DRAFT REPORT: A SCIENTIFIC ASSESSMENT OF THE POPULATION DENSITY (km^2), DISTRIBUTION AND POPULATION STRUCTURE OF THE RED DEER HERD IN GLENVEAGH NATIONAL PARK CO.DONEGAL.

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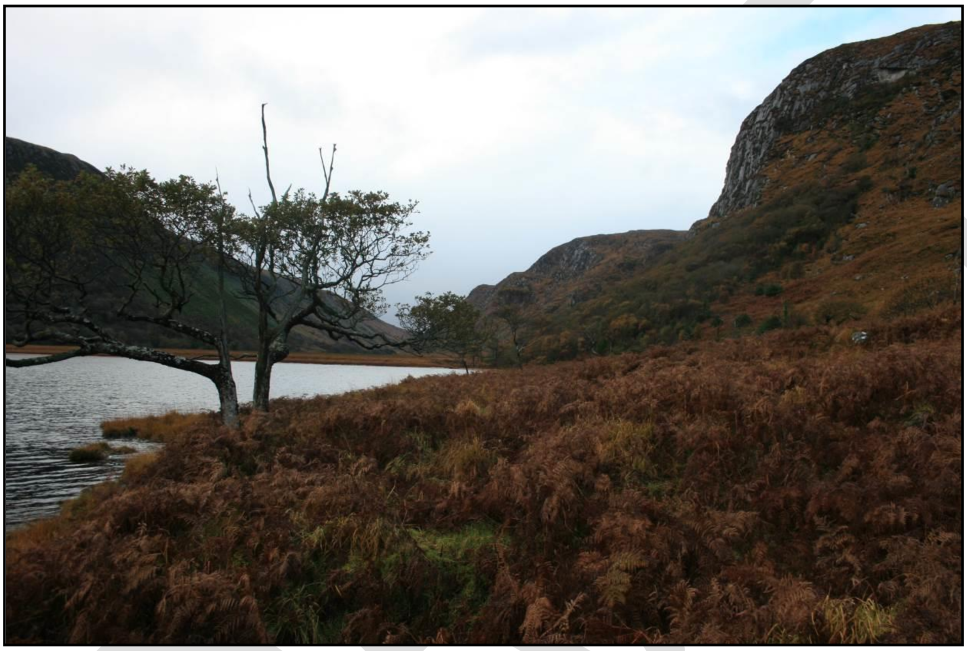

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ABSTRACT

Faecal Standing Crop counts were conducted in eight Deer Management Units (DMUs) over a two week period, covering 6,447 hectares in Glenveagh National Park. Forty strip-transects were walked covering a distance of approximately 74.6 kilometres and a sample area of 57,100m² (5.71 km²). Habitats within the National Park were stratified into three broad categories – Wet Heath / Upland Blanket Bog 6,259ha. (95.5%), Dry Heath / Acid Grassland 88ha. (1.36%) and Woodland 100ha. (1.5%).

Red deer density for Glenveagh National Park was assessed using Faecal Standing Crop (FSC) counts and was estimated to be (Mean ± 90% CI) **5.57km² ± 1.09 or 359 ± 70 deer**. On the eastern side of the National Park deer density was estimated at (Mean ± 90% CI) 5.07 ± 1.71 or 179 ± 60 deer. On the western side of the National Park deer density was estimated at (Mean ± 90% CI) 6.32 ± 1.1 or 179 ± 34 deer. Within the proposed Deer Management Units (DMU), density varied between 2.55 km² in Meenadreen to 8.99 km² in Scollops.

The distribution and ranging behaviour of red deer was assessed from observations taken along Fixed Transects in each Deer Management Unit. Broad patterns of deer habitat use were evaluated throughout the whole area and within individual Deer Management Units using data from FSC transects and observations.

Red deer ranged within DMUs and there was also some movement between contiguous DMUs. There was also evidence of outward and inward migration around the periphery of National Park. Red deer were sporadically distributed throughout the project area and were found at different densities in all three habitat categories varying from 5.50 km² in Upland Blanket Bog habitats to 15.3 km² in Dry Heath habitats. Deer densities in Woodland habitats were estimated at 7.17 km².

Population structure was determined from direct observations in the field during spotlight and thermal assessments. Data on group size and structure was also collected during the daytime on fixed transect surveys. Using all data collected from direct observations it was possible to re-construct the numbers of stags, hinds, yearlings and calves present in the deer population. Stag: hind, yearling: hind and calf: hind ratios were 0.27, 0.21 and 0.46 or 27 stags, 21 yearlings and 46 calves / 100 hinds respectively. This approximates to 50♂, 183♀, 39 yearlings and 87 calves. The net recruitment rate (growth) of the population is calculated at between 10 and 11% per annum.

INTRODUCTION

Glenveagh National Park lies in the heart of the Derryveagh Mountains in north-west of County Donegal covering over 14,000 hectares and is made up of three separate areas. The largest of these is the former 6,547 hectare Glenveagh Estate, which is encompassed by a 45 kilometre, 1.8 metre metal deer fence. The National Park is managed by the National Parks & Wildlife Service of the Department of Culture, Heritage and the Gaeltacht (CHG).

Glenveagh National Park is a large U-shaped valley running north-east to south-west with high mountainous peaks and glens, extensive tracts of Upland Blanket Bog, small mountain lakes, and scattered remnants of native woodland both east and west of the main valley. The steep sided valley holds the 5.5 kilometre long Lough Veagh with the cliffs of Keamnacally rising over 200metres above the lough on the western side. Lough Veagh roughly divides the National Park into two distinct areas. On the eastern side are the peaks of Kinnaveagh (384m), Lehanmore (442m) and Scollops (423m) along with 79 hectares of Mullangore oak woodland amounting to approximately 3,643 hectares in total. On the western side the peaks of Dooish (652m) and Staghall (486m) dominate with remnants of oak woodland at Derrylahan and Sruhanncullia amounting to approximately 2,904 hectares in all.

The National Park contains a wide array of habitats and species many of which are protected (Annex I and Annex II priority habitats) under Irish and European law. Glenveagh is part of the large Cloghernagore and Glenveagh National Park SAC (Site Code 002047).

For this survey, Glenveagh National Park was divided into eight proposed contiguous Deer Management Units (DMUs) based on known catchment areas and varying in size from 460 hectares to 1,365 hectares.

Census methods

Knowledge of population size and structure is essential for the development of effective and sustainable management strategies for deer populations. The methods used to gain such information are classified as either direct or indirect. Direct methods are based on surveys or counts of animals and allow the estimation of the actual number of deer of each sex and age class and only yield estimates of abundance on the actual day or days that the survey was completed. In general, direct counts rely heavily on resources (manpower and time) in addition to the requirement for favourable weather conditions for the duration of the count period. Direct counts often underestimate deer numbers and the correct identification and classification of sex and age classes is often problematic. On the other hand, indirect counts are not weather dependent, require fewer resources and provide estimates of average abundance, usually over several months [1]. Population indices derived from Faecal Pellet Counts have become widely used and are often employed to monitor trends at large regional scales [2, 3, 4]. Faecal Pellet

Counts (FPCs) are one of the most frequently used methods of assessing average animal abundance in both woodland and open habitats and have been used as an indicator of population size for more than 50 years [5, 6]. Indirect counts are generally easy and quick to carry out, are not influenced by prevailing weather conditions, can be carried out in all habitats and on all species. Most importantly, indirect counts give deer density results for identified habitat types and for geographic areas specifically related to deer presence up to periods of 6 months or more. The disadvantages are that because these counts do not rely on sightings of animals, sex ratios and population structure cannot be determined. Nevertheless, regular sample direct counts can be used very effectively to determine sex and age parameters within the target population. Indirect counts have been used to estimate the population density of a wide array of ungulate species such as mule deer *Odocoileus hemionus* [7], white-tailed deer *Odocoileus virginianus* [8, 9], elk *Cervus canadensis* [10] moose *Alces alces* [11], fallow deer *Dama dama* [12] and grey brocket deer *Mazama gouazoubira* [13]. The method is also used to estimate the population density of various species of lagomorphs [14], kangaroos [15], elephants [16] and marmots [17]. It is a method that correlates positively with other population density estimates [18, 19] but it is not exempt from potential errors [20].

STUDY DESIGN AND METHODOLOGY

Sampling

Most census methods require data to be collected by sampling due mainly to time and resource constraints, but also the areas involved are usually too large to allow for a complete census. Once a suitable method has been chosen, it should aim to be precise, accurate and unbiased and that the same methodology is followed without deviation. For this project, two methods were used:
Fixed Transect Thermal Imaging Direct Counts (FT/TIDC) and Faecal Standing Crop Strip Transect Counts (FSC/STC).

Fixed Transect Thermal Imaging Direct Counts – Fixed transect surveys were carried out in addition to Faecal Standing Crop Counts to determine patterns of movement, distribution and population structure. However, these surveys are extremely weather dependent and require good light and visibility for long periods of time. For the duration of this survey, weather conditions were less than satisfactory with poor visibility, rain and strong winds on most days. This hampered fixed transect surveys but did not have a significant overall effect on their efficacy. Nevertheless, it was possible due to the large number of individual observations, to identify patterns of movement and distribution and using the ratios of stags: hinds, hinds: yearlings and hinds: calves observed to effectively re-construct the population.

Eight, Fixed Transects were walked on a sequential basis in each proposed Deer Management Unit. This was to avoid as much as possible movement of deer between Deer Management Units with disturbance to deer kept to a minimum to allow for accurate classification of observed groups and individuals. Transect lengths varied according to topography (and prevailing weather conditions) and averaged between 8-9km on each transect. At specific vantage points along each transect, observations were made using the Thermal camera to detect groups or individual deer. Once detected, groups were counted and each individual classified into adult male, adult female, yearling male, yearling female and calf and the location, time, elevation, weather conditions and direction of movement (if any) noted. Faecal standing crop counts were conducted at specific points along each transect.

Faecal Standing Crop Strip Transect Counts -

Data are collected by counting all pellet groups (of all ages) that are present on one single visit to each survey area. Faecal Pellet Counts exploit the fact that deer deposit a known number of faecal pellet groups at regular intervals over time. The method assumes a positive linear relationship between the number of animals and the number of pellet groups deposited. Deer abundance can then be estimated by counting the total number of pellet groups deposited under the assumption that the number of pellet groups increases in line with the amount of time spent in a particular habitat. Pellet group count data can be therefore be transformed into deer abundance only if the following are known:

(i) The rate at which deer defecate faecal pellets (per day) and

(ii) The rate (per day) at which these faecal pellet groups decompose.

In order to transform pellet group data into a measure of deer abundance, it is crucial to know the habitat specific decomposition rate and the average defecation rate of the species being surveyed. Faecal Standing Crop (FSC) is therefore an indication of the balance between the gains of recently defecated pellet groups and the loss (complete decomposition) of old pellet groups from the system. Over winter, decomposition rates slow down resulting in an increase in the standing crop biomass from October until late April. Conversely, during the summer months decomposition rates may be higher (due mainly to increased invertebrate activity) and the biomass of the standing crop decreases in size until the onset of winter.

Transformed pellet group count data actually quantifies ‘average deer abundance’ over the survey period as it is expected that deer may move into and out of the study area during the survey period and as a result the number of deer present on any one day may not equal the average number of deer present during the study period. Transformed pellet group count data is often referred to as Effective Deer Utilisation or EDU. This acknowledges the fact that the data represent the number of deer that were effectively present in the study area and not actually present.

Sample size

Sample size is usually a compromise between too small a sample that will be too imprecise to be on any use and too large a sample that will be too costly and inefficient. The recommended minimum sample size for Faecal Standing Crop Strip transects is between 400m^2 and 600m^2 / 100ha. or 0.04% - 0.06% of the survey area [21]. However, the intensity of the sampling and therefore the precision and accuracy of the results will inevitably depend on budgetary and time constraints. In this survey a minimum of 800m^2 (0.08%) sample size was chosen to allow for a reasonable sample area to be covered and to increase the precision and accuracy of the results.

Defaecation and Decomposition

Defecation rates are species specific and decomposition rates are habitat specific. Data on decomposition rates have been collected (both seasonally, annually and over-winter) for a wide range of Irish habitat conditions for red deer. For this project, mean defaecation rates and over-winter decay rates for red deer were used. Because of the availability of habitat specific decay rates for red deer and the relatively short sampling timescale Faecal Standing Crop (FSC) was the preferred method for the current project.

Habitats and habitat stratification

Habitat stratification is usually carried out where there is likely to be large variation in the factors being measured across the survey area, but more importantly where there is specific prior knowledge of the site and its' deer population. For this project, habitats were broadly stratified into Wet Heath / Upland Blanket Bog (HH1 / PB2), Dry Heath / Acid Grassland (HH3 / GS4) and Woodland (WN1).

Transects

Transect dimensions usually vary according to the area (ha.) and type of habitat being sampled as the sizes of specific habitats are highly variable. For this survey, linear strip transects (ST) were used and these varied in length from 500m to 1,200m. Transect widths were 1.25m in Woodland habitats and 1.5m in Upland Blanket Bog habitats. Transects were divided into 10m parcels and pellet groups found within each 10m parcel were recorded. A group was counted if at least 6 pellets were present and clearly identifiable [22]. Faecal pellet groups of sheep and hares were noted as present but not counted. Strip transects have a large edge: area ratio and are therefore prone to problems of edge-effects that occur when dung groups lie across transect boundaries. Therefore, decisions on inclusion must be made to reduce the potential for error. Those groups on the transect boundary were counted if more than half of the group was located within the transect itself. Transects must therefore not be too wide as dung groups far from the central line may be missed. Transects must also be sufficiently long to optimise the ratio of time spent counting on them and to increase the proportion of positive counts in areas of low animal density (thus avoiding as far as possible skewed distributions with many zero values).

Start Points & Transect Bearings

The sampling procedure was randomised by starting transects at points described by random co-ordinates located on Fixed Transect routes in each DMU based on 1:50,000 OS maps. Start points were determined at random using the 1:50,000 OS map and where possible on the ground, identifiable features were noted to assist in relocation. Transects were walked along a pre-determined random compass bearing. A SATMAP (Active12) GPS was used in the field to locate transects and start points. Transects in Upland Blanket Bog habitats were walked in a zigzag fashion to improve spatial coverage.

Data Analysis

Deer density was estimated using PELLET, a semi-automatic based procedure in Microsoft Excel®. The density calculation includes a range of variations in defecation and decay rates that eliminate the subjective practice of selecting one single defined value for these parameters. The calculation also incorporates spatial variation and decay time. PELLET comprises four Excel® spread-sheets, the choice of which depends on the type of plot and the number of field samples [23].

Habitats description

Wet Heath (HH3) / Upland Blanket Bog (PB2)

These habitats were exclusively Wet heath / Upland blanket bog (Plate 1.) and were all found at high elevations (>150m above sea level). Vegetation consisted of species such as Deergrass (*Tricophorum caespitorum*), Heath Rush (*Juncus squarrosis*), cottongrasses (*Eriophorum* spp.) and purple moor grass (*Molinia caerulea*) in wetter areas, dwarf shrubs and heaths such as *Calluna vulgaris* and *Erica* spp. in drier areas. This habitat covers approximately 6,397 hectares or 97.1% of the total habitat available.

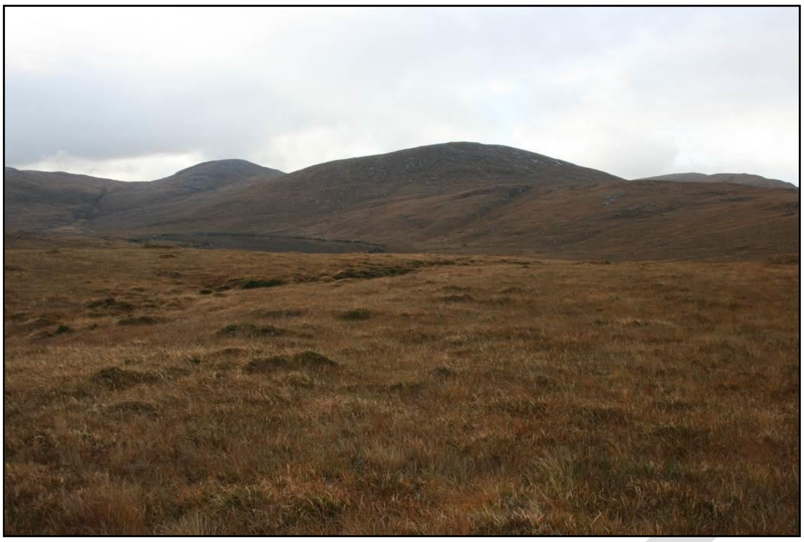

Plate 1. Wet Heath / Upland Blanket Bog (L. Nambradden and Kinnaveagh in the background)

Semi-natural Woodland (WN1)

These habitats are predominantly mature oak (*Quercus petraea*) woodlands with a mixed holly (*Ilex aquifolium*) birch (*Betula* spp.) and hazel (*Corylus* spp.) understory. Tree species diversity is generally low and ground/shrub layers sparse under canopy. Other species, such as beech (*Fagus sylvatica*), sycamore (*Acer pseudoplatanus*), alder (*Alnus glutinosa*) and occasional larch (*Larix* spp.), spruce (*Picea* spp.) and pine (*Pinus* spp.) are also present. This habitat accounts for approximately 100 hectares or 1.5% of the total habitat available.

Plate 2. Semi-natural Woodland at Mullangore

Dry Heath (HH1) / Acid Grassland (GS3) –

These habitats were found on well drained, nutrient poor steep slopes on the valley sides of the Upper Glen, on the valley floors and along burn edges. Typical components of this habitat include heathers (*Calluna* and *Erica* spp), Bilberry (*Vaccinium myrtilis*) mixed with *Molinia* and other commonly occurring grasses such as sedges and bents. The most common species found in this habitat are *Agrostis* spp., Wavy Hair-grass (*Deschampsia flexuosa*) Mat grass (*Nardus stricta*) and fescues such as (*Festuca rubra* and *F. ovina*). Broadleaved herbs such as Tormentil (*Potentilla erecta*) and Sheep's sorrel (*Rumex acetosella*) are also common. This habitat accounts for approximately 88 hectares or 1.36% of the total habitat available.

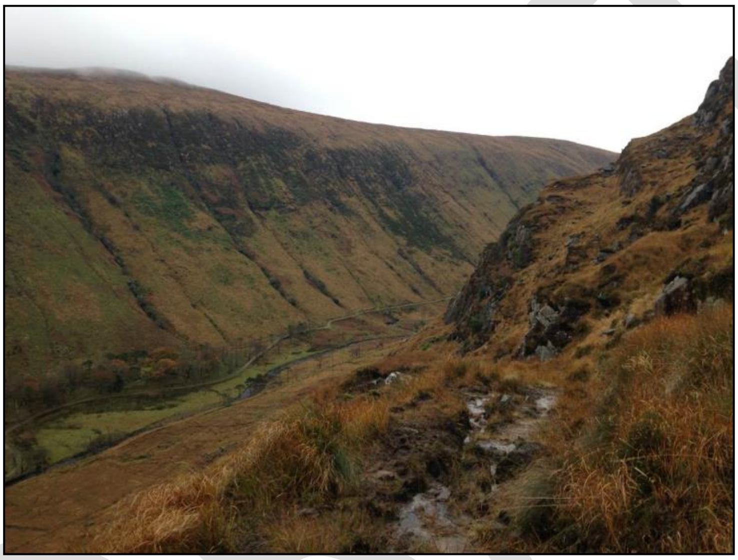

Plate 3. Dry Heath / Acid Grassland on the W. slopes of Scollops in the Upper Glen

<u>**Population density (km^2) of red deer**</u>

The population density of red deer was estimated from Faecal Standing Crop (FSC) transects. Mean defaecation times for red deer and updated mean decay rate data [24] were used to estimate relative abundance.

<u>**Historical Counts**</u>

In Glenveagh National Park, the methodology of counting deer has remained relatively un-changed since 1959. The method, known as Line Counting (LC) is based on the sightings of animals within a defined geographical area on the day that the count takes place. Counters (in radio contact) are strategically placed on high ground and deer are driven towards them. Logistically, this method is heavily dependent on available resources, favourable weather conditions and should be representative of the total land area occupied by deer. If the prevailing conditions are favourable, the deer can be counted and classified into male, female, juvenile and calf. Woodland areas are generally not counted.

However, there are a number of deficiencies that are attributable to this method. Counts are often conducted with the prevailing wind behind the counters resulting in an unknown number of deer not being seen or counted because they escape into woodland or other cover due to disturbance from the approaching counters. In addition, as animals are moving away from counters they frequently congregate into large groups. As a result, accurate counting and classification is often challenging and recurring misclassification is inevitable (most often yearling males are classified as females which, inflates the number of females and skews the calf: hind and stag: hind ratios). Furthermore, the counts are almost always held during the summer, so the results fail to reflect the rate of recruitment because up to 50% of the calves born in any year may die before they are 12 months old.

Deer Distribution and Ranging behaviour

The distribution of red deer was assessed from a combination of direct observations and pellet group distribution in all Deer Management Units. Observations were made on Fixed Transect surveys and pellet group distribution was assessed from faecal standing crop transects. It was also possible to determine broad patterns of habitat use of red deer throughout the whole area and within individual Deer Management Units.

Population structure (sex ratios and Recruitment) of red deer

Population structure was determined from direct observations in the field during Fixed Transect surveys and casual observations. Additional observations were made during spotlight / thermal assessments during darkness and in the early morning. None of these observations were counts.

A total of over 90 observations were made. A thermal imaging camera (Pulsar Quantum LD38 Thermal imager) was used to detect animals in open and semi-wooded terrain and was particularly useful in detecting partially hidden animals (Plate 4.). Once animals were detected, an analysis of the group structure or individuals was made with 8x40 binoculars and telescope. Using data collected from direct observations it was possible to determine the population structure of red deer and to re-construct the numbers of stags, hinds, yearlings and calves present within the red deer population.

Plate 4. Deer exhibiting a thermal signature

RESULTS

POPULATION DENSITY

1.0 Faecal Standing Crop Strip Transects

For this survey, a total distance of approximately 74.6 kilometres was walked along eight fixed transects. The cumulative sample area of 57,100m² was covered divided into forty one linear strip transects (ST) for FSC surveys. Of these, thirty four transects were in Upland Blanket Bog habitats covering 51,300m², four transects were in Woodland habitats covering 2,500m² and two transects were in Dry Humid Grassland / Dry Heath habitats covering 3,300m². Elevation ranged from 43m above sea level to 652m above sea level. Ground vegetation in Upland Blanket Bog habitats was moderate to light and extra search effort was required only in areas of moderate ground cover (for example *Molinia* tussocks and *Juncus* dominated swards). However, because vegetation density in general was at its' lowest at this time of year, search time and effort was generally straightforward. In Woodland habitats, particularly those where deer had free access, ground vegetation was sparse although recent autumn leaf-fall necessitated slightly longer and more dedicated search times. In Dry Humid Grassland / Dry Heath habitats, search effort was straightforward.

1.1 Individual Deer Management Units (East) Table 1.)

1.1.1 [redacted]

Four 800 x 1.5m FSC transects were conducted in Wet Heath / Upland Blanket Bog along [redacted]. Deer density from FSC data was estimated at 2.55km² or the equivalent of 14 deer.

1.1.2 [redacted]

Eight FSC transects were conducted along [redacted], 5 x 1,000 x 1.5m transects in Wet Heath / Upland Blanket Bog and 3 x 500 x 1.25m transects in Semi-Natural Woodland. Cumulative deer density from FSC data was estimated at 5.07km² or the equivalent of 46 deer.

1.1.3 [redacted]

Six 1,200 x 1.5m FSC transects were conducted in Wet Heath / Upland Blanket Bog along [redacted] Deer density from FSC data was estimated at 3.13km² or the equivalent of 41 deer.

1.1.4 [redacted]

Five FSC transects were conducted along [redacted] 2 x 1,100 x 1.5m transects in Wet Heath / Upland Blanket Bog, 2 x 1,100 x 1.5m transects in dry Humid Grassland / Dry Heath and 1 x 500 x 1.25m transect in Semi-Natural Woodland. Cumulative deer density from FSC data was estimated at 8.99km² or the equivalent of 69 deer.

1.15 [redacted]

Twenty four FSC transects were conducted along four fixed transect routes on [redacted] of the National Park. Cumulative deer density from FSC data was estimated at (Mean ± 90%) 5.07 ± 1.71km² or the equivalent of 179 ± 60 deer.

DMU	AREA (ha.)	No. of Transects	Sample area (m²)	Density (Km²)
[redacted]	552.00	4x800m	4,800	2.55
[redacted]	857.00	5x1,000m	7,500	3.74
	59.00	3x500m	1,875	5.82
[redacted]	1,305.00	6x1,200m	10,800	3.13
[redacted]	660.00	3x1,100m	4,950	4.31
	22.00	1x500m	625	10.1
	88.00	2x1,100m	3,300	15.3
[redacted]	**3,543.00**	**24**	**33,850**	**5.07±1.71**

Table 1. Deer density (km²) in individual DMUs on the [redacted] side of the National Park

1.2 Deer Management Units ([redacted]) (Table 2)

1.2.1 [redacted]

Three 800 x 1.5m FSC transects were conducted in Wet Heath / Upland Blanket Bog along [redacted]. Deer density from FSC data was estimated at 8.8km^2 or the equivalent of 40 deer.

1.2.2 [redacted]

Six 1,200 x 1.5m FSC transects were conducted in Wet Heath / Upland Blanket Bog along [redacted]. Deer density from FSC data was estimated at 6.02km^2 or the equivalent of 82 deer

1.2.3 [redacted]

Four 800 x 1.5m FSC transects were conducted in Wet Heath / Upland Blanket Bog along [redacted] Deer density from FSC data was estimated at 6.18km^2 or the equivalent of 36 deer.

1.2.4 [redacted]

Three 900 x 1.5m FSC transects were conducted in Wet Heath / Upland Blanket Bog along [redacted]. Deer density from FSC data was estimated at 5.75km^2 or the equivalent of 29 deer.

1.2.5 [redacted]

Sixteen FSC transects were conducted along four fixed transect routes on the [redacted] of the National Park. The cumulative deer density from FSC data was estimated at (Mean ± 90%) 6.32 ± 1.1km^2 or the equivalent of 184 ± 34 deer.

DMU	AREA (ha.)	No. of Transects	Sample area (m^2)	Density (Km^2)
[redacted]	460.00	3x800m	3,600	8.8
[redacted]	1,365.00	6x1,200m	10,800	6.02
[redacted]	578.00	4x800m	4,800	6.18
[redacted]	501.00	3x900m	4,050	5.75
[redacted]	**2,904.00**	**16**	**23,250**	**6.32±1.10**

Table 2. Deer density (km^2) in individual DMUs on the [redacted] of the National Park

1.3 Glenveagh National Park (Table 3.)

In total forty, Faecal Standing Crop Transects were completed covering a total sample area of approximately 57,100m^2 during this survey. Deer density for the entire National Park estimated from FSC counts was (Mean±90% CI) 5.57km^2 ± 1.09 or 359 ± 70 deer.

DMU	AREA (ha.)	No. of Transects	Sample area (m^2)	Density (Km^2)
[redacted])	552.00	4x800m	4,800	2.55
[redacted]	916.00	5x1,000m 3x500	7,500 1,875	5.07
[redacted]	1,305.00	6x1,200m	10,800	3.13
[redacted]	770.00	3x1,100m 1x500m 2x1,100m	4,950 625 3,300	8.99
[redacted]	460.00	3x800m	3,600	8.8
[redacted]	1,365.00	6x1,200m	10,800	6.02
[redacted]	578.00	4x800m	4,800	6.18
[redacted]	501.00	3x900m	4,050	5.75
NP	**6,447.00**	**40**	**57,100**	**5.57±1.09**

Table 3.   Deer density (km^2) in individual DMUs in Glenveagh National Park

2.0 Fixed Transect Thermal Imaging Direct Counts (Table 4)

For this survey, a total distance of approximately 74.6 kilometres was walked along eight fixed transect routes, one in each DMU. The cumulative sample area of approximately 49.9km^2 was covered and the numbers of observations of deer were totalled for each transect.

DMU	AREA (ha.)	Transect length (km)	Sample area (km^2)	No of Obs.

[redacted]	552.00	10.2	4.19	8
[redacted]	916.00	11.3	6.34	7
[redacted]	1,305.00	10.1	10.6	3
[redacted]	770.00	7.0	4.4	11
[redacted]	460.00	7.0	3.57	6
[redacted]	1,365.00	11.5	8.10	9
[redacted]	578.00	9.6	3.44	6
[redacted]	501.00	7.9	3.31	7
NP	**6,447.00**	**74.6**	**43.95**	**57**

Table 4. Deer numbers in individual DMUs in Glenveagh National Park

2.1 Glenveagh National Park (Fig.10.)

A total of eight, Fixed Transects were walked covering a total area of approximately 43.9 km^2 or 68% of the total National Park area. The cumulative total number of deer observations on all transects was 55 with a total number of deer observed of 297.

3. Habitats (Table 5, Figure 2)

3.1 **Wet Heath (HH3) / Upland Blanket Bog (PB2)**

Red deer densities in Upland Blanket Bog habitats were estimated from Faecal Standing Crop counts at 5.50 km^2.

3.2 **Woodland (WN1)**

Red deer densities in Woodland habitats were estimated from Faecal Standing Crop counts at 7.17 km^2.

3.3 **Dry Heath (HH4) / Acid Grassland (GS3)**

Red deer densities in Dry Heath / Acid Grassland habitats were estimated from Faecal Standing Crop counts at 15 .3 km^2.

HABITAT	AREA (ha.)	No. Of Transects	Sample area (m^2)	Density (km^2)

Wet Heath (HH3) / Upland Blanket Bog (PB2)	6,259.0	34	51,300	5.50
Woodland (WN1)	100.0	4	2,500	7.17
Dry Heath/ Acid Grassland (HH1/GS3)	88.0	2	3,300	15.3
ALL HABITATS	**6,447.0**	**40**	**57,100**	**5.67±1.15**

Table 5. Estimated deer density (km²) in each habitat within Glenveagh National Park

4. Deer Distribution and Habitat use

4.0 Glenveagh National Park (Fig. 11)

Deer were sporadically distributed within the National Park with variable densities throughout each Deer Management Unit. In general, densities were low (<6.0 km^2) in DMUs that had higher proportions of Upland Blanket Bog habitats and were higher in DMUs that provided shelter and higher quality grazing such as Woodland or Dry Heath habitats. Deer densities in these DMUs were almost twice those of DMUs that had greater proportions of Upland Blanket Bog habitats.

4.1 Individual Deer Management Units (East)

4.1.*1 DMU* [redacted]

This DMU contained a small proportion of enclosed Woodland habitat but was predominantly Upland Blanket Bog. As such, deer densities in Meenadreen were estimated at (2.55 km^2) the lowest in all DMUs throughout the National Park. The majority of deer were found in the Owenacally catchment - an area that contained small sheltered glens and flushed stream and burn edges.

4.1.2 *DMU* [redacted]

This DMU contained an estimated 59ha. of [redacted] and although fenced the deer had gained access through numerous breaches in the fence line. Estimated deer densities in this section of the woodland were lower than expected (5.82 km^2) while in the remainder of the DMU deer density estimated at (3.74 km^2) which, was not surprising given the extent of Upland Blanket Bog habitat and the proportion of ground above 200m. Cumulative deer densities in this DMU were estimated at (5.03 km^2). Most deer were found on the [redacted] and also on the [redacted].

4.1.3 [redacted]

This large DMU contained almost exclusively Upland Blanket Bog habitat with no woodland and only small flushed areas of Wet Heath at [redacted] and patches on the southern flank of [redacted]. Estimated deer densities in [redacted] were lower than the average at (3.13 km^2).

4.1.4 *DMU* [redacted] This DMU contained the most varied habitat types of all DMUs within the National Park. The most abundant habitat type was Upland Blanket Bog found on the [redacted] However, this DMU contained two [redacted] both of which offer shelter and food in both Woodland and Dry Heath habitats. The majority of deer were found on the Dry Heath in the [redacted] and in the sheltered woodland of [redacted]. Deer densities in un-protected Woodland habitats were estimated at (10.1 km^2) while densities in Dry Heath were estimated at (15.3 km^2). Estimated densities in Upland Blanket Bog were within expected limits (4.31 km^2). Cumulative deer density in this DMU was estimated at 8.99 km^2.

4.2 Deer Management Units [redacted]

4.2.1 *DMU* [redacted]

This DMU is the smallest of the eight DMUs within the National Park. It is predominantly Upland Blanket Bog forming the [redacted] catchment and includes the [redacted]. One small (<1ha.) block of semi-natural woodland ([redacted] is located on the eastern slopes [redacted]. Deer densities in this DMU were estimated at (8.8 km^2) and were similar to deer densities in Scollops (8.99 km^2).

4.2.2 *DMU* [redacted]

This is a large DMU covering almost 14 km^2 and has historically been known as a favoured area for red deer in Glenveagh National Park. It is exclusively Upland Blanket Bog / Wet Heath habitat and includes [redacted]. Deer densities in this DMU were estimated at (5.76 km^2).

4.2.3 *DMU* [redacted]

This DMU is similar to the [redacted] predominating and little ground below 400m. Two patches of semi-natural woodland, one deer –fenced and the other open are located at the head of the western shore of Lough Veagh are within this DMU. Deer densities were estimated at (5.92 km^2).

4.2.4 *DMU* [redacted]

This DMU contains predominantly Upland Blanket Bog / Wet Heath habitats but is also interspersed with small (1-2ha.) blocks of [redacted], some of which have been fenced to exclude deer. Much of the ground [redacted]. Deer densities in this DMU were estimated at (5.74 km^2) and were within the average range of deer densities found throughout the National Park.

<u>5. Population structure, Sex ratios and Recruitment (Growth)</u>

5.0 Deer Management Units (East) (Figs. 4, 6).

Population structure (the ratio of ♂:♀, Yearling: ♀ and calves: ♀) was calculated from observations of groups of deer on fixed transects and other random observations. Ratios of stags: hinds on the eastern side of the National Park were 0.29 or 29 stags / 100 hinds. The ratio of calves to hinds was calculated at 0.50 or 50 calves / 100 hinds. The ratio of yearlings (male and female): hinds was calculated at 0.19 or 19 yearlings / 100 hinds.

5.1 Deer Management Units (West) (Figs. 5, 7).

Population structure (the ratio of ♂:♀, Yearling: ♀ and calves: ♀) were found to be within normal ranges for red deer in upland habitats in late winter early autumn although there was more variation between DMUs compared to the eastern side of the National Park. Ratios of stags: hinds on the western side of National Park were 0.25 or 25 stags / 100 hinds. The ratio of calves to hinds was calculated at 0.43 or 43 calves / 100 hinds. The ratio of yearlings (male and female): hinds was calculated at 0.22 or 22 yearlings / 100 hinds.

5.2 Glenveagh National Park. (Figure 8, Table 6).

Population structure (the ratio of ♂:♀, Yearling: ♀ and calves: ♀) was found to be within normal ranges for red deer in upland habitats in late winter early autumn. Ratios of stags: hinds in the National Park were 0.27 or 27 stags / 100 hinds. The ratio of calves to hinds was calculated at 0.46 or 46 calves / 100 hinds. The ratio of yearlings (male and female): hinds was calculated at 0.21 or 21 yearlings / 100 hinds.

Based on these parameters the predicted annual growth rate of the red deer population in Glenveagh National Park in 2017/18 is calculated to be 10 – 11%. The calculated proportion (%) of males, females, yearlings and calves within the red deer population is 14% stags, 51% hinds, 11% yearlings (♀ & ♂) and 24% calves.

Sex Ratios	EAST	WEST	NATIONAL PARK
♂ : ♀	0.29	0.25	0.27
YL : ♀	0.19	0.22	0.21
Calf : ♀	0.50	0.43	0.46

Table 6. Sex ratios of the red deer population in Glenveagh National Park

6. Deer Ranging behaviour (Fig.12)

6.0 Movement within individual Deer Management Units

There was little evidence of recent large-scale movement within Deer Management Units given that red deer exhibit relatively large home range sizes. However, there was evidence of small-scale movement with well-defined trails (Plate 6) from higher to lower altitudes and to favoured feeding areas usually along burn edges (Plates 5, 7), at the periphery of woodlands and in glen and valley bottoms. In the majority of DMUs resources (food and shelter) are dispersed prompting daily movement patterns between shelter and feeding areas.

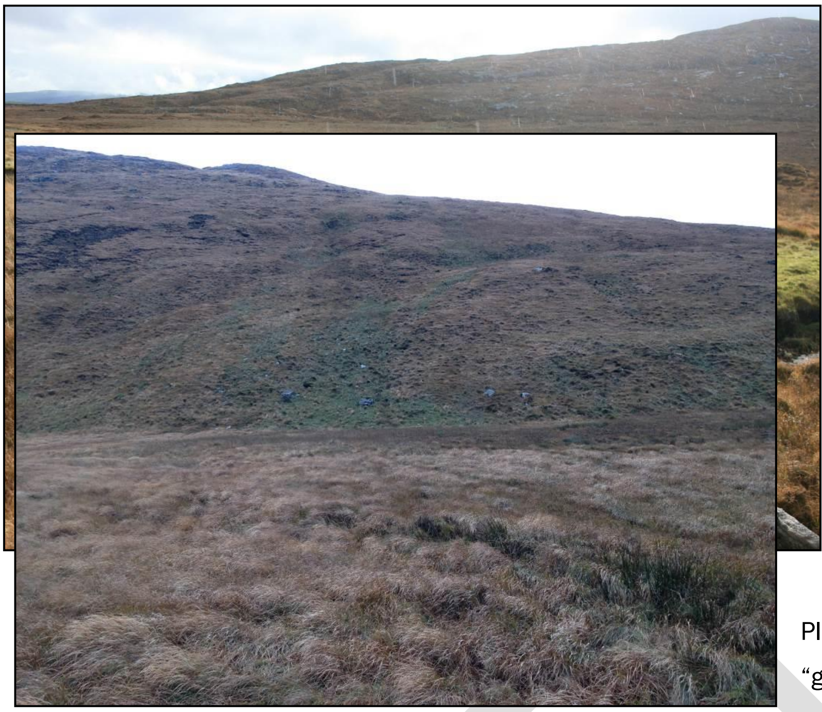

Plate 5. Flushed “greens” along burn edges showing clear evidence of grazing

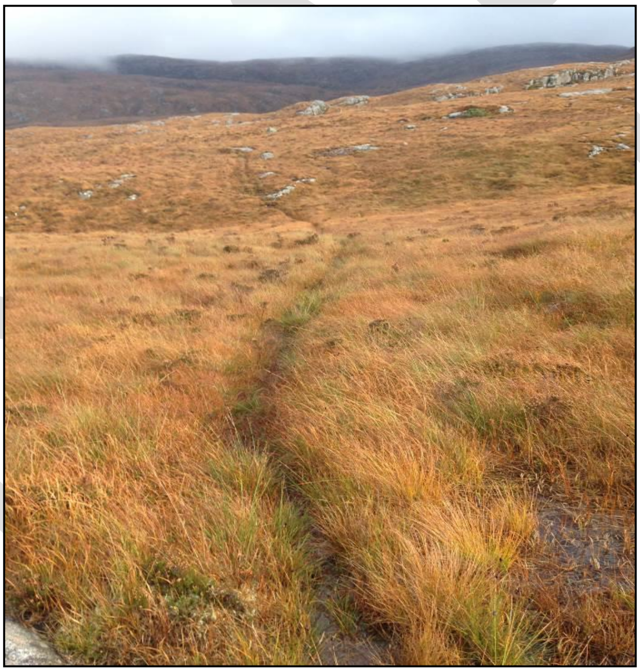

Plate 6. Well defined trails leading to favoured feeding areas

Plate 7. Flushed "greens" along valley bottom (Meenashambra)

6.1 Movement between Individual Deer Management Units

Movement between DMUs was found to be relatively limited, particularly during the period of this survey. In general, some DMUs had a higher proportion of shelter and a higher quality of food resources than others and as a result, deer tended to concentrate in these areas, for example [redacted]

6.2 Movement between East and West

Little or no large scale movement was detected between the Eastern and Western side of the National Park except in the area of the [redacted] In the [redacted] movement was limited to diurnal movements from either side of the valley down to the valley floor but in general deer were strongly hefted to specific areas on one side of the glen or the other.

6.3 Movement between Glenveagh National Park and peripheral areas

Prior to the construction of the main deer fence deer in 1891, deer were initially confined to an area around [redacted] from where they were released into the estate once the main fence had been completed. However, because of the type of fence construction, although

Plate 8. Section of fence missing droppers, showing clear deer movement

conventional for the period, it was never likely to be entirely deer proof and was probably most effective in keeping deer inside Glenveagh in the initial years when density was low (<5km^2). As density increased in the early 1960's through to the mid 1970's (10 – 11 km^2), it was well known that deer movement through the fence was a relatively regular occurrence albeit at particular times of the year. At the same time, State forestry plantations established in peripheral areas around Glenveagh in the 1950s had begun to mature.

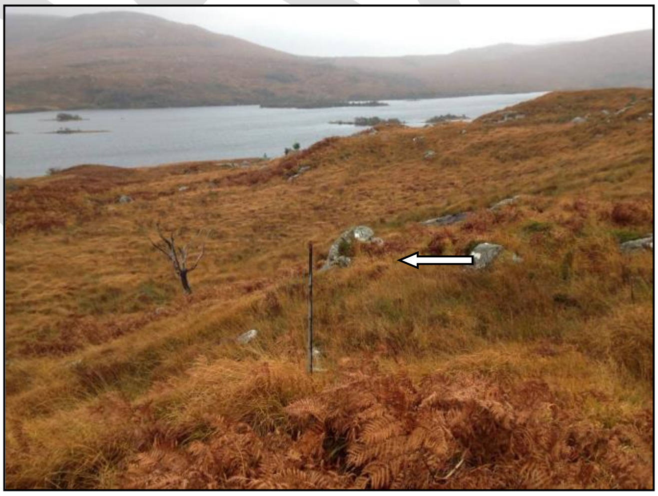

Plate 9. Remains of original deer enclosure at Derrylahan

During the course of this survey, it was found that deer movement from within Glenveagh to peripheral areas was relatively common, due for the most part to the breakdown of the fence. In many areas, complete sections of the fence were found to be missing, particularly sections where droppers had rotten (Plate 9) and the wires had become slack or broken allowing free movement in both directions.

Plate 11. Structurally intact fence line at [redacted]

7.0 Fences

7.1.1 Main deer fence

The 45 kilometre 1.8 metre deer fence (Plate 10) around Glenveagh is a significant piece of engineering history. For most of its 45 kilometre length it is structurally intact (i.e. the strainers and standards are still in excellent condition and remain firmly in place). In some sections however, the fence has begun to disintegrate principally due to lack of investment and maintenance allowing the droppers to decay and the wires to become slack or broken. In other sections, notably from the Altan Gap to Croloughan, sections of the fence have completely collapsed due mainly to snow and ice during the winter months. The decision on the future of the deer fence rests almost entirely on the future management strategy that is adopted for the deer population in Glenveagh National Park.

7.1.2 Woodland Enclosures

Woodland enclosures are generally in better condition than the main deer fence (Plate 11). However, lack of maintenance has resulted in some enclosures becoming porous allowing deer ingress. The initial investment (financial and manpower) in these fences is immense and therefore they should be maintained until such time as they have achieved their specific objective. Once this has been done the fences should be removed in their entirety. In general, woodland re-generation has been successfully achieved in most of the enclosures (e.g. Mullangore wood.

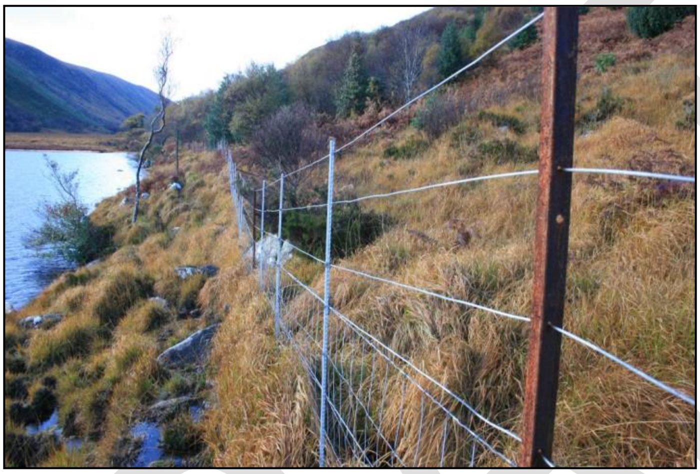

Plate 11. Successful enclosure with an intact deer fence

7.2 Deer density in Peripheral areas (Table 7).

During the 1960s, 70s and early 1980s, the deer population in Glenveagh remained relatively stable with estimated numbers averaging around 600 animals or an estimated density of 9.5 km^2, roughly twice the current average. However, over the years deer periodically escaped from within Glenveagh and gradually began to colonise adjacent State forestry plantations notably, Glentornan, Ards, Laracus, Meeniroy and Meenabol forests all of which lie within <10km of the National Park boundary.

Forest District	Area (ha.)	Deer density (km^2)	Distance from NP	Direction
[redacted]	1,272.82	10.0	<3km	West / Southwest

[redacted]	488.31	8.03	10km	North
[redacted]	1,743.86	9.04	5km	Southwest
[redacted]	374.45	15.6	14km	South
[redacted]	859.99	7.8	24km	Southwest
[redacted]	986.4	8.6	48km	South
[redacted]	2185.49	9.5	40km	Southeast

Table 7. Coillte Forest Districts and relative deer densities From FSC counts in 2014

Currently, deer densities within these forest blocks range between 7.8 km^2 and 15.6 km^2 [25] and red deer have colonised practically every forest block in the county. They are now found as far south [redacted]. Over the last forty years, there has been a significant shift in the distribution of red deer populations in Donegal. In the early years Glenveagh acted as a continuing source population, distributing deer into the wider countryside on a gradual basis. Now, Glenveagh may become the recipient or the sink as deer density in the wider countryside is on average twice that in Glenveagh. As density continues to increase in the wider countryside, density may well stabilise or even gradually decrease within the National Park. However, the scale and timeframe at which this occurs will depend largely on the management strategy adopted and whether the deer fence around the National Park is eventually restored to a deer-proof condition. Many deer that leave Glenveagh are unlikely to return with the exception of adult males. Adult males have been temporarily emigrating form Glenveagh since the early 1970s, spending most of the year in the shelter and security of commercial forestry plantations and migrating into Glenveagh in late Setember early October and leaving again at the end of October. The low stag: hind ratio (0.27) or 27 stags: 100 hinds found is most likely a reflection of this temporary emigration.

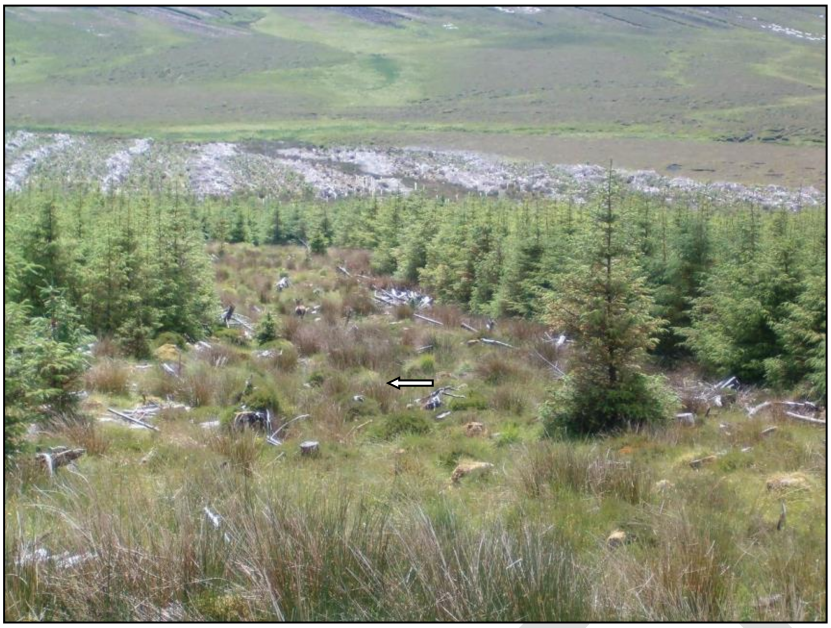

Plate 12. Red deer hind in [redacted] (June 2014)

8.0 Discussion

Population density

This is the first scientific assessment of the red deer population to be carried out in Glenveagh National Park since 1980 [26]. The first recorded census of red deer in Glenveagh took place in the summer of 1959 and returned a total number of approximately 700 red deer or an equivalent density of $10.8km^2$. Over the next 23 years annual counts were conducted and average deer numbers over that period were 633 or the equivalent density of 9.81 km^2. The lowest number of 410 (6.3 km^2) was recorded in 1978 whilst the highest number of 920 (14.2 km^2) was recorded in 1969. During the same period, greater numbers of stags were culled on average than hinds with the exception of 1968/69 when over 180 hinds were culled.

The difficulties in estimating the population size of deer in different habitats are well recognized. Estimates derived from direct counts often underestimate numbers by a substantial margin and although there are no consistent differences in the overall number of deer counted using different methods [27], the accurate classification of deer by sex and age is more problematic. For example, analysis of ground counts carried out on the Isle of Rhum in Scotland, demonstrated consistent systematic misclassification of young stags as hinds [28].

Misclassification leads to discrepancies in sex and age class with the result that the recorded numbers of hinds are often exaggerated. This in turn leads to problems associated with decisions around appropriate culling levels.

For the purposes of managing deer populations, the most appropriate time of year to carry out census work is either the autumn (September / October) or preferably during the spring months (February - April). This has a number of advantages. First, the numbers of juvenile deer counted have experienced, neo-natal and over-winter mortality and the remaining population size in the spring is reflective of the total population for that year. Second, the numbers of juveniles present in the spring are those that have survived to the age of 9-12 months and are an indication of the recruitment rate (or growth rate) of the population. Third, during the spring months, days are longer, weather tends to be more moderate and the vegetation is at its lowest density – making counting (by whatever method) more productive. Culls that are based on counts carried out during the summer usually depend on the numbers of calves counted as a measure of population growth, which takes no account of neo-natal and over-winter mortality. As a result, culling based on summer counts is likely to depress population density by accident rather than by design.

Direct counts have been carried out in Glenveagh National Park based on traditional methodology. This methodology is not only limited in its ability to deliver useful data that can be used to actually manage the deer population, but it is also subject to significant errors in accuracy and classification. It is also heavily dependent on the availability of skilled manpower, resources and favourable weather conditions. Consequently, there is a lack of clarity and consistency on deer abundance and population structure, little data on habitat utilisation and potential impacts on diversity. Furthermore, deer density has always been expressed at a landscape scale which makes it impossible to determine variations in density at finer habitat or management area scales and to take appropriate corrective action.

Faecal Standing Crop counts were used for this survey to estimate deer density, primarily because they are not subject to the same limitations as direct counting and they required fewer resources in terms of time and manpower. One of the main advantages of FSC methods is that they provide a reliable, retrospective (and current) estimate of relative abundance in addition to providing an assessment of approximate habitat use. Crucially, FSC methods give a habitat by habitat or area by area estimate (DMU model) of deer density which is an invaluable aid to future management as density can be regulated at these finer scales. This is in complete contrast to direct counts where the results are only applicable to the day (or days) that counts took place and there is no indication of spatial distribution within each habitat or area.

The estimated deer density in Glenveagh National Park is low (5.57 km^2) in comparison to many red deer populations occupying similar habitat types in Scotland and Ireland. A recent review of red deer density in upland moorland in Scotland by Scottish Natural Heritage, revealed that deer density increased from 8 km^2 in 1961 to 13 km^2 in 2016 (an increase of 60%), but in the last 15 years density has stabilised and was at around 12.5 km^2 in 2016 [29]. Also, in a recent study of red deer densities in upland areas of Killarney National Park densities of almost twice that (9.63 km^2) of the current study were recorded. [30]. However, densities are generally variable across different land areas usually as a result of resource and habitat variables and this was the case in Glenveagh. Results of deer densities in the eight Deer Management Units surveyed in Glenveagh showed that densities ranged from 2.55 km^2 to 8.99 km^2 but that there was little difference in the mean density between the eastern (5.07 km^2) and western (6.32 km^2) side of the National Park.

Considering that little or no substantial systematic culling has taken place for a number of years in Glenveagh, there may be a couple of possible explanations: First, It may well be that the population has reached or is close to reaching its own natural equilibrium. Fluctuations in red deer population size are generally small because density-dependence stabilises population numbers where births almost perfectly balance deaths. This means that as density increases, fertility rates of adult and juvenile females declines because the fecundity of red deer hinds is closely related to their weight which is in turn closely related to food abundance. Thus, increases in density reduce food abundance which in turn affects the critical threshold weight at which hinds conceive. Both fertility rates and mortality rates respond in a similar way to any change in population size because an increase in density decreases survival and fertility rates gradually and equivalently [31].

Second, if low deer density in Glenveagh has persisted for a number of years it is likely that this has resulted in an overall decline in plant species diversity because of lowered grazing pressure. Because grazing pressure is low throughout the National Park, deer density may remain at or close to its current level unless grazing pressure is increased or enhanced (i) by a structured regime of burning or (ii) the re-introduction of sheep and cattle or (iii) a culling regime that stimulates an increase in the population density of deer. Red deer are selective feeders and graze for 10-12 hours per day, obtaining a large proportion of their diet from a small fraction of their overall range and the apparent abundance of food in upland areas is illusory as a large proportion of upland vegetation cannot be used by the deer. A large proportion (40-50%) of the diet of red deer includes broad-leaved grasses (especially bents), and narrow-leaved grasses (especially fescues) with the balance being made up of heather (*Calluna / Erica* spp.) species. These grasses are usually scarce and widely distributed in Mat grass (*Nardus stricta)* and

Purple–Moor grass (*Molinia caerulea)* dominated habitats. Moderate grazing pressure (deer or sheep) can therefore help to maintain and enhance the plant species diversity and to stimulate production of palatable growth of heather and other dwarf shrubs. Also, the beneficial effects of highland cattle have been recognised for many years [32], and on Rhum in Scotland, the introduction of Highland cattle led to the opening up of swards dominated by *Nardus* and *Molinia* and to their increased use by deer [33].

Deer distribution, Habitat use and Ranging behaviour

Most deer management tends to be based entirely on subjective perceptions of abundance, deer condition or negative impacts [34], without any real attempt being made to actually quantify the true scale of the problem. More importantly, there is an unwillingness to even attempt to measure the productivity (recruitment) of the deer population or acknowledge the inevitability of source-sink dynamics and the net rates of immigration and emigration. The failure to quantify deer numbers and productivity will allow high deer density populations to persist as regional sources that will continually contribute to range expansion [35], even though effective management programmes are in place. A greater understanding of the ranging behaviour of red deer within a given landscape is essential before any attempt to quantify or reduce population density is contemplated.

In the majority of DMUs, the availability, proximity and distribution of food and shelter is a critical factor that influences the distribution and density of red deer in Glenveagh. In winter, red deer use lower ground partly because flushed grassland is typically found at lower altitudes and partly because wind (and therefore exposure) increases with altitude. Because of their large body size and vulnerability to exposure they tend to rest and feed in sheltered, south-facing sites whenever possible. In exposed areas and under extreme weather conditions, red deer may lose twice as much body heat as they would do in shelter, thus amplifying their energetic needs and increasing their exposure to starvation. In addition, low temperatures and chilling conditions affect the rate of fermentation in the rumen, thus reducing the efficiency of their digestive system [36]. In summer red deer use higher altitudes due to an improved quality of resources and they tend to show strong preferences for grasses such as *Agrostis, Festuca* and *Deschampsia* and will forage for these grasses within swards that are dominated by *Molinia* and *Calluna* [37].

In Upland Blanket Bog habitats, red deer were found to be widely dispersed throughout the National Park and at low density (5.50km^2). In resource limited habitats such as those found in Glenveagh National Park, red deer range sizes are relatively large (c. 1,300ha.) and these are usually a consequence of resource limitation where scarce resources such as food and shelter are widely dispersed requiring considerable movement on a daily or seasonal basis. Also, there are usually distinct differences between summer and winter ranges with deer using higher altitudes in spring and summer and lower altitudes during the autumn and winter. In a study of red deer ranging behaviour in Exmoor National Park in the south-west of England, data from radio-collared red deer found that range sizes of 1,005–1,055 ha. for both stags and hinds were common. Monthly movement was generally low with stags moving around 9.6 kilometres and hinds 7.2 kilometres [38].

In Glenveagh, movement patterns from observations showed similar patterns with daily movement within and between DMUs limited to 2-4 kilometres per day. Distances covered in seasonal movement (from summer to winter grounds) are between 7-9 kilometres or more.

In woodland areas of Glenveagh National Park, deer were found at moderate density (7.17 km^2) but they are likely to impact negatively on woodland habitats by altering the structural and plant species diversity. However, in many woodland areas within Glenveagh, fencing established in the 1980s has allowed regeneration to take place with the effect that these woodlands are now in relatively good condition. In these circumstances low to moderate deer densities (<5km^2) may even be beneficial as deer browsing helps to control dense shrubs and their selective feeding patterns also facilitates the creation of a mosaic of vegetation types providing niches for a variety of wildlife. However, it is vital to ensure that deer density levels are regularly monitored and deer density does <u>not</u> increase to levels that either slow down or even halt regeneration and reverse the considerable progress made towards improving woodland structure and diversity over the last 30 years. Semi-natural or native woodland habitats may be particularly sensitive to grazing pressure and it is essential that viable density thresholds are established for these woodlands.

[redacted].

These findings are not absolute and it is entirely possible that resident deer in any DMU may undertake movements outside of those described above but given their home range sizes and the hefting behaviour of red deer to specific locations this is unlikely. In the light of the findings and in the absence of either tagged or radio collared animals to determine otherwise, there is a case to be made to reduce the number of DMUs proposed in this survey from eight to six for the entire National Park.

From observations along sections of the deer fence it is clear that some movement of red deer is taking place on an intermittent basis in certain areas. Once animals detect permanent breaches in the fence structure they tend to use these regularly and movement generally occurs in both directions. It is not possible to estimate the scale of movement at these points but evidence from tracks suggests that these exit and entry points are well established but may only be used periodically by deer moving in and out of the National Park. It may well be worthwhile setting Trail Cameras at some of the more discreet points to get a better perspective on the scale of movement.

Population structure

Stag: Hind Ratios

The ratios of males: females found in this survey were within normal ranges for red deer in late autumn and early winter (0.27). However, because of the timing of the survey a substantial cohort of males (most likely mature males) is missing from the population. During the late summer and early autumn ratios of males: females are normally within the range of 0.45 – 0.55 (45 to 55 stags per 100 hinds). Stags tend to be less closely hefted to a particular area and individuals frequently have separate summer and winter ranges as well as separate rutting areas. When stags leave their mothers' groups usually in their third or fourth year of life they tend to wander widely before adopting a new home range [39]. Stags tend to adopt winter ranges in areas adjacent to but separate from the main hind groups. For example in Rhum in Scotland, an area similar in size to Glenveagh, around 50% of stags born in the North Block of the island dispersed to permanent home ranges throughout the rest of the island. In the great majority of non-migratory mammals, males disperse from their natal area while most females adopt home ranges close to their own birth site [40]. In Glenveagh, it is likely that the majority of mature males temporarily emigrate to areas around the periphery of the National Park and return each year to traditional rutting grounds which may explain the wide variation in stag: hind ratios on the western side.

Calf: Hind Ratios

Calf: hind ratios (0.46) found in this survey are within normal ranges for red deer living in upland hill conditions and compare favourably with calf: hind ratios found by Mac Lochlain in 1980 (0.41). However, calf: hind ratios should not be regarded as recruitment (a common mistake) because ratios of calves: hinds recorded even at this time of the year (November) are still likely to experience levels of natural mortality over-winter and during the spring. The level of mortality that occurs depends on density, weather conditions during the spring and summer, the condition of the calves as they enter their first winter and weather conditions over the winter. In benign open winters, calf survival is likely to be high in low density populations. However, calf survival may be low if prolonged periods of rain, wind and low temperatures are experienced over winter. Most calves that survive their first weeks of life live for at least six months with subsequent peaks of mortality usually in March and April.

Yearling: Hind Ratios

Animals in this cohort are aged approximately 17months old and are a reflection of the number of individuals (both male and female) that are successfully recruited into the adult population. Yearling: hind ratios are less than half those of calf: hind ratios (0.21 compared to 0.47) reflecting the level of natural mortality experienced as calves become yearlings. These ratios are within the expected range of red deer living in open hill conditions and are in sharp contrast to high performing red deer populations living in commercial forestry or lowland agricultural areas. For example, a recent study into the population dynamics of red deer living in lowland agricultural areas in Killarney National Park showed yearling: hind ratios of 0.45 over twice that of the current survey while in the same study, yearling: hind ratios in upland areas (0.23) were similar to those found in Glenveagh [41].

Overall, there was little variation in sex ratios on both sides of the National Park but with the [redacted] showing a higher calf: hind ratio but a lower yearling: hind ratio than [redacted]. Stag: hind ratios also showed slight variations between east and west, 0.29 compared to 0.27.

9.0 Future Management and Management Options

In Glenveagh National Park, the management of red deer must now be regarded as integral to the process of achieving biodiversity objectives throughout the National Park as a whole. At the current population density, red deer are having no discernible negative impacts on upland Blanket Bog habitats and a negligible impact on woodland regeneration. These conditions can only be maintained if deer density and other ecological indicators are persistently monitored. Management objectives can then be reviewed and modified if deemed necessary. As a keystone species, red deer can have either positive or negative effects on a range of habitats and their dependent species but this is entirely dependent on a range of variables. Many of these effects, particularly those on birds, vertebrates, insects and invertebrates have never been fully scientifically assessed and the loss, damage or benefits to ecosystem function have never been effectively measured. Therefore, if biodiversity and management objectives are to be successfully achieved, there needs to be a sea-change in the way in which deer management is both perceived and implemented within NPWS.

9.1 Management Options

Below are presented two potential options for the future management of the red deer population in Glenveagh National Park.

Option 1:

Principal Objective: to protect and enhance the array of habitats (including overall species abundance and biodiversity) within the National Park whilst maintaining a viable, healthy and sustainable deer population.

Secondary Objective: to ensure the successful natural regeneration of native woodlands, or at least avert any further deterioration by a combination of targeted culling and or fencing.

This strategy supports low densities of deer (<5km^2) and therefore overall annual expenditure on deer management activities is likely to be relatively low. For it to be successful, it is critical that deer densities are kept below 5 km^2 and maintained at this level into the future. Annual or two-year monitoring of deer densities including the responses of key biodiversity indicators (habitats and species) would be an essential part of this strategy. To maintain the red deer population at its current level would necessitate a 10% annual cull, the equivalent of about 35 animals. There are no risks attached to this strategy and detailed analysis and strategic planning of the mechanisms of this approach would be outlined in the Deer Management Plan.

Option 2:

Principal Objective: to protect and enhance the biodiversity of plants and animals within the National Park.

Secondary Objective: inhibit or control the spread of *Molinia* into other plant communities and encourage the distribution of a more diverse habitat mosaic. The creation of new woodlands would also be a key part of this strategy.

Grazing is an important component of the management of upland communities and can help to maintain plant species diversity, check the spread of some dominant species and stimulate the production of palatable growth by dwarf shrubs. Reduction of grazing pressure is associated with the spread of *Molinia* and a decline in species diversity, especially in areas of *Agrostis / Festuca* grassland. Moderate grazing pressure favours the lateral growth of heather species and helps to reassert its dominance more rapidly [42].

To achieve the desired objective, would require a co-ordinated strategy of managed burning and grazing and as red deer are the only dominant (keystone) herbivore it would require the cessation of culling altogether to allow the population to find its own natural equilibrium. This could see densities rising to 6 - 8 km^2 or higher as high deer density would apply sufficient grazing pressure to maintain species diversity and hinder or at least retard the spread of *Molinia*. This approach would minimise expenditure on deer management per se, though this strategy would be unpopular with immediate neighbours (farming / forestry) and make the concept of collaborative management almost impossible to achieve in the short term. It would mean tolerating reduced growth and fecundity of the deer population, a female biased sex ratio and higher mortality of adults and calves especially in harsh winters. However, there may be an advantage in the increased annual mortality if the aim is to encourage the population of predators or scavengers (eagles or ravens) to increase. There is an inherent risk with this strategy in that the population is likely to experience minor peaks and crashes in between periods of relative stability.

Lightly culled or un-culled deer populations are not necessarily unstable nor are they necessarily associated with irreversible damage to plant populations. Some species (plants and animals) are adversely affected by high grazing pressure while others benefit from it. Whether this is regarded as undesirable, tolerable or desirable depends entirely on the aims and objectives of management [43].

Detailed analysis and strategic planning of the mechanisms of this approach would be outlined in the Deer Management Plan.

9.3 Management Recommendations:

- Top take an ecosystems approach to the management of deer within Glenveagh National Park to be achieved through the Deer Management Planning Process
- A commitment to monitoring population size annually or a minimum of every 2 years to assess trends in deer density and to review the effects of management.
- Assessment of Reproductive (RR) and Recruitment Rates (RCR) is critical as both these rates vary between years so it is essential that they are monitored each spring. Recruitment Rate is the benchmark by which population growth is measured and this rate can only be monitored by carrying out census work during the spring (after neo-natal and post winter mortality) has taken place.
- Woodland enclosures require some remedial maintenance and deer that are in the enclosures should be removed where possible. In some cases (where woodlands have recovered and have regenerated well), there is a need to assess the condition of some of the enclosed woodlands and decisions made as to whether fences should remain or be removed.
- Decisions regarding the future maintenance, restoration or abandonment of the peripheral deer fence are required. The fence is at a point where restoration is still feasible on a section by section basis but further delay in repairs will see the inevitable decline of the structure beyond reasonable economic repair. Given the current low deer density in Glenveagh, management of the deer in future will certainly be more straightforward if the fence is intact.
- If the deer population has reached its own natural equilibrium it may only be necessary to target culling in woodland areas or areas where deer are having a noticeable negative impact. Otherwise an annual cull of c.10% will be required to maintain current deer density. There should be no requirement to cull deer on the open hill.
- Emphasis should be primarily on old hinds, yeld* hinds and poor calves. All biological data should be collected from culled animals.
- It should not be necessary to cull any deer on the open hill.
- Based on the findings of this survey- reduce the number of proposed DMUs from eight to six.

* Yeld hinds are those that do not have a calf at foot – either she did not calve the preceding season or the calf died at a young age. They fall into two categories: poorly performing hinds that regularly fail to conceive or lose their calves or high quality hinds taking a year off, which is increasingly likely as they get older [44].

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Summary of FSC Transect data – [redacted]

DMU	HABITATS	AREA (ha)	SAMPLE (m^2)	∑PG	∑DEER	km^2	EDU
[redacted]	PB2/HH	4,416.0	4,800	50	14	2.55	L
[redacted]	ALL	4,416.0	4,800	50	14	2.55	L

DMU	HABITATS	AREA (ha)	SAMPLE (m^2)	∑PG	∑DEER	km^2	EDU
[redacted]	PB2/HH	857	7,500	132	42	3.74	L
[redacted]	WN1	59	1,875	62	4	5.82	L
[redacted]	ALL	916.0	9,375	194	46	5.07	L

DMU	HABITATS	AREA (ha)	SAMPLE (m^2)	∑PG	∑DEER	km^2	EDU
[redacted]	PB2/HH	1,305.0	10,800	138	41	3.13	L
[redacted]	ALL	1,305.0	10,800	138	41	3.13	L

DMU	HABITATS	AREA (ha)	SAMPLE (m^2)	∑PG	∑DEER	km^2	EDU
[redacted]	PB2/HH	660	4,950	91	49	4.31	L
[redacted]	WN1	22	625	199	5	10.1	M
[redacted]	GS/HH	88	3,300	36	15	15.3	M
[redacted]	ALL	770.0	8,875	326	69	8.99	M

Km^2	EDU
ABSENT	0
LOW	0- 6.0km^2
MODERATE	6.0-12km^2
HIGH	>12km^2

Summary of FSC transect data – [redacted]

DMU	HABITATS	AREA (ha)	SAMPLE (m^2)	∑PG	∑DEER	km^2	EDU
[redacted]	PB2/HH	460.0	3,600	135	41	8.8	M
[redacted]	**ALL**	**460.0**	**3,600**	**135**	**41**	**8.8**	M

DMU	HABITATS	AREA (ha)	SAMPLE (m^2)	∑PG	∑DEER	km^2	EDU
[redacted]	PB2/HH	1,365.0	10,800	265	82	6.02	L
[redacted]	**ALL**	**1,365.0**	**10,800**	**265**	**82**	**6.02**	L

DMU	HABITATS	AREA (ha)	SAMPLE (m^2)	∑PG	∑DEER	km^2	EDU
[redacted]	PB2/HH	578.0	4,800	121	36	6.18	M
[redacted]	**ALL**	**578.0**	**4,800**	**121**	**36**	**6.18**	M

DMU	HABITATS	AREA (ha)	SAMPLE (m^2)	∑PG	∑DEER	km^2	EDU
[redacted]	PB2/HH	501.0	4,050	95	29	5.75	L
[redacted]	**ALL**	**501.0**	**4,050**	**95**	**29**	**5.75**	L

Km^2	EDU
ABSENT	0
LOW	0- 6.0km^2
MODERATE	6.0-12km^2
HIGH	>12km^2

Summary of Deer density estimates from FSCT transects - from PELLET (Microsoft Excel®)

DEER MANAGEMENT UNIT – GLENVEAGH NATIONAL PARK	
AREA (ha.)	6,447.0
NO. OF TRANSECTS	40
SAMPLE AREA (m^2)	57,100 m^2 (5.71 km^2)
TOTAL NO. OF PARCELS	3730
TOTAL NO. OF PELLET GOUPS	1,324
MEAN GROUPS / PARCEL	2.92
AVERAGE DENSITY (km^2)	5.57 km^2
STANDARS DEVIATION (SD)	4.17
STANDARD ERROR (SE)	0.659
MAX DENSITY	8.99 km^2
MIN DENSITY	2.73 km^2
80% CONFIDENCE	5.57 ± 0.85deer km^2 (359 ± 55)
90% CONFIDENCE	5.57 ± 1.09 deer km^2 (359 ± 70)

Summary of Deer density estimates from FSCT transects - from PELLET (Microsoft Excel®)

DEER MANAGEMENT UNIT – [redacted]	
AREA (ha.)	3,543.0
NO. OF TRANSECTS	24
SAMPLE AREA (m^2)	33,950 m^2
TOTAL NO. OF PARCELS	1,980
TOTAL NO. OF PELLET GOUPS	708
MEAN GROUPS / PARCEL	3.0
AVERAGE DENSITY (km^2)	5.07 km^2
STANDARD DEVIATION (SD)	4.92
STANDARD ERROR (SE)	1.005
MAX. DENSITY	8.99 km^2
MIN. DENSITY	2.73 km^2
80% CONFIDENCE	5.07 ± 1.31 deer km^2 (179 ± 46)
90% CONFIDENCE	5.07 ± 1.71 deer km^2 (179 ± 60)

Summary of Deer density estimates from FSCT transects - from PELLET (Microsoft Excel®)

DEER MANAGEMENT UNIT – [redacted]	
AREA (ha.)	2,904.0
NO. OF TRANSECTS	16
SAMPLE AREA (m^2)	23,250
TOTAL NO. OF PARCELS	1,750
TOTAL NO. OF PELLET GOUPS	616
MEAN GROUPS / PARCEL	2.84
AVERAGE DENSITY (km^2)	6.32 km^2
STANDARD DEVIATION (SD)	2.67
STANDARD ERROR (SE)	0.667
MAX. DENSITY	8.8 km^2
MIN. DENSITY	5.61 km^2
80% CONFIDENCE	6.32 ± 0.89 deer km^2 (184 ± 26)
90% CONFIDENCE	6.32 ± 1.1 deer km^2 (184 ± 34)

Figure 9. Deer Management Units showing deer densities km^2 in each

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Figure 10. Red dots show Faecal Standing Crop Transect locations in each Deer Management Unit – Deer Management Unit Boundaries = Blue lines. Fixed Transects T1 – T8. Note: Transect routes deviate to accommodate FSC transect start points

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Figure 11. Deer Clusters observed on Fixed Transects Routes

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Figure 12. Patterns of deer movement- Double headed arrows = internal movement – Single headed arrows = fence-line breaches and outward movement to peripheral zones

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