

Monitoring of the breeding population of grey seals in Ireland, 2009 - 2012



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Monitoring of the breeding population of grey seals in Ireland, 2009 – 2012

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Cover photo: Weaned grey seal pups resting high above the seashore at a breeding site © Oliver Ó Cadhla

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Executive Summary

The present-day population of grey seals (*Halichoerus grypus*) in Ireland was first assessed by means of a comprehensive national survey during the 2005 breeding season. A follow-up moult season survey was also carried out in early 2007. Following these studies and recommendations on future surveillance the monitoring of all key population centres for the species in Ireland has continued via repeat regional surveys during the 2009, 2011 and 2012 breeding seasons. The work undertaken and its results are presented in this report.

The main findings from population monitoring carried out during the 2009-2012 period are as follows:

1. Based primarily on data from seven principal breeding areas, Ireland's current grey seal population numbers approximately 7,284 - 9,365 seals of all ages.
2. These figures are derived from an estimate of 2,081 newborn grey seal pups collated across all regions and their associated survey years. The methodology employed involves a number of key assumptions. Consequently care should be taken in the interpretation of all results presented.
3. The pup production described and associated all-age population estimates exceed national figures recorded in 2005 and the monitoring data support emerging evidence of a level of population growth in Ireland since the mid-1990s and possibly dating to the early 1980s.
4. Observed changes in pup production are variable between breeding areas and survey years, however. Robust statistical data on grey seal population viability or trends in Ireland are not available at present.
5. Recorded mortality of pups at the main breeding sites continues to remain relatively low although this may be indicative rather than comprehensive information.

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2009	2011	2012
Comdt. Ray Keane	Lt. Stephen Byrne	Lt. Damien Kelly
Capt. Paul Grennan	Cpl. Patrick Mahon	Capt. Niall Buckley
Cpl. Pádraig Mulrennan	Sgt. Damian Kelly	Cpl. Patrick Mahon
Comdt. David Mackey	Sgt. Alan Martin	Capt. Séamus McNamara
Comdt. David Corcoran	Lt. Damien Kelly	Lt. Stephen Morrisson
Sgt. Mark Dunne	Cpl. Pádraig Mulrennan	Armn. David Tiernan
Capt. James O’Reilly	Sgt. Niall Dunne	Capt. David Browne
Capt. Anne Brogan	Capt. Séamus McNamara	Lt. Bernard O’Raw
Sgt. Éamonn Magnier	Capt. Mick Sullivan	Armn. Kieran Tobin
Capt. Finbarr McArdle	Capt. David Browne	Lt. Stuart King
Capt. Alan Bray		Capt. Jonathan Lynch
Comdt. John O’Keeffe		Capt. Michael Liddy
		Cpl. Patrick Keaveney
		Comdt. Phillip Bonner

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Go raibh míle maith agaibh go léir.

1 INTRODUCTION

1.1 Grey seal distribution, ecology and legal status

The grey seal (*Halichoerus grypus*) is the larger of two species of true seal (*Phocidae*) that commonly breed around the coast of Ireland and that travel, find food and engage in other ecological functions in its inshore and offshore waters. Grey seals inhabit only the Northern Hemisphere and are predominantly found in cold temperate and sub-polar waters, in the northeastern Atlantic from Iceland and northern Norway to the French coast (Thompson & Härkönen, 2008; Hall & Thompson, 2009). Populations of grey seal in the eastern and western Atlantic are genetically distinct, while the population in the Baltic Sea appears to be largely isolated from adjacent Atlantic dwelling grey seals (Boskovic *et al.*, 1996).

Grey seals in Ireland are generally considered part of a larger interacting population or metapopulation that also inhabits adjacent jurisdictions (i.e., the UK and France at least). They occur widely in estuarine, coastal and offshore marine areas while individual seals may also occasionally travel upstream within river systems to a distance several kilometers from the coast. In addition to its aquatic ecology the species inhabits established terrestrial or intertidal sites (known as haul-out sites, haul-outs or colonies) at which individual seals breed, moult, rest between foraging trips in the open sea and engage in social activity, for example (Bonner, 1990). Use of these haul-out sites follows an annual cycle and in Ireland there is a tendency for the population to select more remote locations on which to come ashore such as uninhabited islands, tidal sandbanks, offshore rocky skerries, caves and isolated cliff-bound beaches (Ó Cadhla & Strong, 2007; Ó Cadhla *et al.*, 2008).



Plate 1. An adult and a juvenile grey seal at an intertidal haul-out site in Ireland. (© Oliver Ó Cadhla)

Adult grey seals and newborn pups are quite readily identifiable, although subadult/juvenile seals can be more difficult to distinguish in the field. Firstly, unlike their smaller Irish and European relative the harbour seal (or common seal, *Phoca vitulina vitulina*), grey seals are notable by a pronounced sexual dimorphism with adult males measuring up to 2.0-2.5m in length and generally weighing up to 300kg in comparison to adult females which tend to be less than 2m in length and weigh between 150-200kg (SCOS, 2012). In a further deviation from harbour seals, newborn grey seal pups are generally born in a distinctive white or off-white natal coat of fur. This is gradually moulted over 3-4 weeks to reveal a denser grey/black mottled or speckled coat. Juvenile and adult grey seals of both sexes continue to moult on an annual basis and they may retain a mottled or blotchy appearance (Plate 1), although in all cases the colouration patterns can be highly variable (Hall & Thompson, 2009) ranging from a slate grey dorsal surface and a lighter, mottled ventral surface to uniformly dark grey-brown. Where the

animal's head is more visible, grey seals can also be identified by their characteristic long muzzle and comparatively straight or convex snout from forehead to nose (Duck, 2007).

All marine mammals occurring in Ireland including both breeding seal species (i.e., grey seal and harbour seal) are afforded legal protection by the Wildlife Acts 1976 to 2012. Under the original 1976 Act and its subsequent Amendments (2000, 2005, 2010, 2012) it is an offence to hunt (except in some instances under licence or Ministerial permit), injure (except when hunting under such licence) or wilfully interfere with, disturb or destroy the resting or breeding place of a protected (listed) species. With regard to their marine jurisdiction, the Wildlife Acts 1976 to 2012 extend to waters within Ireland's Territorial Sea (i.e., within the 12 nautical mile limit from the baselines).

Further legal protection of seals in Ireland is provided by the EC Directive on the conservation of natural habitats and of wild flora and fauna (i.e., the EU Habitats Directive: Council Directive 92/43/EEC). This is transposed into national law by the European Communities (Birds and Natural Habitats) Regulations 2011 (S.I. No. 477 of 2011) which *inter alia* consolidate the earlier European Communities (Natural Habitats) Regulations 1997 to 2005 and the European Communities (Birds and Natural Habitats)(Control of Recreational Activities) Regulations 2010. Under the Habitats Directive all marine mammal species normally occurring in Ireland must be given protection. The two species of seal breeding in Ireland and two cetacean species (harbour porpoise *Phocoena phocoena* and bottlenose dolphin *Tursiops truncatus*) are listed in Annex II of the Directive as species whose conservation requires the designation of Special Areas of Conservation (SACs). Ten such important areas for grey seal have been designated as SACs around the Irish coast (Fig. 1).

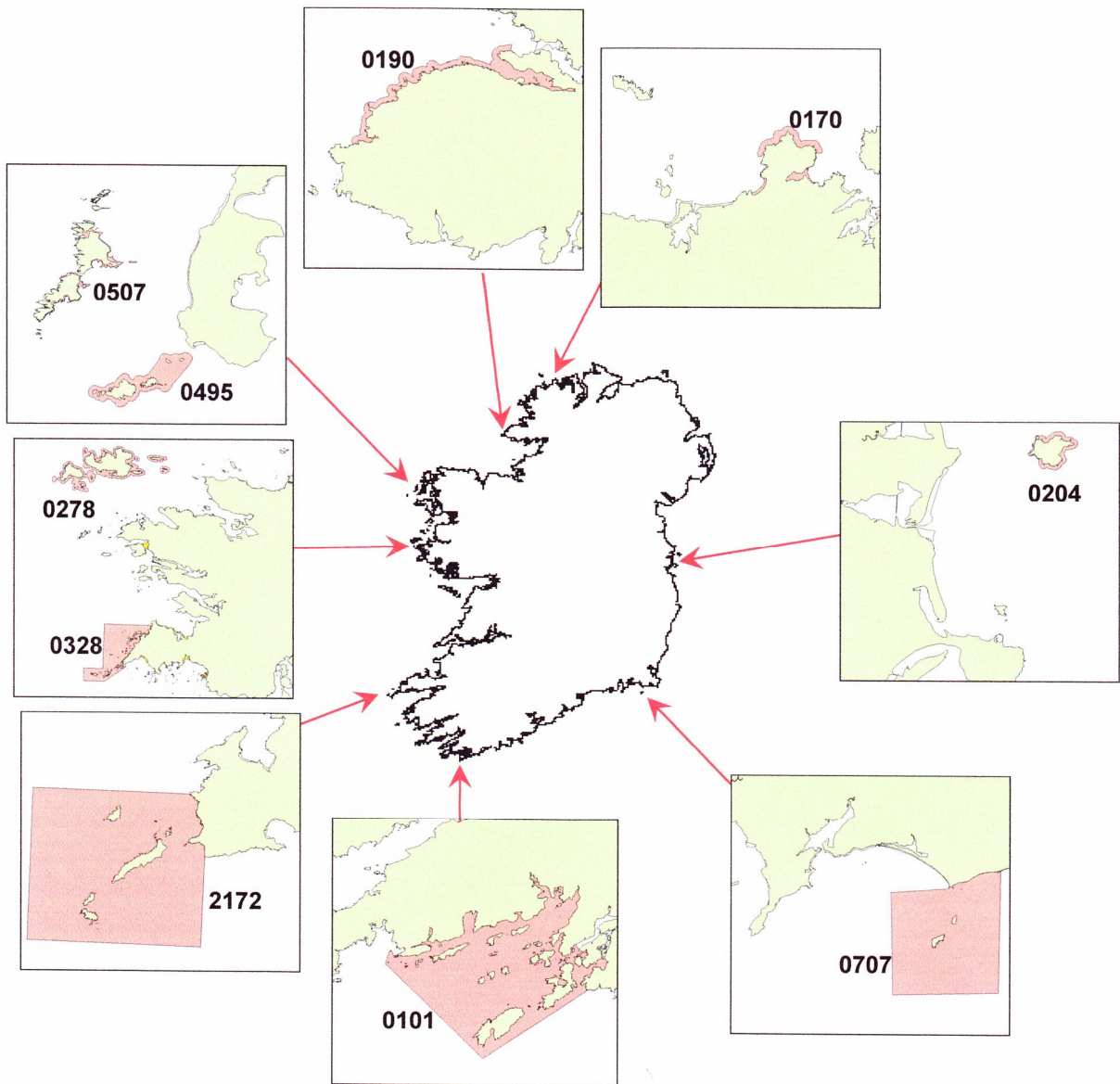
While the Habitats Directive requires various conservation measures to be undertaken to protect Special Areas of Conservation (SACs), among them to avoid "the deterioration of natural habitats and the habitats of species as well as disturbance of the species for which the areas have been designated", it applies within Ireland's 200 nautical mile limit (i.e., within the Exclusive Fishery Zone, also termed the Exclusive Economic Zone or EEZ). Within this remit under Article 11 the Directive also requires Member States to undertake surveillance of the conservation status of all annexed species, such as the grey seal, for example.

1.2 Rationale and monitoring objectives

Prior to the population surveillance or 'monitoring' captured in this report, Ireland's minimum population estimate for grey seal numbered 5,509-7,083 seals of all ages (Ó Cadhla *et al.*, 2008). The figures were based on (a) coordinated nationwide surveys that recorded the production of newborn grey seal pups during the 2005 breeding season and (b) subsequent analysis estimating total production and all-age population size from pup data acquired in the field. This first national assessment for the species since the Habitats Directive came into force also sought to place a range of preceding ground-based, boat-based and aerial surveys (*see* Ó Cadhla *et al.*, 2008: Table I) into an updated and wider geographic context.

Following the 2005-06 study and an ancillary nationwide assessment of distribution and haul-out sites during the 2007 moult season (Ó Cadhla & Strong, 2007), a scientific evaluation of ongoing monitoring methods for populations of seal species was commissioned by the Scientific Unit of the Department's National Parks & Wildlife Service (NPWS). The resulting report by Cronin & Ó Cadhla (2008) outlined monitoring options for Ireland's seal populations based on data and experience obtained during national population assessments and other scientific considerations. This information, together with the results of seal monitoring work carried out by regional staff since 2003 and the potential operational capacity for annual seal monitoring were also considered by the Department in the development of monitoring strategies for harbour seal and grey seal by mid-2009.

With regard to monitoring Ireland's grey seal population, it was decided to pursue a tried and tested strategy targeting the annual breeding season (August-December approx.) but on a regional basis in order to make best use of available resources and weather opportunities. Monitoring surveys would be chiefly directed at breeding areas of national importance, while supplementary information could also be gathered at secondary sites. The primary objectives of this monitoring strategy are the estimation of pup production at all key sites and the provision of estimates for all-age population size associated with grey seal breeding around the Irish coast. The delivery of methodological consistency and compatibility with best practice in neighbouring countries, particularly the UK which holds ca. 38% of the world's breeding population of grey seals (SCOS, 2012), are also key monitoring objectives.



Legend:

<i>Site code</i>	Conservation Site Name	County
000147	Horn Head and Rinclevan SAC	Donegal
000190	Slieve Tooley/ Tormore Island/ Loughros Beg Bay SAC	Donegal
000495	Duvillaun Islands SAC	Mayo
000507	Inishkea Islands SAC	Mayo
000278	Inishbofin and Inishshark SAC	Galway
000328	Slyne Head Islands SAC	Galway
002172	Blasket Islands SAC	Kerry
000101	Roaringwater Bay and Islands SAC	Cork
000707	Saltee Islands SAC	Wexford
000204	Lambay Island SAC	Dublin

Figure 1. Special Areas of Conservation (SACs) for grey seal in Ireland. Sites monitored in 2009-2012 are shaded.

2 METHODS

2.1 Background

Methods employed for grey seal population monitoring in Ireland have developed from international practice in addition to techniques and experience garnered during the 2005 national assessment and a number of preceding Irish studies. Their evolution, implementation and efficacy are described in detail in *Irish Wildlife Manual* No. 34 (Ó Cadhla *et al.*, 2008) which remains a useful reference document with regard to previous and ongoing monitoring of the species in Ireland.

Grey seal pups are unable to swim effectively in their early hours or days of life and are thus dependent on particular terrestrial or near-tidal breeding habitats at which they are born and in receipt of parental care from the mother for about 3 weeks. New pups that are progressively born, nursed ashore and weaned through the breeding season therefore represent a distinctive, readily identifiable cohort of the population that is available for counting whether directly by personnel ashore or via aerial survey methods. Pups that do not survive the initial few days or weeks within the breeding colony are in many cases also available for counting, though the detectability of carcasses can be dependent on site topography, wave exposure and other characteristics, the survey frequency and method used, weather conditions, etc.

Thereafter, knowledge of population demographics, life history and adult fecundity allows the total number of pups estimated to have been born at a breeding site (i.e., its pup production estimate within that season) to be translated into a figure for the all-age population associated with the breeding area surveyed. For grey seals breeding around the coastline of Ireland, direct demographic, life history and fecundity data are not currently available so there is a reliance on background information accumulated at key breeding areas in the UK since the 1960s (Ó Cadhla *et al.*, 2008).

2.2 Study areas

Following intensive and repeated aerial, boat- and ground-based survey effort around the Irish coastline the 2005 national assessment identified seven key breeding areas as responsible for 1,322 out of 1,574 pups (i.e., approximately 84% of the total) recorded in that year (Ó Cadhla *et al.*, 2008). These breeding areas are listed as follows from the north to south to east coasts:

- 1) Sturrall (near Glen Head) to Maghera in south-west Co. Donegal;
- 2) the Inishkea island group (*a.k.a.* Inishkea Group) off north-west Co. Mayo;
- 3) Inishshark, Inishgort and associated islands off north-west Co. Galway;
- 4) islands around Slyne Head, Co. Galway;
- 5) the Blasket Islands, Co. Kerry;
- 6) the Saltee Islands, Co. Wexford;
- 7) Lambay Island and Ireland's Eye, Co. Dublin.

All seven locations, which contain eight of Ireland's ten SACs for grey seal (Fig. 1), were already well documented as important areas for breeding grey seals and they have also demonstrated their importance as regional terrestrial/intertidal habitats for the population outside the breeding season (e.g., Kiely *et al.*, 2000; Cronin *et al.*, 2004; Ó Cadhla & Strong, 2007; Duck & Morris, 2012a; Duck & Morris, 2012b).

In developing a consistent and robust, repeatable approach to the monitoring of grey seals in Ireland (*see* section 1.2) it was decided that ongoing survey effort should concentrate primarily on acquiring high quality pup production data from these major breeding areas. In this way a large component of the national picture regarding grey seal population status could be obtained, while secondary sites and sites with ongoing potential for breeding, etc. could continue to be covered on an opportunistic

basis in order to supplement the information gathered. Given the resources available, previous experience and familiarity with the sites concerned, and operational considerations it was also decided that population monitoring would be conducted each year on a regional basis using aerial survey methods. This would allow greater and faster coverage within a given survey day and weather window, while maintaining compatibility with the 2005 national assessment and its methodology.

The Department's programme of grey seal population monitoring has therefore been conducted across three broad regions since 2008:

- i. East/South-east (2009): from Dublin to Wexford, including Lambay Island, Ireland's Eye and the Saltee Islands.
- ii. West/South-west (2011): from Mayo to Kerry, including Inishshark, Inishgort and associated islands off north-west Galway, the Slyne Head islands and the Blasket Islands.
- iii. West/North-west (2012): from Mayo to Donegal, including the Inishkea Group and south-west Donegal.

This first round of regional grey seal monitoring was completed in time to inform Ireland's recent report under Article 17 of the EU Habitats Directive. Survey effort is continuing into the 2013-2018 reporting cycle.

2.3 Aerial survey technique

The surveying and accurate estimation of grey seal pup production at a breeding site requires repeated sampling visits since the season is protracted and pups are not all born, weaned or ready for their departure to sea at the same time. This results in pups of various ages (or 'stages', Fig. 2) being ashore at breeding beaches and visible to an observer/counter on land, in a boat or in the air (Plate 2). The monitoring programme undertaken in 2009-2012 used aerial surveys to conduct such sampling.



Plate 2. Typical aerial photograph of a grey seal breeding site off western Ireland in mid-October, showing pups of various ages, sizes and stages of moult (circled) and several adults (squared) in close attendance. (© NPWS)

In each year of survey a series of 5-6 regional flights were carried out between the months of September and November with the assistance of the Department of Defence and the Air Corps. Flights were planned to take place at approximately 10-15 day intervals within this main pupping period in order to reduce the potential for missing early leavers from the breeding beaches while also minimising disturbance to the animals and breeding sites concerned. The research and analysis undertaken in 2005-06 showed that a target of six successful overflights spaced at similar intervals could be expected to produce comparatively accurate pup production figures with low coefficients of variation (CVs) (Ó Cadhla *et al.*, 2008).

The aerial survey technique used was based on methods and data collection practices developed in 2005 so that resulting data were fully compatible with previous information. Pre-arranged overflights were conducted of all potential pupping sites within the principal areas targeted for survey (e.g., Great Saltee Island and Little Saltee Island, Co. Wexford). The general survey altitude and speed over ground were set at 500-800ft and 60-100knots, respectively. While priority was given to the full and effective coverage of the seven key Irish breeding areas identified (*see* section 2.2), opportunities for covering additional known and/or potential breeding sites were taken up wherever possible, in order to broaden the monitoring approach and provide ancillary information to inform the overall population assessment.

On each aerial survey, high-resolution still photography was conducted through an open hatch from the side of an Air Corps helicopter. This provided significant additional manoeuvrability and flexibility with respect to survey track-line compared with a fixed wing aircraft, particularly along deeply indented coastlines and those prone to air turbulence. A handheld digital SLR camera (Canon™ EOS 5D Mark II) fitted with a 1.4x extender and 70-200mm zoom lens were used for the photography. Most still images were taken obliquely while efforts were made to collect near-vertical images as much as possible to allow for better identification of living and dead pups. Image sequences and location data were logged in-flight by an assisting data-logger and a distinct image bank was collated after each survey flight for subsequent analysis.

2.4 Data analysis and modelling





The analysis of aerial photographs acquired in the field and subsequent pup production estimation followed identical methods to those used in 2006 (*see* Ó Cadhla *et al.*, 2008).

On completion of each regional survey programme all digital still images were arranged within the assembled image bank for analysis. Data for each aerial survey and its associated imagery were logged using a standard recording format. The images were then viewed on flatscreen computer displays using image handling software that allowed for adjustments to zoom, exposure, sharpness and image resolution.

During the image analysis process, one of two dedicated scientists scanned the still images for the presence of living and dead grey seal pups. Detailed analysis was first preceded by a familiarisation period for each analyst during which they became fully versed with the software and image features, and with the optimal method for performing pup counts. A strict quality control process was also built into each analysis project in order to guard against potential false positives or false negatives.

The 2006 protocol for identification of grey seal pups on all habitat types was used, factoring in all recognisable cues (e.g. flippers, eye sockets) and possible sources of error in counting (e.g. pups in water or juvenile seals). Dead pups were identified as such by their unusual posture, emaciated condition, the presence of large open wounds or empty eye sockets, and their continued position and physical deterioration on images from successive survey dates. Where an object appeared to resemble a grey seal pup but sufficient determining cues were not available to the viewer the item was noted and subsequently reviewed by both analysts before being discounted.

Strict adherence to the identification protocol was necessary to avoid the inclusion in pup counts of various other items (e.g., boulders, buoys, timber, containers) that, depending on their shape, substrate and lighting conditions can resemble seal pups. Where living or dead grey seal pups were positively identified from the still imagery, each pup's approximate developmental stage (Stage I → Stage V, Fig. 2) was recorded along with its site and associated habitat information based on the classification system given by Fossitt (2000). All grey seal pups recorded in the sea, in rock pools or in fresh water streamlets were also noted accordingly.

PUP STAGE	AGE*	CHARACTERISTICS	EXAMPLES
Stage I	0-2 days	THIN BAGGY-SKINNED BODY YELLOW-STAINED or WHITE NATAL FUR CONSPICUOUS UMBILICAL CORD DOCILE AND POORLY COORDINATED	
Stage II	3-7 days	SMOOTHER BODYLINE, FEW LOOSE FOLDS NECK STILL DISTINGUISHABLE UMBILICAL CORD ATROPHIED AWARE AND COORDINATED	
Stage III	7-15 days	ROUNDED OR BARREL-SHAPED BODY NECK THICKENED/INDISTINGUISHABLE MOULTING FROM HEAD OR FLIPPERS MAY BE AGGRESSIVE ON APPROACH	
Stage IV	16-20 days	ROUNDED/BARREL-SHAPED BODY PARTIALLY MOULTED FROM TORSO HEAD AND FOREFLIPPERS MOULTED MOBILE/AGGRESSIVE ON APPROACH	
Stage V	18-25+ days	FULLY MOULTED TO SHORT FUR COAT (<i>< 100 cm² OF NATAL COAT REMAINING</i>) SPECKLED COLOURATION VARIES AGGRESSIVE AND MOBILE	

[Based on published information and research experience. *Ages given are intended as approximations and some variation may occur depending on the health and physical condition of individual pups].

Figure 2. The developmental stages into which newborn grey seal pups are classified (after Ó Cadhla *et al.*, 2008).

Staged pup counts delivered by each survey within the season formed a production spreadsheet for each survey location (i.e., breeding area containing one or more distinct sites/islands). The estimation of total pup production (P) at each survey location then depended on modelling the observed birth

rate against an established statistical framework that describes how the numbers of pups at a breeding site vary over the season (Fig. 3; Hiby *et al.*, 1988; Myers *et al.*, 1997).

The production estimation model (*PEST*) designed for this process was originally developed by Lex Hiby (Conservation Research Ltd., Cambridge, UK) and colleagues at the Sea Mammal Research Unit (SMRU, University of St. Andrews). Previously used to simulate and derive estimates of pup production at UK sites and at numerous Irish breeding colonies including those surveyed in 2005 as part of the national assessment, the *PEST* model allows various parameters (e.g., the degree of pup misclassification, the time to moulting, the time to leaving the breeding site) to be fixed or freed in order to deliver the most accurate model fit to the observed counts (Fig. 3: Kiely *et al.*, 1997), thereby reducing the error (i.e., the coefficient of variation, CV) of each production estimate calculated by the model.

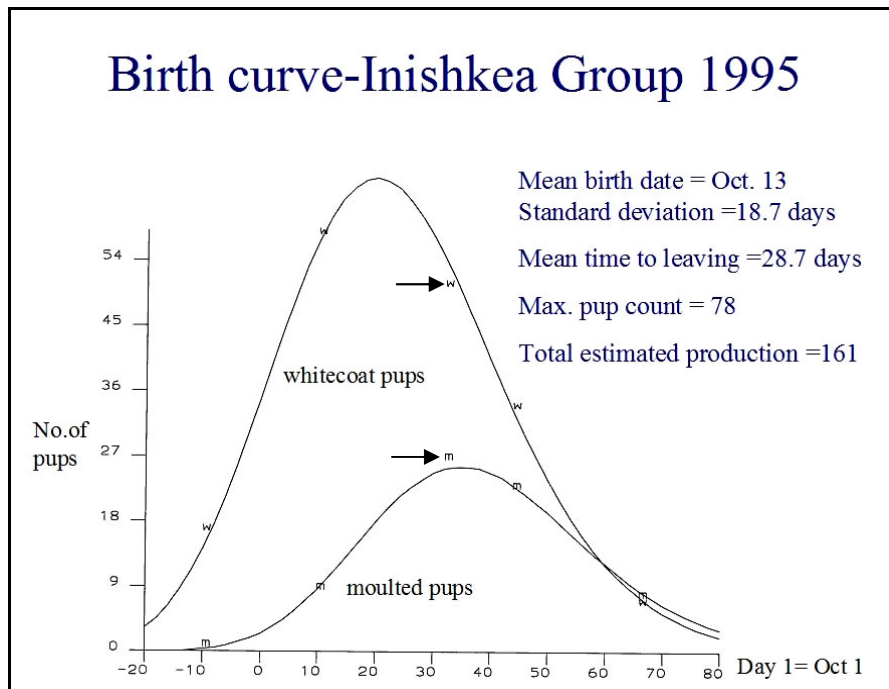


Figure 3. Example of *PEST* model output showing five count samples classified into whitecoat (w) and moulted (m) pups (arrows), and the maximum likelihood best fit to the data provided (smooth lines).

2.5 Pup production and population estimation

Once the statistical analysis for all 2009, 2011 and 2012 data was completed and total production estimates, associated CVs and other pup-related parameters were available for each breeding site, the total estimated production was calculated for each of the seven key areas surveyed. In seeking to correctly geo-reference individual survey locations and discrete sites within those locations, positional data were given for the approximate centre-point of each, whether an individual island or stretch of surveyed coastline (*see* Appendix 1).

The resultant pup production figures for all seven key breeding areas (i.e., from 2009, 2011, 2012) were then combined with outlier pupping data from 2005 for all sites of lesser importance on national/regional scales, in order to yield an updated Irish production estimate. While a degree of variability in grey seal pup production between years is commonplace, it was determined that the overall national pup production figure derived could be considered a reasonable representative sample within the overall 2009-2012 period. An important assumption is made, however, that the breeding sites of lesser importance (c. 16% of the 2005 total) have not seen nationally/regionally significant increases or declines in pup production since they were last surveyed.

The total pup production estimates delivered by the above analyses were then subject to multiplication by a factor of 3.5-4.5 (Harwood & Prime, 1978), representing the ratio of all pups

recorded in that breeding year to an increasing all-age population which produced those pups. This method for estimating the total population size has been the standard method applied previously in Ireland, given the absence of additional demographic or life history data and the lack of a sufficient time-series of pup production estimates from the key breeding colonies (Ó Cadhla *et al.*, 2008). However it does not account for pup survival in the wild within the first year of life which may be quite low, particularly for male pups (Hall *et al.*, 2001) and about which little is known in an Irish context. Thus the size of the population is subject to natural change prior to the next breeding season when a new cohort of pups is produced.

3 RESULTS & DISCUSSION

3.1 Survey effort achieved in 2009-2012

The population monitoring programme established for grey seals by the Department in mid-2009 has been broadly successful to date, achieving satisfactory coverage of each of the seven key breeding areas in Ireland across the prescribed period and delivering accurate pup production estimates with generally low coefficients of variation as a result (*see* Appendix 1).

The target of six replicate surveys of each breeding area was achieved for two of the three regions surveyed while five full surveys were performed in the west/north-west region. A sixth replicate was not possible in this region in 2012 due to persistently poor weather conditions that autumn.

The quality of digital still images obtained during each survey year was high, however, and very few images of a poor quality were recorded during the post-survey analysis of data. While aerial survey imagery gathered during the 2005 national assessment were also of a high quality, the quality of images obtained in 2009-2012 may have been further facilitated by (a) the single-region approach to monitoring each year, i.e., making fewer flights in marginal weather or on poorly lit days, and (b) the use of helicopters for conducting the aerial surveys, which can provide better stability and ease of access for photography along particularly complex or elevated coastlines, as well as the ability to reduce the ground speed considerably where appropriate.

3.2 Pup production estimates and all-age population size

Once the analysis of all aerial survey imagery had been completed in April 2012 the pupping information from each individual breeding site was modelled at the Sea Mammal Research Unit using the *PEST* program. The resultant site-based pup production figures, mean birth dates and coefficients of variation estimated by the model are shown in Appendix 1.

The pup production estimation process, based on aerial count records of living and dead pups, delivered satisfactory results overall. Pup mortality data recorded from the aerial survey imagery for each of the breeding sites covered was notably low, with no dead pups or generally low single figures recorded on the survey imagery. This indicated that mortality levels on the ground at established Irish breeding sites may remain comparatively low (i.e., less than 5-7%), evidence for which has been gathered by several 'through-counting' studies at key colonies since the mid-1990s (Ó Cadhla *et al.*, 2008). Similar ground-level sample data (or 'ground-truthing') could usefully be employed at a few readily accessible breeding sites in order to provide ongoing cross-reference with the data acquired during the aerial monitoring programme.

Despite occasionally small numbers of pups recorded at certain islands, pup count data were modelled quite accurately using the production estimation model. This was done by setting a minimum target of 20-30 pups per estimation unit whereby count data from adjacent sites that contained comparatively low totals were grouped together to exceed the 20-pup threshold and the data were modelled thereafter to obtain a collective production estimate (P_g).

Model runs were conducted assuming (i) a normal and (ii) a lognormal distribution of births over the course of the breeding season. As also indicated in the analysis of data from the 2005 national survey (Ó Cadhla *et al.*, 2008) the use of a normal birth-distribution curve for the 2009-2012 data, rather than a lognormal birth-curve plot, tended to deliver equivalent or slightly lower, more stable coefficients of variation (CVs) for each estimate unit.

Allowing a 5% loss/non-detectability of pups due to mortality and other factors, a series of 19 estimates of pup production were derived from the data acquired in 2009, 2011 and 2012 for individual (P_i) and grouped (P_g) breeding sites (Appendix 1). As in 2005, the figures assume a normal distribution of births over the breeding season since this produced equivalent or slightly lower CVs than the corresponding lognormal birth-curve.

When the data for all survey years were combined, the minimum pup production across the seven main breeding areas in Ireland totalled 1,829 pups.

While appropriate care must be taken in interpreting pooled figures produced across several breeding seasons in comparison with figures produced in a single survey year, the combined estimate for 2009-2012 nevertheless exceeded the 1,322 pups recorded in 2005 (Ó Cadhla *et al.*, 2008). Pup productions recorded at the main breeding areas in 2009, 2011 and 2012 respectively were higher in most cases than their 2005 equivalents with the exception of the Saltee Islands, where a slightly lower figure was recorded in 2009 (Table 1).

Table 1. Pup production and all-age population estimates from the seven most important grey seal breeding areas in Ireland, 2005 and 2009-2012. Production figures (P) represent the combined totals from individual breeding sites or survey locations within each breeding area.

County	Breeding Area	Survey Locations	Minimum Pup Production (P): 2005	Minimum Pup Production (P): 2009-2012	All-age population size 2009-2012
Mayo	Inishkea Group	87–89	386 pups	526 pups (2012)	1,841 – 2,367 (2012)
Galway	Inishshark, Inishgort, etc. (North-west Galway)	71	220 pups	416 pups (2011)	1,456 – 1,872 (2011)
Donegal	Sturrall to Maghera	108–109	227 pups	241 pups (2012)	844 – 1,085 (2012)
Kerry	Blasket Islands	41–42	185 pups	314 pups (2011)	1,099 – 1,413 (2011)
Wexford	Saltee Islands	140	163 pups	151 pups (2009)	529 – 680 (2009)
Galway	Slyne Head islands	68	68 pups	104 pups (2011)	364 – 468 (2011)
Dublin	Lambay Island & Ireland's Eye	134–135	58 pups	77 pups (2009)	270 – 347 (2009)

The combination of the above pupping figures for the 2009-2012 period with a minimum of 252 pups recorded in 2005 outside the seven main breeding areas for grey seal (Ó Cadhla *et al.*, 2008), yielded a minimum national estimate of 2,081 grey seal pups. The corresponding all-age population estimate pooled across all years concerned was 7,284 - 9,365 grey seals of all ages.

As discussed, this exercise assumes no nationally/regionally significant decline or increase in pup production at the additional breeding sites concerned. It also assumes that the pup figures, pup mortality and other parameters measured at all seven key breeding areas in 2009, 2011, 2012 were broadly representative of the status quo within that four-year period. In the absence of additional scientific data, these results and their interpretation should therefore be treated with an appropriate level of caution.

The pup production data acquired during the 2009-2012 monitoring programme, in combination with reliable scientific knowledge of historical production among several breeding areas (*see* Ó Cadhla *et al.*, 2008), together provide supporting evidence for a level of growth in the grey seal breeding population in Ireland since the mid 1990s at least and possibly dating to the early 1980s when the first repeated breeding site surveys were being undertaken by the Forestry & Wildlife Service (Summers, 1983).

The described growth in the grey seal breeding population appears to have continued since the 2005 national assessment eight years ago and it appears to be most pronounced around a number of breeding areas of key importance in a national context (Table 1).

Prior to the comprehensive assessment of Ireland's breeding population in 2005, studies at the Inishkea Group and Blasket Islands off the west and south-west coasts respectively were describing positive differences in pup production between 1995-1996 and 2002-2003 (Ó Cadhla & Strong, 2003; Cronin *et al.*, 2007). While such observations could indicate a change in the distribution of the wider breeding population or improved fecundity in the adult populations associated with these particular sites, and the data were also snapshots across a survey gap of seven years, the possibility of some wider all-age population growth (e.g., more animals of breeding age in the population) was further suggested when all principal and secondary breeding colonies around Ireland were surveyed in 2005 and additional positive changes in pup production were evident (Ó Cadhla *et al.*, 2008).

Although interannual variation in grey seal pup production within a breeding area is common, as borne out in the figures produced for individual breeding sites (Appendix 1) compared with those from 2005 (Ó Cadhla *et al.*, 2008), and these studies are all relatively recent in ecological terms, the current minimum and maximum population estimates derived via annual pup production in 2009-2012 are higher overall than those recorded in 2005 (5,509 - 7,083 seals of all ages; Ó Cadhla *et al.*, 2008).

It should be noted however, that (1) the observed changes in pup production between survey years are variable across the different breeding areas under surveillance, (2) statistical data on pup production trends at individual breeding colonies are not available and further scientific work will be necessary to populate a robust analysis of trends and monitor the species' status on an ongoing basis, (3) information is limited concerning the many secondary breeding sites surveyed/identified in 2005, and (4) overall numbers of grey seals recorded in Ireland remain low compared with the UK (90,100-137,700; SCOS, 2011) especially considering the extent and availability of apparently suitable coastal habitat (Duck & Morris, 2012a; Duck & Morris, 2012b).

Based on the population monitoring and analysis undertaken during the 2009-2012 period, previous data and associated analyses, it is evident that grey seals continue to number in the several thousands nationally and that populations associated with a few key breeding areas have increased in size within the last two decades.

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Appendix 1 Pup production data for all grey seal breeding areas monitored in 2009-2012.

Locations and sites covered during grey seal population monitoring in 2009-2012, selected data and estimated individual (P_i) and grouped (P_g) pup productions with associated coefficients of variation (CVs) delivered by the monitoring programme. A normal birth-distribution curve was selected for modelling.

[I. – Island; Is. = Islands; Hd. = Head; Gp. – Group; * = data incorporated in grouped total].

Location (Year)	County	Breeding area	Site/Area name	Lat. °N	Long. °W	No. of surveys	Mean birth date	P_i	P_g	CV
41 (2011)	Kerry	Blasket Is.	Inishvickillane	52.044	10.608	6	17 Oct		*	
42 (2011)			Great Blasket I.	52.093	10.537	6	17 Oct		*	
			Beginish	52.115	10.507	6	17 Oct	213	*	0.04
			Young's I.	52.120	10.505	6	17 Oct		*	
			Illaunbwee	52.112	10.523	6	17 Oct		314	0.03
68 (2011)	Galway	Slyne Hd. Is.	Ferroon Rocks	53.396	10.215	6	15 Oct	53	*	0.06
			Illaunamid	53.398	10.230	6	19 Oct		*	
			Chapel I.	53.398	10.213	6	19 Oct		104	0.05
71 (2011)	Galway	NW Galway	Glassillan	53.595	10.271	6	11 Oct	30		0.04
			Inishgort	53.597	10.263	6	12 Oct	112		0.05
			Inishshark	53.610	10.280	6	8 Oct		*	
			Inishskinny more	53.605	10.248	6	8 Oct		*	
			Inishskinny beg	53.609	10.249	6	8 Oct		274	0.04
87 (2012)	Mayo	Inishkea Gp.	Keely I.	54.078	10.140	5	4 Oct	27		0.09
			Duvillaun Beg	54.078	10.152	5	2 Oct	101		0.04
			Duvillaun More	54.074	10.171	5	30 Sept	95		0.07
88 (2012)			Inishkea South	54.115	10.218	5	13 Oct	122		0.04
			Inishkea North	54.136	10.196	5	13 Oct	114		0.04
			Carrickawilt	54.154	10.195	5	17 Oct		*	
			Carrigee	54.157	10.195	5	17 Oct		*	
			Carrickmoyle	54.160	10.188	5	17 Oct		*	

Location (Year)	County	Breeding area	Site/Area name	Lat. °N	Long. °W	No. of surveys	Mean birth date	P _i	P _g	CV
89 (2012)	Mayo	Inishkea Gp.	Inishkeeragh	54.202	10.137	5	17 Oct		*	
			Inishglora	54.211	10.129	5	17 Oct		67	0.13
108 (2012)	Donegal	SW Donegal	Sturrall - Glenlough	54.752	8.705	5	1 Oct	55		0.05
109 (2012)	Donegal		Glenlough - Maghera	54.777	8.609	5	30 Sept	186		0.06
134 (2009)	Dublin	Lambay I.	Lambay I.	53.490	6.020	6	21 Sept	75	*	0.06
135 (2009)	Dublin	Ireland's Eye	Ireland's Eye	53.406	6.064	6	21 Sept		77	0.07
140 (2009)	Wexford	Saltee Is.	Great Saltee I.	52.117	6.615	6	23 Sept	138	*	0.04
			Little Saltee I.	52.137	6.586	6	22 Sept		151	0.04