REVIEW OF LIVESTOCK IDENTIFICATION AND TRACEABILITY IN THE UK

Richard W. Small BSc PhD
Livestock Diversity Ltd.
www.livestockdiversity.com

Defra Research Contract GC0146
Development of co-ordinated *in situ* and *ex situ* UK Farm Animal Genetic Resources conservation strategy and implementation guidance

EXECUTIVE SUMMARY

1. Systems of identification and tracing of farm livestock were developed initially as a means of managing animal disease risks, but subsequently adapted to also monitor Common Agricultural Policy subsidies in the European Union (EU).

2. Traceability, transparency and quality assurance are the bases for livestock product assurance and accreditation schemes. Traceability relies on efficient livestock identification and movement recording. Effective systems need both tracking of animals down the food chain from producer to slaughter or to retail, and tracing, which is the ability to follow a meat product up the supply chain by means of the records which have been kept at each stage of the chain.

3. Identification of farmed livestock, including equines but not poultry or waterfowl, is a legal requirement in the UK (and the EU generally) and the movements of cattle, sheep, goats and pigs must be recorded both on farm and centrally.

4. Failure to comply with the regulations constitutes a breach of cross-compliance Statutory Management Requirements under the CAP Single Payment System, jeopardising individual farmer's subsidy payments.

5. A wide range of livestock identification methods are available, but most are not approved for official purposes. Some may be used for on-farm management.

6. Current official animal identification methods are based on electronic identification (EID) tags and visual (i.e. non-EID) tags, although ruminal boluses may also be used for sheep. Only low frequency (LF) EID tags are currently permitted in the EU.

7. Alternative biometric identifiers, such as retinal scans, iris recognition, digital imaging of cattle muzzle patterns, facial recognition and immunological labelling have been developed and used in small scale trials, but are not ready for deployment.

8. DNA shares the advantage of other biometric markers of being permanently present in the live animal, but unlike other biometric identifiers (except immunological labelling) it can be extracted from meat and other animal products and by-products. DNA analysis can be used for pedigree verification, parental identification and in breeding programmes and offers considerable promise for animal identification. However, it is not yet available for 'real-time, on-farm' identification purposes.

9. Ultra High Frequency (UHF) EID devices offer advantages over current Low Frequency (LF) EID tags, particularly in their additional data storage capabilities, but further development and EU agreement to amend existing regulations to permit use of the frequency would be needed before they can be used for official identification of farm animals.

10. For breeding sheep, or those kept for more than 12 months before slaughter, double tagging with one EID tag (or bolus) and one visual tag is required (no pastern band is approved for use in the UK). Sheep for slaughter at less than 12 months of age may be identified with a single tag, but regulations on whether this tag is EID or non-EID vary between UK countries.

11. Goats are also double tagged, but there is no compulsory requirement for EID; individual keepers may opt for EID for farm management purposes.

12. For cattle a primary ear tag, conforming to a prescribed pattern but not EID, is required. A secondary tag (which may be an EID) may be used for herd management purposes. A passport is required.

13. For pigs tattoos (including 'slap marks') are more commonly used than ear tags, although the latter are permitted.

14. All equines must have a passport and those born after 1 July 2009 must also be micro-chipped, although derogations allow semi-feral ponies to be micro-chipped when first leaving their native moor, or not to be micro-chipped if they are moving direct to slaughter.

15. There is currently no requirement for poultry and waterfowl to be individually identified, although there could be benefits in doing so, especially for breeds at risk. Poultry flocks of >50 birds must be registered.

16. Centralised recording of movements differs between species and between the constituent countries of the UK. The Northern Ireland system (which is fully integrated with the Animal and Public Health Information System, APHIS) records movements and other data for all farmed livestock; elsewhere systems are less well integrated, and data quality is insufficient to allow full exploitation of a potentially valuable resource.

17. An example of the use of animal identification for determination of demographic statistics, such as effective population size, for pedigree animals is given to illustrate the potential of centralised databases in the management of Farm Animal Genetic Resources (FAnGR).

18. Estimates were made of the costs of identification and tracing of cattle, sheep and pigs in the UK, although these required many assumptions. The cost of tag purchase for the current UK populations of cattle, sheep and pigs (requiring 21-24 million tags) was estimated to be >£36 million, with an annual cost of *c*. £11.2 million. Associated farm labour costs were estimated to be £5-24 million p.a.

19. Data for the allocation of sheep and goat ear tags in GB were made available by the Ear Tag Allocation System. These data indicated that >22 million sheep and goat tags were allocated in 2011, for a combined sheep and goat population of *c*. 20.5 million, most of which would already be ear-tagged. The difference between the two estimates of tags used is likely to reflect the many (>10 million in 2011) sheep slaughtered before the December survey.

20. Costs to the taxpayer via Government expenditure could not be fully determined, but would include the costs of training (for staff and industry stakeholders), compliance monitoring, administration and data management. The minimum UK Government cost was estimated to be £23.3 million p.a.

21. The cost to owners of micro-chipping all equines in the UK was estimated to be £4.6 million p.a.; net benefits to the UK of £1.66-£2.29 million p.a. are cited in the literature. The additional costs of start-up, running (for six years) and closure of the National Equine Database (NED) were not assessed. Derogations for semi-feral ponies saved their owners an estimated £348,850 and were therefore of great benefit in supporting these at risk genetic resources.

22. General suggestions for improvements to current systems were made:
    - electronic tagging of cattle
    - on-line recording of sheep and goat movements
    - reduced requirements for on-farm paper records
    - removal of standstill periods outside times of disease outbreaks
    - greater use of EID to provide feedback to farmers
    - standardisation of regulations between UK countries
    - individual identification of poultry and waterfowl
    - movement recording of equines

23. Further development of central data recording of livestock identification and movements is desirable from a FAnGR perspective. Additional functionality of the central databases could allow monitoring of breed populations, regular determinations of genetic diversity indicators, calculation of other demographic statistics and determination of geographic distributions, so contributing to the UK's commitments to monitor and protect its FAnGR under the Convention on Biological Diversity, the Global Plan of Action for Animal Genetic Resources and the Interlaken Declaration.

Contents

1 INTRODUCTION

Animal identification has been practised for at least 3,800 years, initially to denote ownership and later to combat animal disease outbreaks and to regulate trade during human disease epidemics (Bowling *et al.,* 2008). Public health, animal health, animal management, trade and consumer demand for traceability of livestock products remain the principal reasons for identifying animals and a wide range of methods of identification have been developed. Some of these offer the potential to deliver additional benefits, such as accurate breeding histories of individual animals, significant contributions to breeding and genetic diversity management programmes and in the implementation of targeted biosecurity measures.

The glossary of the World Organisation for Animal Health's (OIE) Terrestrial Animal Health Code offers three definitions concerning animal identification and tracing (http://www.oie.int/index.php?id=169&L=0&htmfile=glossaire.htm#terme_identification_des_animaux):

- *animal identification is 'the combination of the identification and registration of an animal individually, with a unique identifier, or collectively by its epidemiological unit or group, with a unique group identifier'*
- *an animal identification system is 'the inclusion and linking of components such as identification of establishments/owners, the person(s) responsible for the animal(s), movements and other records with animal identification' and*
- *animal traceability is 'the ability to follow an animal or group of animals during all stages of its life* (OIE, 2012).

The OIE definition of traceability ends with the life of the animal, but increasingly there is demand from consumers, and hence legislators, for traceability beyond the abattoir. Meisinger *et al.* (2008), reviewing earlier studies, suggested two models of traceability: 'farm to retail' and 'batch'. In the former the identity of an individual animal is maintained from the farm, through slaughter and distribution, to the consumer. To achieve this, the animal is traceable from the farm through processing; when the carcass is cut, all of the cuts are kept in a container that is tracked with the animal's identification number. When those cuts are packaged they are marked with the individual carcass number and hence can be linked to the last farm the animal was at before moving to slaughter. In batch traceability the animal is traceable from the farm to the carcass, but the individual identification is lost at some point on the carcass processing line. Instead of individual identification, a batch or lot identification number is used at slaughter.

Traceability is, however, just one element in the food chain accountability required by EU regulation. Equally important are transparency and quality assurance (Liddell and Bailey, 2001). Transparency in relation to meat and meat products refers to the public availability of information on all rules, regulations, procedures and practices governing a food product throughout the lifetime of an animal, during its slaughter and processing and on to the retail outlet i.e. at all stages of the marketing chain. Quality assurance has three key elements – ensuring food hygiene and hence food safety, ensuring quality through grading and other assessments, and providing mechanisms for product recalls (Liddell and Bailey, 2001). Perhaps added to these elements, as revealed by the discovery of horsemeat in a wide range of processed meat products in several European countries, should be regular checks on the authenticity, in terms of species identity, of meat and meat products and increased surveillance for veterinary medicine residues. The horsemeat episode has, however, demonstrated that there are effective mechanisms for product recalls in the EU.

Traceability, transparency and quality assurance are the bases for livestock product assurance and accreditation schemes (for example British Quality Assured Pork; see http://www.bmpa.uk.com/_attachments/Resources/2671_S4.pdf). Assurance schemes can operate at various levels including farm, processor and distributor (including live animal transport); see Liddell and Bailey (2001) for a summary. The best assurance schemes would encompass all stages of the food chain and would include extrinsic (to meat quality) factors such as animal welfare and environmental considerations such as sustainability, provision of environmental services and reduced environmental impacts (e.g. reduced greenhouse gas emission during production and processing). Thus participation in quality assurance schemes, and the receipt of the higher financial rewards to accredited producers, requires, *inter alia*, full identification of the animals and documentation of their movements.

For livestock product assurance schemes to be effective the animals must be reliably and uniquely identified. This enables tracking, which is the ability to follow animals down the food chain from producer to slaughter or to the retail outlet, and tracing, which is the ability to follow a meat product up the supply chain by means of the records which have been kept at each stage of the chain (Bass *et al.*, 2008). Reliable tracing, which is critical in the event of an animal disease outbreak or public health issue, depends on thorough tracking.

In the EU meat and meat products from bovines must be labelled with the following information:

- the country where the animals were born;
- the country where the animals were fattened/bred;
- the country where the animals were slaughtered and licence number of the slaughterhouse;
- country where cutting was performed and licence number of the cutting plant
- the reference number or code establishing the link between the meat and the animal (or group of animals) from which the meat was derived.

(http://europa.eu/legislation_summaries/food_safety/veterinary_checks_and_food_hygiene/l12064_en.htm)

Note that in each case the country is only identified if it is within the EU; beef and veal from non-EU countries is labelled as such (i.e. non-EU). A useful summary can be found at http://www.civ-viande.org/uk/ebn.ebn?pid=57&page=26&item=12&rubrik=2

Similar labelling of pig, sheep, goat and poultry meat within the EU has been agreed but not yet implemented (Livestock and Meat Commission EU Brussels Update week ending 2nd November 2012 available at http://www.lmcni.com/news-and-events/). As recent events regarding the identification of horsemeat in beef products have demonstrated the labelling system is open to deliberate fraud, but some developing biometric techniques can be used to identify meat and other animal products (see next section).

A further need for reliable animal identification is for the selection of individuals for breeding programmes, especially where this involves animals that are held at centralised facilities and where breeding decisions are based on genetic evaluation schemes such as estimated breeding value (EBV), Best Linear Unbiased Prediction (BLUP) or genomic selection. An example is provided by Dürr (2011) for Interbull's genetic evaluation of dairy breeds involving (at the end of 2011) six breeds, 81 populations and 30 countries. Five times a year data on 38 traits are evaluated and flow into the Interbull database, which holds information on more than four million beef and dairy cattle. Dürr (2011) emphasised that before these data can be analysed pedigrees have to be harmonised through verification of every animal: errors would threaten the

accuracy of the genetic evaluations. In turn this requires adherence to international standards for animal identification.

In the EU it is a legal requirement for all farmed mammalian livestock to be individually identified and for movements between holdings to be recorded. Equines must be identified but their movements need not be recorded. Currently there are no identification or movement requirements for poultry or waterfowl, although there could be advantages to its adoption for farmed avian species. The options for identification vary between livestock species. This report reviews the options available for identifying individual animals and their implications, the current identification requirements for farmed livestock and the costs and benefits associated with livestock identification and tracing. The current regulations regarding farm animal identification can be found at https://www.gov.uk/animal-identification-movement-and-tracing-regulations and for equines at http://www.defra.gov.uk/wildlife-pets/pets/horses/.

Failure to meet the legal requirements would mean a farmer is in breach of the Statutory Management Requirements (SMRs) relating to animal identification and movements within the Single Farm Payment system, and hence would jeopardise the single farm payments payable (see Section 2 for details of the relevant SMRs). In a 2009 study, the SMRs relating to animal identification within the Single Farm Payment system achieved the lowest compliance rates with 8.5-9.7% of animals failing inspections between 2005 and 2007 (ADAS *et al.*, 2009). In RPA inspections in 2006 and 2007 failures in respect of animal identification and movement SMRs were recorded in 6%, 23% and 10% of pig, cattle and sheep farms respectively. In the 2011 compliance survey of the 4261 holdings inspected 1080 (25.3%) were non-compliant and 227 of those had penalties imposed.
(http://archive.defra.gov.uk/foodfarm/farmanimal/movements/goats/documents/uk-sag-inspections-report-2011.pdf)

The identification methods described are permitted by the Mutilations (Permitted Procedures) Regulations 2007 (see http://www.legislation.gov.uk/uksi/2007/1100/contents/made) although there are variations between species (see Table 1).

Table 1. Permitted methods of identification of farmed animals (excluding fish) under the Mutilations (Permitted Procedures) Regulations 2007

Identification Method	Cattle	Pigs	Sheep	Goats	Deer	Horses	Birds
Ear clipping	√	√	√	√	√		
Ear notching	√	√	√	√	√		
Ear tagging	√	√	√	√	√		
Freeze branding	√					√	
Hot branding						√	
Micro-chipping	√	√	√	√	√	√	√
Tattooing	√	√	√	√	√	√	
Other methods of identification involving a mutilation required by law	√	√	√	√	√	√	√

1.1 Electronic Identification Devices

There is much relevant technical information on the website of the International Committee for Animal Recording (ICAR; see http://www.icar.org/).

Electronic tags contain a radio frequency identifier (RFID) that emits a signal when stimulated by an appropriate electronic reader. The RFID consists of a microchip and a coiled copper antenna. Two types of RFID are currently in use, full duplex (FDX-B) and half duplex (HDX), but there is little practical difference. Most current electronic tags are low frequency (LF), although ultra-high frequency (UHF) tags are in development (see Section 1.4.3). Low frequency tags operating in the frequency range 120-135 kHz are less susceptible to environmental interference from water and metal than higher frequency tags (Shanahan *et al.*, 2009), although the latter are improving in this respect. Electronic tags for animals should comply with ISO 11784 and ISO 11785 standards and they encode 64 binary bits of information. For full details of the allocation of the 64 bits see Shanahan *et al.* (2009) or the Food Chain Evaluation Consortium (2009), but bits 17-26 are for the country code and 27-64 are for the individual animal number, allowing 274,877,906,943 animals to be identified.

Low frequency RFIDs do not have an internal power source, but are energised by the radio signal emitted from the reader; this requires the reader and tag to be in close proximity (<0.5m), although improvements in tags and readers have extended the operative range (Shanahan *et al.*, 2009). The reader may be hand-held and passed over the electronic tag or it may be fixed in a location past which animals move e.g. the race in an abattoir. Readers which conform to ISO standards should be able to read both FDX-B and HDX RFIDs. The data recorded by the reader can be downloaded to a computer and analysed with appropriate software.

Although it is not necessary for farmers to possess readers, there can be labour cost savings in their use due to reduced time for reading and recording identification numbers; reader use may also improve accuracy. The cost of readers has decreased in recent years, with a simple reader that can store 800 numbers being available at under £100 (excluding VAT). However, more sophisticated models that can record additional information inputted by the operator and which can download to a computer are *c*. £550-600 (serial connection to computer) or *c*. £650 (Bluetooth connection). Thus the time savings required to justify purchase are more likely to be achieved in farms with large flocks/herds. In a pilot study of EID in sheep (ADAS, 2005) a range of problems with the supplied hand-held readers were encountered (e.g. reader failure, battery/charging problems) resulting in 38% of farms returning one model and 100% of farms returning the other model provided for the trial. However, the technology has greatly improved since 2005 as EID and readers are used more widely.

1.2 Identification Methods

1.2.1 Tattoo

Tattoos are most frequently used on pigs, particularly white-skinned breeds, although green ink can be used for dark-skinned breeds. In pigs tattoos are often referred to as a ‘slap mark’ as the tattoo is applied using a tool with a handle of approximately 30cm and a head bearing the tattoo pins which is slapped firmly against the shoulder of the pig. Alternatively compressed air slap markers are available. If used to identify pigs for slaughter the slap mark must be the Defra herd mark for the producer and both shoulders must be ‘slapped’ to improve the chances that at least

one mark would be legible on arrival at the abattoir; some producers requiring the return of the carcass slap mark all four quarters to ensure the correct carcass is returned. A useful guide is produced by BPEX: (http://www.bpex.org.uk/downloads/302628/301975/Work%20Instruction%202.%20Slapmarking%20Slaughter%20Pigs.pdf)

Pigs can also be tattooed on the ear. The tattoo is applied using a pair of pliers with the ear placed between the jaws of the pliers. When the pliers are firmly closed the pins of the tattoo plate make the imprint. In pigs the tattoo is usually on the outside of the ear for ease of reading, but ear tattoos are also sometimes used for pale-skinned sheep and are then usually inside the ear flap. With the advent of compulsory tagging of sheep and goats (see below) tattoos are less commonly used for these species, although tattoos are a legal means of non-electronic identification. In all species the tattoo mark can be divided between the two ears e.g. the flock number on one ear and the individual number on the other.

Tattoos have also been proposed as a means to identify poultry; the tattoo would be applied under the wing where there are few feathers.

1.2.2 Ear Notching

Ear notching is not an approved means of identification but may be used for on-farm management of pigs as an alternative to tattooing or ear tags: a special tool snips out a small piece of the ear flap to leave a permanent V-shaped notch. The position of the notch indicates a number and by using multiple notches it is possible to identify many pigs; there are various numbering systems but as an example notches on the left ear can represent 1, 2, 3 or 5 (depending on position on the ear flap) and those on the right ear 10, 20, 30 or 50. In this system all numbers up to a maximum of 121 (i.e. 1+2+3+5+10+ 20+30+50) can be achieved using up to eight notches. Other examples are given in the BPA information leaflet on pedigree membership (http://www.britishpigs.org/recordingandID.pdf).

Notches could be used (but not as an official mark) to identify a herd number on one ear and an individual on the other, or a litter number on one ear and an individual on the other. Use of ear notching for this purpose is more common in USA than in the UK (Gonzales-Barron and Ward, 2005). There is a risk of infection in newly notched ears and the welfare concerns are greater than for some other identification methods.

1.2.3 Ear Clipping

A similar procedure to ear notching but a more frequently used term when used for livestock other than pigs. Ear clipping is used, for example, to identify commoners' sheep on Dartmoor under the Dartmoor Commons Act 1985. However, it is not an approved method of official identification in the UK.

1.2.4 Ear Tagging

Ear tags are by far the most common method of marking cattle, sheep and goats and are sometimes used for pigs. Ear tags may be electronic or non-electronic and there are numerous

designs, but all entail the piercing of the ear flap. This is achieved by the use of a pair of pliers which must be compatible with each particular tag design. Most tags are now plastic (especially for electronic tags for which metal would interfere with the signal from the RFID), but some non-electronic ear tags are metal. Where metal ear tags are used in conjunction with an electronic tag they should be in different ears.

Ear tags are generally easy to apply, but each design requires a specific design of pliers. Apart from the initial puncturing of the ear flap (with possible introduction of infectious agents), the welfare concerns of ear tags are that some 'loop' types, if incorrectly inserted, may limit the growth of the ear and that all types may catch on fences etc. and be torn out of the ear (see also Section 1.3). Even if this heals inserting a replacement tag (as required by law) may be difficult in an ear flap that has been torn into two sections.

Some breed societies require a further ear tag as a means of identifying registered animals, and fitting even two tags in a lamb's or kid's ear may be difficult. The British Pig Association requires pigs entering shows to be either tattooed or ear-notched; ear tagging is permissible for non-show pigs but there must be a tag in each ear.

1.2.5 Dewlap Tags

Although not approved for official identification, dewlap tags are available for cattle herd management in the UK. The tag is inserted into the dewlap over the brisket, where it is claimed there are few nerves in the skin. A supplied hole-punch is used to make a hole in the skin before passing the hasp of the tag through the dewlap; the tag is then passed over the hasp before the ends of the hasp are bent to retain the tag. Advantages claimed (by the suppliers) for dewlap tags over ear tags are that they are always visible (from in front of the animal) and the right way up, and that they do not snag on fences etc.

1.2.6 Pastern (Leg) Bands

Pastern bands are a non-invasive method in which a band is fitted around the animal's lower leg; the pastern band may be electronic or non-electronic. Pastern bands are allowed under EU regulations as an alternative to ear tags and ruminal boluses (see next section) as a means to identify sheep and goats, but no pastern band has been approved for use in the UK. However, specifications for the manufacture of approved pastern bands have been published (Gray, 2011a).

A comparison of leg bands, ear tags and ruminal boluses for dairy goats found that bands suitable for adult goats were too large for 6 month old goats (Carné *et al.* 2010). Although the initial diameter of the leg band can be set by selecting the appropriate hole of the buckle mechanism, once engaged the position is fixed (both to increase retention rates and preclude removal and re-use). Conversely, a band fitted to a 6 month goat was likely to become constrictive as the goat matured; this is crucial, as EU regulations require goats to be identified by the age of 6 months. The bands were therefore only used for 103 adult goats in the trial, but two (1.0%) of bands had to be removed because they slipped down the leg to rest between the sesamoid bones and the hoof and another (0.5%) was removed because it caused inflammation.

1.2.7 Ruminal Bolus

A ruminal bolus is a bullet-shaped, high density container, usually ceramic, containing an electronic identifier; the bolus is designed to lodge in the rumen of the animal. Ruminal boluses were used as a means of identifying sheep during the National Scrapie Programme (NSP), but are not widely used for general identification as an ear tag is also needed as a visual identifier. If this secondary, visual identifier is lost an electronic reader must be used to identify the animal. In addition, boluses are sometimes regurgitated (although ear tags and pastern bands can also be lost). Anecdotal evidence from the NSP suggested that regurgitation losses were greater for the 15g boluses used initially than for the 20g boluses adopted later, but even the latter were more likely to be regurgitated when the sheep were fed on particular diets such as turnips or silage (Moxey and Walls, 2012). In addition, ruminal boluses are more expensive than ear tags (see Section 4.1).

In the comparison of identification methods in dairy goats Carné *et al.* (2010) found that seven of 197 (3.6%) ruminal boluses were lost over the course of the one year trial. However, this was not significantly different from the leg bands and ear tags used in the trial. However, Carné *et al.* (2009) found ruminal boluses to have a significantly higher retention rate (99.7%) over six months than flag ear tags (97.2%).

A review of bolus use in the EU was conducted for ScotEID (Moxey and Walls, 2012). This found that boluses were not approved for use in many EU countries and in the UK, Ireland, Germany and the Netherlands voluntary use of electronic boluses accounted for less than 2% of identified sheep. In these countries boluses were seemingly perceived as imposing higher costs on farmers, markets and meat processors, whereas in countries where use is not approved the main concern appeared to be potential food chain contamination risk due to less than 100% recovery of boluses at abattoirs (Moxey and Walls, 2012). Other studies had shown retrieval rates of 76-100%; failure to retrieve 100% could result in damage to gut processing machinery as well as risks to consumers. The latter was particularly important to meet Hazard Analysis and Critical Control Point (HACCP) requirements – for details see http://www.food.gov.uk/business-industry/caterers/haccp/#.UTSNuzc3HmI). Additional operational costs for abattoirs would be incurred, especially as systems would have to cope with both EID ruminal boluses and EID ear tags. In addition, the EU requirement for sheep identified by ruminal boluses to also have a (black) ear tag for visual identification meant that the disadvantages of ear tags were still present (Moxey and Walls, 2012).

In contrast, rates of bolus usage were relatively high in Bulgaria, Cyprus, Greece, Italy, Portugal and Spain; in this last an estimated 6 million of a total population of 11 million sheep were identified by means of an electronic bolus (Moxey and Walls, 2012). Boluses were more commonly used for breeding sheep, with ear tags preferred for slaughter lambs. The perceived advantages of boluses were better retention rates, consistently high read rates (>99%, although there can be problems with hand held readers), avoidance of ear-related animal welfare issues and lower susceptibility to fraud because ruminal boluses are less susceptible to tampering.

Bolus usage would involve additional administrative effort for re-identification on-farm or at Critical Control Points (also known as Central Point Recording Centres; see Section 4.3). When losses of boluses and/or black tags occur determining the nature of the incomplete/missing identification would be more difficult than for tag-only identification. For example, any untagged sheep would need to be scanned to check for a bolus; if present, the matching black tag would need to be re-ordered and inserted once it arrives, so either the animal must be kept separate or it must be found again amongst the flock or batch. Similarly, visually spotting incorrectly

identified animals amongst a batch of EID tag only sheep would be easier than amongst a batch of mixed tag and bolus identified sheep. The additional administrative burden of these issues may be individually small but cumulatively significant. Perhaps more significantly, the need to cater for black tag and bolus loss would necessarily incur capital expenditure for on-farm reading equipment. In aggregate, this would negate the significant cost savings offered by the adoption of Critical Control Points and further weaken the cost-benefit results for electronic identification (Moxey and Walls, 2012).

Overall, Moxey and Walls (2012) conclude that the additional costs of ruminal boluses (both initial purchase cost and labour costs of replacement) outweigh the advantage over ear tags of a better retention rate, and that is the probable reason for low usage rates for ruminal boluses in the UK.

1.2.8 Hot Branding

Hot branding is the application of a red hot 'branding iron' to the skin of the animal to cause a permanent mark through scarring of the skin. Despite welfare concerns (13,301 people signed an e-petition calling for the ending of multiple hot branding of equines in June 2012: http://www.change.org/petitions/defragovuk-stop-the-multiple-hot-branding-of-equines-in-england-and-wales) hot branding is permitted for equines (but not other species in the UK). No anaesthetic or pain relief is required; indeed the reaction to the burn is a useful indicator that the brand has been applied for sufficient time. However, some owners use a 'Burneze' spray following branding.

Hot branding is considered the best currently available means of identifying free-ranging native ponies such as Exmoor, Dartmoor and New Forest ponies on their respective moors and heaths (Mansell, personal communication, February 2013). Under such circumstances it is rarely possible to approach the ponies to use a RFID reader to determine an identity, and rounding up an entire herd to identify perhaps a single animal is both stressful for the ponies and impracticable for the owner. Conversely, the ability to read a brand mark from some distance is advantageous, especially where rapid action on welfare grounds is required. There is no evidence that hot branding is more painful than freeze branding, and the cauterisation of the wound means post-branding observation is less necessary (Mansell, personal communication, February 2013). A code of practice on hot branding is in preparation, and will include guidance on penning facilities, training of persons applying the brand and minimisation of the number of brand marks.

The results of a recent study into the behavioural and physiological effects of hot iron branding in semi-feral ponies carried out in the New Forest are not yet available. The research covered the assessment of the pony's behavioural response and the physiological effect of hot branding to include measuring skin temperature, pressure sensitivity and faecal cortisol (Mansell, personal communication, February 2013).

1.2.9 Freeze Branding

Freeze branding is permitted for cattle as well as equines and is now more common than hot branding. The branding 'iron' (copper and brass are preferred metals) is cooled in liquid nitrogen, dry ice or similar coolant. When sufficiently cold the iron is applied to a shaved area of the animal's skin and held there for 15-45 seconds, the longer time on light coloured animals

(see www.farmkey.co.uk/farmkey/index.php?option=com_content&task=view&id=12&Itemid=41). This will cause a swelling which usually reduces over the following 5 days, followed by the shedding of the dead skin over the next month.

Freeze branding destroys the pigment forming cells in the skin, so that white hair grows back on dark coated animals. To improve visibility on light coated animals the longer period of contact between the skin and the iron destroys the hair follicles, so that hair does not grow back and the brand mark is permanently bald. Freeze brand marks may be less visible (without close inspection) when the animal grows a thicker winter coat.

There is no evidence that freeze branding is more humane than hot branding, and the longer period of contact between the iron and the animal's skin makes holding the animal still for sufficient time problematic (Mansell, personal communication, February 2013).

1.2.10 Micro-chipping

Micro-chipping is the insertion of an electronic transponder directly under the skin of the animal where it remains a permanent identifier that can be read with an appropriate electronic reader. The micro-chip is usually encased in a biocompatible (non-allergogenic) material that promotes the re-growth of surrounding tissues. Micro-chipping is widely used for companion animals (e.g. dogs) and equines; in the former the micro-chip is inserted under the skin but in equines it is inserted into the ligamentum nuchae on the side of the neck half way between the withers and the poll. Insertion must be performed by a veterinary surgeon, who is first required to check that the animal has not already been micro-chipped.

There is a risk that the micro-chip will migrate, making it more difficult to locate. For this reason micro-chipping is not commonly used for animals that may be slaughtered for human consumption: if the micro-chip cannot be quickly recovered it will interfere with abattoir throughput or, if not recovered at all, it may pose a risk if ingested by the consumer. The IDEA project found that only 80% of injected transponders could be recovered and only 52% of those could be read (Food Chain Evaluation Consortium, 2009). In an early evaluation of electronic identification of animals conducted by the EC's Joint Research Council (IDEA Project Team, 2001) a trial location for the transponder in cattle was under the scutulum cartilage of the ear, but the report appears to be no longer available electronically.

A more recent evaluation of using injectable transponders in sheep and goats has been undertaken by ADAS (2012a). This compared site of insertion of the transponder in three groups of sheep and goats: groin (young lambs), groin and base of ear (store lambs) and groin and armpit (young goats); in each case the control was an EID ear tag. The injectable transponders were only a little more difficult to insert than the ear tag, but the groin was the easiest site and the ear base the most difficult. Use of antiseptic wipes made insertion more difficult because the skin was wet and made little difference to the rates of infection. Insertion was easier in young lambs than in store lambs (ADAS, 2012a).

The behavioural response of the sheep and goats was least marked with the ear tags and most apparent with transponders injected at the base of the ear. The latter site was also a little more prone to infection than the groin, and the infections in the ear base were markedly more severe than those in the groin: 80% of infections in the ear base were classed as severe compared to none considered severe in the groin (ADAS, 2012a). Transponders injected in the groin and

armpit read as well as the EID ear tag, but those in the ear base were difficult to read and after 8 months only 74.8% were still readable. Movement of transponders was greatest from those inserted in the ear base and least in those in the groin; few of those in the armpit moved but those that did moved furthest (ADAS, 2012a).

At slaughter 100% of ear tags were recovered, but the recovery of injected transponders varied from 60% (base of ear) to 94% from the armpit. When the transponder could not be recovered at one abattoir the Official Veterinary Surgeon (OVS) ordered all relevant joints condemned; at the other abattoir the entire (goat) carcass was condemned. Successful recovery could also damage carcasses and consequently in both abattoirs the loss of, or damage to, meat resulted in significant wastage (ADAS, 2012a). The time taken to recover the injected transponders was also a significant problem compared to the ear tags, which were removed with the head. The conclusion reached was that the use of the best performing EID implants could not be recommended for general use under practical conditions experienced in the UK. More work would be needed to improve recovery rates and a standard approach to non-recovery developed to avoid high meat wastage (ADAS, 2012a).

1.3 Problems Associated with Ear Tags and Evaluation of Performance

In a review of biometric identification Gonzales-Barron *et al.* (2009) summarised the problems that can arise with ear tags (http://www.veterinaryirelandjournal.com/Links/PDFs/CE-Large/CELA_March_2009.pdf). These were:

- **Readability**: In a Dutch survey, over half the farmers reported that the ear tags in ewes and lambs were illegible or barely legible for reasons such as wear and tear, breakage and soiling.
- **Loss**: Tags may be lost due to the tag tearing through the ear flap in lambs. Up to 5% of ear tags in sheep were reported to be lost in the Dutch survey. Survival analysis modelled ear tag loss: median ear tag retention was 272 days, and loss rate was 0.0024 ear tags day^{-1}.
- **Welfare**: After examination of the ears of over 700 sheep, approximately 28% of the animals had suffered slight to moderate ear damage associated with plastic ear tags, including local inflammation, pronounced thickening, traces of haemorrhaging and mild sepsis. Poor application could result in infections and ear damage, and this was more marked in young calves.
- **Tampering**: Ear tags can be substituted from one animal to another, which lessens the reliability of verification (see for example http://www.defra.gov.uk/news/2011/03/31/cattle-bovine-tb/).

However, the specifications for ear tags approved for use in the UK should ensure that the tags are tamper-proof. For sheep and goats the specification is set out in a Publically Available Specification: PAS 66:2009 (British Standards Institute, 2010) available on the Rural Payments Agency website:
http://rpa.defra.gov.uk/rpa/index.nsf/vContentByTaxonomy/BCMS**Tagging**Sheep%20&%20Goat%20Tagging%20-%20Sheep%20&%20Goat%20ETAS**PAS%2066**?OpenDocument.
For cattle the specification is PAS 44:2009 (British Standards Institute, 2009) also available on the Rural Payments Agency website:
http://rpa.defra.gov.uk/rpa/index.nsf/vContentByTaxonomy/BCMS**Tagging**Cattle%20Tagging%20and%20Cattle%20ETAS**PAS%2044%20**?OpenDocument

In addition, manufacturers and suppliers of ear tags for the UK market must sign the Code of Practice published by Defra and the Rural Payments Agency (Gray, 2011b).

To the above list of problems may be added failure during the insertion process. This will vary between tag designs, age and breed of animal and competence of the operator. Although this should be rectified by insertion of a replacement tag, it adds to the costs of identification tagging (see Section 4).

The 'flag' design of tags is susceptible to breakage in which the flag snaps off, leaving the 'button' portion of the tag in the ear. In the comparison of identification methods in dairy goats, Carné *et al.* (2010) found that 45 of 197 (22.8%) 'visual' (i.e. non-electronic) flag tags suffered such damage, although any codes printed on the button part of the tag were still readable. In the pilot trial of electronic identification (EID) in sheep (ADAS, 2005) mean loss rates of different EID tags ranged from 2-9%, but there was considerable variation between farms e.g. 0-32.6% and 0.81-41.57% for two tag types. A further 0.32-1.15% were about to fall out and 0.53-3.16% were electronically unreadable. Damage and infection was recorded in 1.74-8.19% and 1.77-7.52% of ears respectively, but again there were wide variations between farms e.g. for one tag type damaged ears ranged from 0-42.33%, suggesting that the damage was caused by incorrect insertion rather than the tag *per se*. Moxey and Walls (2012) cite tag loss rates of 2.5% to over 10% per year, which implies that within the average life of a breeding sheep 10-40% will have lost at least one ear tag.

Where an ear tag consists of two separate pieces (prior to insertion) one or both can break off, leaving the pin through the ear. Such broken tags should be replaced as the identification information printed on the broken piece(s) will have been lost. This entails removal of the remaining portion of tag and, for sheep and goats, if the identification number is unknown, replacement with a red ear tag. Fold-over tags are less susceptible to this problem, but it can still occur when the 'hinge' portion of the tags weakens and eventually breaks. Incorrect insertion of fold-over tags in lambs can lead to insufficient room for growth of the ear, but if too much room is allowed the tag is more susceptible to being caught on fences etc. and torn out of the ear. For cattle born since 1998 a missing tag must be replaced by a new tag bearing the same number.

Prior to the introduction of compulsory EID for sheep the Scottish Agricultural Organisation Society conducted a pilot study in which 209 farms were issued with over 91,000 ear tags; the pilot also included two abattoirs and six markets (Scottish Agricultural Organisation Society, 2009, 2011). Tag read rates were >96% and read times had a mean of 11 s but a median of 2 s, indicating that although the majority of reads were very rapid, there were a few that took several minutes. Additional survey work improved these read times and read rate to a mean of 4.5 s and 97.4% respectively; 1.7% of ear tags were missing and 1.3% of sheep had ear infections. Insertion of the tag took only one minute but required two people. In Phase II of the study overall read rates were 94%, but with considerable variability. It was estimated that 93% of tags were read on every occasion they were scanned, 5.6% were read sometimes and 1.4% were never read (Scottish Agricultural Organisation Society, 2011).

Scot EID has issued a note on ear tag readability for sheep passing through Critical Control Points in 2011 (summary available at http://www.scoteid.com/Public/Documents/tag_read_rates_2011.pdf). The average read rates were 94.9% for batches and 93.5% for all sheep. Read rates appeared to decline by 3% over 600 days after insertion (i.e. from the introduction of EID for sheep). Read rates varied from

87.62% to 96.11% between tag types, allowing farmers to identify those tags with better read rates from the list provided in the note.

ADAS (2012b) has recently evaluated the readability of EID tags at the point of purchase, in two large abattoirs and on four farms. At the time of purchase all of the 350 tags (from 7 suppliers) tested were effective and compliant with the requirements of EC Regulation 21/2004. In the abattoirs 98.5% of 7518 tags tested were fully functional; of the 1.5% that were not fully functional 0.73% had lost the transponder and 0.57% had a broken component (e.g. glass, coil or ferrite) with the remainder (0.2%) failing for other reasons. On the farms 99.5% of tags could be read with handheld readers and 98.5% with static race readers; of the 14 non-reading tags half had lost the transponder and the rest failed for other reasons. There was no evidence of deterioration in tag performance with time (i.e. with age of sheep; ADAS, 2012b).

Although the results of the ADAS (2012b) trial indicated that much of the criticism of EID tags was unfounded, it did indicate some of the problems that may arise in reading EID tags under 'field' conditions. One of the commissioners of the study, the Approved Livestock Identification Manufacturers' Association (ALIDMA), subsequently published a list of recommendations (http://www.alidma.org.uk/images/stories/tag-reading-trial-recommendations.pdf). Recently Defra published its response to the study and to the recommendations and has undertaken to initiate a review of the PAS 66 standard in 2013 (http://www.defra.gov.uk/publications/files/pb13864-alidma-eid-response-20130208.pdf).

These studies focus on the reliability of ear tags during the lifetime of the animal, but for traceability of animal products ear tags (and some other means of identification) suffer from a fundamental flaw: they are separated from the carcass when the head is removed in the abattoir (usually the first process after slaughter).

1.4 Alternative and Possible Future Technologies

1.4.1 Barcodes

Rather than bearing the 15 digit number required by Regulation (EC) 21/2004 a barcode could be printed on the tag. This would be read using similar technology to that at supermarket checkouts. Barcodes for sheep tags have been ruled out because they may become obscured by muck and can only be read after cleaning. They are permitted for cattle in the EU and are used, for example, on ear tags in the Republic of Ireland, but Shanahan *et al*. (2009) list a number of advantages over barcodes that would accrue from the implementation of RFID in the supply chain, including:

- reduction in labour costs;
- more efficient control of the supply chain due to increased information accuracy;
- better tracking and tracing of products; and
- enhanced profit margins.

Barcodes have not been adopted for cattle tags in the UK.

1.4.2 Biometric Identifiers

Various biometric identifiers have been suggested including retinal scans, muzzle patterns in cattle, facial recognition, immunological labelling and DNA analysis. They are considered more reliable than electronic identification because they cannot be falsified – in theory, the transponder of an RFID could be removed and inserted into the tag of another animal (Gonzales-Barron and Ward, 2005). A brief outline of biometric identifiers is given below; Gonzales-Barron and Ward (2005) give a more detailed account, but there has been much progress since their review.

Retinal scans of sheep were investigated by Gonzales-Barron *et al.* (2008) and Barry *et al.* (2008); initial results gave a false match rate of 0.25% and a false non-match of 0.82%. Later work virtually eliminated false matches and greatly reduced false non-matches (Gonzales-Barron *et al.*, 2009). Importantly, it has been demonstrated that cloned sheep have distinguishable retinal patterns, and also that the retinal pattern does not change as a lamb grows. However, capturing a retinal image of sufficient quality required 15-45 seconds with the technology used in the study (Gonzales-Barron *et al.*, 2009).

Allen *et al.* (2008) evaluated the potential of retinal scans to identify cattle in Northern Ireland. They showed that the 1738 retinal scans (two from each of 869 animals) could be reliably differentiated, both visually and by computer. Images taken at later dates from the same animals showed that 98.3% could be matched by computer and the remaining 1.7% visually. A simulated ear tag switch for 115 animals indicated that all could be detected by subsequent imaging and computational analysis. Crucially, operators could be trained to use the image capture technology in one day, and each image could be acquired in two minutes, although the animal had to be restrained in a crush. The authors concluded that the system could be deployed as a stand-alone technology for animal identity verification and had the potential to improve the performance of ear-tag-based identification systems for cattle.

Muzzle patterns were originally recorded as ink prints on white card and were widely used in Japan for pedigree cattle identification (Gonzales-Barron and Ward, 2005). More recently, digital imaging of muzzle patterns, which maps the ‘beads’ and ‘ridges’ on the muzzle, has been developed (see Gonzales-Barron *et al.* (2009) for an image). Barry *et al*. (2007) demonstrated that digital imaging of cattle muzzle patterns could achieve a recognition rate of almost 99%, but concluded that further work would be needed to automate the systems used. Corkery *et al.* (2007) demonstrated that an algorithm used for human facial recognition systems could identify sheep faces with 96% accuracy.

A bioactive immunological labelling system (‘ImmunoTrack’) was developed in Germany by Responsif GmbH (Gonzales-Barron and Ward, 2005). This uses highly antigenic peptide sequences with appropriate adjuvants to induce strong peptide-specific antibody responses in cattle or pigs. These anti-peptide antibodies can be detected, using standard techniques, in the live animal’s blood serum or the meat ‘juice’ after slaughter. By varying the combinations of peptides the origin (e.g. country, region, farm) and other characteristics (e.g. breed, organic farming) can be encoded (Gonzales-Barron and Ward, 2005).

Although unlikely to become a routine means of identification on farms in the short term, DNA identification is a powerful tool for facilitating traceability and is already used in abattoirs in some countries. In addition, use of archived DNA profiles in conjunction with EID can ensure the integrity of the tag-based identification. Some tag suppliers already offer tags that take a tissue sample as the tag is inserted. This can be used for DNA profiling, although currently such tags

are more commonly used in disease (e.g. bovine viral diarrhoea (BVD)) control programmes such as that implemented by the Scottish Government (http://www.scotland.gov.uk/Topics/farmingrural/Agriculture/animal-welfare/Diseases/disease/bvd/eradication; see also Section 4.1.1). A further use of DNA analyses is the tracing of meat samples; Gonzales-Barron and Ward (2005) provide an account of the principles with examples from Australia, Canada and the USA. Wilkinson *et al*. (2011) used SNP chips to determine the breed of cattle and pigs from which meat samples were taken.

An example of DNA 'finger-printing' as a means of identification, or corroborating identification by other means, is the study by Jimenez-Gamero *et al.* (2006) on Murciano-Granadina goats. Using nine microsatellite markers, the study demonstrated that 16.2% of 388 identifications were clearly incompatible with the recorded pedigree, and a further 11.9% were dubious. This suggested that a high proportion of the information derived from dam identifications may have been erroneous. For the Murciano-Granadina goats at the time of the study identification was by means of a tattoo within the ear, and errors in transcribing these identification numbers was one source of misidentification. There were large variations in mis-recording of dams between farms. The study therefore lent weight to the argument for the introduction of electronic means of identification.

However, Allen et al. (2008) suggest that '*DNA profiling, whilst being a powerful tool for scientifically verifying animal identity, is currently limited by the fact that verification results cannot be generated in real-time i.e. beside animal, for most applications. It is unlikely therefore to become the primary identifier for live animals. It can be used effectively in retrospective audits, meat tracing and parentage verification as a traceability technology and counter-fraud measure*.' Similar cautions could be issued about the other biometric techniques described, especially when considered in the context of on-farm operations involving large flocks or herds, but some at least have the potential to be generated in real time and advances in technology are likely to facilitate their wider use. In addition, DNA profiling (and immunological labelling) could be used for carcasses, whereas muzzle patterns and retinal images suffer from the same problem as ear tags – they are lost when the animal's head is removed during processing at the abattoir.

DNA analysis does provide a means of verifying pedigrees by parental verification, and breeding programmes can be informed by parental identification, in which the parent(s) of an animal with a particular trait (whether positive or negative) are identified retrospectively (Harlizius *et al*., 2011).

An additional use of DNA analysis was announced by the Secretary of State for Agriculture in March 2011 in response to the illegal swopping of cattle ear tags between bovine tuberculosis positive cattle and less valuable animals which were then culled (http://www.defra.gov.uk/news/2011/03/31/cattle-bovine-tb/). From April 2011 cattle testing positive for bovine tuberculosis are immediately DNA tagged, the DNA sample is retained by Animal Health and random cross-checks against animals sent for slaughter are made.

1.4.3 Ultra High Frequency (UHF) Tags

Earlier UHF tags could store up to 96 bits of information (*cf.* 64 bits for LF tags) and had a frequency range of 860-960MHz, which extended the reading range to *c*. 4-5 m (compared to the 0.5 m for LF tags), although this depended on the size of the antenna (Food Chain Evaluation Consortium, 2009). UHF RFIDs can also incorporate an 'anti-collision' mechanism as

standard; when two LF RFIDs are in close proximity both will be stimulated by a reader, and the resulting combined signal cannot be read by the reader. This is known as a 'collision'. Omitting the details (see Food Chain Evaluation Consortium, 2009), UHF transponders can avoid such collisions. However, advanced LF transponders can also incorporate anti-collision mechanisms.

However, Shanahan *et al.* (2009) state that UHF tags are unsuited to animal identification because this frequency range is too susceptible to interference from water and metal, but if these can be overcome UHF tags have advantages. The ability to read UHF transponders is reduced in humid conditions, so the presence of moisture, wet manure etc. on the tag would reduce efficiency. For the same reason, UHF transponders cannot be used internally (e.g. in ruminal boluses or injected microchips). UHF signals reflect well from metal surfaces, meaning that it is possible for a UHF transponder at greater distance to be detected by reflection rather than one nearer to the reader if the latter is poorly positioned relative to the reader (Food Chain Evaluation Consortium, 2009).

These and other disadvantages led the Food Chain Evaluation Consortium (2009) to conclude that UHF tag technology '*has not been proven to be suitable for animal identification*' and that advanced LF transponders represent a better development. However, further development may allow UHF tags to be used for livestock, and there are already UHF tags available (but they are not approved for official use in the EU). For example, in the USA Daily RFID offers a livestock tag that the company claims can be read from distances of up to 5m (http://www.mazine.ws/blog/rfid-uhf-animal-ear-tag-series-make-rfid-livestock-tracking-breeze). One UHF tag has been approved for use in the USA's voluntary livestock traceability system, the National Animal Identification System (http://www.rfidjournal.com/article/view/7304/1); a field trial is underway in Canada and largely successful field trials have been undertaken in New Zealand, Brazil and Taiwan.

More recent designs of UHF tag have extended the memory to 512 bits or more, which gives greater flexibility in the data that can be stored. For example, blocks could be allocated for differing purposes:

- 'read only' blocks (usually 64 bits) that can store the tag's unique tag identifier (TID) specifying the manufacturer, tag type and the tag's own unique number;
- 'write once' blocks (usually 96 bits) that can store the animal's individual number but also information such as date of birth, breed and sex;
- 'read and write' blocks (352 bits assuming 64 and 96 bits for the other blocks) that can be wiped and re-written, so which are available for farm management purposes, such as movement and veterinary medicine records.

An assessment of UHF technology for livestock identification was undertaken by Scottish Agricultural Organisation Society Ltd. (SOAS) for ScotEID (SOAS, 2011). The study focussed on cattle, for which there are currently no EID regulations, allowing greater flexibility in the technology employed. It was found that light rain did not adversely affect tag performance and that the range at which the tested tag could be read was greater (several metres) than for LF tags (60 cm). The greater available memory would allow more cattle passport information to be stored on the transponder, and this was more secure as, unlike LF tags, the unique identifier cannot be re-written or cloned. As well as the 96 bit unique identifier the tested tag could store 416 bit of user defined data (and other UHF tags could store more). The transponder was cheaper than an LF transponder (<£0.10 compared to *c.* £0.35). Fixed readers were significantly cheaper (UHF: £650-£2000, LF: £8000-£15000) and the cost of a hand-held reader was similar (UHF: £700+, LF: £500-£1200; SOAS, 2011).

In March 2012 ScotEID published a progress report on the use of UHF tags for cattle (http://www.scoteid.com/Public/Documents/Initial_UHF_testing_under_ScotEID_290312.pdf). Performance in terms of reading tag information varied with type of tag, model of reader and orientation of tag with respect to the reader, but maximum read distances were 1.5-6.0 m. Potential stakeholders saw the advantages of being able to store passport information on UHF tags, but expressed concern that tags for sheep and cattle might use different technologies. However, there would be interest in developing a hybrid LF/UHF tag.

It therefore seems likely that UHF technology will become more widely available for livestock identification and tracing as systems develop, and that UHF tags will represent a considerable advance in integrating identification, movement, veterinary medicine and other records to the benefit of the public and the livestock industry. However, there would also need to be a change in EU regulations to allow use of the UHF technology.

2 CURRENT LEGAL REQUIREMENTS FOR THE IDENTIFICATION AND MOVEMENT OF FARMED ANIMALS IN THE UK

As noted above the current regulations for the identification of farmed animals can be found at https://www.gov.uk/animal-identification-movement-and-tracing-regulations
The requirement to comply with the identification requirements is embodied in the cross compliance regulations of the Single Farm Payment System (SPS) of the Common Agricultural Policy. Thus if a livestock keeper does not comply with the identification regulations he/she may lose some or all of the SPS payments. The relevant Statutory Management Requirements can be found in the current guides to cross-compliance at

http://rpa.defra.gov.uk/rpa/index.nsf/contentdocs/C469AD87D7F02D5F80257AC5003B49BF/$FILE/cross%20compliance%20guidance%202013%20v1%200.pdf (England: the relevant SMRs are 6 (pig identification and registration), 7 (cattle identification and registration) and 8 (sheep and goat identification)).

http://www.scotland.gov.uk/Publications/2005/12/0990918/09199 (Scotland: the relevant SMRs are 6 (identification and registration of animals), 7 (framework for the identification and registration of animals), 8 (identification and registration of bovine animals regarding the labelling of beef & beef products) and 8a (animal identification and registration - sheep and goats)).

http://wales.gov.uk/topics/environmentcountryside/farmingandcountryside/farming/crosscompliance/farmersguidetocrosscompliance/farmersguidetocrosscompliance/?lang=en (Wales: the relevant SMRs are 6 (pig identification and registration), 7 (cattle identification and registration) and 8 (sheep and goat identification)).

http://www.dardni.gov.uk/index/publications/pubs-dard-grants-and-funding/publications-cross-compliance/statutory_management_requirements.htm (Northern Ireland: the relevant SMRs are SMR (pig identification and registration), 7 (cattle identification and registration) and 8 (sheep and goat identification and registration)).

Where ear tags are a required means of identification they must be replaced if they become illegible or are lost; this must be within 28 days of discovery of the illegibility or loss or before the

animal leaves the current holding. Where one tag remains the replacement may directly replace the lost/illegible tag; if no tag is present/legible replacement tags with a new individual number must be used. Such replacements must be notified to the competent authority (e.g. British Cattle Movement Service, ScotEID or Animal and Public Health Information System (APHIS)).

2.1 Current Requirements for the Identification and Movement of Sheep and Goats

A pdf of the document sent to all sheep and goat keepers in England in 2009 (Defra, 2009a) is available at:
http://www.defra.gov.uk/publications/files/pb13327-sheeps-goats-guidance-091209.pdf
A 'plain English' guide to the regulations (Defra, 2012) is available at:
https://www.gov.uk/sheep-and-goats-identification-registration-and-movement

For other countries within the UK the regulations can be found at:
http://www.scotland.gov.uk/Publications/2010/02/08120157/0 (for Scotland)
http://wales.gov.uk/topics/environmentcountryside/ahw/farmanimaltracing/sheepandgoatidentification/?lang=en (for Wales) and
http://www.dardni.gov.uk/animal-movements-sheep-and-goats (for Northern Ireland)

Currently sheep and goats may be identified by means of two ear tags or one ruminal bolus plus one ear tag, or (by EU regulation but not approved in the UK) one pastern band and one ear tag. For brevity the account below refers to tags and tagging to encompass all these options.

Prior to 2008 sheep and goats in the UK (which had a derogation on the double tagging enforced elsewhere in the EU) needed just one ear tag; the tag bore an individual identity number on one side and the UK flock number on the other. In 2008 the derogation on double tagging was lost and sheep and goats born before 31st December 2009 were required to have two identical ear tags, so that if one was lost the identity of the sheep or goat was still known; such lost ear tags had to be replaced either with a replacement tag bearing the original number (if known) or with two new tags, which had to be recorded. Some sheep and goats identified under these former regulations will still be extant.

For sheep born or first identified after 31st December 2009 the general requirement is for two ear tags, one of which must contain a LF RFID (or, although not approved in the UK, one ear and one EID pastern band). Both tags must also bear the UK flock number on one side and an individual number on the other. In each animal both flock and individual numbers must be identical on both tags. Lost tags must be replaced with a tag bearing the original number (if known) or with two new tags, which have to be recorded. The colours of some ear tags are prescribed under the regulations: the electronic ear tag must be yellow and replacement tags must be red (where the individual number is changed). As an alternative to two tags the RFID device may be within a ruminal bolus with a single visual tag, which must be black. Note that in Scotland the colour of the electronic tag is not compulsory, but yellow is recommended by ScotEID and by ALIDMA following the study by ADAS (2012b; see Section 1.3 above).

The EU stipulates that in countries with goat populations exceeding 160,000 EID for goats is compulsory; however, the UK goat population (95,000) is well under this limit (Defra, 2009b). Thus in the UK for goats born or first identified after 31st December 2009 (and not intended for export) there is no legal requirement for electronic identification, but individuals must be

identified by two identical tags bearing the herd and individual numbers. Goats intended for export must be fully EID identified following the same rules as for sheep.

When ear tags are ordered for use in GB the supplier contacts Defra's computerised Ear Tag Allocation System (ETAS) which informs the supplier of the individual number to be printed on the ear tag; the ETAS ensures individual tag animal numbers are issued sequentially within each flock/herd mark. Similarly in Northern Ireland the Animal and Public Health Information System (APHIS) ensures that tags are issued sequentially. In addition these systems ensure that tag numbers are not duplicated and that there is an official means to monitor tag supply and usage.

In GB there is an exemption from these general regulations for sheep and goats that are intended for slaughter before the age of 12 months; for such animals a single 'batch' tag that bears just the flock number is acceptable. For management purposes this may be an EID but there is no legal requirement in England and Wales, but in Scotland the slaughter tag must be an EID. The derogation for sheep destined for slaughter has not been adopted in Northern Ireland, where all sheep are double tagged.

Sheep and goats born or first identified after 31st December 2009 must be tagged within:

- six months of birth if housed overnight
- nine months of birth if not housed overnight
- when they move off the holding of birth if this is sooner.

The RPA and APHIS maintain lists of approved sheep ear tag suppliers (see Section 4.1).

2.1.1 Current Regulations for the Movement of Sheep and Goats

In England and Wales there is no publicly accessible database of sheep and goat ear tags, movements etc. (*cf*. British Cattle Movement Service, to which movements can be reported on-line), although Defra has recently invited tenders for a sheep movement database. Currently paper copies of movement licences (AML1 or in Wales AML1(W)) must be completed; these are self-carbon quadruplicate forms. One copy is sent to the Trading Standards Department of the Local Authority for the receiving holding, one is retained by the keeper of the departure holding, one is retained by the keeper of the receiving holding and one is retained by the haulier. Local authority officers transcribe the information on the paper licence to the centralised Animals Movements Licensing System.

In Scotland the forms are triplicate (there is no copy for the haulier) and one copy is sent (by post, fax or e-mail) to the Scottish Animal Movement Unit (SAMU) rather than the local trading standards department. There is also a pilot trial of centralised on-line movement recording for sheep and goats through ScotEID (www.scoteid.com). In Northern Ireland sheep movements can be recorded on-line using APHIS.

Currently sheep identified before 2010 do not need to be individually recorded, provided they have not been re-tagged with a pair of ear tags that includes an EID-tag. From 1st January 2015 all sheep except those destined for slaughter will need to be individually recorded on movement documents (http://www.defra.gov.uk/publications/files/pb13711a-historical-sheep-poster-a5.pdf).

Once foot and mouth disease susceptible animals are moved onto a holding it triggers a 'standstill period' during which foot and mouth disease susceptible animals cannot move off that holding for a period of time (which varies with species and country). In England and Wales the standstill period is six days for all foot and mouth disease susceptible species if the animals moved on are cattle or sheep, and for cattle and sheep if the animals moved on are pigs. If the animals moved onto a holding are pigs, the standstill period for pigs is 20 days.

An exemption to the standstill rule may be applied for to allow animals to attend a show. When an animal goes to a show, its movements when it leaves and returns to the farm after the show must be reported. The show secretary should report the on and off movements for the showground.

In Scotland the 'standstill period' is 13 days for cattle, sheep and goats but 20 days for pigs. http://www.scotland.gov.uk/Topics/farmingrural/Agriculture/animal-welfare/Diseases/MovementRestrictions/ApplicationNotesHTML The Northern Ireland Executive's Agriculture Minister recently (19th February 2013) announced the removal of the six day standstill from 4th March 2013, except that an animal moved from a market cannot be returned to a market within six days (http://www.northernireland.gov.uk/index/media-centre/news-departments/news-dard/news-dard-190213-oneill-relaxes-standstill.htm).

2.2 Current Requirements for the Identification and Movement of Cattle

The current requirements for the identification of cattle are described at
https://www.gov.uk/cattle-identification-registration-and-movement
In addition pdfs of relevant documents are available from the Rural Payments Agency (RPA) website:
http://rpa.defra.gov.uk/rpa/index.nsf/a7ed056a97bf831780256f5100562f0b/907392505b99169d8025703b00417e1d!OpenDocument

2.2.1 Cattle Ear Tags

The requirements for ear tags are set out in the Cattle Identification Regulations which can be found at

http://www.legislation.gov.uk/uksi/2007/529/contents/made (for England),
http://www.legislation.gov.uk/ssi/2007/174/contents/made (for Scotland)
http://www.legislation.gov.uk/wsi/2007/842/pdfs/wsi_20070842_mi.pdf (for Wales) and
http://www.dardni.gov.uk/index/animal-health/animal-identification-registration-movements/animal-movements-cattle.htm (for Northern Ireland).

Regulation 4 of the English and Welsh Cattle Identification Regulations and Regulation 5 of the Scottish Cattle Identification Regulations state the requirements for ear tags. The penalties for failing to comply are set out in Regulation 15 of the English and Welsh Cattle Identification Regulations and Regulation 16 of the Scottish Cattle Identification Regulations.

All cattle born on or after 1st January 1998 must have two ear tags, one in each ear. One of these ear tags, called the primary tag, must be a yellow, plastic, two-piece ear tag that meets the requirements of Article 3 of EC regulation 262/97, including a minimum size. Since 1st

January 2000 the primary tag bears the crown logo, the country code (i.e. UK for tags issued to breeders in Great Britain), the herd number, an individual animal number and a check digit. In Northern Ireland the crown logo is replaced by the Department of Agriculture and Rural Development (DARD) logo.

The secondary tag may be the same as the primary tag but may also include specific management information e.g. a name or another unique identification number such as the Herd Society number for pedigree animals. There is no minimum size for secondary tags so 'button' tags (which consist of two discs connected through the ear flap) or metal tags are permitted.

There is no regulatory requirement for either primary or secondary ear tag to be electronic, although individual keepers can choose to use electronic secondary tags for their own management purposes. Similarly, in the UK there is no regulatory requirement for a barcode to be shown on the primary tag but individual keepers may choose to include one on the secondary tag. In some other EU countries a barcode on the primary tag is compulsory. UK born cattle can be exported without a barcode on the primary ear tag.

Cattle ear tags must be inserted within 20 days of an animal's birth, with the exception of dairy cattle, which must have at least one tag fitted within 36 hours of birth. All cattle must be tagged before they leave the holding of birth. Ear tags cannot be removed or replaced without permission from the British Cattle Movement Service (BCMS – see Section 2.2.3) or, in Northern Ireland, the Animal and Public Health Information System (APHIS), unless they are lost or illegible. Lost or illegible tags must be replaced within 28 days of the discovery of the loss or before the animal leaves the current holding.

Cattle imported from another EU member state will already be double-tagged but cattle imported from outside the EU must be re-tagged within 20 days of passing the required veterinary checks.

Ear tags can be obtained from local agricultural merchants, some veterinary surgeons or Defra-approved suppliers. As for sheep and goats, when ear tags are ordered the supplier contacts Defra's computerised Ear Tag Allocation System (ETAS) which informs the supplier of the individual number to be printed on the ear tag; the ETAS ensures individual tag animal numbers are issued sequentially. In addition, when ear tags are ordered the supplier informs the BCMS which issues a passport application form (see below). Similar procedures are operated in Northern Ireland via the Department of Agriculture and Rural Development (DARD).

The RPA and DARD maintain lists of approved cattle ear tag suppliers (see Section 4.1).

2.2.2 Cattle Passports

Cattle born before 1 July 1996 were issued with a Certificate of Registration (CHR3) only; this should accompany the animal when it is moved between holdings. Cattle born in or imported into Great Britain since 1 July 1996 must have a cattle passport. This document identifies the individual animal and its movements and must remain with it throughout its life. The style of the passport has changed twice since 1996, but there may still be some extant animals with the old style passports.

Cattle born or imported between 1st July 1996 and 28th September 1998 were issued with green cattle passports and Certificates of Cattle Tracing System (CTS) Registration (CHR3); both the passport and the CHR3 should accompany the animal whenever it is moved between holdings.

Cattle born or imported between 28th September 1998 and 1st August 2011 were issued with a 'chequebook' style passport (CPP13) which should accompany the animal whenever it is moved between holdings. In addition, these passports included movement cards that needed to be completed and sent in to the BCMS; alternatively, the movement could be notified to BCMS electronically.

For cattle born or imported on or after 1st August 2011 the BCMS issues a single page passport (CPP52) which should accompany the animal whenever it is moved between holdings. All movements between holdings are notified to BCMS electronically or by telephone (see below). The current cattle passports include:

- details of the animal
- details of where it has been throughout its life
- details of the animal's death

Passport applications must be made within 27 days of the animal's birth. An application received by BCMS more than 27 days after the birth of a calf will be refused and a Notice of Registration document issued. The applicant may be able to appeal against refusal of a passport under certain exceptional circumstances.

Applications received with missing or invalid information will be issued with a Notice of Registration document 56 days after receipt of the application if full valid information is not received before this time. If subsequent valid information is provided a passport may be issued if the Notice of Registration is returned.

For cattle imported from other EU member states the animal's EU passport, Export Health Certificate and a completed import application form (CPP16) must be sent to BCMS within 15 days of the animal's arrival at its destination holding. For imports from outside the EU a completed application form (CPP16) must be sent to BCMS within 15 days of having retagged the animal. It must have been retagged within 20 days of passing the veterinary checks, or before the animal leaves the holding.

If a passport is lost, damaged or stolen a replacement must be requested from the BCMS within 14 days of becoming aware that the passport is missing. A replacement will be issued providing the animal's movement history can be traced. There is a charge for this service.

Cattle passport applications may be made to the BCMS using the following methods:

- CTS Online - this is a free, interactive website that is available to all registered cattle keepers in Great Britain.
- CTS Self Service is an automated telephone line (0845 011 1212).
- CTS Web Services is a facility used by a range of farm software packages to feed data directly into CTS. (CTS Online and CTS Web Services are distinct options - one is free, the other requires the user to purchase software from a third party supplier. Both are considered more reliable than email, as information is sent more securely and because they incorporate an early error detection feature. There is a list of suppliers and software

packages on the RPA website: http://rpa.defra.gov.uk/rpa/index.nsf/vContentByTaxonomy/BCMS**CTS%20Web%20Services**Software%20Suppliers**?OpenDocument)

2.2.3 British Cattle Movement Service

The Cattle Tracing System was originally introduced to protect the public from Bovine Spongiform Encephalopathy (BSE) but has subsequently been used to check claims for CAP payments (National Audit Office, 2003). The BCMS has operated since September 1998 and covers England, Wales and Scotland. BCMS was merged with the Rural Payments Agency (RPA) in 2003. Northern Ireland already had a computerised cattle tracing system prior to September 1998; this was approved by the EC in 1999 (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1999:275:0032:0032:EN:PDF) and is now incorporated into the Animal and Public Health Information System (APHIS).

The BCMS runs the Cattle Tracing System (CTS) database, and is responsible for:

- maintaining a register of births, deaths and imports of cattle used for animal health and subsidy control purposes
- issuing cattle passports
- recording individual cattle whereabouts
- operating a dedicated helpline
- providing online services

When a breeder orders ear tags for a calf (or an animal newly imported from outside the EU) the BCMS sends a passport application form, either as a paper copy or electronically depending on the breeder's preference.

The death of a bovine animal on a holding must be reported to BCMS either electronically or by completion of the death details section of the passport. The animal's passport must also be returned to the BCMS within seven days in all cases. Similarly the occupier of a slaughterhouse must notify the death of animals slaughtered on the premises to BCMS by either reporting the death electronically or completing the death details section of the passport and giving it to the official veterinarian or their representative at the time of slaughter.

2.2.4 Notification of Cattle Movements

Whenever cattle are moved between holdings, the conditions of the general licence for the movement of cattle must be followed. These conditions can be found at: http://archive.defra.gov.uk/foodfarm/farmanimal/movements/cattle/documents/general-licence090713.pdf

Movements of cattle on or off a holding must be reported to BCMS within three days; death of a bovine animal must be reported within seven days. These reports can be made by:

- using CTS Online
- using the CTS Self Service telephone line
- using a farm software package linked to CTS Web Services
- asking the local market if they can report movements on the keeper's behalf

- using the tear-out movement cards in the animal's chequebook-style passport
- using an agent.

The details must also be recorded in the movement summary section of the passport.

2.3 Current Requirements for the Identification and Movement of Pigs

Current information on the identification and movement of pigs in the countries of the UK is available at:
http://www.defra.gov.uk/food-farm/animals/movements/pigs/ (for England)
http://www.scotland.gov.uk/Publications/2011/10/28142522/0 (for Scotland)
http://wales.gov.uk/topics/environmentcountryside/ahw/farmanimaltracing/pigkeepersguidance/?lang=en (for Wales) and
http://www.dardni.gov.uk/pigs-irm (for Northern Ireland).

A useful guide to the identification and movement requirements for pigs is available at:
http://www.defra.gov.uk/publications/files/pb13647-new-pig-keepers-guide.pdf

As described above a pig can be identified by an ear tag, tattoo or double slapmark, except in Northern Ireland where pigs over six months of age, or which leave the holding of birth before that age, must be identified by an ear tag. A pig ear tag is printed with the letters "UK" followed by the herd mark. Tags can be metal or plastic but plastic tags on pigs destined for slaughter must be sufficiently heat resistant to withstand carcass processing. If a tattoo is used only the herd mark (UK is not needed) is tattooed on the ear. Similarly slapmarks need only be the herd mark - the use of "UK" is voluntary; it must be legible for the life of the pig and throughout the processing of its carcass.

Pigs over 12 months old can only move between holdings, to any type of market and to slaughter with an eartag, tattoo or double slapmarks bearing the keeper's herd mark. The herd mark must be applied to a pig before it moves off the holding of birth. Moves to a show or exhibition, for breeding purposes, to an AI Centre or for intra-community trade or export must be with a tag, tattoo or slapmarks including a unique individual identifying number.

Unlike other livestock, pigs under 12 months old can be identified by means of a temporary mark e.g. a painted red line, black cross or blue circle during movements between farms (but not other destinations such as markets or abattoirs). The temporary mark must last until the pig reaches its destination. Combined with the haulier summary / movement document (see below), the temporary mark must be able to identify the holding from which the pig moved.

Although owners of 'pet' pigs are subject to the same regulations as other pig keepers they can obtain an annually-renewed 'pig walking' licence that allows the pig(s) to be walked over a specified route that does not pass close to facilities that may pose an animal health risk e.g. a livestock market, high health status pig farm or fast food outlet.

Until March 31st 2012 pig movements could be recorded on form AML2 in England and AML2(W) in Wales; these movement documents were similar to those described above for sheep and goats. From 1st April 2012 movements can be notified electronically using the eAML2 system operated by the British Pig Executive (BPEX) in conjunction with the Meat and Livestock Commercial Services Ltd. (MLCSL); keepers without internet access can use the bureau

facilities offered by BPEX or BPA, but extra time must be allowed as a combined haulier summary / movement document is sent through the post. However, movements must be notified in advance of the movement itself.

The number of copies of the haulier summary / movement document that must accompany the animals varies from one (if both source and recipient keepers use the on-line system) to four (if both source and recipient keepers use the bureau facility). Completed movements are uploaded overnight to Defra's AMLS database.

The requirements for pig identification and movements are the same in Scotland as in England and Wales, except that the movements are notified to the ScotEID centre, by telephone, electronically or in writing (Scottish Government, 2011). Movement documents are needed if ScotEID is notified in writing or the pigs are less than 12 months of age and are identified by means of a temporary mark, or if the pigs are destined for England, Wales or Northern Ireland. In the last case the movement is automatically notified to BPEX by ScotEID.

2.4 Current Requirements for the Identification of Equines

The current regulations governing equines (horses, ponies, donkeys and other members of the Equidae) can be found at:
http://www.defra.gov.uk/wildlife-pets/pets/horses/

A guide to the regulations is available at:
https://www.gov.uk/horse-passport/overview

European Commission Decision 504/2008/EEC required all equines to have a passport and all equines identified after 31 July 2009 must be implanted with a microchip prior to passport applications being made for those animals. (All adult equines had to be micro-chipped and issued with a passport by 31st December 2009). For foals the microchip must be inserted by 31st December of the year of birth or within six months of birth, whichever is the sooner. In the UK there is a derogation for feral and semi-feral ponies (e.g. those kept on Exmoor, Dartmoor and the New Forest). Such ponies may be identified by a temporary tamper proof 'rump-sticker' for movements through sales and to abattoirs; if a pony does not go direct to slaughter from the sale the receiving keeper must microchip it within 30 days (Defra, 2009d).

The primary objective of the legislation is to protect the health of those who eat horsemeat by preventing horses entering the human food chain if they have been treated with any medicine that is not intended for use on food producing animals (e.g. phenylbutazone). To comply with the requirements all passports issued must contain veterinary pages in which the owner may declare whether or not the horse is ultimately intended for human consumption.

In addition, the equine industry considered that two other benefits would result from all horses having passports:

- discouraging the indiscriminate breeding of horses and ponies that may be of low quality or value (http://www.horsedrivingtrials.co.uk/reference/passports/passports_faq.htm#2) and,
- as the passport must accompany a horse being sold, a potential buyer is able to check that the identifying particulars of a horse for sale are correct. This may therefore reduce the likelihood of stolen horses being offered for sale (https://www.gov.uk/horse-passport/overview)

Passports contain a description of the animal (prior to micro-chipping any identifying features were marked on a pre-printed outline drawing), its breed/type, microchip number, age and any veterinary medicines administered. The passport must be completed by a veterinary surgeon or other competent person. Passport applications can be made to a number (>70) of approved passport-issuing organisations; for purebred equines this is often the breed society but for non-purebreds the British Horse Society can issue passports.

Horses cannot be moved without their passports except in special circumstances e.g. where owners take their horse on a short hack/ride. Initially (from 2008) all records of horses were notified to the National Equine Database (NED) but this was discontinued in 2012. It is possible that the equine industry will fund a replacement national database (http://www.horseandcountry.tv/news/2012/08/17/national-equine-database-shut-down) but to date there has not been any obvious progress.

In response to the discovery of horsemeat in a wide range of processed meat products, the UK Secretary of State for Environment, Food and Rural Affairs recently (21st February 2013) met members of the Equine Sector Council for Health & Welfare and was advised that the equine passport system needed to be updated and a replacement central database for equines created (http://www.worldhorsewelfare.org/information/latest-news?view=show&content_id=5439). However, there has been no immediate public response to this suggestion. Given the recent cases of infectious equine diseases such as contagious equine metritis and equine viral arteritis, centralised recording of equine movements is desirable.

2.5 Poultry and Waterfowl

Currently there is no requirement for poultry and waterfowl to be individually identified or movements to be recorded. The Poultry Club operates a closed ringing scheme which is used by many exhibition breeders and the National Poultry Collection operates a wing tagging system related to individual pedigree recording (Defra, 2010). The Poultry Club ringing scheme records the identity of the breeder purchasing the rings but does not record the breed for which they will be used (Defra, 2010). As well as leg rings and wing tags, tattoos (under the wing where there are few feathers) are an option for identification.

Defra does, however, maintain a database of poultry flocks (the GB Poultry Register) in order to better manage disease outbreaks. Registration is mandatory for flocks consisting of >50 birds but is voluntary (although encouraged) for smaller flocks. See https://www.gov.uk/poultry-farms-general-regulations.

Implementing an individual identification scheme for poultry would have the same societal benefits as the identification of other species, especially for pure breeds at risk of being lost to farming. For example, in the event of an outbreak of disease, the Animal Health & Veterinary Laboratories Agency would consider a derogation from culling for breeds at risk, provided disease control is not compromised. AHVLA would use the then current list of breeds at risk compiled by the Farm Animal Genetic Resources Committee (http://archive.defra.gov.uk/foodfarm/farmanimal/diseases/atoz/fmd/documents/uk-breeds-at-risk.pdf). AHVLA would require the poultry keeper to be a member of the relevant breed society and individual identification of birds would be preferred to allow traceability (Barber, *pers. comm.* April 2013).

3 USING REGULATORY IDENTIFICATION TO MONITOR POPULATIONS

As all UK mammalian livestock must be identified and a record of the identification kept, it should be possible to use the identification record to monitor populations. A workshop on indicators of genetic diversity (FAO, 2010) considered a number of candidate indicators, some of which could be derived from demographic data. Such data could be made available from the regulatory identification numbers in existing databases, such as BCMS for cattle, or could be included in future databases for other livestock species.

A study on the potential for using the BCMS database to assess gene flow in the UK beef cattle industry concluded that it did provide valuable information that could be checked against other sources of publicly available data, but that its full potential as a reliable data source was not realised (Todd *et al.* 2011). This resulted from incomplete recording of the identification numbers of sires and variability in the codes used to designate breeds. On the other hand, the BCMS was more useful than many other data sources (e.g. breed society databases) because it recorded deaths. This allowed age at death to be determined and ensured that dead animals were not included in population estimates.

As a case study for this report, the use of UK flock numbers for estimating population parameters such as effective population size (N_e) was demonstrated for Hebridean sheep. In this breed the registration authority is the Hebridean Sheep Society (www.hebrideansheep.org.uk). The publicly available flock book provides a means to assess the breeding population of Hebridean sheep in each year. In 2011 (the last year for which a flock book was available at the time of the study) 1586 Hebridean ewes and 217 Hebridean rams contributed to the 2011 crop of lambs. Although strictly only applicable to populations with random mating and non-overlapping generations, using Wright's (1931) estimate of effective population size

$$(4N_mN_f) / (N_m + N_f)$$

(where N_m = number of breeding males and N_f = number of breeding females) the effective population size of the registered Hebridean flock for that year was 763.5.

This estimate was derived from pedigree registration numbers of sires and dams in the flock book, but the Hebridean Sheep Society requires breeders wishing to register animals to record the UK flock and individual numbers of those animals. Although these UK flock and individual numbers are not shown in the flock book, they are shown on the pedigree certificate issued for each registered animal, demonstrating that the breed society's database electronically links each registered Hebridean sheep to its UK flock / individual identification numbers.

Thus making the UK flock and individual numbers of sires and dams (identified as such) available to (or from) a central database, without any other data, is sufficient to calculate the simple, and some more sophisticated (see Toro *et al.* 2011), estimates of effective population size and possibly other population parameters, such as the mean generation interval as the age of sires and dams can also be linked to their UK flock and individual identification numbers. Similarly the multipliers for estimating populations calculated by Hall (2011), which were derived from pedigree registrations, could also be derived from UK flock and individual numbers. The number of herds/flocks in which breeding had occurred, which may also be a factor in determining whether a breed is at risk, could also be determined. However, additional data would be needed to allow estimates of other potential risks to livestock populations such as geographic concentration.

Such estimates could be made annually, allowing changes in effective population sizes to be tracked and providing the basis of the genetic indicator of farm livestock biodiversity proposed by Villanueva *et al.* (2010). Currently, this indicator is not easily understood by non-specialists (Defra, 2011) but if determined annually the trends could be reported, as suggested by the FAO workshop (FAO, 2010), and would be more easily understood. To ensure that reliable and repeatable indicators (rather than one-off statistics) are developed requires databases to be designed with suitable indicators in mind and *vice versa*.

4 COSTS OF IDENTIFICATION USING EAR TAGS

The European Commission's Directorate-General Joint Research Centre and the Institute for the Protection and Security of the Citizen published a report in 2007 on the costs of implementation of Regulation (EC) 21/2004 at the levels of individual farms and for member states, including an analysis of the benefits of EID (Fiore *et al.* 2007; available at http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/12752/1/reqno_jrc37122_cost%20analysis.pdf).

Although the values obtained from the model will have changed as a result of inflation, changes in the value of the Euro etc., they provide a useful starting point for assessing the costs of livestock identification and the conclusions of the study are reported below.

The analysis considered the costs which would occur to fulfil the minimum requirements of Regulation (EC) 21/2004 for identification and registration of animals at farm level. Additional costs, as well as benefits, e.g. the reading of EID at slaughterhouses or on farms, were quantified where possible. On the costs side the study assessed:

- Costs at flock level with average EU labour costs taking into account a possible derogation for slaughter lambs (i.e. that a single conventional ear tag showing only a flock number would be required for lambs destined for slaughter); it was assumed that 60% of the flock would be identified by slaughter tags only.
- Costs at flock and member state level using average labour costs and the holding structure in the member states.

On the benefits side the study assessed benefits along the production chain. Here just the cost/benefit figures for the EU average (for the 25 member states in 2007) and the UK are presented (Table 2; N.B. costs in the Table are shown in Euros (€) as in the original source; on February 12th 2013 the exchange rate was €1 = £0.86 which is used for equivalents used in the text).

The UK costs were a little (4-13% depending on identification method) greater than the EU average, reflecting higher labour costs. Identification of slaughter lambs requiring only a single tag bearing the holding number was, not surprisingly, least expensive (€0.33 (£0.28) in the UK). The initial identification using an electronic ruminal bolus and conventional ear tag was most expensive (€2.34 (£2.01) in the UK) but re-tagging was less expensive than re-tagging with one electronic and one conventional ear tag (Table 2). In the UK initial tagging with one electronic and one conventional ear tag was 69% more costly than identification by means of two conventional ear tags.

Table 2. Estimated costs per animal (€) for various means of identification allowing for differences in labour costs and average flock size in the UK compared to the 25 Member States of the EU in 2007 (Fiore *et al.* 2007).

	Electronic Ruminal Bolus + Conventional Ear Tag		Electronic Ear Tag + Conventional Ear Tag		Holding Tag	Two Conventional Ear Tags	
	Tagging	Re-tagging	Tagging	Re-tagging		Tagging	Re-tagging
UK	2.34	1.71	1.88	2.64	0.33	1.11	1.64
EU Average	2.25	1.59	1.80	2.52	0.29	1.03	1.52

However, electronic identification reduces the costs for reading of the identifiers due to the saving of time when using an electronic reading device; the greater the labour costs in the Member State the larger the saving from EID. Fiore *et al.* (2007) estimated the (labour) cost of reading a conventional ear tag as €0.17 (£0.15) per head. In comparison, for a large flock of 1000 animals with one reading per year, the cost of reading an electronic identifier was €0.10 and €0.38 (£0.09 and £0.33) per head using a handheld reader and a static reader respectively. When the same equipment is used to read the flock ten times a year, costs would drop to €0.04 and €0.06 (£0.03 and £0.05) per head, respectively.

EID combined with computerised systems such as electronic flock registers or flock management systems could bring additional time savings: Fiore *et al.* (2007) estimated that for larger flocks (>500 breeding sheep) EID would bring immediate cost savings compared to conventional identification, reading and data handling. For flocks of 50-100 breeding sheep where the flock needed frequent recording (e.g. milking flocks) the higher costs for the electronic devices would be compensated by labour cost savings, but this would take many years for most small flocks. For such flocks Fiore *et al.* (2007) suggest that farmers could share reading equipment to reduce the costs of purchase, but there is no assessment of the additional time and travel costs this would incur.

For livestock markets, abattoirs etc., EID reduced reading costs considerably: depending on the throughput of the establishment the per-head EID reading costs were estimated by Fiore *et al.* (2007) to be between €0.02 and €0.13 (£0.02-0.11) compared to €0.50 (£0.43) for reading conventional ear tags. Fiore *et al.* (2007) conclude that individual identification cannot be achieved without electronic identification because of the requirement for a 15 digit identifier imposed by Regulation (EC) 21/2004. Reading large numbers of such identifiers, whether on-farm or at markets, abattoirs etc. demands EID and automated readers. The derogation for single, conventional slaughter tags would bring savings for the holding of birth, but would impose additional costs on markets, abattoirs etc., as not only would they not have the benefit of using automated readers but also they would need to record EID and non-EID animals separately. Fiore *et al.* (2007) suggest that Member States which opt for this derogation would derive only partial advantage of EID regarding official controls, traceability, farm management and consumer information.

As noted above the GB has opted for the derogation, although official guidance to farmers warns of the problems conventional slaughter tags may pose for markets, abattoirs etc. and that

some such facilities may refuse non-EID animals. GB has also opted for the derogation to enable reading of EID tags to be carried out at Central Recording Points i.e. option C of Fiore *et al.* (2007), which significantly reduced implementation costs. It should also be noted that for Scotland and Northern Ireland all sheep, regardless of whether they are slaughter animals, must be electronically identified (see Section 2.1).

4.1 Approved Suppliers and Current Prices for Identification Tags

A list of approved suppliers of ear tags and other means of identification is available on the Rural Payments Agency website: http://rpa.defra.gov.uk/rpa/index.nsf/vContentByTaxonomy/BCMS**Tagging**Sheep%20&%20Goat%20Tagging%20-%20Sheep%20&%20Goat%20ETAS**Approved%20Official%20EID%20Tags**?OpenDocument for sheep and http://rpa.defra.gov.uk/rpa/index.nsf/UIMenu/95E58D9D5D9C0B7E80256F85004737E1 for cattle.

These suppliers have been contacted and current costs of their products collated; these are summarized in Table 3. Additional costs such as application pliers (which are frequently supplied free of charge with orders for tags), VAT and postage are not included in the prices listed in Table 3. There are also many variations in cost depending on size of order, combinations of primary and secondary tags etc. which are not included in Table 3. Detailed costs of replacement tags are not included but single replacement cattle tags, which are produced on a 'one-off' basis, are generally the same price as a single pair of new tags (i.e. with no reduction for bulk purchase). For sheep multiple replacement tags can be purchased; the price of a replacement pair is generally similar to that for a pair of new tags and there are the usual reductions for bulk purchases. Ruminal boluses are not considered in detail as more than 98% of sheep in the UK are identified using tags (Moxey and Walls, 2012).

Table 3. Suppliers of Defra-approved identification tags with costs of their products as at 18th December 2012. All prices ex-VAT and excluding postage etc.; where prices vary with numbers purchased prices shown are minimum price per tag.

Name of Supplier	Contact Details	Products	Species	Price (£)	Notes
Allflex Europe UK Ltd	Unit 6-8 Galalaw Business Park Hawick United Kingdom TD9 8PZ T: 01450 364 120 F: 01450 364 121 www.allflex.co.uk	Ultra Senior Primary+Secondary Ultra Senior Primary+ EID Button Secondary Visual button Bubblegum EID + Visual Babe EID + Visual Button EID + Visual Slaughter Tag	Cattle Cattle Cattle Sheep Sheep Sheep Sheep	1.40 2.10 1.09 0.75 0.85 0.90 0.10	Many tag combinations; prices from £0.99 for non-EID and from £2.10 for combinations with one EID for cattle. (N.B. EID for management purposes e.g. dairy cattle, calf feeding)
Channel Livestock Ltd.	Rothwell Kettering Northants NN14 6HR				No response.

	T: 01536 711883 F: 01933 701808 channel.livestock@yahoo.co.uk				
CountrySide Services Ltd	97 Moy Road Dungannon BT71 7HA T: 028 8778 9770 F: 028 8778 8200 info@countrysideservices.com www.countrysideservices.com	Duflex Pair Duflex Large + Button or Metal EID Foldover & Visual EID Slaughter Tag Slaughter Tag	Cattle Cattle Sheep Sheep Sheep	1.30 0.99 0.80 0.75 0.20	Large or Medium
Cox Agri	1 Greencroft Ind Park Stanley Co Durham DH9 7YA T: 0845 6008081 F: 0845 7836655 eid@coxagri.com www.coxagri.com				Do not supply direct to farmers; prices depend on retailer
Dalton ID Systems Ltd	Dalton House, Newtown Road, Henley-on-Thames Oxon RG9 1HG T: 0800 838 882 F: 01491 419 001 info@dalton.co.uk www.dalton.co.uk	Large or Medium Supertag Primary Tag Button or Daisy Secondary Tag I-Flex Large or Small Button EID Rototag Visual Tagomatic Visual Suretag ST1 Button or ST2 Flag Visual I-Tag Flag or Button + Button EID Pair I-Rototag EID + Rototag Visual I-Rototag Slaughter EID Metal Double Hog Combo Jumbo I-Tag EID	Cattle Cattle Cattle Cattle Sheep Sheep Sheep Sheep Sheep Sheep Pig Pig Pig Pig	1.05 0.85 0.95 2.00 0.16 0.12 0.25 0.90 0.65 0.55 0.38 0.55 0.20 1.60	Many other tag combinations; prices £1.20-1.60 for non-EID and £2.40-£2.70 for combinations with one EID. (N.B. EID for management purposes e.g. dairy cattle, calf feeding)
Datamars SA	via ai Prati CH-6930 Bdeano-Lugano Switzerland www.datamars.com				No response received
Denimex	Northdown Business Park Ashford Road Lenham	Large primary + large secondary Large primary +	Cattle	1.55	Other tag combinations available

	Kent ME17 2DL T: 01622 850057 F: 01622 850097 info@denimex.co.uk www.denimex.co.uk	medium secondary Large primary + button secondary Dentax or Denimex Visual Deniflex Visual EID Slaughter Tag EID+non-EID pairs Denimex Button Denimex Metal	Cattle Cattle Sheep Sheep Sheep Sheep Pig Pig	1.50 1.20 0.12 0.16 0.75 0.85 0.89 0.36	
Fearing International	Creaton Road Brixworth Northampton NN6 9BW T: 0845 600 90 70 F: 0800 581 606 sales@fearing.co.uk www.fearing.co.uk	Large primary flag + button or metal secondary Large primary flag + large or medium flag secondary Large primary flag + EID secondary RD2000 EID + non-EID pair Button R EID + non-EID pair Button R EID + MFR non EID pair Button R EID + MFL non EID pair Slaughter EID Tag Slaughter visual Tag Primaflex Medium Multiflex U Multiflex R Multiflex P Metal	Cattle Cattle Cattle Sheep Sheep Sheep Sheep Sheep Pig Pig Pig Pig Pig	1.39 1.69 2.69 1.30 1.37 1.33 1.35 0.67 0.12 0.69 0.55 0.23 0.36 0.54	Prices are dependent on number of tags ordered; minimum prices shown are for 100+ cattle tags, 1000+ sheep tags and 50+ pig tags. Pig tags printed on one side. Many other combinations and types of tags available (N.B. EID for management purposes e.g. dairy cattle, calf feeding)
Identics	Plasparciau Meidrim Road St. Clears Carmarthen SA33 4DW T: 01994 342100 info@identics.co.uk www.identics.co.uk	ID1 / ID2 Flag or Button Tag + EID Button Tag Clust 1 or 2 Visual Clust 3 Visual	Cattle Sheep Sheep Sheep	0.50 1.25 0.15 0.18	
Ketchum Manufacturing Company Ltd	White Lodge Tadworth Street Tadworth Surrey KT20 3RE T: 01737 812218 F: 01737 814372 enquiries@ketchums.co.uk	Plastic Primary & Secondary Tamp No. 2 K Tag + Tamp No.2 K Tag Secondary Track Tag EID Tag	Cattle Cattle Cattle Cattle Sheep Sheep	1.00 0.30 1.15 0.25 0.16 0.72	

	www.ketchums.co.uk	EID + Track Pair	Sheep	0.84	
Nordic Star Ltd	NMR Building Skipton Road Harrogate North Yorkshire HG1 4LG T: 0800 731 9465 F: 01423 851390 sales@nordicstar.co.uk www.nordicstar.co.uk	Large Flag Primary + Medium Flag pair Large Flag Primary + Button Tag Pair Large Flag Primary + EID Button Foldover EID + Visual Button EID + Visual Slaughter Tag	Cattle Cattle Cattle Sheep Sheep Sheep	1.20 0.99 2.10 0.84 1.35 0.15	Many other combinations and types of tags available
PTS Technologies Pte Ltd	Blk 2 Kaki Bukit Ave 1 #04-05 Singapore 417938 T:+65 67494474 F:+65 67494414 rfid@ptstechnologies.com www.ptstechnologies.com				Do not supply direct to farmers; products sold through other approved suppliers (Symtag, Denimex, Ketchum, Countryside Services, Stocktrace and Tenbury Farm Supplies).
QuickTag	7a Churchfield Road Ballycastle Co Antrim Bt54 6PJ T: 028 20768696 F: 028 20768699 info@quicktag.co.uk www.quicktag.co.uk	EID Button Tag Sheep Tagfaster EID Tagfast Senior EID			Do not supply direct to farmers; prices depend on retailer
Ritchey	Masham Ripon North Yorkshire HG4 4ES T: 01765 689541 F: 01765 689851 info@ritchey.co.uk www.ritchey.co.uk	Dalesman Large Dalesman Medium Dalesman Button FlexoPlus Flag FlexoPlus Button FlexoPlus Flag + Button pair EID Tag Autotaggs EID Autotaggs Visual Button EID Button Visual RD2000 EID RD2000 Visual Snapp EID Snapp Visual	Cattle Cattle Cattle Cattle Cattle Cattle Cattle Sheep Sheep Sheep Sheep Sheep Sheep Sheep Sheep	1.12 0.92 0.75 1.95 0.55 2.35 3.35 0.87 0.15 1.15 0.24 1.10 0.28 0.77 0.16	Various other tags and combinations available.
Roxan ID	Beechwood Philiphaugh	Newflex Large or Medium	Cattle	0.75	

	Selkirk Scotland TD7 5LU T: 01750 22940 www.roxan.co.uk	Tagfaster Visual Tagfast Senior EID + Visual Pair Tagfaster Slaughter EID Rubba Double EID & Visual Pair	Sheep Sheep Sheep Sheep	0.16 0.99 0.84 0.99	
Shearwell Data Ltd.	Putham Farm Wheddon Cross Minehead Somerset TA24 7AS T: 01643 841611 F: 01643 841628 sales@shearwell.co.uk www.shearwell.co.uk	Primary /Large secondary Small secondary EID Visual SET Visual/EID SET Tag Pair Slaughter Tag Flag + Printing Button + Printing	Cattle Cattle Sheep Sheep Sheep Pig Pig	1.09 0.89 2.00 0.09 0.79 0.64 0.39 0.44	Many available combinations of tags at various prices. SET Tags can also be supplied in cartridges for use in an 'automatic' applicator at extra cost
Stocktrace PLC	Unit 11b Ash Court Llys Onnen Ford Y Lyn Parc Menai Bangor LL57 4DF T: 01248 675950 F: 01248 670621 info@stocktrace.co.uk www.stocktrace.co.uk	Primary + Button Secondary EID Tag Visual Tag EID Tag + Visual Tag pair	Cattle Sheep Sheep Sheep	1.10 0.71 0.15 0.83	Prices depend on tag number (1-49 £1.15; 50-99 £1.10; 100+ £1.05)
Symtag	Unit 9 Mendip Business Park Mendip Road Rooksbridge Axbridge Somerset BS26 2UG T: 01934 750410 F: 01934 750404 info@symtag.co.uk www.symtag.co.uk	Large primary + plastic button or Ketchum metal secondary EID Loop Tag Visual Loop Tag EID Loop Tag + Flag Visual Tag	Cattle Sheep Sheep Sheep	1.10 0.72 0.12 0.99	Prices depend on tag number (1-49 £1.15; 50-99 £1.10; 100+ £1.05)
Tenbury Farm Supplies	Swan Garage Tenbury Wells Worcs WR15 8AR T: 01584 810150 F: 01584 811817 tenburyfarmsupplies@yahoo.co.uk	Large flag tag pair EID + Visual pair	Cattle Sheep	1.32 0.79	

4.1.1 Tissue Sampling Tags

Some suppliers (e.g. Fearing, Identics, Nordic Star, Ritchey, Shearwell) offer tissue sampling tags which can be used for DNA analysis or disease testing e.g. Bovine Viral Diarrhoea (BVD); testing new-born calves for BVD allows 'Persistently Infected' animals (which are infected *in utero* or shortly after birth) to be identified at an early stage and culled as part of a BVD management programme. A useful guide can be found at http://www.nordicstar.co.uk/index.php?option=com_content&view=article&id=108:bvd-tag-and-test-faqs&catid=25:animal-tagging-solutions&Itemid=177.

Identics, Shearwell and Ritchey tissue sampling tags for cattle cost £1.40, £1.95 and £2.49 per tag respectively. Identics and Ritchey's tissue sample test charges are £3.60 and £3.50 respectively. Fearing tissue sampling tag with the BVD testing plus a secondary tag start at £5.99 (price depending on number of tags ordered). These tags are not considered further.

4.2 Costs of Identification Tagging to Farmers

In choosing tags farmers will take account of factors other than cost, such as previous personal experience of, or information on, retention rates, ease of reading, ease of application, size of herd/flock and the availability of suitable application pliers (where these are not offered free of charge with an order of tags). However, these factors will vary between individuals and cost is likely to be a significant consideration when choosing which tags to purchase.

From Table 3 the ranges for cattle tags are: single primary £0.30-£1.09, single secondary £0.25-£0.89, pair of primary and secondary £0.99-£2.35, single EID £2.00-£3.35 and a pair including an EID tag £2.10-£2.69. There are too many variations in pricing structure depending on numbers purchased and combinations to determine a mean value (which could also be out of date within days), but reasonable estimates would be £1.25 for a pair of non-EID tags and £2.25 for a pair including an EID secondary.

For sheep single visual tags (including slaughter tags) the range is £0.09-£0.28, for single EID (again including slaughter tags) £0.55-£1.10 and for a pair (one EID, one visual) £0.65-£1.37. These ranges are considerable with the most expensive option at least double the cheapest. For the same reasons as for cattle tags, determining a true mean value is difficult but a reasonable estimate would be £0.15 for a single visual tag, £0.75 for a single EID and £1.00 for an EID/visual pair. For goats, for which EID is not required in the UK (provided they are not to be exported), the cost of tags would be similar to that of a pair of non-EID tags for sheep i.e. £0.18-£0.56.

Fewer tags are offered for pigs, probably reflecting the alternative identification methods described above (e.g. slap marks) and only Dalton appeared to offer an EID tag for pigs (at £1.60). Plastic management tags varied from £0.20 to £0.89 and metal tags from £0.36 to £0.54. Most pig farmers, if using tags at all, might consider £0.50 per pig a reasonable cost.

Using these 'reasonable estimates' of tag costs it is possible to estimate the total cost of tagging livestock in the UK and in its constituent countries (Table 4). These estimates consider only purchasing costs; the time needed to tag an animal may add considerably to these estimates. Data for livestock numbers in Table 4 were taken from the joint announcement by Defra and the agricultural departments of the devolved administrations *Farming Statistics – Livestock*

Populations at 1 December 2011 UK and England and the links within that document, which is available at:
http://www.defra.gov.uk/statistics/files/defra-stats-foodfarm-landuselivestock-farmstats-dec11-120308.pdf

The links within the document are:
http://wales.gov.uk/topics/statistics/headlines/agriculture2012/?lang=en
http://www.scotland.gov.uk/Topics/Statistics/Browse/Agriculture-Fisheries/PubFinalResulsDecCensus
http://www.dardni.gov.uk/agricultural-survey-december-2011-23-february-2012.pdf

These data are for the livestock populations estimated from the December 2011 Surveys of Agriculture conducted by each of the four agriculture departments and were the most recent data readily available. (N.B. the data from the December 2012 Surveys of Agriculture have become available since this report has been in preparation; however, the Welsh data were not available on-line (2nd April 2013) so the December 2011 data have been used). Various simplifying assumptions were made in compiling Table 4:

- Tag prices have not changed throughout the life of the animals alive at the time of the December 2011 agricultural surveys.
- The tagging requirements have not changed throughout the life of the animals alive at the time of the December 2011 agricultural surveys.
- Beef cows and all male cattle would be double tagged without EID at a cost of £1.25 each.
- Dairy cows would be double tagged with one EID to facilitate dairy management at a cost of £2.25 each.
- Breeding sheep would be double tagged with one EID and one visual tag (legal requirement) at a cost of £1.00 per pair of tags.
- In England and Wales 66% of non-breeding sheep would be single tagged with a non-EID slaughter tag at a cost of £0.15 each and 34% would be single tagged with an EID slaughter tag at a cost of £0.75 (proportions supplied by Defra).
- In Scotland non-breeding sheep would be single tagged with an EID slaughter tag (legal requirement) at a cost of £0.75 and in Northern Ireland, which does not operate the derogation for sheep destined for slaughter, tagging costs would be £1.00 per sheep.
- All pigs are tagged at a cost of £0.50 each. (N.B. this is likely to be an over-estimate of costs as most pigs are not tagged, and alternative means of identification are likely to be cheaper).
- No tags are wasted as a result of failure during insertion; this is clearly not the case, leading to an under-estimation of the total costs, but the extent of the problem varies with tag design, age and breed of animal and competence of the operator.

On the basis of these assumptions the data in Table 4 suggest that the UK livestock industry (excluding goats and equines; see Sections 4.4 and 4.5) has incurred a total cost of over £36 million in tag purchase costs. Note that this is for the total population of each of the three species alive on 1st December 2011, not an annual cost (see below). Of the total 43% was for tagging of cattle, 51% for tagging of sheep and 6% for tagging of pigs. By country, 51% of the tag purchase cost was incurred by England, 19% by Scotland, 18% by Wales and 11% by Northern Ireland. Although not shown in Table 4 the total cost for the UK would be increased by more than £500,000 if the *c.* 2% of sheep identified by ruminal bolus were accounted: a ruminal bolus costs £2.61 and a black ear tag £0.19 i.e. £2.80 per sheep (Moxey and Walls, 2012)

compared to the £1.00 per breeding sheep (for which boluses are most commonly used) in the estimates in Table 4.

4.3 Annual Costs of Identification Tagging to Farmers and to the Farming Industry

The 2003 National Audit Office report *Identifying and Tracking Livestock in England* stated that 'identifying the 25 million cattle, sheep and pigs in England and tracking their movements costs government and the livestock industry around £55 million a year - just over £2 an animal'. However, the report precedes the introduction of EID and even compulsory double tagging of sheep and goats. Even so, the estimated costs to keepers of identification by all methods then current, and including maintaining records, was put at £25 million, which is consistent with the estimate for England above allowing for decreases in livestock numbers and the cost of keeping records, which is not included in the estimates in Table 4.

Annual costs of tag purchase can be estimated by considering the number of animals less than 1 year of age in the Surveys of Agriculture. These are shown in Table 5; however, there are variations in the classes of data compiled by the various agricultural departments. For example, Scotland records non-breeding pigs in five weight classes, Northern Ireland has four weight classes but includes also cull sows and boars, whereas in England all non-breeding pigs (including barren sows) are classed as fattening pigs. In England, calves are subdivided as being born into beef or dairy herds; Scotland records male and female calves but does not differentiate between dairy and beef herds and the data for Wales have a single category of calves less than 12 months. For the purposes of estimation it is assumed that:

- Calves are equally derived from beef and dairy herds
- Equal numbers of male and female calves are born and tagged
- Beef calves and male dairy calves (i.e. 75% of all calves) would be double tagged without EID at a cost of £1.25 each
- Female dairy calves (25% of all calves) would be double tagged with one EID to facilitate dairy management at a cost of £2.25 each
- 48% of lambs will be retained for breeding or as store lambs that will be slaughtered at >12 months of age and therefore double tagged with one EID (legal requirement) at a cost of £1.00 each (the assumption of the proportion of lambs reaching 12 months of age is based on the figures in Defra, 2009b).
- 52% of lambs would be slaughtered before 12 months of age; of these in England and Wales 66% would be single tagged with a non-EID slaughter tag at a cost of £0.15 each and 34% would be single tagged with an EID slaughter tag at a cost of £0.75 each (percentages of EID and non-EID tagged supplied by Defra). In Northern Ireland where the slaughter derogation does not apply, all lambs are tagged at a cost of £1.00 each. In Scotland all non-breeding sheep are identified by an EID slaughter tag at a cost of £0.75.
- All pigs are tagged at a cost of £0.50 each. (N.B. this is likely to be an over-estimate of costs as most pigs are not tagged, especially those destined for slaughter).

Table 4. Estimated costs of purchase of identification tags for the UK livestock industry (excluding equines, goats and poultry). See text for sources of data and assumptions. Numbers are in thousands, rounded to nearest thousand. Costs are in thousands of pounds, rounded to nearest thousand pounds. F = females. UK numbers are taken from original data sources and may differ from sum of sub-population totals through rounding errors; UK costs are computed on a *pro-rata* basis for individual country tagging regimes.

Species	Sub-population	England		Scotland		Wales		Northern Ireland		United Kingdom	
		Number	Cost (£)	Number	Cost (£)	Number	Cost (£)	Number	Cost (£)	Number	Cost (£)
Cattle	Beef F	1812	2265	808[1]	1010	457[1]	571	547[1]	684	3550[2]	4438
	Dairy F	2038	4586	444[1]	999	499[1]	1123	589[1]	1325	3510[2]	7898
	Males	1427	1784	479	599	131	164	432	540	2614	3268
	Total	**5275**	**8635**	**1732**	**2608**	**1087**	**1858**	**1567**	**2549**	**9675**	**15604**
Sheep	Breeding	6384	6384	2878	2878	4090	4090	956	956	14208	14208
	Others	3858	1366	1587	1190	1682	595	349	349	7743	4616
	Total	**10242**	**7750**	**4465**	**4068**	**5772**	**4685**	**1305**	**1305**	**21951**	**18824**
Pigs	Breeding F	337	169	32	16	3	2	38	19	409	205
	Breeding Others	78	39	6	3	1	1	5	3	90	45
	Fattening	3074	1537	329	165	22	11	395	198	3827	1914
	Total	**3489**	**1745**	**368**	**184**	**26**	**14**	**437**	**219**	**4326**	**2163**
TOTAL COSTS			**18130**		**6860**		**6557**		**4073**		**36591**

[1] Includes non-breeding females for which beef/dairy is not specified, allocated in proportion to numbers in designated beef/dairy herds.

[2] Female cattle under one year of age are not separated into beef and dairy herds; values shown allocate 761 female calves to the beef herd and 760 to the dairy herd.

Table 5. Estimated annual costs of purchase of identification tags for the UK livestock industry (excluding equines, goats and poultry). See text for sources of data and assumptions. Numbers are in thousands, rounded to nearest thousand and are for animals less than one year of age except for pigs where numbers are for fattening pigs and all piglets. Costs are in thousands of pounds, rounded to nearest thousand pounds. Total numbers are taken from original data sources and may differ from sum of sub-population totals through rounding errors; UK costs are computed on a *pro-rata* basis for individual country tagging regimes.

Species	England		Scotland		Wales		Northern Ireland		United Kingdom	
	Number	Cost (£)	Number	Cost (£)	Number	Cost (£)	Number	Cost (£)	Number	Cost (£)
Cattle	1550	2325	523	785	316	474	462	693	2857	4286
Sheep	3858[1]	2562	1568	1364	1587	1054	328	328	7743[1]	5033
Pigs	3074[2]	1537	329	165	22	11	395[3]	198	3827[2]	1914
TOTAL COSTS		**6424**		**2314**		**1539**		**1219**		**11233**

[1] Includes 'other' sheep
[2] Includes barren sows
[3] Includes cull sows and boars

Table 6. Numbers and estimated costs of tags for Great Britain using data from the Ear Tag Allocation System. Full EID and Batch EID tags are costed at £0.75 each and Visual and Non-EID Batch tags are costed at £0.15 each. Visual tag numbers do not include an estimated 38,000 tags used for goats in the UK.

Year	Country	Full EID		Visual*		Batch EID		Non-EID Batch		Total Number	Total Cost (£)
		Number	Cost (£)	Number	Cost (£)	Number	Cost (£)	Number	Cost (£)		
2011	England	2,340,777	1,755,583	2,340,777	351,117	2,039,458	1,529,594	3,892,012	583,802	10,613,024	4,220,096
	Wales	1,341,696	1,006,272	1,341,696	201,254	623,830	467,873	3,008,033	451,205	6,315,255	2,126,604
	Scotland	1,348,254	1,011,191	1,348,254	202,238	2,378,746	1,784,060	3,270	491	5,078,524	2,997,980
	GB Total	5,030,727	3,773,045	5,030,727	754,609	5,042,034	3,781,526	6,903,315	1,035,497	22,006,803	9,344,677
2012	England	2,689,387	2,017,040	2,689,387	403,408	2,025,877	1,519,408	4,501,914	675,287	11,906,565	4,615,143
	Wales	1,285,632	964,224	1,285,632	192,845	455,862	341,897	3,259,993	488,999	6,287,119	1,987,965
	Scotland	1,187,768	890,826	1,187,768	178,165	2,491,506	1,868,630	2,800	420	4,869,842	2,938,041
	GB Total	5,162,787	3,872,090	5,162,787	774,418	4,973,245	3,729,934	7,764,707	1,164,706	23,063,526	9,541,149

* Visual tags are not recorded separately by the Ear Tag Allocation System but are assumed to be issued in the same number as Full EID tags.

On this basis the annual costs of tag purchase is estimated to be over £11 million. Between species, 38% of the costs are for cattle, 45% for sheep and 17% for pigs. The annual cost to the English farming industry is estimated to be £6.4 million (56% of UK total), to the Scottish farming industry £2.3 million (20%), to the Welsh farming industry £1.5 million (13%) and to the Northern Ireland farming industry £1.2 million (11%). Based on the data in and assumptions for Tables 4 and 5, if the derogation for slaughter lambs operating in GB was to be discontinued, the additional cost to the UK farming industry would be approximately £3.8 million p.a.

Table 5 also allows estimates of the annual number of tags used. On the same assumptions as above for the use of single and double tags (with single tags for pigs) the total tags inserted in England would be 1000((1550x2) + (3858x0.52x1) + (3858x0.48x2) + (3074x1)) = 11,884,000. Similar calculations (allowing for differences in tagging regimes) yield estimates of 3,695,000 tags for Scotland, 3,003,000 tags for Wales, 1,975,000 tags for Northern Ireland and 21,171,000 tags for the UK. Table 5 does not include goats, for which an additional 38,000 visual tags may be required (see Section 4.4); adding these brings the total to 21,209,000 tags.

Another approach to estimating costs is to use records from the Ear Tag Allocation System (ETAS) for GB; the combined data for sheep and goat tags has been made available for this report. ETAS records the number of full EID, batch EID and batch non-EID tags issued each month. The number of each tag type allocated in 2011 and 2012 is shown in Table 6 for each country of the GB (ETAS does not issue tags for Northern Ireland). Visual tags are not recorded separately by ETAS but are assumed to be issued in the same number as full-EID tags (Defra supplied information). However, as goats do not need EID the estimated 38,000 visual tags used by goat keepers each year (see Section 4.4) would be additional.

For 2011 the total number of allocated tags in GB was 22,006,803. The ETAS data do not include Northern Ireland, where for sheep an estimated 656,000 tags were used (see above). Adding the Northern Ireland total to the ETAS total number of tags for GB brings the UK total to 22,662,803 in 2011. This is more than double the estimate (11,035,240) obtained by applying the assumptions for Table 5 listed above to the number of sheep less than 1 year of age in the UK in the December 2011 Surveys of Agriculture. The main cause of the discrepancy between the ETAS data and the estimates derived from Tables 4 and 5 is likely to be the number of tags used for lambs that have already been slaughtered by December. Slaughter statistics can be obtained from the Defra website (http://www.defra.gov.uk/statistics/foodfarm/food/slaughter/); this shows that in 2011 10,709,000 sheep and lambs were slaughtered in the UK. Many of these would bear single slaughter tags, but a proportion (older sheep, those from Northern Ireland etc.) would have two tags.

The ETAS data do not allow the number of tags used in that year to be determined (most farmers are likely to order more tags than are needed immediately, both to save time and to benefit from the reduced price per tag for larger orders), However, in 2011 and 2012 there may have been some over-ordered tags remaining from previous years. In addition, allocated tags (and the estimates from numbers of livestock) do not equate to tags ‘used’ due to failures during the insertion process, leading to discarding of a small proportion of tags. In addition there would be a relatively small number of replacements for lost tags amongst the total allocated.

It is possible to use the mean number of allocated tags per year to estimate the total used (including discarded insertion failures), but presently there are only three years’ data for the current identification regime, which reduces the accuracy of the estimate. However, Table 6 shows the number of tags allocated for each of 2011 and 2012 and the total for 2010 was 25,161,050 for GB (ETAS data supplied by Defra); the mean for those three years is 23,410,460

tags. The estimated cost on the basis of EID tags costing £0.75 each and non-EID tags costing £0.15 each is also shown in Table 6. On this estimate the mean annual costs of allocated sheep and goat tags is *c.* £9.43 million for 2011 and 2012. Adding the £328,000 estimate for tagging sheep in Northern Ireland in 2011 (Table 5) brings the UK total for 2011 to *c.* £9.7 million for sheep and goats alone. This compares to the rather more conservative estimate of costs in Table 5 (*c.* £11.2 million for cattle, sheep and pigs).

Prior to sheep EID implementation Defra (2009c) conducted a cost-benefit analysis that compared the previous identification and movement regulation with the (then) proposed introduction of full EID for sheep. This analysis showed that the sheep industry in England would incur a cost of £44.25 million or £34.43 million if there was no mandatory reading of EID before insertion (as became the case). Extrapolating the results for England to the UK suggested that the UK sheep industry would incur a cost of £90.12 million, equivalent to £3.24 per ewe. Perhaps of greater concern was the proportion of the average income of sheep farms (as at 2006) that the costs of implementation imposed: for upland sheep farms the estimated cost of £2383 represented *c*. 18% of the average farm income, and for lowland farms the proportion was even greater at *c.* 30% (estimated cost £1621, average lowland farm income £5400). Overall the implementation of EID was expected to cost the UK an additional £76.67 million, of which 96% would be borne by sheep keepers, compared to the previous identification regime. On the benefit side there was an estimated maximum 15% reduction in disease control costs, provided all data were transferred electronically (Defra, 2009c).

Unfortunately the direct links from the Defra (2009c) document to the appendices that detail the financial benefits are no longer effective. However, there are two reports by Risk Solutions from 2006 and 2008 which modelled the reduction in the cost of disease outbreaks under various identification options and with or without other disease reduction actions such as the six day standstill. The modelling suggested that 'batch' sheep identification alone (which was the system in place prior to individual identification) reduced overall outbreak costs (£674 million in the model) by 5-9%; this rose to 17-23% (i.e. a saving of £55 million) when combined with the six day standstill. Replacing the batch identification system with EID for all sheep or EID for breeding sheep and batch identification of lambs for slaughter (the system eventually adopted in England and Wales) produced a maximum saving of £7.9 million in the models (Risk Solutions, 2006). Thus 85% of the benefit could be derived from batch identification and the six day standstill (which is consistent with, and may be the basis of, the 15% reduction in costs stated in Defra (2009c)).

In the 2008 update (Risk Solutions, 2008) the models showed that a combination of the six day standstill and any one of the sheep identification regimes considered would reduce the mean cost of outbreaks by 16-27%, with EID contributing 3-13% of the total cost savings, when compared to the same outbreak scenario under the 2001 movement regime. Cost savings ranged from £65-92 million, but of this full-EID contributed a maximum of £14.8 million, and the system eventually adopted in England and Wales (i.e. with a derogation from EID for slaughter lambs) contributed <£2 million. It should also be remembered that these cost savings are only achieved in the event of a disease outbreak, whereas the costs are borne continually. In Defra (2009b) the savings in the event of an outbreak were assumed to be £66 million with an average interval between major disease outbreaks of 30 years, giving a saving to the Government of *c*. £2 million p.a. Offset against this annual savings are enforcement costs of £300,000 (Defra, 2009b).

The project co-ordinator report for a pilot study of EID in the Scottish flock prior to the introduction of compulsory EID (SAOS, 2009) estimated the additional annual costs of EID

introduction to the Scottish sheep industry to be £7.7 million without a slaughter lamb derogation or £6.4 million if the derogation was adopted. The benefits depended on the frequency and severity of disease outbreaks leading to the conclusion '*The main potential benefit identified for EID is improved traceability of sheep, leading to an enhanced ability to combat infectious diseases such as Foot and Mouth (FMD). However, the magnitude of expected savings achieved by avoiding disease costs depends not only on the effectiveness of EID and of enhanced traceability, but also on the expected frequency and severity of disease outbreaks. Given the estimated annual costs of EID, a positive net benefit requires a relatively pessimistic and/or risk averse view on future outbreaks*.'

In addition to the derogation for sheep and goats intended for slaughter, Defra successfully negotiated a further change to the EU regulation to allow 'Central Point Recording Centres' (also known as 'Critical Control Points'). These are locations with appropriate readers, such as markets and abattoirs, which are allowed to read and record individual tag numbers on behalf of farmers. This was estimated to have saved the industry between £3 million and £7.7 million per year as farmers did not need to purchase their own readers and the Central Point Recording Centres reduced individual record keeping (Defra, 2009b). The Phase II report of the pilot study of EID in the Scottish flock (SAOS, 2011) emphasised the value of Critical Control Points: '*Many non-farm partners have registered as "Critical Control Points" (CCPs) offering third-party reading to reduce the capital costs of EID to farmers. In many cases, CCPs are reporting in real-time, updating the central database as sheep move. Relative to the previous paper-based systems, such real-time reporting coupled with faster tracing via interrogation of the central database offers potentially significantly enhanced traceability capabilities in the event of a disease outbreak.*'

The IDEA Project estimated the time to insert an ear tag in cattle as 3-10 minutes; it is unclear whether this included time for gathering the animals. For sheep and pigs the time may be less than the maximum for cattle, especially if inserted in young lambs or piglets; the study by SAOS (2009) gave a figure of 1 minute per sheep, but two people were needed. Using a 2-10 minute range for the UK equates to 705,700-3,528,500 hours of labour, which at Agricultural Wages Board minimum rates for a Grade 2 worker (£6.96 h^{-1}) http://www.defra.gov.uk/publications/files/awo12.pdf) equates to UK totals of £4,911,672-£24,558,360. Note that in the evaluation of cross compliance (ADAS *et al.,* 2009) the rate for labour employed to assess costs to farms was £16.23 h^{-1}, which would more than double the estimates of labour costs derived in this report.

On a per holding basis, using the number of beef, dairy, sheep and pig holdings in the UK reported in the final (2010) report of the England Advisory Group on Responsibility and Cost Sharing for Animal Health and Welfare (available at: http://www.defra.gov.uk/publications/files/pb13450-rcsag-report-101213.pdf) and the assumptions described above for Tables 4 and 5, the average figures in Table 7 are derived. These very approximate estimates suggest the annual costs vary from *c.* £55 for the average beef farm to *c.* £311 for a pig farm on which all animals are tagged. The ADAS report concluded that the additional costs for the 17% of farms making changes to meet cross compliance with animal identification SMRs were £81.15 in labour and £250.00 in other costs; the ADAS total per farm (£331.15) was then averaged across all farms to obtain a mean cost per farm of £56.00. However, those estimates were based on mid-points of the time class 0-10 hours and the other costs class of £0-500, which introduces considerable uncertainty to those estimates.

Table 7. Estimated mean annual costs for purchase and time for insertion of identification tags for UK agricultural holdings. Number of holdings taken from England Advisory Group on Responsibility and Cost Sharing for Animal Health and Welfare (2010); other data taken from Tables 4 and 5. Male cattle are allocated in proportion to number of dairy and beef cows.

Holding Type	Number of Holdings	Number of Tags per Holding	Purchase Cost (£) per Holding	Time for Insertion (h) @ 300s tag^{-1} per Holding	Labour Cost (@£6.96 h^{-1}) per Holding	Total Cost per Holding (£)
Dairy	26800	110	192.50	9.2	64.03	256.53
Beef	65900	30	37.50	2.5	17.40	54.90
Sheep	73900	105	51.45	8.8	61.25	112.70
Pig	13300	288	144.00	24.0	167.04	311.04

Prior to implementation of EID for sheep, the training needs for farmers and other stakeholders in the livestock industry were assessed (ADAS, 2009). Although most of the estimated expenditure has presumably now been made, the figures indicate another demand on Defra's and farmers' recent budgets. The ADAS study suggested that the costs of providing the required training would be £669,965 but that the cost in farmers' time would amount to £1,530,705. The latter figure assumed a half-day (4h) training session (which may be self-delivered) at an hourly rate of £10.16. Thus the total cost of training for EID implementation was estimated to be £2,200,670. An earlier analysis of the costs of EID implementation had estimated training costs to be £216,500, of which £17,500 was for farmers, £67,000 for markets and £132,000 for abattoirs.

In addition to these costs there is the cost to the government of compliance monitoring, administration, data management etc. It has not been possible to isolate these costs from broader headings such as the net operating costs (£307 million in 2008-9) of the RPA (which includes BCMS) or the £357 million spent on animal health in 2009-10 (England Advisory Group on Responsibility and Cost Sharing for Animal Health and Welfare, 2010). In 2002-3 the Cattle Tracing Service cost £28 million, but that preceded the wide use of the on-line reporting system (National Audit Office, 2003).

The final report of the England Advisory Group included a figure of £3.7 million for livestock identification, comprising administration (£1.5 million), sheep and goat identification implementation (£856,000), sheep and goat inspection (£725,000) and other (£622,000) including £249,000 for equine identification measures (England Advisory Group on Responsibility and Cost Sharing for Animal Health and Welfare, 2010). It is not clear whether the costs of BCMS are included in these figures. In addition, the Defra Exotic Disease Programme incurred costs of £8.6 million (from a total budget of £12.6 million) for Local Authority Trading Standards Departments for animal movement licensing. Thus the minimum cost to Defra is £12.3 million (£3.7 million + £8.6 million). This estimate is considerably greater than the figure cited in the ADAS *et al*. (2009) report for the RPA costs of cross compliance for the animal identification SMRs in 2007 (£5.098 million, of which £3.645 million was for inspection costs and £1.452 million for administration).

The devolved administrations will also incur costs for livestock identification and movements; it has not been possible to identify these costs, but assuming that costs incurred are proportional to the total livestock population it can be estimated that UK costs are *c*. £23.3 million.

4.4 Costs of Goat Identification

There were an estimated 95,000 goats in the UK in 2009 (Defra, 2009b), well below the 160,000 for which compulsory EID would be required by the EU. Assuming that 19,000 goats are born each year and applying the current regulations that each requires two (non-EID) tags at a cost of 30p per pair, the annual cost of tags for identifying the UK goat population would be £5,700. Assuming that two minutes per tag (four minutes per goat) and the £6.96 h^{-1} rate used above, labour costs would be £8,816 (excluding the labour costs of record keeping and movement licences), bringing the annual cost to £14,516.

4.5 Costs of Equine Identification

In addition to the three species of livestock considered in Tables 4-6 and goats considered in Section 4.4., but excluding exotic species, there are an estimated 1.3 million equines in the UK (England Advisory Group on Responsibility and Cost Sharing for Animal Health and Welfare, 2010), although before its closure the National Equine Database (NED) held records for 1.2 million live equines (Robin *et al.*, 2013). Prior to introduction of the requirement for micro-chipping, Defra published an impact assessment of the (then) proposed equine regulations which put the equine population at 1.35 million (Defra, 2009d). The majority of these will have been born before 1st July 2009 and hence will not have needed to be micro-chipped, provided that a passport had been issued by 30th June 2009.

From a superficial internet search the cost of micro-chipping an equine appears to vary considerably with £15-£35 cited on the Horse and Hound discussion forum (http://www.horseandhound.co.uk/forums/showthread.php?t=239569) in 2009. Elsewhere charges of £20-£25 are cited, but the veterinary surgeon usually also charges a call out charge, which may be £40-£50. In addition the horse owner is charged for a passport, which may be £20-£25 (e.g. the British Horse Society charges £25.00 for a single passport, but £16.00 each for 10+ applications submitted at the same time); completing the passport application may require a further visit from a veterinary surgeon.

Assuming that an owner obtains a passport application form in advance and can combine visits by the veterinary surgeon for the micro-chipping and passport completion, an average cost might be £22.50 for the microchip + £25.00 for the passport + £45.00 call out charge = £92.50. This may be a small element of the cost of keeping sport and leisure horses, but can be a highly significant cost in relation to the value of native ponies kept on fells and moors, many of which are classified as Native Breeds at Risk. The derogations for these ponies are therefore of considerable significance to the conservation of their genetic resources. Defra (2009d) estimated that the total savings of the derogations to be £348,850. Most of this (£284,750) was the saving from the ponies on the moors not needing identification; in addition 500 foals and 360 older ponies moved directly to slaughter from these semi-feral herds each year, representing a saving of £64,100 to the owners (Defra, 2009d). Thus although the slaughtered foals do not directly contribute to the genetic resources of their populations, the derogation makes the economics of keeping native ponies on the moors more favourable and hence aids the conservation of the live, *in situ* population.

Defra (2009d) stated that 65,000 passports are issued each year; since 1st July 2009 these 65,000 equines are required to have a microchip inserted, although some imported equines may already have a microchip. Defra (2009d) also stated that 50,000 foals are born each year in the

UK. Using this lower figure the annual cost to individual owners of identification is approximately £4.6 million (50,000 x £92.50).

Deducting the *c.* 200,000 foals born since July 2009 from the UK total of 1.30 million equines yields an estimated 1.1 million equines that needed a passport but not micro-chipping. Using a passport cost of £25.00 the total cost for these older equines would be £2.75 million. For the four years in which both passport and micro-chip have been needed the total would be £18.4 million (4 x £4.6 million). Thus the total cost of equine identification in the UK may be of the order of £21 million. In addition, the government paid the set up and running costs of the National Equine Database (NED) from 2006 until it was discontinued in 2012. Efforts to determine the net costs incurred for NED have been unsuccessful. Defra (2009d) estimates costs to the UK governments of monitoring and enforcement to be £30,000 p.a.

Set against these costs are the value of the benefits. Defra (2009d) identified the following benefits (with economic estimates where possible – see Defra (2009d) for assumptions):

- Protection of the human food chain from veterinary substances such as phenylbutazone (bute)
- Improved equine identification systems in the event of a disease outbreak
- Avoidance of EU fines for non-compliance
- Avoidance of EU sanctions banning the export of horsemeat from the UK (4200 horses slaughtered in the UK for human consumption each year; 1473 tonnes of horsemeat exported to the EU in 2007, with an estimated value of £2.5 million. A ban on export would cause a loss of £600 per horse to the owners (carcass value £400 + alternative disposal £200). Thus total loss to UK owners could be 4200 x £600 = £2.5 million).
- Avoidance of additional costs of more expensive veterinary products to replace phenylbutazone (estimated to be £2.3 million).
- Inability to implement the derogation for semi-feral foals.

Thus the net benefit range was estimated to be £1.66-2.29 million p.a. (Defra, 2009d).

4.6 Projected Future Costs of Electronic Identification

The EU is considering the introduction of electronic identification for cattle (Gurnhill, *pers. comm.,* April 2013). The Food Chain Evaluation Consortium (2009) assessed the costs of implementation of EID for bovine animals throughout the EU. Full details can be found in that report, but the data for the preparatory phase in the UK and for the EU are shown in Table 8. These are essentially the costs of training in the first year only, including the labour costs of trainees, set at 5 hours for each holding, 10 hours for markets, assembly centres and abattoirs and 300 hours for competent authorities. The estimated cost to the UK in the first year of the preparatory phase is €12,773,477 (£10,985,190 at the February 12th 2013 exchange rate of €1 = £0.86).

The cost per bovine animal was also estimated on two bases: one-off regulation and a transitional approach. The former leads to higher costs in the first year, but then becomes equivalent to the cost under a transitional process. For the UK the estimated costs are shown in Table 9 using the exchange rate cited above.

Table 8. Estimated costs (€) of the preparatory phase for introduction of electronic identification of bovine animals in the 27 countries of the EU and the UK (Food Chain Evaluation Consortium, 2009)

	Holdings	Markets and Assembly Centres	Abattoirs	Competent Authorities	TOTAL
UK	12,610,800	75,218	80,352	7,107	12,773,477
EU (27)	145,735,259	932,689	1,629,860	113,703	148,411,510

Table 9. Estimated costs (£) per animal of the introduction of electronic identification of bovine animals in the UK (Food Chain Evaluation Consortium, 2009)

Identification Method	One-off Regulation			Transitional Approach		
	Equipment	Labour	Total	Equipment	Labour	Total
EID Ear Tag + Conventional	24.85	18.37	43.21	10.54	8.68	19.40
EID Bolus + Conventional	30.91	19.73	50.64	13.02	8.33	21.35

Much further data are contained within the Food Chain Evaluation Consortium (2009) report, but cannot be reproduced even in summary here.

5 DISCUSSION AND CONCLUSIONS

The identification and tracking of livestock has been adopted by many countries and is seen as conferring a number of advantages. For example, the National Audit Office (2003) suggests the following advantages:

- Protecting human and animal health
- Improved administration of subsidy payments
- Helping consumers (e.g. product assurance)
- Helping farmers' businesses
- Providing data for government.

Conversely Dürr (2011) suggests (in relation to the dairy industry, but extensible to other livestock sectors and products) the following adverse consequences for countries without a well developed animal identification and recording programme:

- Suboptimal herd management practices
- Erratic technical support to dairy farms
- Ineffective programmes for improving milk quality
- Lack of strategic planning for the sector as a whole
- Lack of effective traceability of animals and products
- Impossibility of genetic evaluation of livestock.

Some of the earlier examples of animal identification programmes demonstrated their value in disease control. In Australia the Property Identification Code introduced in the 1960s as part of the bovine brucellosis and TB eradication programme is still used and is encoded into the

current EID tags for cattle (Bowling *et al.*, 2008). In the USA the bovine brucellosis eradication programme identified vaccinated cattle by means of a tag and ear tattoo and the pig industry has operated an identification programme to eradicate pseudorabies (Murphy *et al.*, 2008). Such programmes have specific goals and clear benefits to the farming industry, and consequently were successful despite being voluntary. The costs of implementing a mandatory livestock identification and tracing system impose considerable financial burdens on individual farmers, other livestock industry sectors and government. It is therefore crucial for all stakeholders that the maximum benefit is derived from the system.

Bowling *et al.* (2008) compared the cattle identification and tracing systems in the EU and 11 other countries and provided a useful summary table. The mandatory premises identification, individual animal identification, movement record and death registration can be viewed as positive features of the EU system, but the lack of mandatory electronic identification of bovines, as practised in Australia, Botswana, Canada and Uruguay, might be considered an obvious potential improvement. In Australia the National Livestock Identification System individual animal number is linked to an individual barcode that identifies the carcass, hide and other by-products following slaughter; farmers are also able to receive feedback information on carcasses from the abattoir provided prior arrangements have been made. Although perhaps not so relevant to the UK, the ruminal boluses used for cattle in the Livestock Identification and Trace-back System in Botswana (which is EU-compliant) records owner's name, animal's hide colour, sex, brand mark and position of the brand and other information. In South Korea the central database records, and consumers can access, breed, sex, quality grade, location of birth and subsequent premises, brand name of the product, owner's personal information, feed administered, medications given, location of slaughter, date of slaughter, date of inspection, and location of processing (Bowling *et al.*, 2008).

Another example is the database run since 2002 by the Irish Cattle Breeding Federation (ICBF) which integrates pedigree data from 22 cattle breed herdbooks with production data from 11 milk recording organisations, five AI providers, the Irish Farmers Association and the Irish Creamery Milk Suppliers Association. All 40 organisations are members and hold shares in the database (http://www.icbf.com/aboutus/database.php). As well as herdbooks ancestry information is obtained from cattle passport applications which specify sex, date of birth, dam and sire of the calf: the principle is that farmers should only need to provide this information once. Dairy animal performance data are obtained from:

- Milk recording organisations (milk, fat, protein, SCC).
- Calf registration (calving interval - how long since the last calving, survival - how many calves a cow has had, calving performance - how easy/difficult are the calvings from a particular bull).
- Slaughter facilities (culled cow weights/grades, fattened animal weights/grades).
- Linear scoring data - used as a predictor of survival.

Beef animal performance data are obtained from:

- Calf registration (as above).
- Weaning weights and linear scores.
- Slaughter facilities (as above).

The benefits are stated to be reduced administration, improved management information and increased genetic gain. Operating costs are covered by charges for services provided, a levy on

ear tags supplied to farmers and a grant from the Irish Department of Agriculture, Food and the Marine (http://www.icbf.com/aboutus/costsbenefits.php).

These examples are cited to demonstrate the range of information that could be recorded and made available to farmers, consumers and other stakeholders, and which could contribute to breeding programmes to develop animal productivity and conservation measures for FAnGR. However, to provide feedback would require the introduction of EID for cattle and all sheep; the consequent loss of the single, non-EID tag derogation for slaughter sheep in England and Wales would probably be unpopular with sheep farmers (Gurnhill, 2013).

In the UK, as elsewhere, there have been changes in the livestock identification and tracing regimes as technology developed, but also in response to animal disease outbreaks. The Cattle Tracing System, which evolved into the BCMS, was a response to BSE, and the earlier sheep and goat systems were prompted by the 2001 Foot and Mouth Disease outbreak. Thus the EU identification and tracing regulations were developed to safeguard animal health by ensuring member states would be better equipped to trace animal movement in the event of a disease outbreak. Subsequently the need to demonstrate efficient, transparent and reliable administration of EU subsidies has led to additional regulations. There were several examples of fully functional livestock databases as long ago as 2003, including that in Northern Ireland, in the National Audit Office (2003) report. In GB many improvements to the process were made in the years following the £14 million fine for failure to complete the required cross-checks of claims relating to cattle in 2000 (National Audit Office, 2003), and the lifting of the ban on export of beef in 2006 demonstrated that the EU was satisfied with the identification and traceability systems that had been implemented.

Although the systems are now more robust, there is a remarkable (and to many outside the industry confusing) diversity of systems for the various species. In England (consideration of the Devolved Administrations would further complicate the issue, but see earlier sections for the details) the current systems can be summarised as:

- Sheep: identification by compulsory EID plus visual tags for breeding stock, visual or EID slaughter tags for animals destined for slaughter at <12 months of age; paper movement licences, centralised Animals Movements Licensing System, but data fed in via Local Authority Trading Standards officers who transcribe the information on the paper licences.
- Goats: two identical tags, but no requirement for an EID; otherwise as for sheep.
- Cattle: identification by compulsory visual tags plus a passport; movements recorded by the centralised British Cattle Movement Service using data supplied on-line or by telephone.
- Pigs: compulsory identification, by one of various (non-EID) means; movements notified to centralised Animals Movements Licensing System either electronically or via bureau services offered by two industry bodies.
- Equines: identification by means of an injected micro-chip with a passport; centralised database (National Equine Database) recently discontinued, but may be resurrected by the industry and/or government following the identification of horsemeat in processed meat products. No compulsory recording of movements (but passport must accompany movement) despite recent incursions of equine diseases.
- Poultry and Waterfowl: no individual identification or movement recording; larger (>50 birds) flocks must be registered.

It should also be noted that the current systems, for sheep and goats particularly, have evolved after passing through several iterations with the regulations changing repeatedly in the last decade. In part this was to reduce the immediate additional burden on farmers by instituting transitional periods when derogations, often agreed through Government consultations with the various sectors of the livestock industry, were in place. It also reflects the differing business needs of those sectors. Although few farmers have to contend with the regulations for all species they have had to invest their time in keeping abreast of the changes in regulations and to adapt to new technology, and may also have incurred additional expenditure on such technology. The linking of compliance with CAP subsidies through the cross-compliance measures, although effective in accounting terms, has also placed additional stress on farmers (ADAS *et al*., 2009).

Perhaps as a consequence of the variability in systems between the species and the changes over time, some of the benefits suggested by the National Audit Office (2003) do not seem to have been fully realised. To take the example of protecting animal and human health, there have been a number of new, or rarely reported, exotic diseases of livestock reported from the UK in recent years. Midge-borne diseases such as bluetongue and Schmallenberg virus would probably not be contained by efficient livestock movement recording, but others such as contagious equine metritis and equine viral arteritis may be contained. It is a concern that there is currently no recording of equine movements. Risks to human health also continue, such as the detection of horsemeat in a wide range of processed meat products in February 2013, with the risk being from undeclared equine medicines such as phenylbutazone (bute) rather than the meat *per se.* Although this risk is minimal, it is the most common justification for the equine identification regulations.

However, it is clearly the case that electronic systems of identification and tracing would increase the accuracy of, and reduce the time taken to identify, movement records in the event of a disease outbreak. This is likely to decrease both the extent and duration of the outbreak, and hence its economic impact. Electronic reading avoids transcription errors, can report in real-time and the central database can trace movements in minutes (Scottish Agricultural Organisation Society, 2011). This compares with paper based systems where notifications and movement recording could take a few days, and most tracings took up to seven days but with some taking several weeks (Scottish Agricultural Organisation Society, 2011). In this respect the full benefits of EID for sheep will not be realised while paper-based movement licences continue to be used.

Despite the costs to individual farmers, the wider livestock industry and taxpayers there probably would be cautious acceptance of more effective and uniform livestock identification and movement recording. Where EID has been adopted farmers frequently come to appreciate its value in farm management (Food Chain Evaluation Consortium, 2009). There are numerous examples in the scientific literature of the potential of RFID devices in farm management (see, for example, Reiners *et al.*, 2009; Voulodimos *et al.*, 2010; Ruiz-Garcia and Lunadei, 2011). Farmers, like the general public, are becoming increasingly IT literate and are likely to become increasingly willing to use on-line services. The Scottish Agricultural Organisation Society (2011) report suggested that one reason for farmer disappointment with EID was that there was no flow of information (for example, on carcass characteristics) back along the supply chain. If EU regulations are changed to allow UHF tags they may present better opportunities to achieve this feedback of information to guide production management, but as noted above it is already possible under the Australian National Livestock Identification System (Bowling *et al.*, 2008).

There are opportunities to utilise the available technology to better effect. The Scottish Agricultural Organisation Society (2011) report suggested that integration of the sheep movement database with those of other species would increase the overall benefits of traceability. The report also suggested that farmers' views on EID would be enhanced if it led to a reduction in other perceived burdens, such as the need for paper-based flock registers and movement documents or routine standstill periods outside a disease outbreak. This last has been adopted recently by the Northern Ireland Executive (with the exception of animals acquired at a market not returning to a market within six days).
Although many farmers need to become familiar with only one system of identification and movement reporting, there is considerable cross-border trade in livestock within the UK and this requires knowledge of other systems. Standardisation of the regulations between UK countries would reduce the administration burden on farmers, markets and abattoirs. An example is given in the Scottish Agricultural Organisation Society (2011) report: in Scotland EID tags for slaughter lambs were specified so as to avoid the problem of mixed EID and non-EID tagged sheep at markets and abattoirs. However, the authorities in England opted for non-EID slaughter tags, so that mixed batches can occur in Scotland.

Where good data on livestock identification becomes available, the potential to use those data for more than disease control and compliance monitoring becomes an attractive option. Under the National Audit Office's benefit of 'providing data for government' could be the monitoring of livestock populations, including breeds at risk, for example by allowing calculation of a genetic indicator (Villanueva *et al.,* 2010) or other demographic statistics (Hall, 2011). This would be an invaluable contribution to meeting the UK's obligations under the Convention on Biological Diversity, the Global Plan of Action for Animal Genetic Resources and the Interlaken Declaration. For cattle the identification data are already available and it would be relatively easy to collect the data for sheep and goats, but it does require clear objectives to ensure the data are robust. For example, the BCMS database in its current form was not a useful basis for determining gene flow (Todd *et al.*, 2011).

However, such data can be analysed using Geographic Information Systems (GIS), which can be used in disease management, population dynamics, geographic concentration assessment etc. (Clark, 2008), provided the Data Protection Act allows access to the databases. An example, which demonstrates the value of the BCMS database for understanding the epidemiology of animal disease and which may suggest a better way of managing animal disease, is provided by Gilbert *et al.* (2005). Using BCMS archive data the authors were able to model the spread of bovine TB, and demonstrated that incorporating cattle movements significantly enhanced previous models based on environmental, demographic, agricultural and climatic parameters. The models were also able to predict areas that are likely to become new foci of bovine TB at considerable distances from the current core areas of south-west England.

The BCMS was set up in the recovery period following identification of bovine spongiform encephalopathy (BSE) and was not designed to respond to rapid disease outbreaks such as the 2001 foot and mouth disease epidemic (Gilbert *et al.*, 2005). The need for, and ability of, national databases that allow rapid tracing of contacts was modelled by Scanga *et al.* (2007). Selecting one cow at random from a sub-set (2 million animals) of the Colorado cattle population as a hypothetical disease carrier, algorithms were developed that allowed track forward and trace back of the contacts of this cow in 215 s. Perhaps more striking was the increase in the number of contacts at each level (where Level 1 is direct contact with the 'infected' cow, Level 2 is contact with a Level 1 individual etc.): there were 540 Level 1 cattle, but by Level 4 there were almost 1.3 million animals that had been in contact with an animal at a lower level. In all 90% of the 2 million cattle in the simulation had some degree (up to Level 11)

of connectedness with the 'infected' cow. Scaling the problem up to national herds, and (in the event of a disease such as foot and mouth, which affects several farmed species) including other species makes the problem of tracing and tracking all contacts daunting, but EID and centralised databases would greatly reduce the response time.

Such use of databases, combined with effective animal identification, provide the means to manage disease outbreaks with more targeted approaches than the extensive culling of livestock employed in the 2001 foot and mouth outbreak. It is therefore of great concern that the proposals for a new EU Animal Health Law omit the capacity allowed under the current regulation 2003/85/EC for animal health authorities to apply a derogation from culling to save nucleus breeding groups of breeds at risk. To not retain the ability to apply a derogation from culling would be a retrograde step that is all the more incomprehensible given the improvements in animal identification and movement tracing that have been achieved since 2003 when the current regulation was enacted.

Provided they are fit for purpose databases do not have to be Government operated and funded (National Audit Office, 2003). As noted above the ICBF database is partially funded by the Irish farming industry (although a grant is provided by the Irish government). In Denmark, the database for cattle is operated by a farmer-owned private company funded by an annual levy (£1.40 per animal in 2000) on farmers. In Finland the national cattle database is operated by a private company owned by abattoirs and dairies. In the Netherlands and Northern Ireland the databases are government operated, but the former includes veterinary information, is integrated with the industry's performance and pedigree database and is funded by annual and variable fees of 7-30 Eurocents (in 2003). The latter includes data on cattle, sheep and pigs and supports assurance schemes, through incorporating meat inspection findings, and medicines and residues surveillance programmes. Such databases may be at least partially funded through levy boards such as the Agriculture and Horticulture Development Board and its equivalents in the devolved administrations, or for equines the Horserace Betting Levy Board, or by levies on livestock product processors.

These considerations lead to a number of suggestions for improvements to current identification and traceability systems:

- electronic tagging of cattle
- on-line recording of sheep and goat movements
- reduced requirements for on-farm paper records
- removal of standstill periods when there is no disease outbreak
- greater use of EID to provide feedback to farmers
- standardisation of regulations between UK countries
- individual identification of poultry and waterfowl
- movement recording of equines

Most of these suggestions were presented to Defra staff during the preparation of the report and the feedback from Terry Gurnhill of Defra's Animal Identification team was especially useful. In brief:

- Electronic tagging of cattle is under consideration by the EU and is likely to be introduced in the next few years.
- Defra has invited tenders for a sheep and goat identification and movement database that would allow on-line recording of movements.

- Reducing the requirements for on-farm paper records could only be achieved if all livestock keepers were willing to record identification and movements electronically, which is considered unlikely in the near future.
- Removal of standstill periods is also unlikely, although Defra is considering the possibility that if animals moved on to a holding can be kept in a Defra-approved isolation facility other livestock could be moved off that holding within the six days.
- Greater use of EID to provide feedback to farmers might be possible, but to provide this service abattoirs would require all animals going for slaughter to be electronically identified; the removal of the derogation for non-EID of slaughter sheep would be unpopular with English and Welsh sheep farmers.
- Standardisation of regulations between UK countries would be desirable and in some cases harmonisation might be possible, but complete standardisation was unlikely to be fully achieved.

What most individual farmers, wider livestock industry partners and taxpayers desire is value for money and effort. Farmers may be more tolerant of, and perhaps more willingly compliant, if the data collected (or at least available to be collected) were seen to be used for a beneficial purpose. With the passing of time the contributions that accurate identification and tracking made to the tackling of BSE and the consequent resumption of beef exports, and the contribution it could make to better control of outbreaks of diseases such as foot and mouth disease, become of less immediate concern to farmers, but the Government must maintain a readiness to respond to future challenges. This strategic preparedness should include, *inter alia*, the provision of data to enable effective breeding programmes and conservation strategies.

6 REFERENCES

ADAS. 2009. Training needs to support the implementation of electronic identification of sheep in England. ADAS UK, Wolverhampton. http://archive.defra.gov.uk/foodfarm/farmanimal/movements/sheep/documents/eid-adas090519.pdf

ADAS. 2012a. Research to improve the evidence base and inform policy on the possible authorisation of injectable transponders for electronic identification of sheep and goats. ADAS UK, Stratford-upon-Avon. http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=18772

ADAS. 2012b. *ALIDMA: EID tag reading study*. Defra / Approved Livestock Identification Manufacturers' Association. ADAS UK. http://www.alidma.org.uk/images/stories/tag-reading-trial-report.pdf

ADAS, Central Science Laboratory and Countryside and Community Research Institute. 2009. *Evaluation of cross compliance.* Report prepared for Defra Agricultural Change & Environment Observatory, York. http://archive.defra.gov.uk/evidence/statistics/foodfarm/enviro/observatory/research/documents/Xceval_mar09.pdf

Allen, A., Golden, B., Taylor, M., Patterson, D., Henriksen, D. & Skuce, R. 2008. Evaluation of retinal imaging technology for the biometric identification of bovine animals in Northern Ireland *Livestock Science* **116**: 42-52.

Barber, C. 2012. Conservation Officer, Rare Breeds Survival Trust. Personal communication. April 2013.

Barry, B., Gonzales-Barron, U., McDonnell, K., Butler, F. and Ward, S. 2007. Using muzzle pattern recognition as a biometric approach for cattle identification *Transactions of the American Society of Agricultural and Biological Engineers* **50**: 1073-1080.

Bass, P.D., Pendell, D.L., Morris, D.L., Scanga, J.A., Belk, K.E., Field, T.G., Sofos, J.N., Tatum, J.D. and Smith, G.C. 2008. Sheep traceability systems in selected countries outside of North America. *The Professional Animal Scientist* **24**: 302-307.

Bowling, M.B., Pendell, D.L., Morris, D.L., Yoon, Y., Katoh, K., Belk, K.E. and Smith G.C. 2008. Identification and traceability of cattle in selected countries outside of North America. *The Professional Animal Scientist* **24**:287–294.

British Standards Institute. 2009. *Official identification for cattle – specification*. British Standards Institute, London. http://rpa.defra.gov.uk/rpa/index.nsf/vContentByTaxonomy/BCMS**Tagging**Cattle%20Tagging%20and%20Cattle%20ETAS**PAS%2044%20**?OpenDocument

British Standards Institute. 2010. *Official identification eartags for sheep and goats – specification*. British Standards Institute, London. (http://rpa.defra.gov.uk/rpa/index.nsf/vContentByTaxonomy/BCMS**Tagging**Sheep%20&%20Goat%20Tagging%20-%20Sheep%20&%20Goat%20ETAS**PAS%2066**?OpenDocument

Carné, S., Caja, G., Rojas-Olivares, M.A. and Salama, A.A.K. 2010. Readability of visual and electronic leg tags versus rumen boluses and electronic ear tags for the permanent identification of dairy goats. *Journal of Dairy Science* **93**: 5157-5166.

Carné, S., Gipson, T.A., Rovai, M., Merkel, R.C. and Caja, G. 2009. Extended field test on the use of visual ear tags and electronic boluses for the identification of different goat breeds in the United States. *Journal of Animal Science* **87**: 2419-2427.

Clark, R. 2008. Use of Geographic Information Systems (GIS) in veterinary activities. *Government Veterinary Journal* **18**: 5-10.

Corkery, G., Gonzales Barron, U., Butler, F., Mc Donnell, K. and Ward, S. 2007. A preliminary investigation on face recognition as a biometric identifier of sheep. *Transactions of the American Society of Agricultural and Biological Engineers* **50**: 313-320.

Defra. 2009a. *Guidance for keepers in England: rules for identifying sheep and goats*. Department for Environment, Food and Rural Affairs, London. http://www.defra.gov.uk/publications/files/pb13327-sheeps-goats-guidance-091209.pdf

Defra. 2009b. *Impact assessment for the introduction of sheep and goat EID under EC Regulation 21/2004.* Department for Environment, Food and Rural Affairs, London. http://archive.defra.gov.uk/foodfarm/farmanimal/movements/sheep/documents/ia-sheep100226.pdf

Defra. 2009c. *UK EID Evidence Report: Electronic identification of sheep and goats: Commission report in connection with article 9(4) of Regulation (EC) No 21/2004.* Department for Environment, Food and Rural Affairs, London. http://archive.defra.gov.uk/foodfarm/farmanimal/movements/sheep/documents/eid-defra-evidence-rpt.pdf

Defra. 2009d. *Impact assessment of new equine ID regulations.* Department for Environment, Food and Rural Affairs, London. http://archive.defra.gov.uk/foodfarm/farmanimal/movements/horses/documents/ia-equineidreg.pdf

Defra. 2010. *Poultry in the United Kingdom: The Genetic Resources of the National Flocks*. Department for Environment, Food and Rural Affairs, London. http://www.defra.gov.uk/publications/files/pb13451-uk-poultry-faw-101209.pdf

Defra. 2011. *A guide for pig keepers*. PB 13647. Available at: http://www.defra.gov.uk/publications/files/pb13647-new-pig-keepers-guide.pdf

Defra. 2011. *Biodiversity 2020: Developing indicators for measuring success*. Technical Discussion Paper, August 2011. Department for Environment, Food and Rural Affairs, London. http://www.defra.gov.uk/consult/files/discussion-paper-biodiversity-indicators-strategy.pdf

Defra. 2012. Sheep and goats identification, registration and movement. https://www.gov.uk/sheep-and-goats-identification-registration-and-movement

Dürr, J. 2011. *Animal identification, recording and evaluation – Interbull's perspectives*. Paper presented at the Workshop on "Animal identification and recording systems for traceability and livestock development in countries of Latin America and the Caribbean" 5-7 December 2011. Santiago (Chile). ICAR, Rome.
http://www.icar.org/Documents/Santiago%202011/Papers/Durr.pdf

England Advisory Group on Responsibility and Cost Sharing for Animal Health and Welfare. 2010. *Final Report*. Department for Environment, Food and Rural Affairs, London.
http://www.defra.gov.uk/publications/files/pb13450-rcsag-report-101213.pdf

FAO. 2010. *Report of a workshop on indicators to measure trends in genetic diversity of domesticated animals, held in Rome, 9–10 February 2010.* Eds. D. Pilling & B.D. Scherf. FAO, Rome.

Fiore, G., Hofherr, J. and Solinas, I. L. 2007. *Cost Analysis for Small Ruminant Holdings in Member States: Electronic Identification (EID) of Small Ruminants in Accordance with Regulation (EC) 21/2004.* JRC 37122. European Commission Directorate-General Joint Research Centre and the Institute for the Protection and Security of the Citizen. Luxembourg.
http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/12752/1/reqno_jrc37122_cost%20analysis.pdf

Food Chain Evaluation Consortium. 2009. *Study on the introduction of electronic identification (EID) as official method to identify bovine animals within the European Union. Final Report*. DG SANCO, European Commission. Brussels.
http://ec.europa.eu/food/animal/identification/bovine/docs/EID_Bovine_Final_Report_en.pdf

Gilbert, M., Mitchell, A., Brown, D., Mawdsley, J., Clifton-Hadley, R and Wint, W. 2005. Cattle movements and bovine tuberculosis in Great Britain. *Nature* **435**: 491-496.

Gonzales-Barron, U., Corkery, G., Barry, B., Butler, F., McDonnell, K. and Ward, S. 2008. Assessment of retinal recognition technology as a biometric method for sheep identification. *Computers and Electronics in Agriculture* **60**: 156–166.

Gonzales-Barron, U., Butler, F., McDonnell, K. and Ward, S. 2009. The end of the identity crisis? Advances in biometric markers for animal identification. *Irish Veterinary Journal* **62**: 204-208
http://www.veterinaryirelandjournal.com/Links/PDFs/CE-Large/CELA_March_2009.pdf

Gonzales-Barron, U. and Ward, S. 2005. *Review of biometric and electronic systems of livestock identification. The BioTrack Project: Development of a protocol for biometric-based animal tracking and tracing.* Report to the Department of Agriculture and Food for Ireland, Dublin.
www.ucd.ie/bioresources/biotrack/Downloads/**Biometrics**.doc

Gray, A. 2011a. *Approval of pastern tags – specifications*. Department for Environment, Food and Rural Affairs, London.
http://rpa.defra.gov.uk/rpa/index.nsf/15f3e119d8abcb5480256ef20049b53a/10a46638ba9648e18025766400475488/$FILE/Pastern%20Tags%20Specification%20v1.0.pdf

Gray, A. 2011b. *Great Britain sheep and goat ear tag manufacturers/suppliers Code of Practice*. Department for Environment, Food and Rural Affairs, London.

http://rpa.defra.gov.uk/rpa/index.nsf/15f3e119d8abcb5480256ef20049b53a/cf3a079ba0c5a50d802578a3004dce0d/$FILE/SheepGoat%20Code%20of%20Practice.pdf

Gurnhill, T. 2013. Defra Animal Identification Team. Personal communication. April 2013.

Hall, S.J.G. 2011. Number of females in cattle, sheep, pig, goat and horse breeds predicted from a single year's registration data. *Animal* **5**: 980-985.

Harlizius, B., Lopes, M.S., Duijvesteijn, N., van der Goor, L.H.P., van Haeringen, W.A., Panneman, H., Guimaraes, S.E.F., Merks, J.W.M. and Knol, E.F. (2011). A single nucleotide polymorphism set for paternal identification to reduce the cost of trait recording in commercial pig breeding. *Journal of Animal Science* **89**: 1661-1668.

IDEA Project Team, 2001. *IDEA Project: IDentification Electronic des Animaux, 1998–2001*. European General Directorate on Agriculture and European Commission Directorate-General Joint Research Centre. Luxembourg.

Jimenez Gamero, I., Dorado, G., Munoz Serrano, A., Analla, M. and Alonso-Morago, A. 2006. DNA microsatellites to ascertain pedigree recorded information in a selecting nucleus of Murciano-Granadina dairy goats. *Small Ruminant Research* **65**: 266-273.

Liddell, S. and Bailey, D.V. 2001. Market opportunities and threats to the US pork industry posed by traceability systems. *International Food and Agribusiness Management Review* **4**: 287-302.

Mansell, S. 2013. Exmoor Pony Society. Personal Communication February 2013.

Meisinger, J.L., Pendell, D.L., Morris, D.L., Belk, K.E. and Smith, G.C. 2008. Swine traceability systems in selected countries outside of North America. *The Professional Animal Scientist* **24**: 295-301.

Moxey, A. and Walls, H. 2012. *Electronic boluses and sheep identification. Report for ScotEID.* Scottish Agricultural Organisation Society, Edinburgh.

Murphy, R.G.L, Pendell, D.L., Morris, D.L., Scanga, J.A., Belk, K.E. and Smith, G.C. 2008. Animal identification systems in North America. *The Professional Animal Scientist* **24**: 277–286.

National Audit Office. 2003. *Identifying and Tracking Livestock in England*. The Stationery Office. London.
http://www.nao.org.uk/publications/0203/tracking_livestock_in_england.aspx

OIE. 2012. *Terrestrial Animal Health Code*. World Organisation for Animal Health. Paris.
http://www.oie.int/en/international-standard-setting/terrestrial-code/access-online/

Reiners, K., Hegger, A., Hessel, E.F., Böck, S., Wendl, G. and Van den Weghe, H.F.A. 2009. Application of RFID technology using passive HF transponders for the individual identification of weaned piglets at the feed trough. *Computers and Electronics in Agriculture* **68**: 178–184.

Risk Solutions. 2006. *Impact of sheep e-ID on disease control*. A report for Defra. RiskSol Consulting Ltd. London.

http://archive.defra.gov.uk/foodfarm/farmanimal/movements/sheep/documents/eid-impact-aug06.pdf

Risk Solutions. 2008. *Impact of Sheep EID on disease control: additional analysis*. A report for Defra. RiskSol Consulting Ltd. London.
http://archive.defra.gov.uk/foodfarm/farmanimal/movements/sheep/documents/eid-impact-sept08.pdf

Robin, C.A., Lo Iacono, G., Gubbins, S., Wood, J.L.N. and Newton, J.R. 2013. The accuracy of the National Equine Database in relation to vector-borne disease risk modelling of horses in Great Britain. *Equine Veterinary Journal* DOI: 10.1111/evj.12018
Available at http://onlinelibrary.wiley.com/doi/10.1111/evj.12018/pdf

Ruiz-Garcia, L. and Lunadei, L. 2011. The role of RFID in agriculture: applications, limitations and challenges. *Computers and Electronics in Agriculture* **79**: 42–50.

Scanga, J.A., Hoffmann, T., Picanso, J., Rajopadhye, S.V., Kim, D.G., Gupta, A., Forbes, R., Ladd, J. and Burns, P.J. 2007. Development of computational models for the purpose of conducting individual livestock and premises traceback investigations utilizing National Animal Identification System-compliant data. *Journal of Animal Science* **85**: 503-511.

Scottish Agricultural Organisation Society. 2009. *Electronic Identification in the Scottish Sheep Flock. Project Co-ordinator's Report. Industry-led EID research pilot 2008 – 2009. Phase I Report.* Scottish Agricultural Organisation Society, Edinburgh.

Scottish Agricultural Organisation Society. 2011. *Electronic Identification in the Scottish Sheep Flock. Project Co-ordinator's Report. Industry-led EID research pilot Phase II 2009 - 2011*. Scottish Agricultural Organisation Society, Edinburgh.
http://www.scoteid.com/Public/Documents/EID_Pilot_Phase_2_report.pdf

Scottish Government. 2011. *Pig identification and registration – guidance for keepers in Scotland*. Scottish Government, Edinburgh.
http://www.scotland.gov.uk/Publications/2011/10/28142522/0

Shanahan, C., Kernan, B., Ayalew, G., McDonnell, K., Butler, F. and Ward, S. 2009.
A framework for beef traceability from farm to slaughter using global standards: an Irish perspective. *Computers and Electronics in Agriculture* **66**: 62-69.

Todd, D.L., Woolliams, J.A. and Roughsedge, T. 2011. Gene flow in a national cross-breeding beef population. *Animal* **5**: 1874-1886.

Villanueva, B., Sawalha, R.M., Roughsedge, T., Rius-Vilarrasa, E. and Woolliams, J.A. 2010. Development of a genetic indicator of biodiversity for farm animals. *Livestock Science* **129**: 200-207.

Voulodimos, A.S., Patrikakis, C.Z., Sideridis, A.B., Ntafis, V.A. and Xylouri, E.M. 2010.
A complete farm management system based on animal identification using RFID technology. *Computers and Electronics in Agriculture* **70**: 380–388.

Wilkinson, S., Wiener, P., Archibald, A.L., Law, A., Schnabel, R.D., McKay, S.D., Taylor, J.F. and Ogden, R. 2011. Evaluation of approaches for identifying population informative markers from high density SNP Chips. *BMC Genetics* **12**: 45 (14pp).

Wright, S. 1931. Evolution in Mendelian populations. *Genetics* **16**: 97-159.