National Genetic Conservation Strategy Document

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Executive Summary

- Ireland lists seven populations of livestock as endangered. These include three populations of cattle, three populations of equines and one population of sheep

- Through signed international and pan-European agreements, Ireland has committed to providing resources to document and to protect our national farm animal genetic resources

- Pedigree analysis and key population statistics are limited for some populations due to restricted access to their pedigree registers

- To date, there has been little emphasis on marketing and promotion of endangered populations in Ireland. This is an area which has been beneficial to endangered populations in other countries

- To ensure sustainable development of endangered populations, a scientifically sound breeding programme which takes cognisance of the traits of importance to the population while simultaneously minimising relatedness in the population and the avoiding the mating of carriers of genetic defects is required

- The preferred method of genetic conservation is in-situ in-vivo conservation, however cryopreservation of semen of selected animals will complement in-vivo conservation and can be used to recreate genetic diversity in the event of breed extinction

- Incentives to promote the use of rare breeds in Ireland should be reviewed

- It is recommended to establish a Farm Animal Genetic Resources Committee comprising representatives from all partners involved nationally in genetic conservation

- A national genetic conservation strategy could be put in place protecting all endangered populations with a start-up cost of €55,100 and annual running costs of €65,725

Background

Diversity refers to the differences in appearance or function between individuals. Livestock species are typically artificially bred to improve aspects of their performance, for example milk production in dairy animals, meat production in beef or sheep populations, and agility in horses. Sires are selected as mates for females on the basis of their elitism in these performance characteristics, and as genetic merit improves, often the genetic similarity between elite animals in populations simultaneously increases. Increased genetic similarity amongst individuals is concomitant with loss in genetic diversity. As genetic diversity diminishes in populations or species, the ability of the population or species to adapt to changing circumstances also diminishes. For example, the more genetically similar animals in a population are, the greater the risk that the population cannot overcome a disease outbreak or is unable to adapt their product to meet changes in market demands.

Through genetic conservation, we strive to maintain maximum levels of genetic diversity in populations, or as a minimum to preserve germplasm ex-situ to facilitate regeneration of genetic diversity should this be required. In this document, we outline a national scientific approach to genetic conservation for livestock species. We focus on development of a general in-situ conservation strategy as the preferred method of conservation which is complemented by ex-situ in-vitro cryopreservation of germplasm as a safeguard to future genetic diversity of endangered populations.

This document is the output from a workshop held at the Animal and Grassland Research and Innovation Centre, Teagasc Moorepark on the 18th September. International and national experts in genetic conservation attended and contributed to discussions on a national genetic conservation strategy for Ireland.

1. International Obligations

Ireland has international obligations to conserving genetic resources through signed international as well as pan-European agreements and contributes to international genetic conservation.

Agreements to which Ireland is committed to include:

1) The Convention on Biological Diversity (CBD)

Genetic Diversity focal and advisory groups to which Ireland contribute include:

1) European Regional Focal Point (ERFB)

2) Domestic Animal Diversity Information Systems (DAD-IS)

3) Food and Agriculture Organisation of the United Nations Commission on Genetic Resources for Food and Agriculture

Ireland is one of 168 signatories to the CBD thus is committed to conserving biodiversity. In response to the CBD Strategic Plan for Biodiversity 2011-2020, including Aichi Target 13, Ireland produced a National Biodiversity Plan (http:// http://www.cbd.int/reports/search). The National Biodiversity Plan, Actions for Biodiversity 2011 – 2016 lists strategic objectives, national targets, and actions, however deals with biodiversity of the national ecosystem with no detail pertaining specifically to the diversity of farm animal genetic diversity. The National Biodiversity Plan lists all conservation measures to which Ireland is committed to under the CBD. These are mostly relevant to farm animal genetic resources and include:

- Conservation of ecosystems, habitats and species in their natural surroundings, both within and outside protected areas (in situ conservation)

- Conservation of the components of biological diversity outside their natural habitats (ex situ conservation)

- Impact assessment

- Identification and monitoring

- Sustainable use of ecosystems, species and other biological resources

• Adoption of incentive measures

• Research and training

• Public awareness and education

• Policies and mechanisms for equitable sharing of benefits of genetic resources

• Facilitating access and transfer of technology

• Exchange of information

• Technical and scientific cooperation

• Access to and safe use of biotechnology

• Provision of financial resources to achieve the Convention's objectives, both nationally and to developing countries (Source: Irelands National Biodiversity Plan, Actions for Biodiversity 2011 – 2016).

The Irish Department of Agriculture Food and the Marine (DAFM) hold a national co-ordinator position on the European Regional Focal Point for Animal Genetic Resources (ERFP) which supports both in-situ and ex-situ conservation and facilitates the FAOs Global Plan of Action for Animal Genetic Resources in Europe. Ireland also contributes data to EFABIS database.

In summary, Ireland has committed 1) to identifying and monitoring biological diversity, 2) to undertake research and promote public awareness of genetic diversity, and, 3) to provide the financial resources necessary to undertake these objectives.

2. Overview of Livestock Breeds in Ireland

Breed, in this context refers to "*Either a sub-specific group of domestic livestock with definable and identifiable external characteristics that enable it to be separated by visual appraisal from other similarly defined groups within the same species, or a group for which geographical and/or cultural separation from phenotypically separate groups has led to acceptance of its separate identity*" (FAO, 1999).

Breed standards are typically set by the breed organisation in charge of pedigree registration and describe the physical characteristics which animals must conform to, for pedigree registration eligibility. Livestock characteristics typically include restrictions on size, function and colour. Additional characteristics associated with temperament and performance are often listed however are not judged. Where no breed organisation exists, the responsibility for setting breed standards lies with the advisory committee on Genetic Resources for Food and Agriculture.

Ireland’s livestock genetic diversity comprise populations of ass (n=1), buffalo (n=1), cattle (n=27), chicken (n=65), deer (n=4), duck (n=17), goat (n=8), goose (n=1), horse (n=13), pheasant (n=1), pig (n=1), sheep (n=17), and turkey (n=9), (Source: Domestic Animal Diversity Information System of the FAO). The complete lists of livestock and poultry breeds registered to Ireland are detailed in Appendix 1 and 2, respectively.

Breed Function

The primary species involved in commercial agriculture in Ireland include cattle, chicken, horse, pig, sheep and turkey. Ireland’s temperate maritime climate promotes high quality grass growth throughout the majority of the year and this is the cheapest form of feed available to Irish agricultural producers. Optimal livestock production therefore maximises production or performance from grazed grass and favours individuals which can produce or perform intensively from a high grass diet. Less intensive producing or performing livestock are required to satisfy some other niche. Typically, endangered breeds fall into the less intensive category, making them unpopular with commercial producers and threatening their existence. Irish endangered populations of cattle, sheep and horses share common characteristics. These are the ability of animals to survive, reproduce and to perform from limited grazing under harsh weather conditions. These populations are capable of producing or performing off land that otherwise may not be suitable for agriculture.

3. Changing Dynamics of Livestock Production in Ireland

The dynamics of livestock populations in Ireland is changing. A national strategy document, Harvest 2020, (DAFM 2010) set targets for increased quantity and quality from agriculture between 2010 and 2020. Targets set include an increase in milk production from the national herd of 50%, an increase in value output from the beef industry of 40% and an increase in value output of 20% from the sheep industry. Although some of these increases in production will arise from improved genetic capability and improved management, it is anticipated that livestock population numbers, in particular dairy cow numbers will increase. This may result in displacement of some industries as the dairy industry strives to achieve its proportionally larger target. Beef, sheep and horse populations may subside to facilitate this expected increased population size of the national dairy herd on our limited land base. University College Dublin recently summarised the economic contribution of sport horses to Ireland (UCD, 2012). That report showed that although the number of horses exported increased more than five-fold between 2007 and 2011 the total value of exports declined from €5.2 million to €3.8 million (UCD, 2012). However the authors of that study acknowledged the monetary value assigned to imports and exports was unreliable and movements through Northern Ireland were not captured. In addition, the average price paid for a horse at auction decreased from €4,285 to €2,296 in the period between 2007 and 2011, indicating that overall the value attributed to horses at auction is declining.

Whilst the changing dynamics of the livestock industry and the declining economic return from horse sales may appear to be a challenge to endangered populations, these changing dynamics also offer opportunities to endangered populations which produce in extreme conditions. As intensive producers seek to increase animal numbers on their land base, they may consider using endangered breeds to maximise output from areas of the farm previously unused, or under used.

Population numbers for all livestock populations are available online and remain stable or are increasing for endangered native Irish livestock populations (http://dad.fao.org/). Through carefully monitored genetic conservation schemes, it should be possible for population numbers of endangered breeds to remain stable with minimal impact on long term genetic diversity.

Monitoring changing population dynamics to determine risk status

Access to the registration data of breed societies is necessary to monitor trends in population numbers. It is stated in the Global Plan of Action for Animal Genetic Resources (FAO, 2007), that "Complete national inventories, supported by periodic monitoring of trends and associated risks are the basic requirements for the effective management of animal genetic resources".

The Irish Cattle Breeding Federation (http://www.icbf.com) houses the national database for dairy and beef cattle populations; Sheep Ireland (http://www.sheepireland.ie) houses the national database for sheep populations. The majority of major cattle and sheep breed societies registered in Ireland routinely contribute registration data to these databases. This has enabled the pedigree analysis, including the quantification of trends in inbreeding of major populations of Irish beef, dairy and sheep livestock in the past (McParland et al., 2007; McParland et al., 2012). However, the unavailability of registration data has limited the pedigree analysis and quantification of population statistics of some Irish endangered populations. Examples of such population statistics include: individual animal and population mean inbreeding coefficients, co-ancestry coefficients between breeding animals, the germplasm contribution of individual animals to the current population and the breed fraction of registered animals.

Data required to complete a risk assessment of a population include:

- Unique animal identification number
- animal ancestry (as deep as is available),
- sex (separate categories for castrated vs whole males),
- date of birth,
- date of death,
- geographical location,
- registration status (ie will breeding animals be used widespread or are they supplemental to the main register).

These data can be used to determine the biological material required for DNA analysis and is also ideal to establish parentage and breed assignment. In addition, the data can be used to determine population demographics such as the trend in population size, the number of breeding males and females, the ratio of males to females, the number of offspring produced per breeding animal (i.e. reproductive capacity), the variation in number of offspring produced per breeding animal (i.e. total and marginal contributions), the generation interval, the geographical spread of breeding animals, the effective population size, the degree of ancestry recording, and the rate of inbreeding. These data are also essential requirements for the development of a scientific-based mating plan to conserve genetic diversity.

The advantage of having all registration data from all breeds available in a single database is that trends in population demographics can be routinely re-estimated thereby continually monitoring the risk of genetic diversity loss, particularly of the endangered populations. Also, all populations can be compared using similar criteria and thus breeds can be prioritised for action, if necessary.

Thresholds for the categorisation of populations into risk categories of extinct, critical, critical maintained, endangered, endangered maintained, not at risk and unknown have previously been defined (FAO, 1998); a copy of these thresholds are provided in Appendix 3 and should be followed. The Kerry, Irish Maol and Dexter cattle, Irish Draught horse, Connemara pony, Kerry Bog Pony and Galway sheep are designated as endangered (DAFM, 2013a). Guidelines on the appropriate follow-on actions of breeds categorised other than "not at risk" are also available (FAO, 2013) and are not repeated here.

4. Value of Genetic Resources

One of the major threats to genetic diversity is meeting the demands from the Agri-Food sector to produce high quantities of product from limited a land base. Populations which cannot meet this intensive demand can be lost forever unless they are able to provide some other value to consumers. To date, there has been limited marketing of our national genetic resources, an aspect which could be improved. The Aberdeen Angus is a success story for the United Kingdom where once an endangered breed, a successful marketing campaign based around the quality product produced by Angus cattle revived annual registration numbers, subsequently removing the Aberdeen Angus from the endangered breeds' lists. Genetic improvement is cumulative and permanent, however if populations have not traditionally been genetically selected for improved performance, it will take several generations before they can compete with intensively selected commercial populations. Small populations may reap more benefits by simultaneously adding value to their product whilst seeking to achieve genetic gain in maximising output.

The potential to use marketing as a tool to improve the status of our endangered populations particularly in the area of value added product, product for export, and tourism is great. If competition with commercial breeds in performance traits is not realistic, then each endangered breed should identify its own potential niche products, services and markets This will require documented breed improvement schemes (discussed later) together with a complete marketing (and public education) strategy. Simultaneously raising public awareness of genetic diversity and the importance of native populations to Ireland should be undertaken through joint educational marketing campaigns. This provides an opportunity for breed societies to work together for mutual benefit.

Breed societies should seek out and engage directly with commercial companies (contractors) who will use and promote aspects of the endangered breeds. Recently, a local ice-cream producer began using and promoting the milk of Kerry cattle in the manufacture of their ice-cream. This has provided a specific outlet for Kerry milk and also promotes the breed and provides a good example of a niche market exploited by a native local breed. Other potential markets for the product of native Irish breeds include:

- Internationally, the alleged health benefits accruing from milk produced from animals carrying a particular gene variant have been promoted. To-date, Ireland has not seen a large marketing campaign around this "new" type of milk, A2 milk. However, Dexter and Kerry cattle both carry the A2 gene variant of interest in high frequency and together could promote and supply milk to this niche, high value added market.

- Irish Moiled cattle carry the polled gene variant meaning that only a proportion of Moiled cattle born must be dehorned. This is a trait which is likely to become more important into the future.

- Breeds with lower maintenance requirements, a characteristic of most Irish native livestock breeds, may be suited to high value added organic food production.

These examples are just some of the benefits to be achieved through marketing the genetic uniqueness of endangered native breeds. The risk status of the breeds can be exploited to promote the breeds and simultaneously to promote Irish business.

To be successful, supply to these “new” markets must be regular and continual. This may place stress on endangered populations, particularly at the beginning of a breed improvement or marketing strategy when population size is limiting. However this highlights the importance of a well structured breed improvement scheme with a balanced breeding objective to meet the long term market demands. For example, it will be important not to let fertility suffer as new traits are aggressively selected for since fertility is a key component to regular and continual market supply. Moreover, inbreeding may have major implications, particularly in the case of reproductive performance.

5. Breed improvement schemes

To be considered as valuable to commercial production, all populations require a breed improvement scheme based on an agreed breeding objective from which animals are selected for future generations. Ireland already has separate breeding objectives for national dairy, beef and sheep populations. All breeds within the species use the same breeding objective and research experiments are continually ongoing to validate all breeding objectives. The national dairy herd select animals according to the Economic Breeding Index (EBI), beef populations use the terminal and maternal indices, and sheep populations use the Sheep Value Index. No overall breeding objective for horses exists, although some within breed breeding objectives are available (http://www.irishsporthorse.com).

Current national livestock breeding objectives are based on maximising profit through maximising output of the most valuable product from that species. This may not be suitable as selection criteria for endangered populations. It may be necessary for small populations to modify national breeding objectives to include traits which are applicable specifically to their population or to adapt a desired gains approach where a "public good" value is put on particular attributes. This will particularly be the case where populations strive to meet the needs of a niche market and the requirements are not included in the national index.

Breeding objectives which are modified for specific populations must be developed using peer reviewed scientific methods and be balanced (i.e. understand and appropriately account for other performance traits including reproduction and health). In the case of populations threatened by declining numbers, genetic diversity and the avoidance of mating carriers of lethal recessive alleles must be considered in the breeding scheme design. It is possible to increase genetic gain whilst simultaneously minimising the loss in genetic diversity (McParland et al., 2009).

Inbreeding refers to the mating of two related animals; the resulting progeny from such a mating is termed inbred and has a higher level of homozygosity across its genome than a non-inbred animal. Inbreeding within endangered populations should be restricted for several reasons

1. Inbreeding results in the loss of genetic diversity and once lost it is not possible to readily regain unless methods of cryopreservation of genetic material have already been taken

2. Inbred animals have, on average, poorer performance, particularly in relation to fitness and fertility traits relative to non-inbred animals

3. The frequency of homozygosity (i.e. animal has two identical copies of a gene) is higher across the genome of an inbred animal.

Lethal recessive alleles refer to copies of a gene which when present in the homozygous state result in death of the animal. Since the level of homozygosity in populations increase with increased relatedness in the population, the risk of obtaining two copies of lethal recessive genes from parents increases in inbred populations. Due to the restricted numbers of breeding males and females in endangered populations, these populations tend to be at greater risk of inbreeding than other commercial populations. DNA tests to simultaneously confirm parentage, to identify carriers of lethal recessive genes and to identify known congenital defects are available (Mullen et al., 2013) and can be used to identify non-suitable mates for carriers of such recessive defects. It is advisable that such tests are included in the development of a breeding programme for an endangered population.

6. Genetic Conservation

Genetic conservation can be considered as either 1) in-situ conservation where populations are maintained in their natural environments or 2) ex-situ where populations are maintained elsewhere, often in zoos or animal sanctuaries. In-situ and ex-situ conservation can be further categorised into 1) in-vivo conservation where animals are maintained live, or 2) in-vitro conservation where germplasm is cryopreserved and stored for future use. The preferred method of genetic conservation is in-situ-in-vivo conservation complemented by cryopreservation.

Cryopreservation

Cryopreservation refers to the freezing of biological material so that it may be used in future generations to recreate genetic diversity in the event of breed extinction or major loss of population allelic diversity. Semen, oocytes or embryos may be cryopreserved; however semen is the most accessible and cheapest form of genetic material which can be stored. Therefore, since semen can be used to (almost) entirely reconstruct a population, consideration is not given in this document to the preservation of embryos or oocytes, a considerably more expensive option of in-vitro conservation (Appendix 5). One option for semen collection which bypasses the health and safety risks of traditional semen collection, is the collection of sperm from the epididymus of slaughtered males. This method of semen collection would require collaboration between breeders, the breed societies and the administrator of the cryo-banks.

Identification of donors for semen cryopreservation. Donor animals can be selected according to 1) random sampling of the population, 2) selection based on particular phenotypic or genetic markers, or 3) selection based on the relationship with existing donors in order to maximise genetic diversity.

Populations which collect sufficient semen from their top male animals for use in artificial insemination, should store semen samples from these males as a minimum. Additional semen collection can be then based around complementing the existing DNA in storage.

The number of males selected as donors, and the degree of sampling undertaken to identify donors is a function of the size of the population, the degree of genetic diversity within the population and the funding available for the collection and long term storage of the semen.

Regeneration of a population through grading up using preserved semen

Populations with no living breeding females are considered extinct. However if sufficient quantities of cryopreserved semen are available, “extinct” populations can be (almost) entirely recreated through grading-up as described by Hill (1993). Grading-up involves using cryopreseved semen from the extinct population on a female from another population, and subsequently back-crossing her progeny to stored semen from the extinct population. Each generation, the offspring produced are backcrossed to stored semen of the extinct population until the proportion of genes in the backcross reach almost 100%. In Table 1, the increasing proportion of genes from the original (extinct) population obtained through backcrossing to stored semen is demonstrated. If generation 1 represents the F1 cross (ie first progeny born using cryopreserved semen of the extinct population), the animals in the third generation are on average 7/8 purebred. However after five generations, the marginal increase in the proportion of genes from the original population in the backcross is limited (Table 1).

This process requires sufficiently genetically diverse semen, such that stored semen can be used on each backcross without reaching excessive levels of inbreeding. It also requires large quantities of semen since 50% of the resulting matings will be female (unless sexed semen is stored), the female reproductive rate may be low and male fertility may be poor. Where sexed semen is stored, the reduced conception rates achievable from the semen must be accounted for to partly counteract the reduced levels of semen required for storage. Genomic information can be used to identify the optimal semen for use in backcrossing to minimise relationships and to keep track of favourable alleles (for example, polledness in Moiled cattle), and unfavourable alleles (for example, lethal recessive alleles) in the up-graded population.

Table 1. The proportion of genes from the original reconstructed population at each generation of backcrossing to semen stored from the extinct population

Backcross Generation[1]	Proportion of Genes from Extinct Population
1	0.5
2	0.75
3	0.875
4	0.9375
5	0.96875
6	0.984375
7	0.9921875
8	0.99609375
9	0.998046875
10	0.999023438

[1]Generation 1 represents the F1 between the original and the alternative populations

6. State of the Art

6.a. Nationally

DAFM established an advisory committee on Genetic Resources for Food and Agriculture in 1996. The role of the committee is to guide DAFM to co-ordinate management of farm animal genetic resources. There currently are no dedicated personnel, companies or charities registered in Ireland working solely on livestock genetic conservation. However, the Irish Cattle Breeding Federation provides pedigree analysis services for populations which provide data to the national database and Teagasc and the national universities promote and support endangered breeds through research.

The Irish Cattle Breeding Federation and Sheep Ireland manage the national cattle and sheep databases, respectively. These databases are live and contain all registration and movement data of the majority of cattle and sheep breeds in Ireland.

Addition of new breeds to these databases is welcome and would require no financial contribution from the breed society contributing the data. Despite this, data on numbers and trends in population statistics as well as the geographic location of members of endangered native livestock populations is lacking for some populations due to restricted access to registration data. There are neither financial incentives for inclusion nor penalties for exclusion of endangered breeds in national registers or to monitor trends in inbreeding.

In addition, there is no indication of the geographical location of the majority of populations. These data would be useful to determine risk status of breeds in the event of a disease outbreak.

6.a.i National Support Strategies

National schemes to promote endangered native livestock populations have been successful. The Rural Environmental Protection Scheme (REPS) rewarded environmentally friendly farming and received applicants from 1994 until 2009 by which time over 62,000 farmers were involved (DAFM, 2013b). As a supplementary measure to the scheme, farmers were rewarded with €234 per livestock unit of an endangered breed which was registered with the relevant breed society. This included populations of cattle (Kerry, Dexter and Irish Moiled), equines (Connemara pony, Irish Draught and Kerry Bog Pony) and the Galway sheep.

The Agri-Environment Options Scheme (AEOS) followed REPS and also included conservation of animal genetic resources as a complementary action (DAFM, 2012). Participating farmers who registered an animal from an endangered breed (same breeds as REPS) with the relevant breed society were rewarded with €200 per livestock unit (up to 10 livestock units) per calendar year. Additional requirements relating to the registration of animals and their progeny were listed.

The Kerry Cattle Scheme rewards farmers with more than five registered breeding females with €76.12 per purebred calf subsequently registered with the herdbook.

In 2014 a new scheme will be opened. It is unclear at this stage how genetic conservation of farm animal genetic resources will be included. The new scheme provides opportunity to restrict financial incentives to breed societies to encourage registration of all data in the national database (See Section 7).

6.b. Internationally

Across Europe, the policies employed to monitor endangered breeds differ. Up to three full time equivalents are dedicated to endangered livestock control in both the UK and in The Netherlands, respectively. However the number of endangered breeds in each of those countries is considerably greater than endangered native Irish populations (n = 7); in the UK, approximately 42 breeds are classified as endangered; in The Netherlands 39 breeds or lines are currently cryo-conserved, however not all of these are classed as endangered.

In the UK, the Rare Breeds Survival Trust is a charitable organisation (receiving money from member fees and charitable donations only) established and dedicated to the promotion and caretaking of endangered breeds. The UK committee on farm animal genetic resources meet three times annually to discuss progress.

In The Netherlands, it is a requirement to produce a document detailing how inbreeding is managed and reporting animal inbreeding statistics before they can receive financial support from the government. The Centre for Genetic Resources in The Netherlands co-ordinates a national gene bank for endangered populations. The gene bank is held at two centres both operated by research centres. This allows males with unknown health status (eg old bulls) to be stored without breaching EU regulations for health status. This is however an expensive form of genetic conservation paid for by the government and industry.

7. The Financial Cost of Genetic Conservation

Costs involved in in-vivo conservation include: 1) incentives to bridge the profit gap between animals of endangered populations and commercial populations, 2) optional (but ideal) DNA testing (of some, but ideally all) animals to assess breed purity, genomic relatedness, and to identify carriers of lethal recessive genes, 3) performance and ancestry recording, 4) technical assistance in the development and running of breeding programmes and mating plans, and 5) administrative assistance to operate the breed society.

Current schemes to incentivise breeders and caretakers of endangered populations in Ireland (Section 6.a.i) should be reviewed. One option is to promote better "buy-in" from breed societies regarding the centralised recording of data, the suitable development of a breeding programme and proven management of inbreeding and mating plans by restricting incentives to populations which actively participate in performance recording and review. Another option is to use a proportion of the money paid in incentives to cover the cost of genomically assessing the purity and genomic relatedness of all animals with respect to its population, and to identify the carriers of lethal recessive genes. A similar proposal is underway currently in all Irish beef herds as a continuation of the Suckler Welfare Scheme. The current cost is €40 per animal but is expected to reduce considerably in the coming years, to as low as €20 per animal (personal communication, Donagh Berry, Teagasc). If genomic testing for this purpose was a registration requirement, this option could simultaneously add value to the breeding programmes of endangered breeds while making better use of the funds used to pay incentives since animals entitled to incentives would be better regulated.

The costs of in-vitro conservation include: 1) genomic sampling of animals to identify those for cryopreservation, 2) technical expertise, 3) assessment of genomic relatedness to identify donors, 4) purchase of germplasm from donors, 5) semen collection (from live animals or from the epididymus of slaughtered bulls) and 6) semen storage, including personnel, equipment, consumables, electricity and rent. Quantification of these costs is difficult since the length of time for which semen must be stored is unknown, however cost estimates and assumptions are provided in Appendix 4.

Funding Genetic Conservation

Currently DAFM provide funds for genetic conservation through incentivising the use of breeds on farms and through awards granted on a competitive basis for applied research into genetic conservation of rare breeds. The Government is obliged to contribute financially to support genetic resources under the CBD agreement.

However the funding provided by Government for genetic conservation has reduced in recent years.

Other national institutions which benefit from promotion of genetic resources include 1) the rare breed societies through increased registration numbers, 2) The Irish Cattle Breeding Federation and 3) Sheep Ireland through increased livestock numbers contributing data to the national genetic evaluations, 4) the Universities, 5) Teagasc and, 6) the Royal Dublin Society through increased opportunity for research and the use of genetic resources as an education tool, 7) Bord Failte through using imagery of rare breeds and their surrounding natural landscape to promote tourism, 8) Bord Bia and 9) The Irish Dairy Board through increased opportunity for niche products and markets from rare breeds, and 10) other small and medium enterprises which exploit endangered populations to promote their business.

Organisations benefitting from our native genetic resources should contribute to their upkeep. This may be through contributing to a national dedicated fund, or through the provision of benefit in kind, for example through providing technical assistance in the development of breeding, education or marketing programmes aimed at promotion of genetic resources.

8. Six Steps Required Developing a National Genetic Conservation Strategy

To support the long term sustainable development of rare breeds, some key criteria are listed below.

1) Centralised data recording

    - A unique animal identification system is required for all animals. For cattle and sheep populations, the national identification number must be used when recording all ancestral and performance data; for horse populations the microchip number issued to each animal must be used.

    - All registration data must be routinely recorded to the relevant national data base, the Irish Cattle Breeding Federation database for cattle populations, and the Sheep Ireland database for sheep populations; the feasibility of developing a national database for horse populations should be evaluated. Data pertaining to animal ancestry, sex, date of birth, date of death, geographical location (e.g. Herd or flock Identifier) and registration status should be provided to the database.

- All animals born of purebred matings must be recorded to the national database, whether alive or dead. This is to ensure unbiased recording of data.
- All genetic defects must be recorded to the national database.
- Records of biological material stored should be maintained centrally.

2) Breed Characterisation

- Physical breed characteristics must be recorded by each breed society. For breeds which do not have an active breed society, the Advisory Committee to Farm Animal Genetic Resources is responsible to define breed characteristics.
- Existing (live) animals already registered with their breed society must all provide a DNA sample to the breed society. These samples can be used to determine the purity of each breed.
    i. Hair samples stored on hair cards should be adequate for subsequent testing and will require minimal storage resources.
- Subsequently, a DNA sample must be provided for each animal as part of the registration process. Each sample can be tested for breed purity. Animals may only be included in breed registers where the DNA sample deems the animal to be genetically pure.

3) Breeding Programme

- Each endangered breed must provide the Farm Animal Genetic Resources Committee with a scientifically sound, well documented breeding programme.

- The three requirements to each breeding programme are:

    i. Breeding objective. Endangered breeds which will use the national breeding objective for animal selection must state this in their breeding programme. However it is likely that the national breeding objective will not account (correctly) for traits of importance specifically to endangered populations; for example the ability of these populations to perform on limited grazing. In such situations, a customised breeding objective should be developed. Breed societies which customise their own breeding objectives must provide all relevant data including the traits included and their relative emphasis in the breeding objective. In addition, if a customised breeding objective is used, breed societies must provide details of how the details of the breeding objective will be relayed to breeders. Finally, the expected responses to selection on this breeding objective must be quantified.

    ii. Consideration of genetic diversity. Each breed society must provide details of how genetic diversity will be monitored and controlled. This must include population statistics and mating plans as well as the methods employed to quantify the statistics.

    iii. Consideration of lethal recessives. Matings between carriers of lethal recessives must be avoided. Details pertaining to the flagging of carriers and the use of carrier animals in the breeding programme must be provided.

- The breeding programme provided by each breed society must be approved for scientific content. It is the responsibility of each breed society to ensure their breeding programme is scientifically sound. It is the responsibility of the Farm Animal Genetic Resources Committee to nominate a body to approve the scientific content of breeding programmes.

4) Cryo-conservation of genetic diversity

- Two separate sites for storage of genetic material should be established (i.e cryo-banks) with biological material (eg semen, oocytes or embryos) from all cryopreserved animals duplicated across both sites. Each site must have:

    i. Facilities to store hair cards

    ii. Facilities to store cryopreserved biological material

    iii. A barcode system to easily quantify and locate biological material

- One person should be nominated to dedicate a portion of their time to maintaining the cryo-bank. The person responsible for maintaining the cryo-bank must:

    i. Archive all existing genetic material from endangered populations. This includes biological material such as semen, oocytes or embryos, as well as DNA already extracted from tissue.

    ii. Maintain a live register of all tissue maintained in the cryo-banks

    iii. Identify the animals to be sampled within each breed to find suitable donors of genetic material for cryoconservation

    iv. Liaise with breed societies to collect and store genetic material from endangered breeds. This will include the continuous collection and storage of all animals born (alive and dead) to the population as well as the semen, oocytes or embryos of selected animals.

- Genetic material representative of as large a range of genetic diversity for each population should be cryoconserved. Selection of donors should not be based on the breeding objective, since this will limit the diversity of animals selected, and the breeding objective may change in the future. Semen, oocytes or embryos may be cryoconserved; semen is the most accessible and cheapest form of genetic material which can be stored. To determine which bulls should contribute semen to cryoconservation, a principal components analysis of the diversity of all bulls within each population should be undertaken ideally on the genotypic information of the population

- It is the responsibility of each breed society to

    i. Undertake the genomic sampling of animals to identify donors. Breeding animals should be genotyped to identify the optimal donors to the cryo-bank.

    ii. Liaise with scientists to determine the optimal donors for cryoconservation.

    iii. Collect the genetic tissue from donors for cryoconservation.

    iv. Liaise with the person in charge of the cryo-bank regarding the storage of the genetic tissue.

    v. Procure funding to support conservation of their breed. This funding will be supplemented by other funding as mentioned above (Section 7.a).

- The quantity and type of genetic material and the degree of sampling of donor animals is a function of the amount of funding available, including the long term funding available to store the material.

5) Review the role of institutions in providing funding for farm animal genetic resources

    - Long term continuous funding is required to support genetic conservation and the on-going requirements of the DNA banks.

    - All institutions and organisations which benefit from and make use of our national genetic resources should contribute to their upkeep.

- A review quantifying the contribution required of each institute and organisation is required. Contributions may be in the form of financial or benefit-in-kind, for example through providing professional advice to genetic conservation.

6) Establish a Farm Animal Genetic Resources (FAGR) Advisory Committee**.**

One committee dedicated to the management of farm animal genetic resources should be established. This committee would report to the committee on Genetic Resources for Food and Agriculture already established.

Committee members should include representatives from Government (n=2), Breed societies (n=1 representative to represent all breeds), The Irish Cattle Breeding Federation or Sheep Ireland (n=1), the breeding industry (veterinary or AI services; n=1), the Royal Dublin Society (n=1), the scientific community (n=2) and one other impartial member (for example, a representative from An Bord Bia or Failte Ireland). The committee should meet a minimum of twice per calendar year.

Roles of the committee include:

- To act as the international interface for Irish FAGR and as such liaise with the Genetic Resources for Food and Agriculture Committee to oversee that DAFM are meeting international obligations
- To refine the strategy outlined in this document.
- To implement the refined strategy outlined in this document
- To nominate a person to oversee the management of the DNA banks
- To nominate a body to approve scientific acceptance of breeding programmes
- To lobby DAFM to provide funding for FAGR
- To engage with other institutions to provide funding for FAGR
- To set priorities for optimal use of limited funding provided for FAGR
- To lobby DAFM to provide for FAGR in new agricultural or environmental schemes
- To encourage and foster co-operation between breed societies, Teagasc and the national Universities for well conducted scientific research into endangered breeds.

- In the absence of a breed society the FAGR Advisory committee will establish breed characteristics required for successful breed registration.

FAGR Advisory Committee Coordinator

The newly established FAGR Advisory Committee will nominate one single co-ordinator of the FAGR Advisory Committee.

Responsibilities of the co-ordinator will include:

- Liaising between the FAGR Advisory Committee, the Genetic Resources for Food and Agriculture Committee, breed societies and DAFM.
- Setting the date and communicating meetings of the FAGR Advisory committee
- Overseeing decisions made at FAGR Advisory committee meetings are implemented.
- Acting as the point of contact in DAFM for all FAGR queries
- Dealing directly with breed societies.

The additional responsibilities and duties of the coordinator will be reflected through increased time recording to FAGR.

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Appendix 1. All livestock breeds (with the exception of poultry breeds) in Ireland[1]

Cattle	Sheep	Horse	Pig	Others
Aberdeen Angus	Belclare	Appaloosa	Duroc	***Deer***
Aubrac	Beltex	Arab	Greyhound	Fallow
Ayrshire	Berrichon du Cher	Connemara Pony	Irish Landrace	Killarney
Bazadais	Blackfaced Mountain	Irish Cob	Large White	Red
Belgian Blue	Bleu du Maine	Irish Cob Part Bred	Meishan	Sika
Blended Milking Shorthorn	Bluefaced Leicester	Irish Draught	Pietrain	
Dexter	Charmoise	Irish Miniature		***Ass***
Droimfhionn	Charollais	Irish Piebald & Skewbald		Donkey
Hereford	Cladore (extinct)	Irish Pony		
Holstein-Friesian	Galway	Irish Sport Horse		***Buffalo***
Irish Blonde d'Aquitaine	Ile de France	Irish Warmblood		American Bison
Irish Charolais	Rouge De L'ouest	Kerry Bog Pony		
Irish Limousin	Scottish Blackface	Thoroughbred		***Goat***
Irish Moiled	Suffolk			Alpine
Irish Shorthorn	Texel			Anglo-Nubian
Irish Simmental	Vendeen			Angora
Jersey	Wicklow Cheviot			Feral
Kerry				Irish Goat
Marchigiana				Pygmy
Meuse Rhine Yssel				Saanen
Montbéliarde				Toggenburg
Normande				
Parthenaise				
Piedmontese				
Romagnola				
Salers				
Speckle Park				

[1] Taken from the DAD-IS report which is available online: http://dad.fao.org/cgi-bin/EfabisWeb.cgi?sid=c37f90b86fc3af7ffa0638cf0b230535,reportsreport12_50000014

Appendix 2: All poultry breeds in Ireland[1]

Chicken	Chicken	Others
Ancona	Norfolk Grey	***Duck***
Andalusian	North Holland Blue	Abacot Ranger
Appenzeller Spitzhauben	Old Dutch Bantam	Appleyard
Araucana	Old English Game	Aylesbury
Aseel	Orloff	Black East Indian
Barbu d'Anvers	Pekin Bantam	Call
Barbu d'Uccle	Phoenix	Campbell
Barnevelder	Plymouth Rock	Cayuga
Booted Brahma	Poland	Crested
Campine	Rhodebar	Indian Runner
Cobb 500	Rhode Island Red	Orpington
Cochin	Rosecomb Bantam	Pekin
Creve-Coeur	Rumpless Game	Rouen
Dorking	Scots Dumpy	Rouen Clair
Faverolles	Sebright	Saxony
Friesan	Shamo	Silverhill Duckling
Frizzle Hamburgh	Sicilian Buttercup	Swedish Blue
Houdan	Silkie	Welsh Harlequin
Indian Game	Spanish	
Irish Pit Game	Sulmater	***Turkey***
Isa Brown: Tetra	Sultan	Black
Japanese	Sumatra Game	Blue
Jersey Giant	Sussex	Bronze
Ko-shamo	Transylvanian Naked Neck	Buff
La Fleche	Vorwerk	B.U.T.(British United Turkeys Ltd.)
Lakenvelder	Welsummer	Lavender
Legbar	Wyandotte	Mammoth Bronze
Leghorn	Yokohama	Red
Lincolnshire Buff		White
Magpie		
Malay Game		***Pheasant***
Marans		Old English Pheasant Fowl
Minorca		
Modern Game		***Goose***
Muscovy		Legarth Int Denmark
Nankin		
New Hampshire Red		

[1] Taken from the DAD-IS report which is available online: http://dad.fao.org/cgi-bin/EfabisWeb.cgi?sid=c37f90b86fc3af7ffa0638cf0b230535,reportsreport12_500000

Appendix 3. Categorisation of Risk Status according to the FAO Secondary Guidelines for the Development of National Farm Animal Genetic Resources Management Plans (FAO, 1998).

1. Extinct
A breed is categorized as extinct if it is no longer possible to easily recreate the breed population. This situation becomes absolute when there are both no breeding males (semen) and breeding females (oocytes) nor embryos remaining. In reality extinction may be realized well before the loss of the last animal, gamete or embryo.

2. Critical
A breed is categorized as critical if: The total number of breeding females is less than 100 or the total number of breeding males is less than or equal to 5; or the overall population size is close to, but slightly above 100 and decreasing and the percentage of females being bred pure is below 80%.

3. Critical maintained
As for Critical, but for which active conservation programmes are in place or populations are maintained by commercial companies or research institutes.

4. Endangered
A breed is categorized as endangered if: the total number of breeding females is between 100 and 1000 or the total number of breeding males is less than or equal to 20 and greater than 5; or the overall population size is close to, but slightly below 100 and increasing and the percentage of females being bred pure is above 80%; or the overall population size is close to, but slightly below 1000 and decreasing and the percentage of females being bred pure is below 80%.

5. Endangered maintained
As for Endangered, but for which active conservation programmes are in place or populations are maintained by commercial companies or research institutes.

6. Not at risk
A breeds is categorized as not at risk if: the total number of breeding females and males are greater than 1000 and 20, respectively, or If the population size approaches 1000 and the percentage of females being bred pure is close to 100%, and the overall population size is increasing.

7. Unknown
Self explanatory, but also a call to action: find out! If categorization of a particular breed is borderline, further consideration should be given to factors such as:

- degree of crossbreeding in the population
- reproductive rate and generation interval of the population.
- special peculiarities and characteristics of the production system
- historic and current rates of decline in population numbers
- geographic isolation of the population or its concentration in one or a few locations that would place it at risk as a result of climatic, economic or political changes or disease outbreak.

Appendix 4. Costs of a National Genetic Conservation Strategy

Table A4.1. Population assumptions of Irish endangered breeds[1]

Breed	Census Popn Size	Breeding females	Breeding males	Prop. of all populations
Kerry	1,000	0.60	0.08	0.07
Irish Moiled	400	0.23	0.63	0.03
Dexter	350	0.41		0.02
Cattle Average		0.42	0.35	0.12
Connemara Pony	2,500	0.69	0.10	0.17
Irish Draught	8,500	0.17	0.02	0.58
Kerry Bog Pony	420	0.23	0.08	0.03
Equine Average		0.36	0.07	0.77
Galway Sheep	1,600	0.83	0.05	0.11

[1] Source: DAD-IS database. Available online: http://www.dad.fao.org

Table A4.2 Assumptions upon which costs are based

Assumptions	€	
Set up costs		
Roll out breeding programme	5	per breeder to be notified and educated on the breeding programme
Install Barcode system*	5,000	
Alarmed Tanks*	8,000	per tank; 2 tanks
Personnel*	50,000	0.5 FTE year 1; 0.25 FTE thereafter @ €50,000 full salary
Running Costs		
Recording parentage	0	per animal recorded
Recording Genetic Defects	0	per defect recorded
Genotyping	40	per sample for all populations of cattle, sheep and equines
Genotyping males only	40	assuming a 50% sex ratio
Ongoing re-evaluations	200	per population
Storage hair cards	1	per hair card stored - hair cards stored for all animals born
Storage hair cards males	1	per hair card stored - hair cards stored for all males born only
Collect Semen	1,000	bull / stallion / ram jump costs for 2% of breeding males
Overheads*	5,000	per year
Identify donors	0	no costs additional to the genotyping already undertaken
Advisory committee meetings	500	per meeting - two meetings per annum

* 50% of the total cost is split across all populations equally, the remaining 50% of the cost is split across populations weighted by population size

Table A4.3 Estimated set up and annual running costs of a National Genetic Conservation Strategy across each endangered population

	Kerry	Moiled	Dexter	Connemara	Irish Draught	KBP	Galway	Total
Set Up Costs								
Roll out breeding programme	375	58	91	4,320	3,683	240	333	9,100
Install Barcode system	526	425	416	780	1,796	428	628	5,000
Purchase Alarmed Tanks	1,684	1,360	1,332	2,497	5,747	1,370	2,009	16,000
Person (half year work at start)	2,632	2,124	2,082	3,901	8,979	2,141	3,140	25,000
Total Set-Up-Costs	5,218	3,967	3,921	11,499	20,205	4,180	6,111	**55,100**
Annual Running Costs								
Recording parentage	0	0	0	0	0	0	0	0
Recording Genetic Defects	0	0	0	0	0	0	0	0
DNA sampling	16,800	2,604	4,060	41,472	35,352	2,304	63,984	166,576
DNA sampling males	8,400	1,302	2,030	20,736	17,676	1,152	31,992	83,288
Ongoing re-evaluations	200	200	200	200	200	200	200	1,400
Storage hair cards	420	65	102	1,037	884	58	1,600	4,164
Storage hair cards males	210	33	51	518	442	29	800	2,082
Collect Semen	3,160	10,000	5,818	10,000	6,000	1,400	3,200	39,578
Person (one quarter year annually)	1,316	1,062	1,041	1,951	4,490	1,071	1,570	12,500
Overheads	526	425	416	780	1,796	428	628	5,000
Identify donors	0	0	0	0	0	0	0	0
Advisory committee meetings	105	85	83	156	359	86	126	1,000
Total Running Costs	31,138	15,776	13,801	76,850	67,198	6,727	104,099	**65,725**

[1]KBP = Kerry Bog Pony; [2]Total annual running costs are exclusive of genotyping costs

Appendix 5. Assumptions and Costs for Embryo Transfer

Assumptions include:

- 4 eggs harvested per flush
- 50% success rate to implanted embryos
- 90% success rate to established pregnancies
- No cost to purchasing embryos or use of recipient wombs

Based on these assumptions, 28 embryo donors are required to provide 50 live births from embryos

Table A5.1. Costs of embryo transfer to obtain 50 live births from embryos

	Cost per unit (€)	Total Cost (€)
67% response to superovulation treatment	100	4,146
2.5 semen straws required to establish pregnancy	15	1,042
Flush all donors	300	8,333
Implant embryos into all recipients	110	12,222
Total Cost		25,743