SETTING OF FAVOURABLE REFERENCE VALUES FOR HEN HARRIER CIRCUS CYANEUS IN IRELAND

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BirdWatch Ireland Report

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- The Hen Harrier *Circus cyaneus* is listed on Annex 1 of the Birds Directive (Directive 2009/147/EC) and is Amber listed on Birds of Conservation Concern in Ireland (Colhoun & Cummins, 2013).

- The 2015 national survey recorded an estimated 108 – 157 breeding pairs of Hen Harrier, representing a national decline of 15.6% in the number of confirmed breeding pairs since 2010 (Ruddock et al. 2016). The six SPA sites designated for Hen Harrier held between 43% and 46% of the national population (50 – 68 pairs) and notably, the population of Hen Harriers within the SPA network has declined by 27.7% since 2005 (Ruddock et al. 2016). The production of site management plans and the consideration of **'Favourable Reference Values (FRVs)'**and **'Favourable Conservation Status (FCS)'** at both site and national level is an urgent requirement for this species.

- This document explains what Favourable Reference Values (FRVs) are, and how they are an important part of any species or habitat conservation strategy. The term **Favourable Reference Value** may also be referred to as a *threshold value*; above which a measured attribute such as population size is considered favourable; but below which the same measured attribute is deemed to be unfavourable. The term *Favourable Reference Value* is often used interchangeably with the terms '*target'* or '*conservation objective'* meaning essentially, the value at which the attribute measured is deemed to be favourable. FRVs are therefore important as they define measurable objectives that are required to achieving favourable conservation status, and in terms of the SPA network, would allow the performance of the SPA network to be monitored, facilitating reporting (e.g. Article 12), conservation planning and implementation of management plans on a site specific basis. It would also inform the development of measures in the 'wider countryside' for this species.

- National and regional FRVs will be important in any long-term conservation strategy. However, the formulation of site-specific FRVs for Hen Harrier SPA sites would be a good starting point. Based on a review of literature and previously-adopted methods, the 'Baseline' and 'Habitat' approaches could potentially be used to set FRVs for the Hen Harrier in Ireland. Access to data (population and habitat mapping) held by NPWS and the relevant expertise to undertake the research, are all that are required to commence this process. While the process may not be without constraints, commencement of it may quickly highlight where data gaps or constraints exist and in turn highlight where further data are required or research efforts should be focused.

- The potential for population modelling should be investigated further. Currently, this method may be constrained and/or potentially unfeasible due to limited available data on breeding success and productivity, however, collaboration and cooperation between stakeholders/data holders may well enable successful population modelling of the Irish Hen Harrier in the future.

1. Introduction & Background

The Hen Harrier *Circus cyaneus* is listed on Annex 1 of the Birds Directive (Directive 2009/ 147/EC) and is Amber listed on Birds of Conservation Concern in Ireland (Colhoun & Cummins, 2013). In 2007, six Special Protection Areas (SPAs) were designated for the conservation of breeding Hen Harrier, while they are also listed at a further two SPAs that support important roost sites outside the breeding season.

The most recent national survey of Hen Harrier was undertaken during 2015 when an estimated 108 – 157 breeding pairs were recorded. This represents a national decline of 15.6% in the number of confirmed breeding pairs since 2010 (Ruddock et al. 2016). The aforementioned Hen Harrier SPA sites held between 43% and 46% of the national population (50 – 68 pairs) with four SPAs recording a decline and two recording an increase since 2005. Notably, the population of Hen Harriers within the SPA network has declined by 27.7% since 2005 (Ruddock et al. 2016).

Over half of the national breeding population of Hen Harrier therefore occurs outside of these designated protected areas and could therefore be more at risk to pressures and threats as a consequence. The '**Wider Countryside**' element is increasingly more relevant to the conservation of this species at the national scale (NPWS, 2015). Recent concerns due to population declines as well as concerns about the extent and rate of change to the Hen Harrier's habitat has led to the formulation of a Hen Harrier Threat Response Plan (HHTRP) and within this process, eNGOs have called for the production of site management plans and the consideration of 'Favourable Reference Values' and 'Favourable Conservation Status' at both site and national level.

2. What are 'Favourable Reference Values'?

An important component to developing an effective conservation strategy for any given habitat or species is the formulation of targets that define '*favourable conservation status'*.

The overriding objective of the Habitats Directive is to ensure that the habitats and species covered achieve '*favourable conservation status'* (FCS) and that their long-term survival is secured across their entire natural range within the EU (EU Commission, 2012). Therefore, in its most general sense a *conservation objective* is the specification of the overall *target* for the species and/or habitats for which a site is designated, in order for it to contribute to maintaining or reaching FCS. Importantly, EU guidance indicates that defined targets are necessary in cases where the current conservation status is deemed to be unfavourable and these targets should therefore indicate the degree of maintenance or restoration required (i.e. overall improvement) in order for the status to be considered favourable.

The EU Habitats Directive defines favourable conservation status for both habitats and species. For species the definition is as follows:-

The conservation status of a species is the sum of the influences acting on the species that may affect the long-term distribution and abundance of its populations. The conservation status will be taken as 'favourable' when:

- *the population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats; and*
- *the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future; and*
- *there is, and will probably continue to be, a sufficiently large habitat to maintain its populations.*

The attributes most often used to define the targets/conservation objectives for a species are: population size, range and area.

The term Favourable Reference Value (FRV) was first used in Article 17 Guidelines (EU Commission, 2011) and is referred to as a *threshold value*; above which a measured attribute is favourable; but below which the measured attribute is unfavourable. The term *Favourable Reference Value* is therefore often used interchangeably with the terms '*target'* or '*conservation objective'* meaning essentially, the value at which the attribute measured is deemed to be favourable.

3. Setting Favourable Reference Values (FRVs)

3.1 General Principles

Following on from the definitions of favourable status, FRVs are often defined for the criteria abundance and demography (population size), and range and area (distribution) of individual species.

At its simplest, FRV can be equal to the baseline population level of a species, if that level is accepted as being in favourable conservation status (BLI, 2006). However, it may not be easy to determine if the baseline population size was favourable, e.g. the population may have already been in decline when monitoring first began. Furthermore, a species population may have increased since the baseline and therefore require a higher FRV than the baseline level.

BirdLife International recommends that a FRV should be high enough to allow a species to fulfil its ecological functions and to allow for resilience to climate change (Tye et al. 2013). The task for EU Member States is to set FRVs for the species and habitats that they are obliged to protect, which are scientifically sound and realistic in light of irreversible changes that may have occurred to habitats. Such FRVs should allow assessment of the degree to which Member States have achieved FCS for species and habitats, as well as providing solid targets for conservation action.

To date the definition of what constitutes FCS has been interpreted differently by EU Member States. Broadly speaking there have been two approaches (1) Member States that have focussed on ensuring range and population are at least at the level when the Directive came into force (i.e. the minimum requirement under the European Topic Centre on Biological Diversity guidance (ETC/BD, 2011)) and (2) Member states that have taken extra steps to ensure the FRV represent a sufficient range and population to ensure long-term survival of the species (McConville & Tucker, 2015).

Setting a FRV can be a difficult task and any methodology must take into consideration numerous factors, such as the life history of individual species, amount of habitat available with and without restoration, minimum viable population size etc. EU guidance lists the following standards for setting conservation objectives; equally applicable to FRV's:-

- **be specific** - relate to a particular interest feature (species or habitat type) and define the condition(s) required to satisfy the conservation objective;
- **be measurable and reportable** - enabling monitoring to be undertaken to determine whether the conservation objectives are being met and for the purposes of Article 17 of the Habitats Directive (and Article 12 of the Birds Directive);
- **be realistic** - given a reasonable time frame and application of resources;
- **be consistent in approach** - the structure of conservation objectives should, as far as is possible, be the same across all Natura 2000 sites;
- **be comprehensive** - the attributes and targets should cover the properties of the interest feature necessary to describe its condition as either favourable or unfavourable.

3.2 Setting FRVs for birds

Three main approaches have been adopted to-date (after Christodoulou–Davies et al. 2012):-

1. Baseline approach;
2. Population viability analysis;
3. Habitat Approach.

(1) **Baseline Approach** - this approach involves taking a historical figure for a population considered to be in favourable status, and using this population figure as the FRV. Through comparing the FRV against current population levels it can be decided whether a species is at favourable conservation status or not. Application of the baseline approach requires a long-term dataset on the population under assessment. There are a number of constraints:-

- it is often difficult to agree when to set the baseline.
- relatively few European countries have bird-monitoring data going back before the 1980s, by which time many species had already suffered large declines.
- irreversible habitat changes often mean it would be impossible to re-establish the baseline population level.
- the baseline population size could in fact reflect an unambitious and arbitrary target and could result in attempts being made to maintain certain species at population levels not sufficient for long-term survival.

(2) Population Viability Analysis / Minimum Viable Population Approach – the Habitats Directive sets out to ensure that species are capable of maintaining themselves on a long-term basis as a viable component of their habitats within the context of the biogeographical region in which it occurs. A critical issue, therefore, is population size; because as a population decreases in size, its long-term viability becomes increasingly compromised by factors affecting survival and reproduction (Soulé, 1987; cited in Brambilla et al, 2011). The identification of **Minimum Viable Population size (MVP)** has therefore become popular in conservation biology as a means of establishing the threshold after which extinction becomes more likely (McConville & Tucker, 2015). Yet critics argue that PVAs are only practically useful for predicting extinction risk where data are extensive and reliable, and projection time frames are short (Fieberg & Ellner, 2000).

Through the use of Population Viability Analysis (PVA), a modelling program is used to calculate the probability of extinction of a species or population over a predefined period of time (or calculate the probability that a population does not fall below a certain size within a given amount of time). The size of the population is then altered in the model to find a population size that has an acceptably low risk of extinction, the 'minimum viable population'; i.e. the smallest number of individuals required for a population to have a specified probability of persisting in its natural environment (Shaffer, 1981). This MVP, or ideally a level higher than the MVP (depending on a range of factors to be taken into account) is then taken as the FRV for the species or population.

The use of MVP, while generally considered useful, is not without constraints however including (after McConville & Tucker, 2015):-

- The generation of species-specific MVPs requires adequate data which only exists in exceptional circumstances for highly studied species;
- In order to assess conservation status, there needs to be good data to produce population estimates, which in many cases are lacking.

(3) **Habitat Approach** – This involves calculating the amount of habitat in a given area which is considered suitable for the species and using this to derive the carrying capacity of that area. The habitat approach is based on knowledge of breeding densities in optimal habitat. Looking back at changes in land use over time allows assessment of changes in the amount of suitable habitat that was available and estimation of the population size this could have supported.

When calculating an FRV by this method it is important to consider that some changes to habitat are irreversible. A major advantage to this method is that it allows modelling predictions that can be valuable in management decision-making. For instance, the total area of habitat may be theoretically increased to show potential benefits of restoration work, or decreased to show what effect further development on and fragmentation of existing habitats may have on population size.

3.2.1 UK Example

In the UK, the last national Hen Harrier survey undertaken in 2010 estimated a population of 662 territorial pairs, a decline of 18% since 2004 (Hayhow et al. 2013).

Prior to the 2010 survey, the Joint Nature Conservation Committee published a report outlining the conservation status of Hen Harrier in the UK (Fielding *et al.* 2011). This conservation framework had two elements:

1. Modelling targets for favourable status based on criteria of abundance, demography and distribution, and an assessment of whether these targets are being met; and
2. Consideration of constraints identified to be acting on Hen Harrier populations, regionally and nationally, and an assessment of policies influencing these.

Using both population and habitat modelling techniques, the UK Conservation Framework for Hen Harriers arrived at the following national and regional favourable conservation status targets:

- a minimum of 1.2 young fledged per breeding attempt (productivity/population dynamics);
- at least 44% of the apparently suitable habitat occupied (range/distribution/area occupied)
- density (number of pairs per 100 km^2) - threshold of 2.12 pairs per 100 km^2 of suitable habitat (density is used as a measure of population size).

4. The potential for setting FRVs for the Hen Harrier - Feasibility Study

While consideration of FRVs at national and regional level will be important in any long-term plan to conserve the Hen Harrier, better data (both population and habitat data) are available for SPA sites, and we suggest that initial focus be directed towards setting FRVs for Hen Harrier SPAs. Furthermore, setting FRVs for Hen Harrier populations within the SPA network is paramount as these would:-

- Define measurable objectives required to achieving favourable conservation status;
- Allow the performance of the SPA network to be determined on an on-going basis which would allow effective reporting (e.g. Article 12), conservation planning and implementation of management plans on a site specific basis;
- Provide transparency to stakeholders as to the performance of the SPA network which would facilitate more efficient and realistic resource planning.

Following on from other European examples (e.g. Brambill et al. 2011; Tye et al. 2013), methods (1) Baseline Approach and (3) Habitat Approach above, could potentially be used to set FRVs for the Hen Harrier in Ireland. An essential first step, the feasibility study focuses on identifying and reviewing available data and assessing their suitability for inclusion within these methods. In addition, the feasibility of population modelling is also discussed.

4.1 Baseline Approach

This approach involves taking a historical figure for a population considered to be in favourable status, and using this population figure as the FRV. Through comparing the FRV against current population levels it can be decided whether a species is at favourable conservation status or not. Where data allow, FRVs can be set at a higher level than the baseline population, if, for example, the population was known to be in decline before the baseline population size was identified. This approach has been used in Ireland for the Otter (*Lutra lutra*) (NPWS, 2009).

For Hen Harriers in Ireland, a relatively straightforward and effective way to set FRVs for SPAs would be to use the baseline population at the time sites were selected as candidate SPAs. Whilst this approach is not always ideal, the Hen Harrier is one of few species for which we have enough good quality baseline population/trend data to facilitate such analysis. There have been four national Hen Harrier surveys to date (1998-2000 (Norriss et al. 2002), 2005 (Barton et al. 2006), 2010 (Ruddock et al. 2012) and 2015 (Ruddock et al. 2016)), while the rationale for SPA selection for Hen Harrier is set out in NPWS (2007).

The **baseline approach** in combination with the habitat approach would result in better overall targets, and in the absence of robust population modelling methods, these targets could be viewed as minimum/conservative requirements only.

4.2 Habitat Approach

Using the area of potentially suitable Hen Harrier habitat within a SPA, the habitat approach extrapolates existing density to estimate the potential abundance of Hen Harriers that the habitat could support, and in so doing calculates the FRV for abundance, range and distribution.

The **habitat approach** is based on knowledge of breeding densities in optimal habitat. The approach requires the calculation of the amount of habitat in a given area that is considered suitable for the species, and therefore good habitat mapping data is essential. In the Republic of Ireland these data are available for the six SPAs designated for Hen Harrier following the Hen Harrier Habitat Mapping Project (Moran & Wilson-Parr, 2015). While there are limitations to these data (Moran & Wilson-Parr, 2015), this study represents the most comprehensive habitat mapping of Hen Harrier SPA sites to date. The **habitat approach** is therefore feasible within the six designated Hen Harrier SPAs. In addition, some habitat data may be available from the SPA selection process. Given access to these data and Hen Harrier population figures from that time, it may be possible to extrapolate to determine how Hen Harrier densities and suitable habitat have changed over time and what proportion of habitat restoration is required for the population to once again reach the population FRV (i.e. that based on the baseline approach).

4.3 Population modelling

Background

For a population to have a favourable conservation status it should be capable of maintaining itself or expanding, without a requirement for recruitment from other populations. At its simplest this is achieved when reproduction and survival are greater than the combined effects of mortality and dispersal to other populations (Fielding et al. 2011).

PVA analyses developed by Brambill (et al. 2011) for Italian breeding birds used the program Vortex (Version 9.72) which evaluated the extinction risk for species and populations with fewer than 2,500 breeding pairs. The analyses included demographic parameters: age structure, mortality at different ages (before adulthood/during adulthood), reproductive parameters (type of reproductive system, first and maximum age of reproduction, sex ratio at birth, percentage of males and females taking part in reproduction, percentage of successful nests and/or number of young fledged) and environmental parameters (occurrence of catastrophes, carrying capacity of the habitat). Model parameters were sourced from published references.

The UK Conservation Framework for Hen Harriers (Fielding et al. 2011) used key demographic parameters (survival and productivity) to model the threshold fledging rate above which a population would be deemed stable or increasing. Two approaches were used. In the first approach, population trajectories were studied over a wide range of possible key population parameter values, the aim being to explore the combination of values which predicted a stable or expanding population. In the second approach, the population trajectories of specific populations were modelled using largely empirical values. The main data required were productivity e.g. fledging rates (mean number fledged /pair and number of females fledged per pair) and survival (with known ages).

Models were calculated for NHZs, subdivided regions that reflect the variation in biological and landscape qualities across Scotland; and at site-level. The models calculated that populations with a fledging rate below one per pair were unlikely to be self-sustaining in the medium term. The threshold for favourable conservation status was set at a fledging rate of at least 1.2 young per breeding attempt.

4.4 Modelling Hen Harrier populations in Ireland

While **population modelling techniques** have been used successfully for Golden Eagle and Hen Harrier in the UK (Whitfield et al. 2008; Fielding et al. 2011) the potential in Ireland is more likely constrained at present due to limited/unavailable data on breeding success and productivity (much of this arising from private research), overall small sample size, or unavailability of other key data (Table 1). However, we would recommend further feasibility studies in this regard to include consultation with key data holders/stakeholders.

Table 1. Summary details of studies that have collected data on breeding success/productivity for Hen Harriers in Ireland.

Study	Data collected
Research study Planforbio (Irwin et al. 2012)	Study of the breeding biology of Hen Harriers in four study areas (Slieve Aughty Mountains, West Clare, Kerry and Ballyhoura Mountains) 2007 – 2011 (although only Kerry was studied in the first three years of the project). Fledged brood size was calculated as the average number of young fledged from successful nests. As this is biased towards successful nests, the Mayfield method was used to calculate daily survival rates and to estimate success of all nests in the study. Breeding productivity was therefore calculated as the average number fledged across all nests. Nest success rate was calculated as the percentage of nests that fledged at least one young. Data available for up to 200 nests, with productivity data (average number of fledged young); number of nests included in analyses varied from 20 to 60 for the five-year period.
National Survey 1998 – 2000 (Norriss et al. 2002)	Collated some data on breeding success and productivity for some pairs.
National Survey 2005 (Barton et al 2006)	Breeding success was recorded where possible but was not a major focus of the study. 58 nests were confirmed as successful, six were confirmed as failed, and the outcome was unknown at 68 nests.
National Survey 2010 (Ruddock et al. 2012)	20 successful breeding attempts recorded within SPAs, which were confirmed to have fledged at least one young. There were 17 failed breeding attempts and 18 territories at which the breeding outcome was unknown (i.e. 33% unknown).
National Survey 2015 (Ruddock et al. 2016)	108 confirmed breeding pairs. The final breeding outcome was established for 97 of the 108 confirmed pairs with the remainder being unknown (i.e. 10% unknown).
Fernández-Bellon et al. 2015	Studied breeding performance at 84 nests. Calculated nest success, fledged brood size, productivity.
Barry O'Donoghue	Independent research. No details.
NPWS	Study in the Slieve Blooms. No details.

5. Recommendations on the way forward: Defining FRVs for Hen Harrier

Given recent concerns over population declines (Ruddock et al. 2016) as well as concerns about the extent and rate of change to the Hen Harrier's habitat, setting FRVs for Hen Harrier should be a top priority.

Based on this review, the '**Baseline**' and '**Habitat**' approaches could be used now to set FRVs for the Hen Harrier in Ireland. Access to data (population and habitat mapping) held by NPWS and the relevant expertise to undertake the research, are all that are required to commence this process. While national and regional FRVs will be important in any long-term conservation strategy, we suggest that the formulation of site-specific FRVs for Hen Harrier SPA sites is a good starting point. While the process may not be without constraints, commencement of the process may quickly highlight where other data gaps or constraints exist and in turn highlight where research efforts should be focused.

Existing data can be used to readily calculate, via the **baseline approach**, whether the species is at favourable conservation status or not. While this approach is not always ideal, if, for example, the population was known to be in decline before the baseline population size was identified,

there is scope for FRVs to be set at a higher level. Furthermore, the baseline approach in combination with the habitat approach will result in better overall targets.

The **habitat approach** is based on knowledge of breeding densities in optimal habitat. While adequate habitat mapping data appear to be available for Hen Harrier SPAs, an important first step in this work would be to determine where pressures/threats may compromise the utility of suitable breeding/foraging habitat. For example, recent national survey results found Hen Harrier numbers had declined at Slieve Beagh with a notable spatial redistribution resulting in the loss of breeding pairs to the Slieve Beagh – Mullaghfad – Lisnaskea SPA in Northern Ireland (Ruddock et al. 2016). While the site has a relatively high extent of both foraging and nesting habitat, Moran & Wilson-Parr (2015) suggest that the quality of the breeding habitats may be compromised by turf-extraction and recent burning. In this way, the **habitat approach** will likely require an initial assessment of habitat quality in most cases. However, the approach could prove useful to:

(a) determine how Hen Harrier densities and their preferred breeding habitats have changed over time and what proportion of habitat restoration is required for the population to once again reach the population FRV and;

(b) model/estimate how habitat suitability may change over time (e.g. in relation to pre-thicket plantation forestry) and how this may drive population change/declines and hence direct habitat conservation measures in the future.

The potential for **population modelling** in defining FRVs for breeding Hen Harrier in Ireland should also be investigated further. Currently, this method may be constrained and/or potentially unfeasible due to data constraints (limited available necessary data on breeding success and productivity), but we recommend a future feasibility study in this regard to include consultation with key data holders/stakeholders. Defining the best approach for setting FRVs for Hen Harrier in Ireland will involve collaboration and cooperation with key stakeholders, including data providers and species experts to ensure any decision-making on the best approach to be taken is underpinned by the most comprehensive scientific data available.

6. References

Barton, C., Pollock, C., Norriss, D.W., Nagle, T., Oliver, G.A. & Newton, S. (2006) *The second national survey of breeding Hen Harriers Circus cyaneus in Ireland 2005.* Irish Birds (8).

BirdLife International (2006) Position paper of the Birds and Habitats Directives Task Force on the Favourable Conservation Status of Special Protection Areas (SPAs) adopted 6 February 2006.

Brambilla, M., Gustin, M. & Celeda, C. (2011) Defining favourable reference values for bird populations in Italy: setting long-term conservation targets for priority species. *Bird Conservation International* 21, 107-128.

Christodoulou–Davies, C., Tye, A. & and Apostolidou, M. (2012) Report of the workshop: 'Setting Favourable Reference Values (FRVs) for Annex I bird species in Cyprus as part of the LIFE project: "Restoration and Management of Oroklini Lake SPA in Cyprus".

EU Commission (2011) Assessment and reporting under Article 17 of the Habitats Directive. Explanatory Notes & Guidelines for the period 2007-2012. Final Draft. July 2011.

EU Commission (2012) *Commission note on setting Conservation Objectives for Natura 2000 sites.* Final version 23/11/2012. DG Environment.

Fieberg, J. & Ellner, S.P. (2000) When is it meaningful to estimate extinction probability? *Ecology* 81, 2040–2047.

Fielding, A., Haworth, P., Whitfield, P., McLeod, D. & Riley, H. (2011) *A Conservation Framework for Hen Harriers in the United Kingdom.* JNCC Report 441. Joint Nature Conservation Committee, Peterborough.

Fernández-Bellon, D., Irwin, S., Wilson, M. & O'Halloran, J. (2015) Reproductive output of Hen Harriers *Circus cyaneus* in relation to wind turbine proximity. *Irish Birds* 10, 143-150.

Hayhow, D.B., Eaton, M.A., Bladwell, S., Etheridge, B., Ewing, S.R., Ruddock, M., Saunders, R., Sharpe, C., Sim, I.M.W. & Stevenson, A. (2013) The status of the Hen Harrier, *Circus cyaneus*, in the UK and Isle of Man in 2010. *Bird Study* Vol 60, Issue 4, 446-458.

Irwin, S., Wilson, M.W., Kelly, T.C., O'Mahony, B., Oliver, G., Troake, P., Ryan, B., Cullen, C., O'Donoghue, B. and O'Halloran, J. (2011) The breeding biology of Hen Harriers in Ireland over a five year period. *Irish Birds.* Vol 9: 165-172.

Irwin, S., Wilson, M., O'Donoghue, B., O'Mahony, B. Kelly, T. & O'Halloran, J. (2012) *Optimum scenarios for Hen Harrier conservation in Ireland.* Report for the Department of Agriculture, Food and the Marine. Final Report.

JNCC (2004) *Common standards monitoring for birds.* Version August 2004. Joint Nature Conservation Committee. ISSN 1743-8160 (online).

McConville, A.J. & Tucker, G.M. (2015) *Review of Favourable Conservation Status and Birds Directive Article 2 interpretation within the European Union*. Natural England Commissioned Reports, Number 176.

Moran, P. & Wilson-Parr, R. (2015) Hen Harrier Special Protection Area (SPA) Habitat Mapping Project 2014. *Irish Wildlife Manual*s, No. 83. National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Ireland.

NPWS (2007) Recommendations for Special Protection Areas (SPAs) for breeding Hen Harrier. Unpublished report, National Parks & Wildlife Service June 2007.

NPWS (2009) *Threat Response Plan: Otter (2009-2011).* National Parks & Wildlife Service, Department of the Environment, Heritage & Local Government, Dublin.

NPWS (2015) Hen Harrier conservation and the forestry sector in Ireland. Version 3.2. http://www.npws.ie/sites/default/files/publications/pdf/HHTRP%20-%20Forestry%20-%20V3.2.pdf

Ruddock, M. & Dunlop, B.J., O'Toole, L., Mee, A., Nagle, T. (2012) *Republic of Ireland National Hen Harrier Survey 2010. Irish Wildlife Manual, No. 59.* National Parks and Wildlife Service, Department of Arts, Heritage and the Gaeltacht, Dublin, Ireland.

Ruddock, M., Mee, A., Lusby, J., Nagle, A., O'Neill, S. & O'Toole, L. (2016) The 2015 National Survey of Breeding Hen Harrier in Ireland 2015. *Irish Wildlife Manual*s, No. 93. National Parks and Wildlife Service, Department of the Arts, Heritage and the Gaeltacht, Ireland.

Shaffer, M. (1981) Minimum population sizes for species conservation. *Bioscience*, No 31, (2) pp131-134.

Tear, T. H., Kareiva, P., Angermeier, P. L., Comer, P., Czech, B., Kautz, R., Landon, L., mehlman, D., Murphy, K., Ruckelshaus, M., Scott, J. M. & Wilhere, G. (2005) How much is enough? The recurrent problem of setting quantitative objectives in conservation. *BioScience* 10, 835–849.

Traill, L. W., Brook, B. W., Frankham, R. R. and Bradshaw, C. J. A. (2010) Pragmatic population viability targets in a rapidly changing world. *Biological Conservation*, No 143, (1) pp28-34.

Tye, A., Christodoulou–Davies, C., Papazoglou, C. & Apostolidou, M. (2013) Setting Favourable Reference Values for Annex I bird species at Oroklini marsh as part of the LIFE project: "Restoration and Management of Oroklini Lake SPA in Larnaca, Cyprus. BirdLife Cyprus.

Whitfield, D.P., Fielding, A.H., Mcleaod, D.R.A. & Haworth, P.F. (2008) *A conservation framework for the golden eagle: implications for the conservation and management of golden eagles in Scotland*. Scottish Natural Heritage Commissioned Report No. 193, Perth.

Wilson, M.W., Irwin, S., Norriss, D.W., Newton, S.F., Collins, K., Kelly, T.C. and O'Halloran, J. (2009) The importance of pre-thicket conifer plantations for nesting Hen Harriers *Circus cyaneus* in Ireland. *Ibis* 151: 332-343.