessary Measurement, Reporting and Verification (MRV) required to achieve such[14]. The study applied the same methodology to the dairy sectors of the UK, Chile and Kenya, based on assumptions and modelling initially applied in the UK and considers some economic case scenarios in each country. Importantly the study also explored the cost benefit of the AHIMs to individual farmers as this is a key driver for adoption. Vaccination to control BVD was one key example modelled (**Figure 3**).

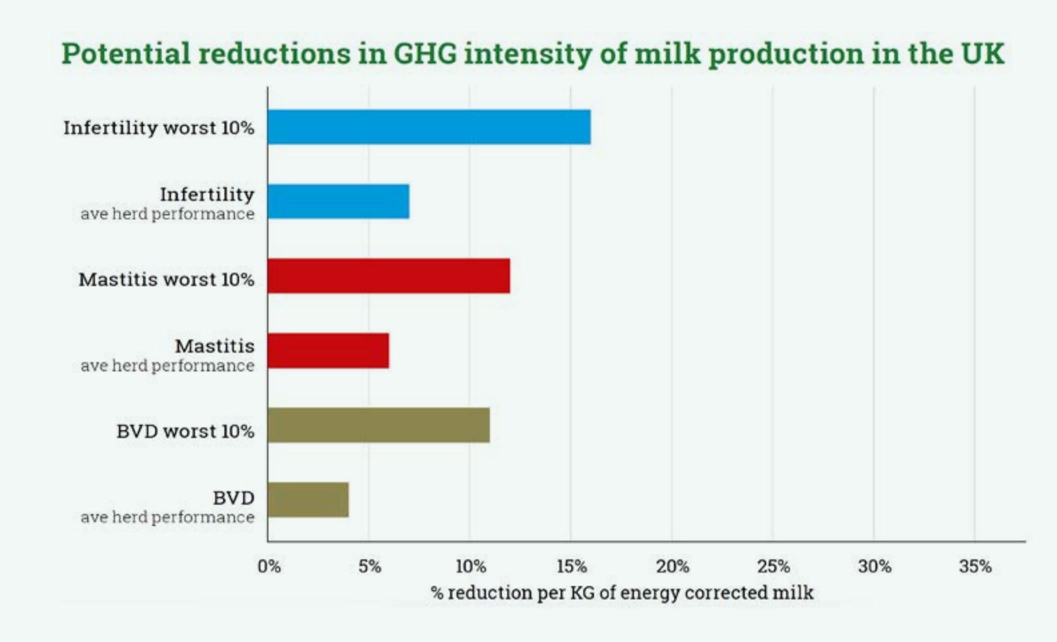


Figure 3: BVD control mitigates GHG emissions intensity[14].

Food security

Livestock farming specifically offers a contribution to global food security through provision of high quality protein sources. The dairy sector produces calcium and essential fatty acids from dairy products, together with beef as a by-product from cull cows and beef crossed calves for the beef industry. It may also support the income of those engaged in the production, processing and marketing and ultimately to a countries' GDP[15]. Global sustainability of food and farming is discussed in detail by Beddington and others (2011) in 'The Future of Food and Farming'[16]. Importantly, there is a wide contrast in food security between countries throughout the world[17].

Globally, livestock farming accounts for 40% of agricultural GDP, employs 1.3 billion people and supplies approximately one third of the protein consumed by the human population. Livestock farming today is expected to produce more food than ever before, from fewer resources and with the smallest possible impact on our environment, to help feed and nourish a growing world population, which is predicted to reach 9.8 billion by 2050[18] and require 70% more animal protein[19]. Global production of meat is projected to more than double from 229 million tonnes in 1999/2001 to 465 million tonnes in 2050 and global milk production to double from 580 to 1 043 million tonnes[20]. The environmental effects of each unit of livestock production must consequently halve in this time period just to prevent increased impact.

Livestock farming activities are socially and politically highly significant and impact on virtually all aspects of the environment. This impact may be direct, for example through emission of GHGs such as methane, or indirect, such as the expansion of soybean production for feed replacing forests in South America. However, the idea that ruminant agricultural systems are inherently inefficient methods of food production needs challenging; 70% of the world's agricultural area is grassland and much of this could not be converted to cereal production for mainly climatic reasons but also due to the risk of damage to ecosystems. In these areas ruminants can convert the grassland energy and protein (much of which is fibre bound or present as non-protein nitrogen source) into human food. Furthermore, in countries with large food-processing industries, the disposal of food-residue is a significant issue, and this residue can often be converted to milk or meat by ruminants.

A progressive livestock vaccination strategy

Vaccines are already available against a wide range of pathogens, from viruses and bacteria to nematodes and protozoal parasites.

The economic and welfare impact of almost every disease is such that disease prevention is significantly preferably to treatment. For some diseases, particularly those that are due to viruses, no effective treatment is available and so vaccines are often the main form of control. For other diseases the time between infection, disease expression and death can be very short, meaning that the only viable means of protecting the herd is by vaccination e.g., blackleg (see **Table 3**).

An important aspect in getting the most from vaccinating livestock includes the handling and administration of these complex biological products. For maximum benefit they must be handled, stored and administered as per the manufacturer's instructions. In a study of 19 farm refrigerators during 2018, none of them kept the vaccine constantly at the correct temperature of between 2–8°C degrees and only a third of farmers used cool bags to transfer vaccines[21]. While the cost of vaccines is often small compared to the cost of disease, they are a waste of money if inappropriate handling renders them ineffective.

Why is vaccine uptake not higher across the ruminant livestock sector? Motivations are a complex social science topic but understanding different types of farmers and how to engage is a key part of herd health. This is important to overcome inevitable challenges of cost, limited labour, and time. Alongside this is the overwhelming need for education across all livestock food production: from vets to farmers to policy makers and consumers. At a basic level being able to transport, store and administer vaccines is a genuine challenge. Opportunities to deploy technology to make vaccinating easier and safer such as needle-less vaccines and multivalent single dose products are desirable, alongside new vaccine development and secure supply chains.

There is a real opportunity to build a more resilient and sustainable ruminant livestock farming system with the vaccines currently available.

While future advances and research into technology and genetics will play a part, there is much that can be achieved with available vaccines. There is a real opportunity to build a more resilient and sustainable ruminant livestock farming system with the vaccines currently available, by employing a progressive and strategic approach to vaccination in herd and flock health management. Such an approach has been adopted in the integrated pig and poultry sectors as standard practice. This paper provides a framework to facilitate a strategic approach for the ruminant livestock sectors. A high-level categorisation approach to vaccination is proposed with rationale and practical advice. This can be used as a tool to review and prioritise current vaccination strategies on farm. A key element of this approach is the recognition that some vaccines are needed to protect from diseases where all or most livestock in the UK are at risk, have public health significance, are highly infectious and/or pose a risk severe disease.

Category One describes those highest priority 'opt-out' vaccinations considered as default for herd and flock health management. Within this context, the question for vets and farmers when regularly reviewing Category One vaccinations is to ask, *'why not vaccinate?'*.

The objective is to foster an ethos of harnessing the value of population level thinking, which delivers maximum benefit for each livestock farm across the UK. Working with their animal health teams, vets are vital frontline animal health and welfare ambassadors that have a key role to play in affecting this step change.

Category One
These are highest priority vaccinations and are considered highly important in flocks and herds. It should be considered that flocks or herds are vaccinated as a default unless appropriate justifications have been clearly identified by the vet and farmer working together. These justifications should be regularly reviewed.

Category Two
These vaccinations are usually recommended as best practice with flexibility to apply their use depending on farmer and vet review and discussion.

Section 2: Dairy

Dairy sector

Jonathan Statham

Background and motivation

Vaccination to control infectious disease is a key tool in the dairy cattle sector. Lowering the incidence of disease through vaccination can have a major impact on animal welfare by greatly reducing suffering and distress associated with disease.

Although a range of vaccines are commercially available, and described below, how well is the true potential of vaccination really being harnessed and how can we improve our current approach? To answer this question requires a fresh and challenging review of current practice that disrupts the assumptions that can limit the potential uptake of available vaccination or development of novel biological veterinary medicines. Although the bigger picture for policy makers should be considered, above all, vaccination is a vital tool at the hands of the herd veterinary surgeon that should be deployed in effective partnership with the farmer and farm team to address the specific needs of that herd.

How well is the true potential of vaccination really being harnessed and how can we improve our current approach? This question requires a fresh and challenging review of current practice.

Vaccination strategies for UK dairy herds

Vaccination in dairy herds can be categorised in a variety of ways such as single agent infectious disease versus multifactorial/management disease, adult stock versus youngstock and syndromic conditions versus pathogens. Vaccination can also be categorised by priority (i.e., Category One or Category Two, see **Tables 4 and 5** for summary). Single agent infectious diseases generally represent a threat to all herds, including the very best managed, whereas multifactorial conditions may have less indication for vaccination programmes in herds where management conditions effectively reduce disease risks. Many Category One vaccines in the dairy industry are therefore to control single agent infectious disease, although that need may still vary by region and timeframe.

Single agent infectious diseases of dairy cattle

BVD

Bovine viral diarrhoea (BVD) is a highly contagious disease of cattle, which suppresses the animal's immune system and increases its susceptibility to other disease. Much of the damage BVD causes to the beef and dairy cattle industries is through secondary infection. Classic effects of either primary or secondary infection include infertility, abortions, calf scour and pneumonia. Some of the secondary effects are typically treated with antibiotics, particularly in calves. The between-herd prevalence of active BVD infection in the UK is estimated to be 20%[11] and the cost of the disease to the UK cattle (beef and dairy) industry is around £40 million/ year[22]. The mean cost per cow per year is £46.50, a cost mostly attributed to fertility losses[23]. However, studies on which this estimate is based are probably vastly underestimating the financial cost of secondary infections due to immune suppression[23]. Further research is required to quantify antimicrobial use in animals that require treatment of secondary diseases because of immune suppression due to BVD virus infection.

A control strategy for BVD revolves, primarily, around preventing the birth of persistently infected (PI) calves, which result when the dam is infected with BVD in the first 120 days of gestation. A PI calf remains infected throughout its life and constantly sheds the virus, serving as a permanent source of infection for other animals. Vaccination of female, adult breeding stock to protect them from viral infection during pregnancy is the central pillar of BVD control, alongside testing, identifying, and removing PI animals from herds. Vaccination also reduces the incidence of infertility associated with BVD infection, and reduces adverse clinical effects seen in acutely infected youngstock, such as a rise in temperature, reduced immune cell counts, and subsequent virus shedding[24,25,26]. Nevertheless, vaccination is only currently undertaken in 45% of eligible stock in the UK[27]. BVD control and eradication strategies are centred around surveillance, vaccination and identification and removal of PIs. This approach is high on the UK agricultural sector's agenda, with national eradication schemes already adopted in Scotland and Northern Ireland, and other schemes being rolled out in England and Wales.

Read further information
on BVD in the beef chapter.

IBR

Infectious bovine rhinotracheitis (IBR) is a respiratory disorder caused by bovine herpesvirus type 1 (BoHV-1), but this virus also causes a range of other problems, including poor fertility[28,29]. Infected dairy cows also exhibit a drop in milk production while calves can go on to develop fatal secondary bacterial respiratory infection[29]. The effects of BoHV-1 are particularly damaging in a naïve herd suffering exposure to the virus for the first time. The virus also establishes a lifelong latent infection in individuals which can be reactivated and spread at times of stress[29]. Infection can be a barrier to international trade in livestock and semen, particularly to countries that have eradicated the disease or categorised it as notifiable. In the UK, BHV-1 is estimated to be present in 70% of herds[29], costing £36 million per year[22,30]. Subclinical infection is estimated to cost £200/cow/year to dairy herds in lost income because of reduced milk yield[31].

Nevertheless, control measures, including vaccines, are effective and eradication is possible over a period of time[29]. Currently only 22% of eligible cattle are vaccinated against the disease[27] and a much higher uptake would be required to achieve this aspiration. As well as reducing clinical disease and spread[29], vaccination has been shown to improve fertility, increase milk production and reduce culling[32]. Research is needed to establish the extent to which antibiotic use could be reduced through the control of BoHV-1, particularly with respect to its involvement in respiratory disease. Marker vaccines are available. Effective youngstock vaccination programmes are important to protect heifers prior to entering the adult milking herd. Herd specific combinations of live intranasal vaccines in the face of outbreaks and as a priming primary dose that can be followed by parenteral vaccine, offering both cell-mediated and humoral immunity. Duration of protection can vary by specific approach and challenge but ranges from 3–12 months; booster doses are therefore important and herd specific.

Leptospirosis

Leptospirosis in cattle is caused by the organisms collectively referred to as Leptospira hardjo. There are two serotypes, *Leptospira interrogans serovar hardjo* (L. *hardjo prajitno*), and *Leptospira borgpetersenii* serovar *hardjo* (*L. hardjo bovis*). Up to 60% of British farms may be infected. The bacteria are present in the reproductive tract and kidneys and spread of infection is from cow to cow via urine, foetuses and uterine discharge, and from bull to cow via infected semen. The main source of infection is via carrier cows or infected calves. The organisms often pass into streams and other water sources so these can also be a source of infection. The disease can cause a “milk drop syndrome” (severe or mild) in cattle. In the severe form there is a sudden drop in milk yield affecting all four quarters with pyrexia. The udder secretion becomes thickened and clotted. The udder itself is not swollen or inflamed but tends to be flaccid. The condition usually resolves over seven to 10 days. In the mild form many cows are infected and show only a slight drop in milk yield. Leptospirosis can cause infertility and abortions which usually occurs 6–12 weeks after the dam is infected. Abortion can occur on its own or be preceded by the milk drop syndrome. Most cases of abortion occur during the second half of pregnancy. If infection occurs late in pregnancy the birth of weak calves can also result, and calves born to infected animals are often sickly. There may also be some apparent infertility in the herd.

This is a zoonotic disease and people can be infected if exposed to concentrated infection, i.e., contact via urine during milking. Although infection is present in the milk it quickly dies off once taken from the udder. Meat does not carry infection. Leptospirosis in humans causes a usually treatable meningitis, provided the cause is diagnosed.

There are two vaccines available which contain either *Hardjo bovis* or *Hardjo prajitno* strains. Cross protection has been shown between *Hardjo prajtino* vaccine and the *Hardjo bovis* strain. Both vaccines will control abortion and improve fertility in endemic herds. Vaccination involves two initial doses separated by a 4–6 week interval. If cattle are young when vaccination commences then two doses are required after five months of age as Maternally Derived Antibodies (MDA) may interfere with the immune response. An annual booster is recommended but two vaccinations a year may be required in herds that calve in the autumn. Vaccination does not affect animals that already have milk drop syndrome. Vaccination does however help prevent abortion, but infected cows may still excrete leptospira.

Read further information on IBR and Leptospirosis in the beef chapter.

Salmonellosis

Salmonellosis can affect most species including cattle, sheep, pigs and poultry and people as it is zoonotic. Many species of Salmonella can cause disease in cattle including *S. dublin, S. typhimurium, S. newport,* and *S. arizona*. The two commonest in the UK are *S. dublin* and *S.typhimurium*. *S. dublin* can be endemic in a herd. Recent estimates suggest that approximately 20% of UK cattle herds may be infected at any one time, although obvious disease is a much rarer event. The disease is usually introduced by infected cattle, a wildlife vector or contaminated water source. Identification of Salmonella spp. infection in the UK in food producing animals is reportable, i.e., must be reported to the relevant authorities. In cattle, the majority of cases are self-limiting intestinal infections although occasionally there may be a high mortality even when animals are treated. A feature of salmonellosis is that some strains have developed resistance to one or more antibiotics. In calves the disease typically causes diarrhoea, enteritis and/or septicaemia. In adult cattle it can cause a number of diseases including enteritis and abortion.

Inactivated vaccines containing *S.dublin* and *S.typhimurium* are available in the UK and can be used in the face of a disease outbreak. Vaccination can help reduce the spread of disease and reduce the shedding of infection by infected cattle. When the disease has been confirmed, all at-risk stock not showing overt clinical salmonellosis can be vaccinated. Calves can be vaccinated from 21 days of age and a second dose must be given after 14–21 days. Adult cattle require two doses 21 days apart. For pregnant cows, this primary vaccination course can be given irrespective of their reproductive status. All cows that have not calved within 8 weeks of the second dose should be revaccinated 3–4 weeks before calving. Vaccinated cattle should receive a booster dose at least two weeks prior to each period of risk or at intervals of not more than 12 months.

Control of salmonellosis in cattle involves the use of strict hygiene measures, antibiotics, and vaccinations, either singly or in combination. To prevent the introduction of salmonellosis into herds it is necessary to provide animals with uncontaminated feed and water, to control ingress of rodents and birds and limit human contact. Vaccines have an important role to play in the control of bovine salmonellosis, but they should not be used as a substitute for good husbandry and hygiene.

Lungworm (Husk)

Lungworm (*Dictyocaulus viviparus*) is a parasite that typically affects young cattle during their first season at grazing. In certain situations, infection is found in older cattle, and it has been recognised as a cause of milk drop, respiratory signs, and occasional deaths in dairy cows. The parasite has a complicated life cycle, the speed of which is affected by temperature and moisture levels. The prevalence of infection therefore depends on the time of year. Disease is typically seen in mid-summer to autumn. The signs range from occasional cough to severe respiratory disease and death and reflects the number of infective larvae ingested during a relatively short period of time.

A live attenuated oral vaccine is available which provides excellent protection. Each dose comes in a bottle that should be shaken well and the contents given orally. Calves should be at least 8 weeks old when dosed and the second dose is given 4 weeks after the first. Calves should not be exposed to any potential source of lungworm infection for at least 2 weeks after the second dose. During subsequent grazing seasons exposure to lungworm infection reinforces this initial immunity. Vaccinated stock should not be grazed with unvaccinated animals or follow behind unvaccinated stock in a grazing system since any increase in pasture lungworm burden may cause an overwhelming of immunity. Only healthy calves should be vaccinated. Careful consideration should be given to calves suffering from respiratory disease before dosing. It is advisable not to use any other live vaccine for a period of 2 weeks either side of vaccination.

Ringworm

Ringworm is a fungal infection of hair and skin keratin caused by *Trichophyton verrucosum*. The incidence is considered to be high and it is particularly common in young stock between 2–7 months of age and during the autumn and winter months of the year. Adult cattle are quite frequently infected. Animals kept in close contact with one another, e.g., under intensive management systems, are particularly at risk. Although not giving rise to serious debilitating signs, the effect of ringworm is on the value of the animal or its hide. The disease is usually non-pruritic in cattle. Lesions are greyish-white and have an ash-like surface. There can be hair loss and, if the skin is itchy, it can lead to reduced weight gain in growing cattle. Ringworm infection is generally considered to be self-limiting, and the course of the disease is usually 1–4 months, although in some cases a period as long as 9 months has been necessary for resolution to take place.

A vaccine prepared from a live attenuated strain of *T. verrucosum* has been available historically. If available, it can be used to reduce clinical signs of ringworm (prophylactic dose) or to shorten the recovery time of cattle showing clinical signs (therapeutic dose). The prophylactic dose is generally 4 ml and the therapeutic dose 8 ml, both are administered by intramuscular injection, but may be reduced in younger animals. Calves as young as 2 weeks of age can be injected. Two doses at an interval of 10 to 14 days are recommended. Initially the whole herd should be vaccinated and then, in a closed herd, only the young calves need subsequently to be vaccinated. Onset of immunity occurs 3 weeks after completion of the course. All new animals introduced to the herd should be given a full vaccination course. Once vaccinated, booster doses are usually not required. Occasionally a small crusty lesion may develop at the site of injection. Cattle infected with or exposed to ringworm should not be vaccinated with the prophylactic dose as such animals can develop very severe signs of ringworm. Vaccination can help reduce the impact of the disease in herds with a history of a problem. Ringworm is zoonotic and cause serious skin lesions in people.

Arboviruses

Arbovirus is an informal name for any virus that is transmitted by arthropod vectors. They are likely to become a greater threat associated with climate change. Vaccines are intermittently available in UK following initial incursion from continental Europe 2007 onwards. Examples include Bluetongue virus (BTV)-8 and Schmallenberg virus (SBV).

Multifactorial diseases of dairy cattle

Mastitis

Mastitis is one of the most significant and complex diseases affecting dairy cows and has a high financial and welfare cost. Caused by a wide range of pathogens, the average incidence on UK dairy farms is 47 to 65 cases per 100 cows per year[33]. The annual cost to the UK industry is £200 to £300 million[34,35], while the total cost of a severe case is calculated at £435.80 per affected cow[36]. Milk production can drop by over 400kg per lactation for a clinical case[11]. Clinical cases require prompt treatment, which usually takes the form of antibiotics administered via intra-mammary tubes and/or systemic injections. Some products contain antibiotics considered critically important for human health.

During the 1970s, the National Institute for Research in Dairying released the Five Point Plan for mastitis control which focused primarily on contagious pathogens (passed from cow to cow) and was widely adopted. One of the focus points was implementing blanket antibiotic dry cow therapy: instilling antibiotics in the udders of all milking cows at the point of drying off, to cure any existing infection and as an attempt to prevent new infection during the dry period. The Plan resulted in significant progress in the control of mastitis in the UK, particularly with respect to contagious pathogens. However, it did little to tackle ‘environmental’ pathogens – those picked up by the cow from the environment. These are controlled via attention to environmental hygiene, and dry cow antibiotic therapy is not as applicable, as the bacteria involved do not tend to persist in the udder from one lactation to the next. In the early 2000s, internal teat sealants were introduced, which contain no antibiotic, but provide a physical barrier to ascending infection throughout the dry period, preventing new infections during this time.

Today, the UK dairy industry as a whole is moving away from the concept of administering antibiotic to all cows at drying off, and towards ‘selective dry cow therapy’, where cows deemed at low risk of having infection at the point of drying off, are given teat sealant only, and no antibiotic, as routine. The original Five Point Plan has been superseded in the UK by the AHDB Dairy Mastitis Control Plan, which takes into account all manner of data from an individual farm, including disease infection patterns from somatic cell count data and monthly milk recordings in addition to bacteriology results, to inform a specific action plan for the farm in question.

Vaccination can also play a part in control, depending on pathogens present on the farm and research is ongoing in this area. Vaccination to control *Staphylococcus aureus, Strep uberis* and *E.coli* are commercially available in the UK. However, an effective control strategy is all-encompassing and may include almost any aspect of animal husbandry and environment management, ranging from milking routine to the choice of bedding.

Coliform Mastitis, caused by many different strains of *E.coli*, can affect dairy cattle at any time during the lactation but is associated with dry period infections and fresh cow cases. A dramatic form is peracute mastitis around calving. Around 50% of peracute cases die. The primary source of infection is bovine faeces, so appropriate management of the environment and attention to detail in the parlour is required. Vaccination can also help by boosting the cow’s immunity in the period of greatest risk, just prior to calving. The vaccine works by promoting an immune response to J-5 a core antigen found in most coliform bacteria. Three doses are recommended. The first dose is given to cows at drying off and heifers two months prior to calving. This is followed by a second dose four weeks later and a third dose two weeks after calving. The protection afforded by this regime increases with each inoculation and is 10%, 30–40% and 60–80% respectively. The vaccine does not totally prevent intramammary infection in the first 100 days of lactation, but significantly reduces the severity of clinical signs. It is best considered as an aid to the control of coliform mastitis but will never be a substitute for good dairy cow management. Herd vaccination has been shown to be profitable when more than 1% of cows in the herd are affected with clinical coliform mastitis. The available vaccine is licensed to reduce the incidence of sub-clinical mastitis and the incidence and the severity of the clinical signs of clinical mastitis caused by *Staphylococcus aureus*, coliforms and coagulase-negative staphylococci.

A vaccine is now also available in the UK for active immunisation of healthy cows and heifers to reduce the incidence of clinical intramammary infections caused by *Streptococcus uberis*, to reduce the somatic cell count in *Streptococcus uberis* positive quarter milk samples and to reduce milk production losses caused by *Streptococcus uberis* intramammary infections.

Bovine Respiratory Disease (BRD)

Bovine respiratory disease (BRD) in youngstock has a high economic cost to a farm and the industry, occurring in almost half (45.9%) of all dairy heifers[37]. The most recent estimates have assigned a cost of £60 million (calculated from data published by Statham (2018)[38], although the harm caused can persist, through longer-term damage to animals' lungs.

BRD is a complex of diseases often referred to as pneumonia. It is the biggest cause of death in calves from weaning to 10 months[39], and is caused by a range of pathogens, including viruses and bacteria. These infective agents invade the respiratory tract and can quickly result in permanent damage to the lungs. Death can result within as little as 24 to 36 hours and surviving animals can suffer a growth check which could impact their productivity. Around half of all cattle herds are thought to be affected and within those herds, the prevalence of the disease is estimated at 28% for dairy and 52% for beef[11]. The high prevalence is backed up by abattoir data which notes lung damage as the cause of 23.3% of problems found in calves at post-mortem inspection in abattoirs[40]. Lung damage is associated with both slower growth and lower carcase grades[41]. The cost to the industry is estimated at £50 to £80 million[42,43], or between £30 and £500 per affected calf [39,44,45,46]. The wide variation in these figures is a result of the difficulties associated with obtaining absolute prevalence figures both between and within herds in the UK, and also the complexities associated with quantifying the effects of infection during an outbreak. The impact on mortality resulting from an outbreak is estimated as 1.62%[11], but long-term morbidity (reduction in liveweight gain and effects on long-term productivity) is more difficult to quantify from the literature.

Antibiotics are commonly used for the treatment of BRD, and anecdotally, a substantial proportion is used for this purpose on farms in the UK. This is driven, in part, by frequent repeat treatment for recurring cases and blanket treatment of whole groups, despite the lack of evidence to support this approach[46]. There is scope to reduce the need for antibiotic use through better disease prevention, which, for such a multifactorial disease, should be based on improving biosecurity, husbandry and environment, and providing protection through vaccination. Since only 17% of eligible animals are currently vaccinated[27], there is an opportunity to significantly improve protection across the whole national herd. With a wide range of vaccines available, protection can be tailored to the individual farm based on the rearing system and pathogens present. Single dose intranasal modified live vaccines are now available against viruses RSV & PI3 and may be administered from 1 week old, offering protection within 1 week and 12 weeks duration. Two dose primary course inactivated or modified live parenteral vaccines are now available against combinations of RSV, PI3, BVD, IBR and Mannheimia, with up to 6 months duration of protection. IBR, Mannheimia and *histophilus somnus* vaccines are also available separately as part of BRD management. *Mycoplasma bovis* is a growing BRD threat and although both autogenous and imported vaccines are in use, a vaccine with a UK licence (Marketing Authorisation) is not currently available. A field study conducted in the Netherlands showed that controlling respiratory disease through the vaccination of young calves led to a reduction in daily doses of antibiotic by 14.5% on 40 veal farms[47].

Diarrhoea (enteritis)

Diarrhoea (scouring) in youngstock also comes with a high economic cost to a farm and the industry, occurring in almost half (48.2%) of all dairy heifers[37]. Diarrhoea or scour in the new-born calf is widespread and under reported. A survey of over 1,000 farmers conducted in 2010 suggested over 70% of farms had experienced deaths in calves due to scour[48]. Recent estimates suggest diarrhoea causes the death of 1–2% of calves born in the UK[11]. Surviving animals experience reduced growth rates as a result of damage to the gut, and reduced food conversion efficiency[11]. Neonatal scour costs the cattle industry around £11 million a year, or £58 for every animal affected[22]. Once an outbreak has occurred, treatment should be focused on electrolyte and fluid therapy to replace lost fluids. As the main causes are non-bacterial, treatment with antibiotics is often inappropriate – yet they are commonly used. Historically, antimicrobials could be included in ready-mixed milk powders to feed calves on a unit as a method of disease prevention. This strategy was banned by the UK regulator, the Veterinary Medicines Directorate (VMD) in 2012. In addition, unlicensed use of oral antibiotics to treat scour can upset the balance of the calf's natural gut microflora.

Calf scour is therefore best controlled by preventive vaccination of breeding cows and improved management practices, with particular attention paid to the environment, hygiene and diet. Plenty of good quality colostrum should be fed promptly as it contains high levels of antibodies which are vital to fight infection in very young calves. By vaccinating the cow, between 3 weeks and 3 months prior to calving, against the key pathogens known to cause nearly half of scour cases – rotavirus, coronavirus and *E. coli* – immunity is passed through the colostrum to the calf, which is then better able to fight disease[49]. This improved immunity in the calf to prevent disease occurrence could be expected to reduce the need for antibiotic use, although quantifying this reduction requires further research. However, only 13% of eligible animals are currently protected by vaccination[27].

Clostridial Diseases

The clostridial organisms are common and responsible for many serious diseases in cattle as summarised in **Table 3**. These bacteria are principally found in the environment, particularly the soil. Some areas appear to harbour greater numbers of organisms than others. The organisms produce toxins that cause severe tissue damage, and infection quickly leads to disease, often with death before the animals have been noted to be ill. For this reason, protection through vaccination is the best way of controlling disease.

Table 3: Causative clostridial *spp* and associated disease

Causative Organism	Disease
C. chauvoei	Blackleg, Postparturient gangrene
C. septicum	False blackleg
C. novyi type B	Black disease
C. haemolyticum type D	Bacillary haemoglobinuria
C. tetani	Tetanus
C. botulinum type C and D	Botulism
C. perfringens type A, B, C and D	Enterotoxaeimia
C. sordelli	Sudden death, abomasitis
Mixed clostridial species	Gas gangrene

There are polyvalent vaccines available, including a 10-valent vaccines containing *C. perfringens types A, B, C and D, C. chauvoei, C. novyi, C. septicum, C. tetani, C. sordelli* and *C. haemolyticum*. Animals should receive two doses with an interval of not less than 6 weeks. Booster vaccination must be given at 6-monthly intervals for continuous protection, but where there is no period of risk in the winter, an annual booster vaccination is sufficient. A univalent *C. chauvoei* vaccine can be used in calves over 3 months old with 2 initial doses 3-4 weeks apart. Booster vaccination should be no more than 12 months apart and ideally given 2-3 weeks before a period of risk.

Tetanus is a severe, often fatal, disease of all species of livestock. The disease is produced by the toxin of the bacterium *Clostridium tetani* and is characterised by hyperaesthesia, tetany and convulsions. The organism exists in the soil and cattle are usually infected through wounds or lesions. In areas where tetanus infection has been identified, vaccination is often the best way of reducing risk. A monovalent tetanus toxoid vaccine, which is prepared from purified tetanus toxin treated with formalin, should only be used where a tetanus threat is suspected or has been experienced.

Conclusions

Poor health and subclinical disease can be a major cause of losses in all forms of dairy and beef production, including organic production. Many disease conditions can be avoided or minimised by using management practices that reduce exposure to disease, lower stress, and include good hygiene and biosecurity. Vaccination programmes are an important element in a comprehensive, well-planned herd health control strategy. Vaccination can eliminate or reduce treatment costs, as well as preventing the reduction in growth, milk production or fertility that may otherwise result. Treatment of disease is not as effective or as economical as prevention. These aspirations also fit clearly with the One Health agenda. In addition, a reduction in greenhouse gases, and in the use of non-renewable resources and chemicals, per litre of saleable milk, is an inevitable consequence of improved health and fertility.

Summary of key recommendations

Table 4: Dairy Category One Vaccinations

Vaccination	Details
BVD	All herds. Breeding females prior to start of breeding with annual boosters.
IBR	All herds in affected regions. Effective youngstock vaccination programmes to protect heifers prior to entering the adult milking herd. Herd specific combinations of live intranasal vaccines in the face of outbreaks and as a priming primary dose that can be followed by parenteral vaccine offering therefore both cell-mediated and humoral immunity. Duration of protection can vary by specific approach and challenge but may range 3–12 months. booster doses are therefore important and herd specific.
Leptospirosis	All herds. Breeding animals prior to breeding and first grazing season as risk associated with spring and watercourse access. Zoonotic risk so herd surveillance important.
BRD	All herds. Youngstock by herd specific risk and programme. Early intranasal vaccine and/or parenteral multivalent protection cost-effective in great majority of herds.
Calf scour	All herds. Single dose vaccination of breeding females 3 months to 3 weeks prior to calving offering great protection against rotavirus, coronavirus and E.coli K99 associated diarrhoea in conjunction with effective colostrum protocols.

Table 5: Dairy Category Two Vaccinations

Vaccination	Details
Salmonella	Herds with history of salmonellosis. Often underdiagnosed and zoonotic risk potential. Two dose primary course of heifers and adult herd and may require youngstock vaccination too with herd specific risks. Calves up to 6 months of age – 2 ml and adult cattle – 5 ml. Second dose 21 days later and booster interval can be variable depending on challenge but no more than 12 months.
Ringworm	Herds with clinical signs or risks of ringworm. For active immunisation of cattle to reduce clinical signs of ringworm caused by *Trichophyton verrucosum*. (prophylactic dose) and to shorten the recovery time of infected cattle showing clinical signs of ringworm (therapeutic dose). If vaccine is available, initially the whole herd should be vaccinated with a course of 2 vaccinations, 10–14 days apart. Subsequently, for closed herds only young calves require revaccination at around 2 weeks of age, followed by a second injection 10–14 days later. New animals introduced into the herd should receive a full vaccination course at the appropriate dosage. No subsequent doses are usually required.
Mastitis	Herds with mastitis control issues to reduce the incidence of sub-clinical mastitis and the incidence and the severity of the clinical signs of clinical mastitis caused by *Staphylococcus aureus*, coliforms and coagulase-negative staphylococci or *Streptococcus uberis* protected by a separate vaccine.
Lungworm	Herds with a history of lungworm challenge in young or adult cattle. Calves should be at least eight weeks old when dosed and second dose is given four weeks after the first. Calves should not be exposed to any potential source of lungworm infection for at least two weeks after the second dose.
Clostridial	Herds with a history of unexplained sudden death in apparently healthy cattle of all ages, especially associated with riverbank or disturbed soil. Animals should receive two doses of multivalent vaccine with an interval of not less than six weeks. Booster vaccination must be given at six-monthly intervals for continuous protection, but where there is no period of risk in the winter, an annual booster vaccination is sufficient. A univalent *C. chauvoei vaccine* can be used in calves over three months old with two initial doses three to four weeks apart. Booster vaccination should be no more than 12 months apart and ideally given two to three weeks before a period of risk.
Arboviruses	Arbovirus are likely to become a greater threat associated with climate change. Vaccines are intermittently available in UK following initial incursion from continental Europe 2007 onwards. Examples include Bluetongue virus (BTV)-8 and Schmallenberg virus (SBV). BTV vaccination has to be given by injection twice (three weeks apart) in cattle and sheep, so it can take up to six weeks for the animal to be fully immune. SBV vaccination protects cattle for up to six months and can be used from 14 weeks of age to cover the window of susceptibility during pregnancy, which is from day 70 to day 150 in cattle.

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Section 3: Beef

Beef sector

Joseph Henry

Background and motivation

There are well known challenges to the profitability of beef production in the UK. Profit is governed by output: weight of weaned calf per hectare of farm minus the costs.

Increasing the cow's output occurs in two ways. Firstly, increasing the total weight of weaned calf by increasing the number of calves conceived and reared per 100 cows put to the bull. Secondly, by increasing the average weight of calves at weaning and by having a compact calving pattern with 65% calving in the first 3 weeks, so more calves are older and therefore heavier at weaning. Achieving this starts with good fertility. A lower mortality rate reduces the replacement rate so also increases output. The third way to lift the farm's output is to increase stocking density to increase weight of weaned calf produced per hectare, however this must not be done by just buying in more feed or fertiliser, which are often some of the most expensive inputs, but should utilise and grow more grass through for example, rotational grazing.

Vaccination has many roles to play in delivering more profitable and sustainable beef production. For example, healthy cattle are more likely to be profitable and vaccines are one critical part of achieving good fertility in beef cows. However currently only 85% of suckler cows put to the bull rear a calf to weaning and that is with an extended 16-week mating period. This shows there is room for improvement and a role for vaccination[50]. Vaccination can also reduce the impact of disease on calves, which ranges from slow growth rates to mortality. Vaccines help to achieve higher total weaned calf weight, as part of an overall management plan put in place with the farm vet. By preventing disease, and its associated pain and morbidity, vaccination also directly contributes towards higher welfare in cattle.

Finally, there are management considerations as suckler cows are not handled very frequently, so it makes sense to proactively consider how vaccination sits with the timings of other activities such as pregnancy diagnosis or pre calving metabolic checks. **Table 6 and Table 7** at the end of this section summarises beef Category One and Category Two vaccinations.

Vaccination has many roles to play in delivering more profitable and sustainable beef production.

Vaccination strategies for UK beef herds

Suckler cows

Fertility

BVD

When considering vaccines that stop diseases acting like a handbrake on a beef herd's fertility, the most important one is Bovine Viral Diarrhoea (BVD). BVD is one of the most important diseases for the UK beef industry as it is associated with both significant clinical and economic losses. Those losses arise due to naïve cows experiencing early embryonic reabsorption, due to the development of persistently infected (PI) foetuses and to abortion depending on stage of gestation when cows are infected. These PI animals, which can look clinically normal, spread the virus further causing immune suppression and leading to increased rates of illness amongst the calves and cows. The estimates of the cost of BVD vary, but all are over £10,000 per 100 cows. Despite these impacts, it was reported that only 42–45% of eligible stock are vaccinated (2017–2020)[51,52].

Throughout the UK, there are BVD programmes at various stages of progress. For example, the BVDFree scheme in England and Scotland's BVD eradication scheme, which has been in place for 10 years and has reduced the prevalence from 40% to 10% in breeding herds[53]. Arguably, there is clear evidence that all professional suckler farmers should know their BVD status. This can be achieved by tissue testing soon after birth and looking for PI animals or by antibody testing from 5 calves from each management group from 9 months old. If they are free of disease, then they should vaccinate as insurance against infection, as this could have devastating effects in a naïve herd. If BVD is active in the herd then the farmer should vaccinate to reduce the impact of infertility along with culling all PI's, which reduces the chance of pneumonia and scours in youngstock. It is entirely appropriate to vaccinate and test to check the herd is clear.

Vaccination should apply to all breeding animals prior to mating. Some vaccines need two doses to complete the primary course and others require just one. Some have annual boosters, while others last six months. A discussion between vet and farmer is helpful to determine the most appropriate BVD vaccine for specific herds or farms.

Read further information on BVD in the dairy chapter.

Leptospirosis

The next most important disease to consider in terms of fertility is leptospirosis, which not only causes embryonic death and abortion but is also zoonotic risk to people. For these reasons, it is appropriate for all beef farmers to work with their vet to ascertain their herd's leptospirosis status. If livestock have leptospirosis, then vaccination should commence following the manufacturer's instructions. If the results of testing are negative, then the vet can help design quarantine protocols for all bought in animals and examine the risk of introduction onto the farm through watercourses. If the risk is considered to be moderate, then vaccination of the breeding herd should be considered as an insurance.

IBR

There is evidence from studies in dairy herds that the virus that causes Infectious Bovine Rhinotracheitis (IBR) affects conception, and although there is a lack of studies focused on suckler herds, there is strong anecdotal evidence that is may adversely affect conception rates. IBR may cause abortions or more rarely, may be responsible for infection of the penis or vulva.

Vaccines are either modified live or inactivated and intra-nasal or intra-muscular (IM). For reproductive disease the IM route is preferred and should be given before onset of breeding in heifers and bulls and boosted annually in cows. Young bulls destined for sale should not be vaccinated in case of discrimination in terms of antibodies produced.

Read further information on Leptospirosis and IBR in the dairy chapter.

Campylobacteriosis

Campylobacter fetus venerealis or *fetus fetus* is a venereally transmitted disease which causes early embryonic death and abortion. It can be devasting when first arriving in a herd and in endemically affected herds will reduce conception rates by up to 20%. Diagnosis is difficult because this bacteria is hard to culture and only lives for 6–8 hours outside the body, so it is likely to be under-diagnosed in the UK. At least 5 animals should be sampled and it requires culture of either bull penile fornix washes or cows vaginal mucus. There is a vaccine, which can be imported if disease is confirmed, that should be given to cows before mating and, which is appropriate to use alongside either artificial insemination, preferably, or otherwise treated bulls.

Neonatal scour

Neonatal scour can have devasting effects on a herd and is usually multi-factorial in origin. Important considerations are lack of attention to hygiene and failure of passive transfer of antibodies. Diagnosis of the causative agent should be attempted early in the course of the disease. If the cause is rotavirus, corona virus, or *E coli* then vaccination of those cows expecting to calf pre-parturition will greatly boost antibody levels in the colostrum and so protect calves by preventing disease, assuming that those calves have had enough colostrum! In practice, the calves born as soon as a week after vaccination have less chance succumbing to disease hence indicating the benefits of in early diagnosis. In following years, if the challenge is likely to be the same, then vaccination of all pregnant cows between 12 and 3 weeks pre-calving should be considered and possibly at the same time as some pre-calving metabolic profiling to establish adequate dam nutrition.

General, including clostridial disease

Clostridial spores are widespread in the environment, particularly in the soil. Disease occurs when factors are triggered activating the latent spores and causing toxin production, which generally leads to acute death in the bovine. As cost of vaccination against clostridial disease is generally low, and the first sign seen is generally death, then vaccination has a good cost versus benefit ratio. If one cow is saved every 16 years in a 100 cow herd the vaccine will have paid for itself. By boosting the cows pre-calving, this will increase antibody levels in the colostrum to help protect the calf over the first few months of life, as well as the cow for a year. Providing two doses to calves in their first grazing season can be problematic logistically in spring calving herds. Nevertheless, the primary course for calves (from 2 weeks of age) is two doses 4–6 weeks apart, which should be given at least 2 weeks before the risk period. If dams have been vaccinated, vaccination of calves should be delayed until 8–12 weeks of age. Protection lasts a year, so feeding cattle or in calf heifers and cows should get a booster every 12 months. Using this protocol all cattle should be protected. Depending on risk and farm history, use of vaccine including *C. Sordelli* in the 10 components vaccine as compared to the vaccine containing 8 Clostridial strains may be appropriate.

While there are farms where it may be deemed necessary to vaccinate against Salmonella, ringworm or Mycoplasma this should be done after consultation with the farm vet. Occasionally there are incursions of Bluetongue or Schmallenberg to the UK and it may be necessary to vaccinate to protect beef cows.

Read further information on Clostridial disease in the sheep chapter

Read further information on arboviruses in the dairy chapter

Suckler calves

Pneumonia

Bovine respiratory disease (BRD) known as pneumonia in calves causes huge losses to the industry through calf mortality, cost of treatment and the biggest lost is lack of growth with the farmer keeping and feeding a calf that does not thrive. This last cost often goes unseen as no "cheque" is written out for it. As far back as 2000 the cost of BRD per suckled calf was thought to be £82[54]. BRD is multifactorial with contributing factors such as shed design, nutrition, parasites and stress events, all within the farmer's control. Even with these elements addressed, the majority of calves under a year old that are housed should be vaccinated against Respiratory Syncytial Virus (RSV) due to its ubiquity[55]. As a virus, antibiotics do not treat RSV and it "opens the door" to other pathogens which attack the lungs. Intranasal RSV vaccines (often combined with PI3 another viral BRD causing agent) give the fastest protection with a single dose and are effective for 12 weeks. Other vaccines are injected and need 2 injections 3–4 weeks apart. Some injectable vaccines available also protect for BVD, but if the farm is BVD free and the cows vaccinated (see above), BVD vaccination may not be required for the calf. Some vaccines also contain components to give protection to *Mannheimia haemolytica*.

Calf pneumonia vaccination levels have increased over the last 9 years from 29% to 43% which still leaves the majority of calves unprotected[51].

The key message it that a discussion between vet and farmer should occur regularly to determine an appropriate course of action for the farm, which in addition to vaccination, which is not a panacea, includes all elements needed to decrease the potential for BRD. An effective and proactive approach can work and where suckled calf producers manage to effectively control, and not have to treat, for BRD.

Growing and feeding cattle

IBR

Feeding cattle over a year old, which are mixed and are subject to a change of environment, have a high risk of IBR BRD. Often IBR is endemic in finishing units and there is seldom use of an all in / all out policy. The risk therefore is such that cattle should have a vaccine before the stress factor and when provided via the intranasal route, this offers the fastest protection. Additionally, this group of cattle are also susceptible to infections caused by *Mannheimia haemolytica*. Vaccination to confer protection may be appropriate following a discussion between vet and farmer.

Husk

Husk is caused by a lungworm parasite and mainly affects younger cattle. Outbreaks can be devasting, although rare in spring born calves during their first grazing season with the suckler cow. Yearlings or autumn born calves during their first summer are more at risk. Other factors to consider are previous grazing management practices regarding class of stock and whether sheep were included, as well as stocking rate, and anthelmintic treatments.

Vaccination is preferrable to strategic anthelmintics due to the variability in disease occurrence and outbreaks can often happen at busy harvest times of year in August and September. Husk can present as very acute leading to death before treatment. Vaccination consists of 2 doses orally 4 weeks apart with no anthelmintic to be used from the start until two weeks after the second dose. It is important to ensure that any long acting anthelmintics are clear from the calves system before the primary course commences. In practice vaccination is usually advisable during the housed winter period prior to turnout.

Conclusions

There are a range of effective vaccines available to support high output in suckled calf production. **Table 6** in the summary of key recommendations outlines the Category One vaccines, which are considered the highest priority and these vaccinations should be used as standard, along with Category Two vaccines, summarised in **Table 7,** that are usually recommended as best practice and are applied their use depending on farmer and vet review. Choosing which of these Category Two vaccines to use depends on knowing the farm's disease status and taking into account of the risk of the disease arriving. In all cases, outcomes should be measured to show the value in investing in disease prevention.

Summary of key recommendations

Table 6: Beef Category One Vaccinations

	Vaccination	Details
Suckler cows	BVD	Heifers and young bulls to complete primary course prior to first breeding season. Older cows and breeding bulls booster as per data sheet. Monitor disease status through CHeCS scheme annually.
	Leptospirosis	Heifers and young bulls to complete primary course prior to first breeding season. Older cows and breeding bulls booster annually. Can often be given concurrently with BVD vaccine at a different injection site as per data sheet.
	Clostridial	Often boosting primary course given to young stock so annual booster pre calving. If unknown vaccine status to complete primary course of two dose 4–6 weeks apart.
Suckler calves	RSV	For calves over 3 months old a single intranasal vaccine given prior to weaning and or housing is often the most appropriate, but other options available depending on risk and history. Discuss protocol with vet.
	Clostridial	If cows are vaccinated pre calving then protection from colostrum should last 12 weeks. Difficulty in suckler calves is achieving the primary course of two doses 4–6 weeks apart during the summer grazing period while the mother is getting bulled. Often left until autumn if risk is not too high.
Growing and feeding cattle	Clostridial	If complete primary course as a calf then single annual booster. If vaccine history unknown then repeat primary course.
	IBR	Live IBR vaccine given intranasally to achieve fastest cover.

Table 7: Beef Category Two Vaccinations

	Vaccination	Details
Suckler cows	IBR	If appropriate after discussion with vet. Intramuscular live IBR vaccine primary course given to heifers once selected for breeding (over 3 months old) to be repeated after 6 months and then annually.
	Rotavirus, *E.coli*	Injection of cows during 3 weeks to 3 months prior to start of calving. Must ensure calf drinks colostrum to be effective.
Suckler calves	PI3	Often combined with RSV vaccine. Discuss protocol with vet.
	IBR	For pneumonia prevention intranasal gives quickest immunity. Given prior to housing and or weaning. Discuss protocol with vet
	Ringworm	Given intra muscularly either at preventative prophylactic dose 4ml or therapeutic 8ml dose for cattle over 4 months. Repeated after 10–14 days. No need for boosters.
	Mannheimia haemolytica	Can be in a combined vaccine with RSV and PI3- primary course is 2 injections 3–4 weeks apart with immunity 2 weeks later so given prior to housing and or weaning
Growing and feeding cattle	*Mannheimia haemolytica*	Can be given as a single injection with cover lasting up to 17 weeks.
	Lungworm	For those susceptible cattle – often in first grazing season as weaned calves then 2 doses orally 4 weeks apart prior to grazing season and avoiding any anthelmintics during this period and for 2 weeks after second dose.

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Section 4: Sheep

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Sheep sector

Fiona Lovatt

Background and motivation

The decision to vaccinate the sheep under our care is primarily motivated by animal welfare and our wish to optimise welfare by giving sheep the best chance to be free from avoidable disease.

If optimum protection from all disease were the only driver, then there would be no need for debate as to which diseases to vaccinate against, or the level of risk required to motivate vaccination. However, most sheep flocks are kept as commercial ventures that need to be economically sustainable. There is a balance to be struck between optimum flock welfare, performance and productivity. In most cases there is no conflict between the three and almost always a compromise in welfare occurs to the detriment of both performance and productivity. However, to maintain the economic viability of a flock we need to carefully consider the cost-benefits of vaccinations and strategies over a sufficiently long period of time.

In the short term, an unvaccinated flock might be ‘lucky’ and ‘get away’ without the protection of vaccination. However, as prey animals that are often kept extensively, there may be limited opportunities for shepherds to quickly identify and diagnose individual sheep that are clinically ill. Once identification of the individual and appropriate action has been taken, there is a high chance that the disease will have already spread to other sheep in the flock. For these reasons, vaccination is a key tool within the ‘Plan, Prevent, Protect’ ethos to enable flock owners to protect their animals and to reduce the spread of disease. **Table 8** summarises important UK sheep diseases and their vaccination categories.

Table 8: sheep diseases and vaccination in UK flocks (see **Table 9 and 10** for more details)

UK sheep diseases and vaccination categories	
Category One	**Category Two**
Clostridial diseases	Orf
Lameness: Footrot	Ovine Johnes Disease
Abortion: Toxoplasmosis	Others: Mastitis – Staph Aureus *Arboviruses as required*
Abortion: EAE (Enzootic Abortion of Ewes), Chlamydia abortus	
Pasteurellosis: Pasteurella (*Mannheimia haemolytica* and *Bibersteinia trehalosi*)	

Vaccination is a key tool within the 'Plan, Prevent, Protect' ethos to enable flock owners to protect their animals and to reduce the spread of disease.

Vaccination strategies for UK flocks

Category One Vaccinations

Clostridial diseases

Numerous studies have identified key clostridial pathogenic species, as either vegetative cells or endospores, in most farm soils[56]. Indeed, the ubiquitous presence of clostridial pathogens in soil represents a key route of infection for susceptible grazing animals, such as sheep. Commonly clostridial diseases in sheep present as sudden death[57] with a range of diseases that include enterotoxaemias[58] such as lamb dysentery or 'pulpy kidney', other alimentary tract infections, such as caused by *Paeniclostridium sordellii* as well as tissue damage diseases such as 'blackleg' and 'black disease', and neurotoxic diseases, such as botulism and tetanus[59].

Pulpy kidney (*C Perfringens D*) was the third most common cause of lamb death found in 2733 lamb carcasses examined by Farm Post Mortems Ltd over a five year period up to 2019[60] and Pulpy kidney and Lamb dysentery (*Clostridium Perfringens B)* were both in the top seven most common diagnoses in young lambs up to seven days old submitted to APHA over the same time period[60].

Clostridial disease is often precipitated by a trigger factor, such as change in management, or traumatic or parasitic damage to tissues[61], so good flock management and feeding practices are considered important factors in the control of clostridial disease[59]. However, the ubiquitous nature of the causative bacteria resulting in a wide range of common sheep diseases alongside the ready availability of effective vaccines means that flock control by vaccination is widely considered as best practice[62–65].

Read further information on Clostridial disease in the beef chapter.

Lameness

Lameness is a significant issue on UK farms with surveys suggesting over 3% of ewes are lame at any one time with footrot and Contagious Ovine Digital Dermatitis (CODD) as predominant causes of lameness[66–68].

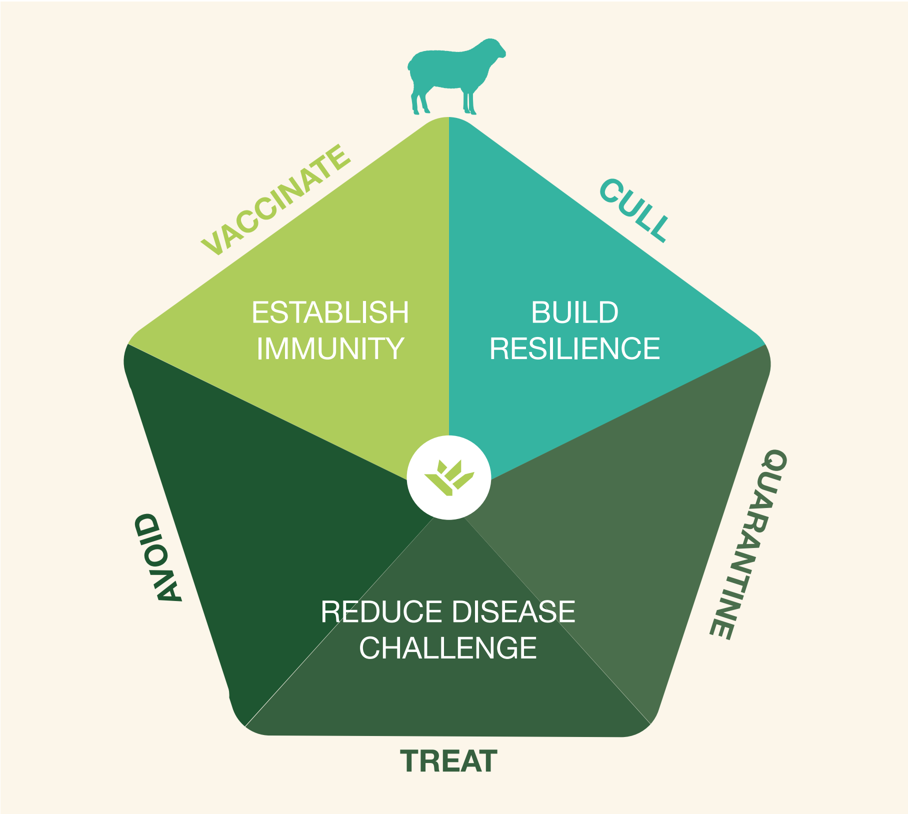
Footrot alone has been shown to cost individual farmers an average of £3.60 per ewe on a farm with >10% lameness costing up to £6.35[69], or even as much as £14[70], per ewe, in the flock per year. Footrot vaccination has been associated with a reduction in prevalence of lameness of between 20% and 70%[66], with some efficacy against both footrot and CODD in co-infections.

Surveys of sheep farmers since 2013 have suggested that uptake of footrot vaccination has increased from 16%[66] to 29.2% in 2015[67] and to 36.1% in 2018[68], though national sales data do not reflect this large increase in penetration. In the AHDB Vaccine Report[71], levels of penetration have been between 13% and 16% since 2017 (here it was assumed that all ewes intended for first time breeding and all rams should receive two doses of vaccine and all other ewes receive a single dose).

In the practical and clinical control of lameness on farm, there is good anecdotal evidence of the usefulness of vaccination[68]; however it has been shown that sheep farmers tend to consider vaccination as a reactive tool and that non-vaccinating farmers will not put it in place until their lameness levels reach a prevalence as high as 19% on average[68]. Evidence suggests that lameness prevalence is only lower in flocks that have been vaccinating for over five years and that it should be considered a long-term preventative measure rather than a short-term reactive one[66, 68].

In 2014, English sheep industry stakeholders agreed that the Five Point Plan[72] (**Figure 4**) should be adopted as a national protocol, to encourage better management of lameness and to contribute to achieving the FAWC (Farm Animal Welfare Committee) goal of achieving <2% lameness at any one time[73]. Vaccination is a key component of the Five Point Plan though evidence indicates that in practice, there is little association between use of vaccination and uptake of the other points of the plan, with full adoption of the Five Point Plan only undertaken by 5.8% of sheep farmers[68].

Figure 4: The Five Point Plan to control lameness on farm



Abortion

Approximately a third of all lamb losses have been shown to occur between scanning and lambing and so could be attributed to abortion (**Figure 5**). **Figure 6** illustrates the diagnoses of GB sheep abortion/fetopathy from 2012–2021[74] and shows EAE and Toxoplasmosis are the top two diagnosed. An unpublished study in 2014 indicated that 81% of 500 GB flocks had been exposed to *T. gondii,* 52% to EAE and 43% to both organisms[75]. Funded by a commercial company, private veterinary surgeons collected up to eight samples from each flock, taken from primarily barren or aborted ewes. In 2009, out of 3,539 sera collected from 227 GB flocks, 74% were found to be positive for *Toxoplasma gondii* when tested using latex agglutination[76]. This study further indicated that seroprevalence increased from 20.5% in sheep up to one year old to 64% in sheep between one and two years of age, with a peak of 81.5% in animals that were between three and four years old. This study indicated that there is a high chance that sero-conversion has occurred by the time the ewe is two years old. Although this measured ewe exposure to Toxoplasma rather than direct links with pregnancy outcomes, the financial costs associated with sheep abortion are such that there is a strong argument that all flocks should be vaccinating replacement ewes against *T. gondii* before they go to the ram for the first time[77].

Figure 5: Lamb losses recorded in a Hybu Cig Cymru (levy board) project in Wales in 2010/11

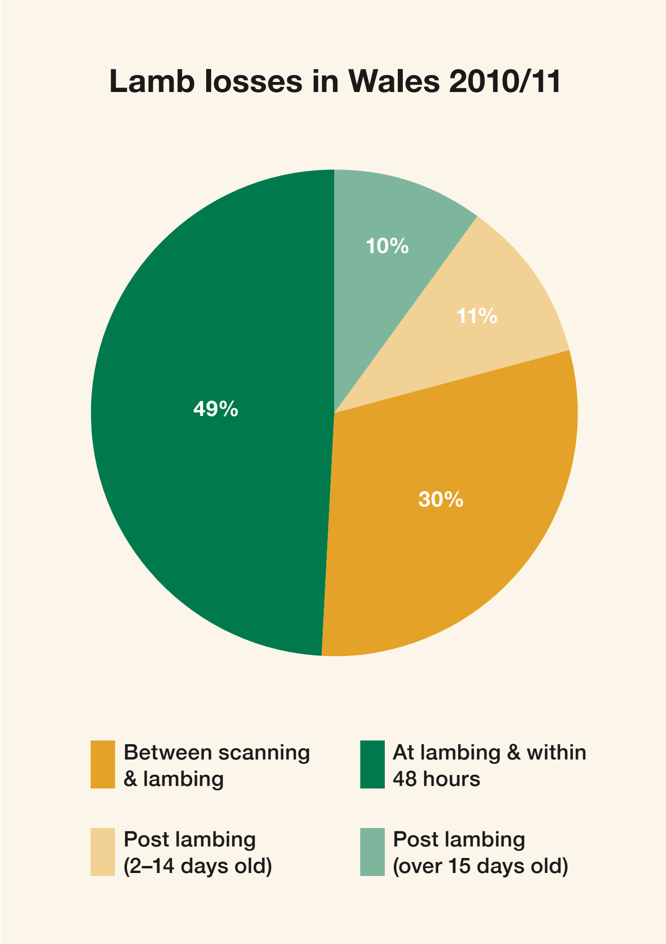
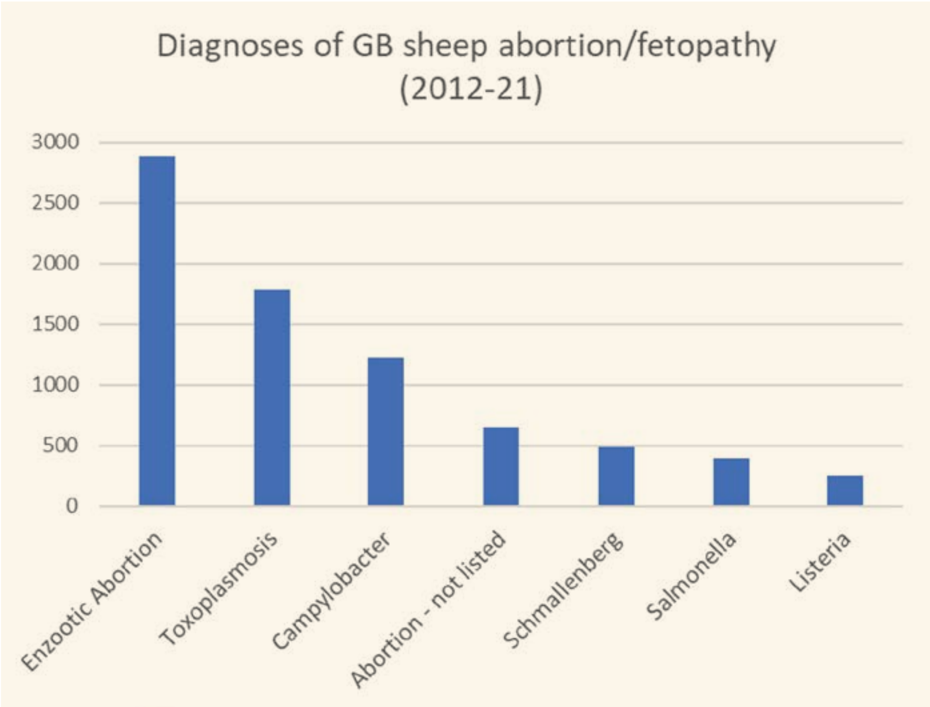


Figure 6: Graph taken from GB sheep disease surveillance dashboard for all years from 2012–2021[74].

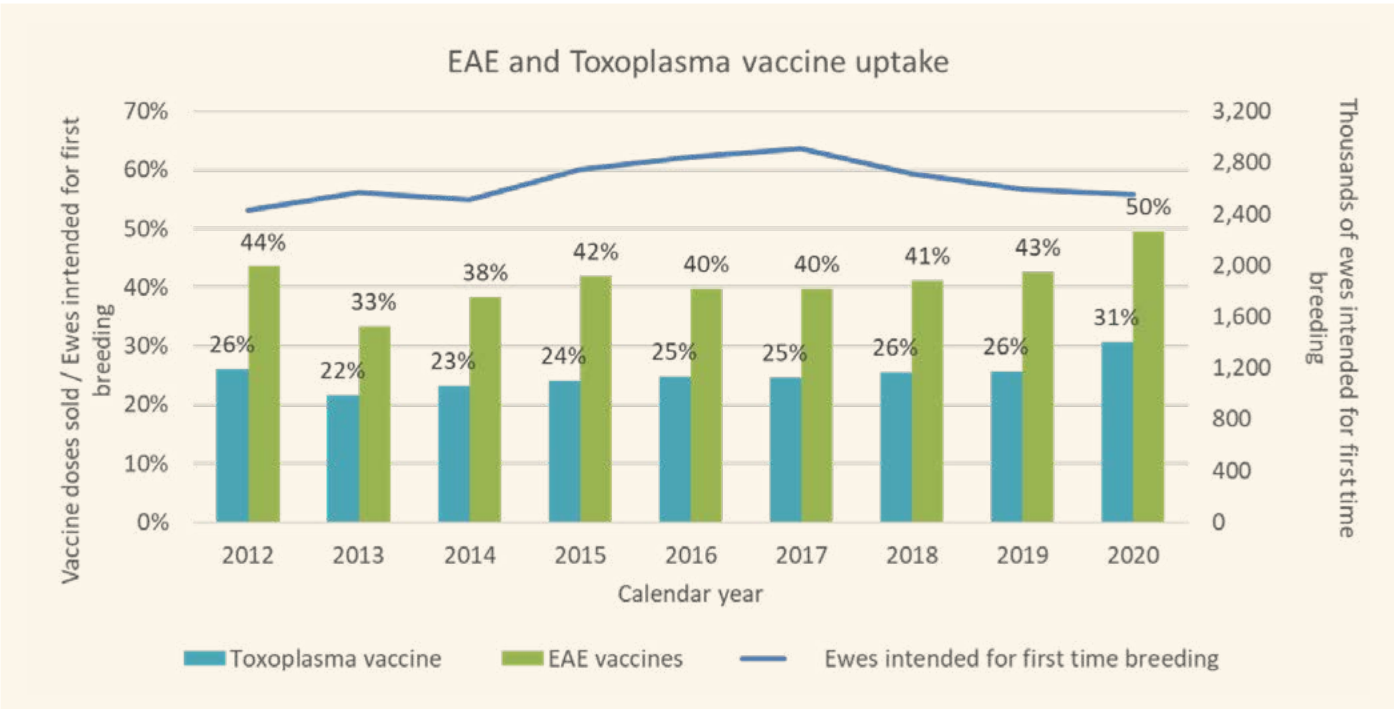


A 2016 study of 648 UK sheep flocks suggested that 93% vaccinated their ewe flock against clostridial agents and 39% used abortion vaccines[78]; however, this study population, of flocks supplying finished lambs deadweight rather than via markets, was not necessarily representative of the entire industry. In the AHDB Vaccine Report[71], the national uptake of clostridial vaccine has been fairly steady over the past six years at around 62% penetration (here it was assumed that all ewes and rams should receive an annual booster and that all lambs on farm in June should receive two doses).

Abortion vaccine uptake appears to have increased with 49% of first-time breeding ewes vaccinating against Chlamydia and 30% vaccinated against Toxoplasmosis in 2020. The average vaccine uptake from 2015 to 2019 was 41% for EAE and 25% for Toxoplasmosis (**Figure 7**)[71].

Investigation of UK flocks that had had EAE over 4 or more years demonstrated that failure to vaccinate was a consistent feature[79] . Given the potential for widespread economic losses due to EAE[80], all flocks that are bringing in replacements should be vaccinating replacements for EAE, including those that are sourcing replacements from EAE accredited flocks[77]. Vaccination need not be considered essential in flocks that do not bring in replacement ewes or have other sheep flocks as direct neighbours and who have diligent biosecurity and proactive investigation of all cases of abortion[77].

Figure 7: AHDB Vaccine Report[71] based on Kynetec data supplied via MSD Animal Health

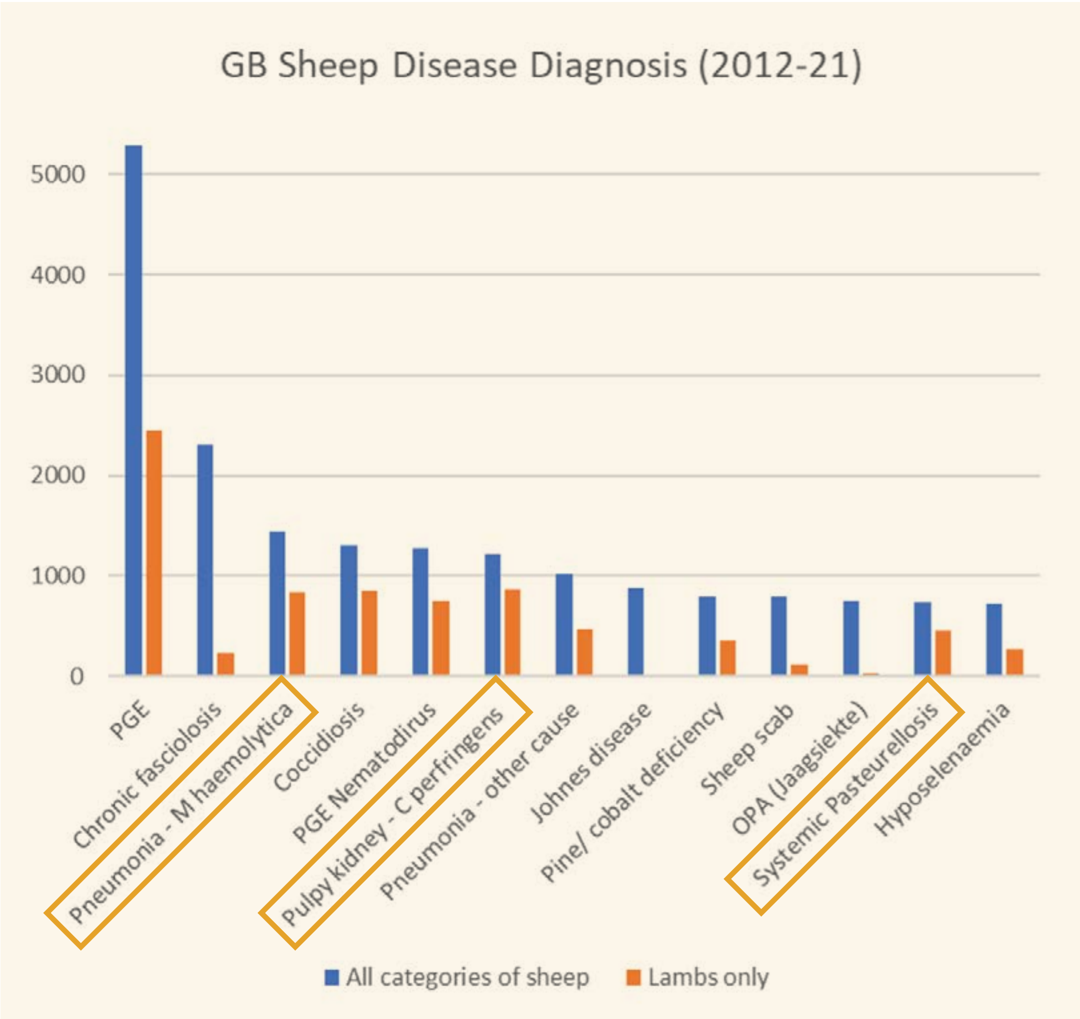


Pasteurellosis

Pasteurellosis is the most commonly diagnosed cause of death in UK lambs. Out of the 2,733 lamb carcasses submitted to Farm Post Mortems Ltd via a fallen stock centre, 11% were diagnosed with Pasteurella septicaemia and over 4% with Pasteurella pneumonia in the five year period up to 2019[60]. Additionally, pneumonia (Pasteurella-like) was recorded for 4.7% of 3.64 million CCIR (Collection and Communication of Inspection Results) records over a fifteen month period in 2019–2020[60]. Pasteurellosis accounted for just over 2% of ewe deaths (out of 1,815 ewe carcasses submitted to Farm Post Mortems Ltd over five years up to 2019)[60] and significant numbers of cases recorded annually by the GB Sheep Disease Surveillance Dashboard (**Figure 8**)[74]. The cost of bacterial pneumonia has been shown to be a significant percentage of the value of lamb in Europe (6–7% of lamb value) and in New Zealand (1.36 NZD per lamb)[81]. Cases usually occur a month after housing, when lambs are moved to richer pasture in late summer, or due to stress following handling, extreme weather or other respiratory pathogens[82].

Vaccines containing iron-regulated proteins of five *M haemolytica* serotypes as well as four *B trehalosi* serotypes have good efficacy, suggested to be over 80% protection including cross-protection of other serotypes though without a clear increase in antibody titres[83]. It is recommended that lambs should be vaccinated at least two to three weeks before the period of maximum risk[84]. The available UK vaccine is authorised from three weeks old, with a second dose four to six weeks later and supplementary boosters suggested within three weeks of expected seasonal outbreaks, which occur in Autumn in the UK.

Figure 8: Graph taken from GB sheep disease surveillance dashboard for all years from 2012–2021[74].



Category Two Vaccinations

Orf

Orf, a parapoxvirus that is also described as ovine ecythma, scabby mouth, or contagious pustular dermatitis, is highly contagious and widespread. Prevalence rates in England have been calculated as 1.9% for ewes and 19.5% of lambs[85] with associated high costs resulting in a loss of profit margin of between £1.06 and £7.92 per ewe in flocks that experience outbreaks of orf[86].

Vaccination is only recommended in flocks where there is already orf disease present. Two separate surveys, one with 762 English sheep farmers in 2012[86] and another with 570 UK sheep farmers in 2018[87], suggested that 36% of respondents used the orf vaccine. However, market penetration of the orf vaccine is estimated at 16% (2% of ewes and 13% lambs)[87]. Of the farmers who did not vaccinate, 63% reported that there was no justifiable need to vaccinate, including no orf present on their farm[87]. It has been suggested that orf is present on 25% of UK farms and evidence suggests clear welfare and cost benefits to the use of vaccination, specifically of all lambs born on these farms and ideally, also in the ewes[85].

Ovine Johnes Disease

Johnes Disease (paratuberculosis) is an infectious chronic wasting disease caused by *Mycobacterium avium paratuberculosis* (MAP). With a worldwide distribution, it is commonly recognised as having significant production-limiting effects on multiple species. There is currently a lack of published information as to the prevalence of Ovine Johnes Disease (OJD) in the UK, and an absence of good data, although one survey of 50 large commercial UK flocks indicated a farm level prevalence of 64% based on faecal PCR and post-mortems of cull ewes[88]. Recent UK industry publications[60,89] have suggested that OJD is of high significance both in terms of prevalence and economic impact at flock level with one study suggesting that only 17% of lowland breeding ewes are retained for more than three years in flocks infected with OJD compared with 40% in uninfected flocks[88].

Vaccination has been shown to reduce the onset of disease, incidence of mortalities and faecal shedding of MAP all by approximately 90% in Australia[89]. A meta-analysis of 49 sheep studies across the world showed positive effects of vaccination in terms of production, epidemiological and pathogenetic effects on flocks[90]. Good UK flock data is limited but there is good evidence to suggest that flocks that produce breeding sheep should be routinely undertaking post mortems of fallen stock and screening older ewes to test pooled faecal samples for MAP by PCR. There is a strong argument to suggest that breeding sheep that are born into a flock with OJD positive ewes, should be vaccinated by four months old. Reasons not to vaccinate may include aspirations to export sheep or concerns that vaccinates cannot be differentiated from naturally exposed animals on serology.

Other sheep diseases

Other sheep diseases for which there are UK vaccines available include mastitis caused by Staphylococcus aureus and abortion caused by *Salmonella abortusovis*, though this is not currently detected in the UK. Vaccines for *Campylobacter fetus* and caseous lymphadenitis are imported under a special import licence by vets for use in their clients' flocks but neither are currently authorised for use in the UK.

Arbovirus is an informal name for any virus that is transmitted by arthropod vectors. They are likely to become a greater threat associated with climate change. Vaccines are intermittently available in the UK following initial incursion from continental Europe since 2007. Examples include Bluetongue virus (BTV)-8 and Schmallenberg virus (SBV).

To preserve high standards of sheep welfare and flock performance and productivity, every flock should be considering Category One vaccines by default and working through risk assessments with their vet to justify not using them in certain circumstances.

Conclusions

Vaccination is a key tool for the protection of the flock and the prevention of disease in sheep. To preserve high standards of sheep welfare and flock performance and productivity, every flock should be considering Category One vaccines by default and working through risk assessments with their vet to justify not using them in certain circumstances. Clinical evidence and diagnostic screening will indicate whether orf or OJD vaccines are required to minimise the impact of either disease in the flock. **Table 9 and 10** provide a summary of specific recommendations for Category One and Two vaccinations in UK sheep flocks.

Summary of key recommendations

Table 9: Sheep Category One Vaccinations

Vaccination Details	Class of sheep to vaccinate	Veterinary discussions specific to flock Circumstances
Clostridial Seven, eight or ten components depending on the perceived risk of *P sordellii*	**All adult breeding ewes.** **All replacement breeding ewes.** **Ewe lambs destined for breeding.**	Ensure continuous cover of primary course (two doses) and an annual booster (given in late pregnancy) for ewes in all flocks. Especially consider timely boosters for ewes breeding for the first time at eighteen months old.
Clostridial Four, seven, eight or ten components depending on the perceived risk of *P sordellii*	**Breeding rams.** **Teaser rams.** **Ram lambs destined for breeding.**	Ensure continuous cover of primary course (two doses) with annual booster for rams in all flocks
	All lambs destined for slaughter.	Primary course of two doses required for protection. Maternally derived immunity lasts until 12 weeks old assuming the dam was fully vaccinated. There is no need to vaccinate lambs that are due to be slaughtered below 12 weeks old and that were born to fully vaccinated dams.
Pasteurellosis Delivery alongside appropriate clostridial vaccine or as separate Pasteurella vaccine	**All adult breeding ewes.** **All replacement breeding ewes.** **Ewe lambs destined for breeding.**	Ensure continuous cover of primary course (two doses) and an annual booster (given in late pregnancy). In some flocks (where there is no concurrent OPA and where Pasteurella cases are closely monitored and found to be low), there may be an economic case for only maintaining Pasteurella vaccination cover in the youngest cohort of breeding ewes.
	Breeding rams. **Teaser rams.** **Ram lambs destined for breeding.** **All lambs destined for slaughter.**	The economic value of rams generally justifies continuous Pasteurella vaccination cover with boosters given at least annually and always before times of high risk (e.g., Autumn). Primary course of two doses required for protection. Maternally derived immunity lasts until approximately 3–4 weeks old assuming the dam was fully vaccinated. It may not be economically justified to vaccinate slaughter lambs that are due to be slaughtered at a young age and that were born to fully vaccinated dams, though they will be at some risk from 4 weeks old. In cases where lamb are considered at high risk, they should be vaccinated in the first two weeks of life[23], again 3–4 weeks later and given a third dose from three months old, before the high risk Autumn season.

Vaccination Details	Class of sheep to vaccinate	Veterinary discussions specific to flock Circumstances
Toxoplasmosis	**All replacement breeding ewes before they go to the ram for the first time.**	Single vaccination given at least three weeks before breeding to protect at least the first two pregnancies. This is an expensive vaccine that means vaccination is sometimes not undertaken for financial reasons and following a risk-based veterinary discussion. Arguably this is a risk that is only worth taking if it is known that local contamination is such that ewe lambs are naturally exposed to Toxoplasma well before they go the ram for the first time.
	Older breeding ewes.	Consideration should be given to vaccinating older ewes where risk increases (eg change of location or draft ewes coming off the hill). Otherwise, clinical experience suggests that few ewes require a booster vaccination later in life, presumably due to widespread natural exposure.
EAE	**All replacement ewes before they go to the ram for the first time. Older breeding ewes.**	All bought-in replacement ewes in all flocks should be vaccinated. All home-bred replacement ewes in flocks that buy in replacements or have direct sheep neighbours, should be vaccinated. Flocks that do not buy in replacement ewes or that do not have direct sheep neighbours may decide not to vaccinate replacements – though these naïve flocks are at high risk of an EAE outbreak if circumstances change. Older unvaccinated ewes should be vaccinated where there is an ongoing risk of exposure to EAE (such as the possibility of mixing with sheep of unknown EAE status when pregnant). Even in endemically infected flocks, there is evidence that levels of enzootic abortion remain low in ewes that were vaccinated four years previously. The cost and implications of an EAE outbreak means that delaying vaccination until after one has occurred is to be particularly discouraged.
Footrot	**All adult sheep and all replacement breeding sheep.**	It should be standard for at least one annual vaccine for all adult sheep and replacement youngstock in flocks that are not truly closed (ie sheep bought into the flock) with a primary course of two injections advisable. Further booster vaccinations should be implemented before times of high risk. Where flock circumstances are such that there are no sheep bought in, where all the other points of the Five Point Plan are rigorously adhered to and the prevalence of footrot is consistently below 2% of ewes in the flock, then a veterinary-led risk-based discussion may conclude that vaccination against footrot is not financially justified. However, the cost of lost productivity from an outbreak of footrot, suggest that the footrot vaccine is not one that should be reserved for reaction to outbreaks.
	Lambs	It is not common that lambs need to be vaccinated against footrot, assuming that the adult sheep in the flock are vaccinated and that levels of footrot are low. However, at times of high risk, there can be benefit in implementing vaccination alongside other points of the Five Point Plan.

Table 10: Sheep Category Two Vaccinations

Vaccination Details	Class of sheep to vaccinate	Veterinary discussions specific to flock Circumstances
Orf	Lambs on farms where orf is known to be present.	There is clear evidence to show that there are cost and welfare benefits to the vaccination of lambs (from two days old) on farms where orf is known to be present.
	Ewes on farms where orf is known to be present.	There is evidence to suggest that when a lamb has orf there is a very high likelihood its mother is also infected[86] and on infected farms, vaccination of both ewes and lambs is advisable[85] with ewes vaccinated at least eight weeks before lambing. It is not usually advisable to vaccinate ewes on farms where lambs are not vaccinated[85].
	Adults and lambs on farms where there is currently no orf.	Orf vaccination should not be used on farms where there has been no evidence of the disease.
Ovine Johnes Disease	Lambs to be kept for breeding in flocks where OJD has been diagnosed.	Lambs should be vaccinated between one and four months old. There is considerable evidence from overseas that there is a cost and welfare benefit to vaccinating against OJD and there is emerging evidence that it is a disease of significant prevalence and impact within the UK sheep industry. However, there is limited UK data or industry awareness of the disease and currently it is a vaccine that is not widely used.
	Adult sheep in flocks where OJD has been diagnosed on cull ewe screens.	There is limited benefit to the vaccination of adult sheep.

Click here to learn more about the author

Section 5

Jonathan M E Statham

MA VetMB DCHP FRCVS

Jonathan graduated from Cambridge University Veterinary School in 1996 and combines more than 25 years of experience in veterinary practice with a range of wider industry and academic roles. He is Chief Executive of RAFT Solutions Ltd, an innovation led sustainability company combining applied research with advanced breeding, food futures, consultancy and training and director of VetDx. As chair of Bishopton Veterinary Group, a 40+ vet independently owned practice (members of XL Vets) based in Yorkshire, he remains active in practice with a Royal College of Veterinary Surgeons (RCVS) Diploma in Cattle Health & Production. Jonathan has also held a range of representative or policy linked roles including past President of the British Cattle Veterinary Association (BCVA) and the Yorkshire Veterinary Society, has sat on the GB 'Cattle Health & Welfare Group' (CHAWG), GB 'Sheep Health & Welfare Group' (SHAWG), the Veterinary Policy Group (VPG) of the British Veterinary Association (BVA) and is a past director of Cattle Health Certification Standards (CHeCS) and member of the 'Farmskills' Steering Group. He is an examiner for the University of Liverpool, member of the Royal College of Veterinary Surgeons (RCVS) Advanced Practitioner Panel, a member of the Nottingham Dairy Innovation Forum & the International Embryo Transfer Society. He currently sits on UK Animal Science Advisory Board (ASAB) Knowledge Transfer Network (KTN) and is a fellow of Askham Bryan College. He serves on the Veterinary Products Committee (VPC) of the Veterinary Medicines Directorate (VMD), sits on the UK Antimicrobial Resistance (AMR) Strategy Group, GB Ruminant Health & Welfare Steering Group (RH&WG) and is currently Chair of the Animal Health & Welfare Board of England (AHWBE). In 2020 he also took up a chair at the new veterinary school at Harper and Keele and is now Professor of Sustainable Livestock Health & Welfare and chairs the InSHAW Sustainability Leadership Group. Main veterinary and research interests include progressive herd health, reproductive technologies and Precision Livestock Farming (PLF) approaches to Sustainable Food. He has published a wide range of papers and is a co-author of textbook 'Dairy Herd Health'. He is a RCVS recognised specialist in Cattle Health & Production, Fellow of RCVS and was named UK Dairy Vet of the year 2015.

Joe Henry
BVMS Cert SHP MRCVS

Since graduating from Glasgow in 1998, Joe has worked in Northumberland and in New Zealand, primarily with suckler and sheep clients focusing on preventative medicine, production KPIs and grazing management. In 2018 he undertook a study tour to large cow-calf operations in the western USA. Joe also runs a farm with his wife Rachel, including a Luing-based herd of about 100 head.

Fiona Lovatt
BVSc PhD DSHP FHEA DipECSRHM FRCVS

Fiona Lovatt runs the sheep veterinary consultancy business, Flock Health Ltd which works collaboratively with veterinary surgeons, farmers, processors, retailers and pharmaceutical companies in both UK and abroad. She is particularly passionate about getting pro-active veterinary involvement on UK sheep farms, particularly enthusing both vets and sheep farmers to interact better through proactive individual flock health planning and Flock Health Clubs.

Fiona is a European Recognised Specialist in Sheep Health and Production, a clinical associate professor at the University of Nottingham and a past president of the Sheep Veterinary Society. She is the clinical lead for the RCVS Knowledge-led initiative, Farm Vet Champions as well as the sheep veterinary member of the RUMA Target Task Force.

Abbreviations

AHDB	Agriculture and Horticulture Development Board
AHIM	Animal health Improvement Measures
AMR	Antimicrobial Resistance
BRD	Bovine Respiratory Disease
BTV	Bluetongue Virus
BVD	Bovine Viral Diarrhoea
CODD	Contagious Ovine Digital Dermatitis
EAE	Enzootic Abortion of Ewes
FAO	The Food and Agriculture Organization of the United Nations
FVC	Farm Vet Champions
GDP	Gross Domestic Product
GHG	Greenhouse gases
IBR	Infectious Bovine Rhinotracheitis
IM	Intra-muscular
IPC	Infection Prevention and Control
MACC	Marginal Abatement Cost Curve
MAP	Mycobacterium avium paratuberculosis
MRV	Measurement, Reporting and Verification
NDC	Nationally Determined Contribution
OIE	The World Organisation for Animal Health
OJD	Ovine Johnes Disease
OPA	Ovine Pulmonary Adenocarcinoma
PI	Persistently Infected
PI3	Parainfluenza Virus 3
RAMA	Registered Animal Medicines Advisor
RSV	Respiratory Syncytial Virus
RUMA	Responsible Use of Medicines in Agriculture Alliance
SBV	Schmallenberg Virus
SQP	Suitably Qualified Person
UNFCC	United Nations Framework Convention on Climate Change
VMD	Veterinary Medicines Directorate

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noah.co.uk noah@noah.co.uk @UKNOAH