NPWS Phocid monitoring methods and interval assessment

Recommendations for monitoring of the harbour seal (*Phoca vitulina vitulina*) & grey seal (*Halichoerus grypus*) populations in the Republic of Ireland

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1. INTRODUCTION

The EC Habitats Directive (92/43/EEC) confers on Member States an obligation to monitor the conservation status of Annex II seal species and to report thereon every six years. Population monitoring is not restricted to designated Natura 2000 sites. Ireland's first report for on the conservation status of its seal populations was submitted to the EC in 2007 (*see* Cronin, 2007; Ó Cadhla, 2007).

Research programmes in the Republic of Ireland established effective national population baselines for harbour seals (*Phoca vitulina vitulina*) in 2003 (*see* Cronin *et al*., 2004; Cronin *et al*., 2007) and grey seals (*Halichoerus grypus*) in 2005 (*see* Ó Cadhla *et al*., 2007). To date, national monitoring programmes have not been established for either species. The ability to scientifically determine population trends from numerical data depends on the efficacy of methods used and the frequency at which monitoring is conducted. Annual monitoring programmes are recommended in the scientific literature as by far the most effective method for determining population trends, details of which are given below.

The population assessment methods used in the Republic of Ireland in 2003 and 2005, for harbour seals and grey seals respectively, incorporated current best practice for both species within their north-east Atlantic range. The 2003 harbour seal population assessment, carried out during the moult season, determined that at least 229 distinct haul-out sites are used by a minimum population of 2,905 harbour seals. Haul-out sites occurred along the entire coastline during the 2003 moult, with discernibly lower numbers of harbour seals recorded along the southern and eastern seaboards.

The 2005 grey seal assessment, conducted during the breeding season, determined that a minimum population of 5,509-7,083 grey seals inhabits breeding colonies in the Republic of Ireland, over 80% of which is associated with seven key breeding locations along the east, southeast and Atlantic coasts. Many secondary and new breeding locations were identified. A further study to assess moult population size was conducted in 2007 (*see* Ó Cadhla & Strong, 2007). Its results also now contribute towards the understanding of grey seal population distribution and appropriate methods for future monitoring.

Following further review of current national and international scientific knowledge, CMRC recommendations for national seal population monitoring in the Republic of Ireland are outlined below.

2. HARBOUR SEAL POPULATION MONITORING

2.1 Background information and the current status of the harbour seal in the Republic of Ireland

The harbour seal (*Phoca vitulina* Linnaeus, 1758) is classified within the family Phocidae and has a wide distribution in coastal habitats of both the North Pacific and North Atlantic oceans. Five subspecies are recognised, distinguished principally by their geographical distribution (Reeves *et al*., 2002). The subspecies *Phoca vitulina vitulina* occurs in Europe from the Arctic Ocean at Svalbard, Norway, to the Barants Sea, the southern Baltic Sea and the eastern North Atlantic from the British Isles south to Portugal (Reeves *et al.,* 2002). Studies on the genetic population structure of the harbour seal have identified 17 distinct populations of harbour seals across its geographical range in the north Atlantic (NAMMCO, 2006). Based on information from neutral markers, mitochondrial DNA and a suite of nuclear micro-satellite markers, harbour seals in Northern Ireland and Scotland are considered to be part of the same population (Andersen *et al*., 2006). It is likely that harbour seals using terrestrial haul-out sites and the waters surrounding the Republic of Ireland are of the same genetic stock or population, however in the absence of information on the genetic structure of harbour seals in the Republic of Ireland this has not been confirmed. Whilst acknowledging that a distinct 'population' of harbour seals in the Republic of Ireland is unlikely, the term is used here to represent harbour seals using terrestrial haul-out sites and the waters surrounding the Republic of Ireland.

Lockley (1966) first estimated the size of the Irish harbour seal 'population' to be 1,000, based on data collected incidentally, during two autumn surveys focusing on grey seals *(Halichoerus grypus),* during 1964 and 1965. The first dedicated harbour seal census of the island of Ireland was undertaken in July 1978. Based on a combination of boat and aerial surveys, this gave a minimum estimate of 1,248 but it was considered that population size could be between 1,500 and 2,000 individuals (Summers *et al*., 1980). A national census of the harbour seal, using aerial surveys of haul-out sites on the coastline of the Republic of Ireland during August 2003, proved to be an effective means of obtaining a minimum population estimate (Cronin *et al.,* 2007a). The minimum estimate of 2,905 animals in the Republic of Ireland, when combined with a near identical survey of Northern Ireland in 2002 (Duck, 2006), gives an All-Ireland minimum population of 4,153 harbour seals. Although this estimate is more than three times the total estimate (1,248) in 1978, the figures are not directly comparable due to different timing and survey techniques. The 2003 estimate should instead be considered as a more reliable baseline figure against which future estimates can be compared to assess population trends.

There is some evidence to suggest an increase in numbers of harbour seals at selected haul-out sites in the southwest of Ireland. Counts of harbour seals at haul-out sites in this region have been conducted by National Parks & Wildlife Service (NPWS) rangers during April to October from 1985 to 1999 and during August and September from 2000 to 2006 and have shown an 8% and 13% annual increase in the Kenmare River and Bantry Bay respectively (Heardman *et al.,* 2006). The increase in harbour seal numbers in

southwest Ireland may be attributed to lack of persecution following the 1976 Wildlife Act, which affords protection to the species in Ireland. This may reflect a national trend but in the absence of an historic national population estimate directly comparable to the 2003 estimate it is not possible to ascertain this.

2.2 Rationale for establishing a monitoring program for the harbour seal in the Republic of Ireland

Generally, harbour seal population monitoring programs are designed to detect medium to long-term changes in population size (Thompson *et al*., 2005). Such information is necessary to fulfill conservation obligations under the European Community (EC) Habitats Directive (92/43/EEC), which requires member states to develop monitoring programs to determine the status of species and habitats protected under the Directive. The harbour seal is listed as an Annex II species under the Directive, requiring the designation of Special Areas of Conservation (SAC), to protect listed species and their habitat. Under the Directive, member states are obliged to maintain 'favourable' conservation status of Annex II species and to report on this every 6 years. The NPWS recently initiated conservation assessments of the Irish harbour and grey seal populations (Cronin, 2007a; Ó Cadhla, 2007). Reliable population estimates and up-to-date information on harbour seal distribution are needed to effectively assess the conservation status of the species in Ireland, which takes into account range, habitat and population conservation status. It is considered that the minimum population estimate derived in 2003 by means of a comprehensive national survey (2,905 animals, Cronin *et al*., 2007a) represents the 'Favourable Reference Population' (EC, 2006) for the Republic of Ireland. Changes to population size and/or distribution will have potential affects on the conservation status of a species. In order to identify population trends and potential changes in distribution it is imperative that ongoing monitoring of population size and distribution be undertaken.

Under the Directive member states are obliged to designate and manage SACs for Annex II species. Up-to-date information on harbour seal haul-out group size and distribution is necessary for the identification, management and monitoring of SAC required for harbour seals under the Directive. Moreover, assessing year round changes in harbour seal abundance within SACs contributes to the monitoring obligations under the Directive and to the understanding of national population trends.

In some areas across the species' range the numbers of harbour seals are increasing (Small *et al*., 2003; Thompson *et al.,* 2005; Waring *et al*., 2006; Heardman *et al*., 2006; Jemison *et al.,* 2006). However declines in abundance have also been observed in many areas and have been attributed to recruitment failure, competition for resources, disturbance and disease (Frost *et al*., 1999; Thompson *et al.*, 2001; Matthews & Pendleton, 2006; Lonergan *et al*., 2007). Epidemics of phocine distemper virus (PDV) affected European harbour seal populations in 1988 and 2002 and harbour seal abundance has fluctuated in the northeast Atlantic due to outbreaks of this disease (Dietz *et al.,* 1989; Harding *et al.,* 2002); there is currently a suspected PDV outbreak in the Kattegat and Skagerrak Seas (CWSS, 2007). It is known that harbour seals in Ireland were affected by outbreaks of PDV in 1988-89 and 2002 (CWSS, 1991; Reineking, 2002;

Barrett *et al*., 2003). Yet, in spite of apparent local increases in seal deaths and changes in haul-out counts at a few sites in western Ireland (Gilleran, J., NUIG, *pers. comm.*) and confirmed pathology from an animal found on the Aran Islands (Kennedy, S., DARDNI, *pers*. *comm.*), in the absence of consistent monitoring of regional haul-out groups in the Republic and a reliable up-to-date population estimate, it was not clear if the disease caused a significant decline in population size in the Republic or indeed around the island of Ireland as a whole. Predicting the potential long-term effects of disease such as PDV on harbour seal populations requires information on pre-epidemic population trajectories (Harding *et al*., 2002; Lonergan & Harwood, 2003). In light of the recent potential outbreak of PDV amongst harbour seal populations in the Baltic Sea (CWSS, 2007) and the fact that it has been over four years since the last national harbour seal survey an urgency exists to establish the current population estimate.

There is recent evidence of a general decline in most of the large harbour seal colonies around Britain, between 2001 and 2006, the population in Orkney and Shetland declined by 40% indicating substantially increased mortality or very low recruitment over this period (Lonergan *et al.,* 2007). These declines are more than four times the current threshold for possible corrective action defined under the OSPAR international convention. The convention states that 'taking into account natural population dynamics and trends, there should be no decline in harbour seal population size of > 10% as represented in a five-year running mean or point estimates within any eleven sub-units of the North Sea' (OSPAR, 2006). The widespread decline in harbour seal numbers around Britain ranging from Shetland to the Wash suggest that the causes may be present over a large part of the North Sea (Lonergan *et al.,* 2007) and is a cause for concern. It is possible that harbour seal numbers in Ireland have declined since the 2003 census and highlights the necessity for another harbour seal census in the immediate future.

2.3 International harbour seal monitoring/surveys

The standard methodology across the harbour seals global geographical range for estimating population size is via fixed-wing, occasionally helicopters, aerial surveys of haul-out sites during the pupping or molting periods when a larger fraction of the population of seals are hauled out (Heide-Jørgensen & Härkönen, 1988; Thompson & Harwood, 1990; Reijnders *et al.,* 1997, 2003; Frost *et al.,* 1999; Huber *et al*., 2001; Jeffries *et al.*, 2003). While breeding season counts provide reliable estimates of abundance as well as valuable pup production data, Härkönen *et al.* (1999) concluded that in non-stable age-structured populations the influence of the differential haul-out behaviour on estimating abundance is likely to be greater during the breeding period than during the moult period. Reijnders *et al*. (2003) recommended future use of moult count data to obtain a reliable and consistent index of population abundance of harbour seals in the Wadden Sea, while Thompson *et al.* (1997) suggest that counts made during the August moult provided more reliable population estimates for harbour seals hauling out on rocky shores in the UK. Large-scale surveys of harbour seal populations occurring in rocky-shore habitats in the northeast Atlantic and northeast Pacific are generally conducted during the annual moult (Reijnders *et al.,* 1997; Huber *et al.,* 2001; Small *et al*., 2001, Boveng *et al*., 2003; Duck *et al*., 2005).

2.4 Index of population versus true abundance estimates

The population estimate obtained during a survey can only be considered a minimum population estimate as a fraction of the population will be at sea and not available for counting. Minimum population estimates are sufficient for assessing long-term population trends, however an assumption must be made that the proportion of animals at sea during the count does not vary between years or geographical areas (Thompson & Harwood, 1990). Alternatively, the proportion of the population at sea during surveys can be estimated and the count corrected to obtain an estimate of 'absolute abundance'. Such estimates are necessary for incorporation into ecological models and assessing predation pressure by seals on commercially important fish stocks.

Determining the variation in harbour seal haul-out behaviour over time and what factors influence this allows the approximation of what proportion of the population is ashore during counts. This information can be used to devise a correction factor for counts at haul-out sites, improving the accuracy of population estimates. A variety of approaches have been used to estimate this proportion, including telemetry (Yochem *et al*., 1987; Thompson *et al.,* 1989, 1997; Ries *et al*., 1998; Huber *et al.,* 2001; Simkpins *et al*., 2003; Sharples, 2005), a bounded count method (Olesiuk *et al.,* 1990), time lapse photography (Stewart, 1984; Thompson & Harwood, 1990) and photo-identification of individuals (Moran, 2004). The average proportion of seals hauled out during peak haul-out times has generally been estimated to lie between 0.50 and 0.75, however values of 0.40 and 0.88 have been reported from telemetric and bounded count approaches respectively (Olesiuk *et al*., 1990; Sharples, 2005).

In a telemetric study of harbour seal haul-out behaviour in northwest US, no difference was found in the proportion of seals ashore amongst survey areas, between stocks or between years during the pupping season which suggests that the estimated correction factor can be applied to aerial counts of harbour seals in the Washington and Oregon area (Huber *et al*., 2001). Simpkins *et al*. (2003) suggest that haul-out proportions of harbour seals under locally ideal conditions in Alaska may be constant between years and geographic regions at least during the moult. However, correction factors will vary temporally and spatially and whether correction factors devised for one area can be used elsewhere or for all future surveys of that area depends on the relative importance of biotic or abiotic factors influencing the haul-out behaviour of harbour seals. If abiotic factors dominate, a correction factor devised from one area would not be appropriate to apply to another; if biotic factors dominate, the correction factor would be appropriate to use in another area provided the sex-ratio and age structure of the tagged individuals are representative of the population (Ries *et al*., 1998).

A major shortcoming of using telemetry to estimate the proportion of the population ashore during counts is tag loss associated with the moult and the resulting gaps in information on haul-out behaviour during this period. However, certain approaches have been applied to try to overcome this limitation. Ries *et al*. (1998) developed a maximum likelihood estimator to infer rate of radio-tag loss in the Dutch Wadden Sea and to estimate the size of the local pre-pupping population. Flipper mounted telemetry devices have been used to obtain information on the haul-out behaviour of harbour seals during

the moult in northwest US (Huber *et al.,* 2001; Simpkins *et al.,* 2003). Sharples (2005) combined telemetry data with ground counts over the year until tags fell off prior to moult to devise a mean harbour seal population estimate for St. Andrews Bay, Scotland; this was compared to a minimum population estimate obtained by aerial means during the moult and the proportion of seals ashore during this period subsequently estimated.

In telemetry studies that have used large samples of tagged seals the proportion of seals hauled out during counts or during 'ideal conditions' has been used to devise correction factors for count data (Thompson *et al*., 1997; Huber *et al.,* 2001, Simpkins *et al*., 2003). Recent telemetry efforts in southwest Ireland have provided valuable data on the haul-out behaviour of harbour seals (Cronin, 2007a; Cronin *et al*., 2007c *in review*) however sample size of tagged seals is small to date and it is not possible at this stage to derive a correction factor that could be applied to the population. Statistical modelling can overcome some constraints associated with small sample size, however, identifying an optimal model of the haul-out behaviour of a small sample of tagged seals as a function of covariates, using mixed modelling techniques and treating tag as a random factor, is only applicable if all seals behave with random variations around the main pattern. The data resulting from the studies in the southwest shows large variation in behaviour between individuals. Moreover, this study is the first to demonstrate variability in the haul-out behaviour of harbour seals between different tidal periods. If the reason for the variation in haul-out behaviour between individuals was established (e.g. demographical, seasonal and/or geographical) this could be accounted for in a random effects model and haul-out probabilities under 'ideal' conditions or during surveys could be estimated, providing a means for correcting count data. Increasing the sample size of tagged seals, with a more balanced age and sex ratio and including as many covariates as possible in the analysis would help to achieve this (Cronin, 2007a).

2.5 Thermal imagery versus conventional photography

Conventional aerial photography of harbour seal haul-out groups is effectively used to obtain seal counts on sandy or muddy haul-out substrate and is used at many haul-out sites throughout the species range e.g. the Wash and surrounds in the UK, East and West coast US, Canada, Scandinavia and Holland (Reijnders *et al.,* 1997; Härkönen *et al.,* 2002; SCOS, 2005; Gilbert & Guldager, 1998). Hauled out seals are counted visually or from reading photographs taken with 35mm still or digital cameras with 70-300mm telephoto lens and high speed color slide film. On rocky or seaweed covered rocks harbour seals are difficult to detect. Thermal imaging provides a means of detecting otherwise well-camouflaged seals on rocky or seaweed-dominated shores as well as on sand or mud-banks. This technique has been used to survey the Scottish coast for harbour seals since 1988 (Hiby *et al*., 1993, 1996) and was adopted for the harbour seal survey of Northern Ireland in 2002 (Duck & Thompson, 2003) and the Republic of Ireland in 2003 (Cronin *et al*., 2004, 2007a). Since the thermal imaging camera operates in the infra-red spectrum, it is not influenced by light conditions and seal haul-outs can easily be detected from distances of up to 3km (Duck, C., SMRU, *pers. comm*.) minimising disturbance to the animals. The technology also enables the detection of the heat-shadow or thermal footprint of animals that have entered the water, improving the accuracy of aerial-counts over those conducted by eye. Biases due to differences in land-based observer ability are

avoided and any errors in aerial survey data (e.g. misidentification of harbour seals in mixed species groups) can be assessed by ground-truthing at a number of accessible sites (e.g. Cronin *et al*., 2007a). The use of a helicopter allows for maximum area coverage in a short period of time thereby reducing the manpower required to conduct such an extensive survey. In addition, aerial surveys can operate in certain weather conditions that would impede boat surveys such as moderate to strong wind and high sea swell.

2.6 Covariate effects on population estimates

Harbour seal haul-out behaviour is known to be influenced by environmental and climatic variables, particularly the tidal cycle, time of day, wind speed, wind direction and degree of precipitation (Pauli & Terhure, 1987; Yochem *et al*., 1987; Thompson *et al.*, 1994; Grellier *et al.,* 1996; Withrow & Loughlin, 1996; Small *et al*., 2003). In general, the number of harbour seals ashore at a site appears to reach a maximum within two hours of low tides occurring in the afternoon (Thompson *et al*., 1997), though this can vary with location, haul-out habitat type and site availability during the tidal cycle (Stewart, 1984; Yochem *et al*., 1987; Thompson *et al*., 1989; Thompson & Miller, 1990). While it is not possible to control for all of these variables simultaneously, they are taken into consideration when planning the daily timing of population surveys.

Studies have shown that the influence of environmental covariates on estimates of population trend is substantial and thus biologically significant (Frost *et al*., 1999; Olesiuk, 1999; Adkison *et al*., 2003; Small *et al*., 2003) and it is recommended that covariates are integrated into abundance estimates (Boveng *et al*., 2003) and trend analyses (Small *et al*., 2003) to produce more accurate trend estimates required for the management of harbour seals. The use of mean or maximum counts by site without covariate correction can lead to a substantial bias and low power in trend determination (Adkison *et al.,* 2003). Modeling the effects of environmental covariates using advanced statistical modeling techniques such as GLMs, GAMs or GAMMs has been used to obtain more precise population estimates (Frost *et al*., 1999; Boveng *et al*., 2003; Cronin, 2007b; Cronin *et al.,* 2007b *in review*).

2.7 Survey replication and inter-annual frequency of surveys

Replicate counts within a survey region have been used to obtain more precise population estimates and periodic replicate surveys have been used to examine trends (Pitcher, 1990; Frost *et al*., 1999; Adkison *et al*., 2003; Jeffries *et al*., 2003; Small *et al.,* 2003).

The ICES Working Group on Marine Mammal Ecology proposes that annual replicate surveys of the seals in the entire area of interest are required to make it possible to detect changes in trends within a reasonable time. This is based on statistical power analyses which have shown that it will taken seven years to detect a 5% change in annual rate of increase, when using three replicate flights (ICES, 2003)

Teilmann (2006) carried out statistical power analyses to determine the number of surveys that should be conducted in a single year, and the inter-annual frequency of surveys, which would maximize the power to detect trends in a harbour seal population.

This was carried out using a large dataset of aerial surveys conducted between 1979 and 2006 in Denmark, Sweden and southern Norway. The study showed that there is much more power gained by surveying every year rather than several surveys every other year. In addition trying to reduce the variation between surveys will have a great effect in some areas. In this area, most power was gained by using a ”trimmed mean” of the highest 2 of 3 counts at a particular site, although using the highest count was almost as good. There was little advantage to surveying more than 3 times per year.

Power is a principle consideration in designing a survey and interpreting the results (Peterman, 1990). A comprehensive study by Adkison *et al*., (2003) used simulation to investigate robust designs and analyses for detecting trends from population surveys of Alaska harbour seals. The study showed that a robust estimate of trend may be calculated in as few as five years yet statistical power will be low for annual trends <-5%. If the population boundaries are known, the ability to detect a trend of a specified magnitude is a power calculation based on the number of sites surveyed from the population. If the boundaries are unknown, surveying a larger number of sites will increase power, particularly for annual trends <-4%. Annual counts from < 20-25 sites will provide minimal power except for dramatic trends (>6%/yr) (Adkison *et al.,* 2003).

The observed growth rates in several apparently closed harbour seal populations have approached 10-13% per annum, representing the intrinsic rate of increase in an undisturbed harbour seal population (Heide-Jørgensen & Härkönen, 1988; Olesiuk *et al*., 1990; Boveng *et al*., 2003; Jeffries *et al*., 2003). In the absence of major mortality incidents, real population declines of greater than 5% per annum would be unusual in seal populations at or below carrying capacity levels (ICES, 2003).

To satisfactorily fulfill Irelands’ obligations under the EU Habitats Directive, to report on the status of Annex II species every six years, reliable estimates of population size, trends, distribution and range are essential. At present we have a ‘one point’ estimate of minimum population size for the harbour seal obtained in 2003, however, as this is not reliably comparable with previous estimates (e.g. Summers *et al.,* 1980) due to differences in survey timing and methodologies, no estimate of trend and therefore status of the species is possible. It is critical therefore that surveys are repeated as frequently as is financially viable to maximize our power to detect trends. Summarising the aforementioned scientific literature available on trend analyses of harbour seal count data it would appear that even surveying annually (with 2-3 replicate surveys) it will take at least five years to robustly estimate annual trends greater than 5%, but as changes of more than 5% per annum are unusual in stable seal populations then realistically it will take even longer than 5 years (Adkison *et al.,* 2003; ICES, 2003). Adkison *et al.,* 2003 suggest that a commitment to obtain 10-12 consecutive annual surveys with 2-4 replicates will provide the opportunity to estimate robust site-specific trends and increase power over a broader range of trends.

2.8 Survey coverage options, national versus regional

Surveying the entire known range of the 'population' on an annual basis is the optimal way to monitor the population as it maximises power to detect population trends (section 2.7) and it ensures potential changes to the terrestrial distribution are observed and 'new' or unknown haul-out sites located, thereby improving the accuracy of the minimum population estimate.

It was proven possible to survey the entire coastline of the Republic of Ireland in a nine day window during the annual moult (Cronin *et al.,* 2007a). In other parts of the harbour seals range (e.g. Alaska, UK) it is not possible to cover the entire range within the moult 'window' and in these areas regional surveys are conducted annually and 'added together' over the period of a number of years to provide the minimum estimate. This is not ideal however as it significantly reduces power to detect trends; in acknowledgement of this the monitoring program for harbour seals in the northwest USA is currently being reconfigured by NOAA and in August 2008 a new design will be implemented which aims to cover as much of the entire range of the species as possible within the moult window. The estimates will therefore be updated annually, everywhere, rather than at 5-year intervals for each region separately by allocating survey effort to sites according to the expected numbers of seals at each site, very large sites will be surveyed every year and smaller sites less frequently. A spatial model will be used to produce the estimates (P. Boveng, NMML, NOAA *pers comm*.)

It is acknowledged that annual surveys of national scale, although logistically feasible in Ireland, may not be financially feasible, in which case annual regional surveys combined with less frequent national surveys (e.g. 2-5 year intervals) are an option. The regional survey effort would be allocated to areas with significant numbers of seals, some if not all of which may be possible to survey in a fixed wing aircraft and photographed with a digital stills camera. This provides a significantly cheaper alternative to the helicopter/thermal imager/digital stills combination. The latter is necessary when surveying the entire coastline as some of the smaller, dispersed haul-out sites are not easily visible without the aid of a thermal imager and a helicopter is necessary to hover so the imager can be operated. The helicopter also ensures optimal coverage of the indented coastline and therefore a comprehensive and accurate search of all potential terrain for existing known and potentially new/unknown haul-out sites. Where the location of haul-out sites are known (and have been recorded on a gps for accurate relocation) and effort is concentrated regionally, the fixed-wing aircraft/digital stills camera may be a viable cheaper alternative (Table 1).

Regional surveys should be conducted on an annual basis and effort focused on significant areas i.e. those with a large proportion of the national population e.g. areas 2, 4, 5, 7 (fig. 1), these areas are also potentially possible to survey using fixed-wing aircraft as haul-outs are concentrated and/or on sandy/muddy habitat. SACs with the harbour seal listed as a qualifying interest also occur within these areas so annual surveying of these areas will also contribute to SAC monitoring obligations. It is suggested effort be prioritized to these areas and if enough time and resources available smaller, less significant sites be covered within the allocated survey period.

All haul-out groups within a specified survey area will be surveyed as sub-sampling within an area at 'indicator sites' is not ideal as it has been shown that growth rates at indicator sites do not necessarily follow the same trajectory of change as that of the population (SMRU unpublished data). It may be possible to conduct replicate flights of the survey area within the survey period and 2-3 replicate flights would significantly increase the accuracy of the count; if this is unfeasible then replicate counts can be conducted by ground counting at selected sites.

It is imperative that regional surveys of this nature be considered as an augmentation to and not a replacement of the national survey. National surveys are necessary to provide a synoptic assessment of the population size and distribution and ideally should be conducted annually and/or in response to a catastrophic event e.g. a PDV epidemic, but if this is not financially feasible then a combination of annual regional surveys and less frequent (e.g. 2-5 year intervals) national surveys would be a pragmatic alternative.

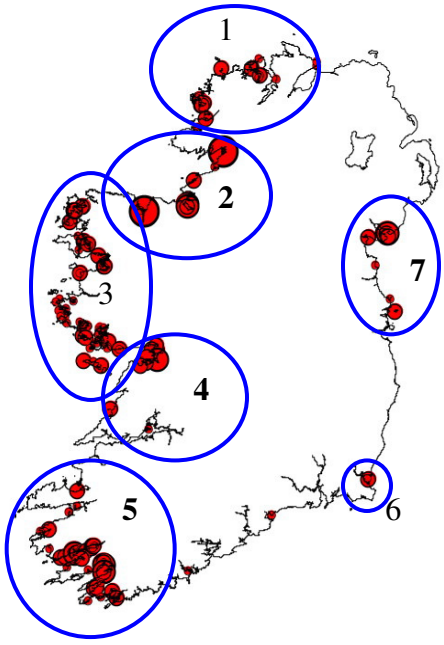


Fig. 1. Harbour Seal Regional Survey Areas, selected on the basis of habitat type and group size. Areas 2, 4, 5, 7 are potentially possible to survey by fixed-wing aircraft and photographed using digital stills camera. Areas 1 & 3 potentially more suited to survey by helicopter as haul-out sites smaller and more dispersed.

Table 1. Summary of methods appropriate for monitoring the harbour seal population size in Ireland, their scales and deliverables, based on information available. Indicative Cost estimates given are for the options considered most cost-effective. More details are given in detail in Sections 2.8 -2.11

Code	Target Season	Survey Mode	Scale	Assessment Type	Survey Interval	Survey Interval within year	No. of Surveys (per year)	Result	CV 95% C.I.	Statistical Power (to detect trends)	Indicative Cost € With air corp (Commercial aircraft)
A-1	Moult	Aerial Heli/Thermal Imager/Digital Stills	National	Haul-out count	Annually	Consecutive days	9-10	Minimum Population Estimate	Yes	At least 7 years to detect a 5% change in annual rate of increase [1]	52.4K (131K)
		Ground Counts	Significant haul-out sites	Haul-out replicate count & Ground truthing		Consecutive days	24 (e.g. 3 surveys at 8 sites)	Improve accuracy of minimum population estimate by accounting for covariate effects			
B-1	Moult	Aerial Fixed Wing/Digital Stills	Regional	Haul-out count	Annually	Consecutive days	4-6	Minimum Count	Yes	Unknown	40.4K (59.4K)
		Ground Counts	Significant haul-out sites	Haul-out replicate count & Ground truthing		Consecutive days		Improve accuracy of minimum counts by accounting for covariate effects			

[1] ICES (2003). Report of the Working Group on Marine Mammal Ecology, Helsinki, Poland, 25-29, March 2003. Advisory Committee on Ecosystems. ICES CM 2003/ACE:03. 81 pp.

Notes:

A-1 Details given below and are based on survey methods & results in Cronin *et al*., 2007.

B-1 This option should be used not as an alternative to A-1 but to augment A-1 if it is not financially feasible to repeat A-1 annually.

2.9 Survey design recommendations for harbour seal surveys in Ireland

A scientific committee working group on harbour seals was recently established by the North Atlantic Marine Mammal Commission (NAMMCO) to assess the status of harbour seals across the North Atlantic and to evaluate threats to the species (NAMMCO, 2006). The current status of the harbour seal in Ireland was evaluated as part of this process (Cronin, 2006). The NAMMCO working group proposed the following survey design for assessing harbour seal populations: Define the target total population or index of population size; Survey in either breeding or moulting season, or preferably both as different segments of the population are surveyed at each of these times; Survey the entire area at intervals to be aware of new colonies or movement between colonies; Conduct multiple surveys, preferably 3 on different days within any season; Timing and duration of surveys should take into consideration environmental variables (*e.g.* tide, weather) as well as potential human disturbances; Possible changes in the timing of the moulting and pupping seasons should be taken into consideration in establishing the timing of surveys, and interpreting the results; Aerial surveys provide more accurate counts in most cases than counts conducted from land or by boat; Photography should be used to determine numbers in groups hauled out, especially large groups; Coordinate surveys to ensure that the entire survey/management area is covered within a short time frame; If estimating total population size from surveys, additional information on length of time ashore from telemetry or individual based studies is required (NAMMCO, 2006).

Considering international best-practice, published and unpublished reports and reviews and discussions with harbour seal monitoring program leaders in the UK and US (SMRU and NOAA respectively) **the following are survey design recommendations for surveying the Irish harbour seal population:**

- Conduct counts of harbour seals at haul-out sites on the entire coastline of Ireland by air. A comprehensive national survey of harbour seals is **urgently required** as the last survey was conducted in 2003 and the current status of the species in Ireland is unknown. **Aerial survey** allows the entire survey area to be surveyed in as short a time period as possible. **Daily 'back to back' surveys are ideal** if weather permits. It has been proven possible to survey the entire coastline of the Republic of Ireland for harbour seals over nine consecutive survey days (Cronin *et al*., 2007a). A **helicopter** enables enhanced maneuverability along an indented complex coastline over a fixed wing aircraft.

- Considering the likelihood that harbour seals using haul-out sites in Northern Ireland are part of the same 'population' as those using the Republic of Ireland it is recommended that efforts be coordinated with EHS, Northern Ireland and future population estimation surveys be conducted **over the entire island of Ireland.**

- The surveys should ideally be conducted during the species **annual moult in August**.

- Use a **thermal imager** to detect often camouflaged harbour seals on seaweed dominated rocky shores and obtain a real time count of numbers of seals ashore at haul-out sites, providing a minimum population estimate for the species and information on the distribution of haul-out sites on the Irish coast during the annual moult. This methodology was used during the 2003 harbour seal census thereby allowing direct comparability of results.

- **Photograph haul-out sites using a high resolution digital camera** and analyse images in the laboratory to obtain a count of the numbers of seals ashore. This will provide a means of testing the accuracy of the real-time thermal image counts and improve the accuracy of the resulting minimum population estimate. All images should be geo-referenced using a Garmin GPS and geo-referencing software to improve data and metadata management and for archival purposes.

- **Surveys on a national scale should ideally be repeated annually** in order to maximize the power to detect population trends. If this is not financially feasible, then a combination of annual regional and less frequent (2-5 year intervals) national coverage as described in section 2.8 is preferable (see also table 1). In this case a fixed-wing aircraft and digital stills camera could potentially be used as effort would be focused on known haul-out sites of significant size (location marked on gps during national survey). The feasibility of using a fixed-wing aircraft to survey harbour seal haul-out habitat in Ireland would need to be confirmed by conducting a trial/feasibility fixed-wing survey of the selected areas.

- **Replicate counts** will provide a more precise population estimate. Obtaining 2-4 replicate surveys of the entire coastline is not financially or logistically feasible, however replicate counts could be **obtained at 'index' sites**. These sites would ideally be conducted at 7-10 haul-out sites of a relatively significant size nationally and that can be easily surveyed from land or boat, such as sites in Bantry Bay, Kenmare River, Dungloe Bay, inner Galway Bay, Donegal Bay, Ballysadare Bay and Killala Bay. Criteria used in the selection of ground-truthing sites for the 2003 harbour seal census could be used (Cronin *et al.,* 2007a). Experienced NPWS rangers could conduct such counts.

- Large scale surveys, generally directed at establishing reliable population estimates and resolutely focusing on periods of peak abundance, lack associated data on within-year variation in counts at particular haul-out sites. Consequently data resulting from such surveys cannot explain between year variability in abundance resulting from for example redistribution, changes in habitat use and fluctuations in demographic parameters such as pup production or survival. **Counts should be carried out at the 'index' sites throughout the annual cycle,** providing important data on the influence of covariates on seal haul-out behaviour at these sites and potentially providing information on pup production and breeding season population estimates. Index sites are useful adjuncts to, not replacements of national aerial surveys. Index site counts provide the opportunity to simultaneously collect covariate information, useful for enhancing aerial survey design as well as the accuracy of counts. Such effort will also contribute to SAC

monitoring obligations under the Habitats Directive. Efforts for such index site counts should be coordinated centrally by NPWS and a standardized survey protocol developed and initiated. Counts to date have been carried out on an ad-hoc basis; counts and covariate information will be more valuable when efforts are standardized. Experienced NPWS rangers could conduct the counts.

- **Statistical modeling of the count data with environmental data to account for covariate effects** (e.g. Cronin, 2007a; Cronin *et al.,* 2007b *in review*) will provide a more accurate population estimate and more accurate trend analyses. All potentially pertinent information on covariates should be colleted during surveys with the majority of counts conducted under as standard a set of conditions as possible (with regards to time of day, state of tide and weather conditions) and timed to coincide with peak haul-out numbers. However, some effort should also be devoted to counting under contrasting conditions e.g. later in the season, as the effect of a covariate is much better estimated when observations from contrasting conditions exist (Adkison *et al.,* 2003).

- **Telemetry based studies** will provide more detailed information on the influence of covariates on haul-out behaviour over longer time periods than is possible with aerial surveys but with less intensity of effort than land-based counts. With a large enough sample size it will be possible to obtain confidence in the stability of the proportion of the population hauled out during the moult and as a result have confidence in using minimum population estimates or index of abundance to assess population trends accurately. Furthermore with such data it would be possible to devise a correction factor for haul-out counts to derive a true abundance estimate (necessary for determining pressure on fish stocks). Additionally telemetry based studies will address other important aspects of the species ecology such as home range, distribution, habitat use and foraging ecology. These aspects also need to be taken into account when assessing the conservation status of the species. Information on the offshore distribution of harbour seals is essential for identifying critical habitat for the species, necessary under the Habitats Directive and for assessing spatial overlap with fisheries. Telemetry efforts in southwest Ireland in recent years (Cronin, 2007b) have been somewhat constrained by moult associated tag loss which resulted in relatively short tagging periods. Information on the haul-out behaviour of individuals throughout the entire annual cycle would enable further exploration of potential seasonal changes in behaviour suggested by the data that resulted from the research (Cronin, 2007b; Cronin *et al*., 2007c *in review*). Moreover information on the haul-out behaviour of seals during the moult is useful for the derivation of a correction factor for simultaneously collected count data, thereby improving the accuracy of population estimates. It is recommended therefore that future telemetry research efforts focus on (i) obtaining fine-scale information on habitat use using the most advanced technology e.g. tags combining fast acquisition GPS and dive-depth recorders and (ii) obtaining information on year-round haul-out behaviour using flipper mounted tags. As the sample size of tagged seals increases, potential sex and age related variation in behaviour can be examined and more robust inferences can be made at the population level. It is suggested

that telemetry efforts in southwest Ireland be extended to other parts of the species range on the Irish coastline.

- No information exists on the **genetic structure** of harbour seals in the Republic of Ireland; the genetic population structure of the species across most of its geographical range has been established (NAMMCO 2006) with notable absence of information from the Irish 'population'. To effectively manage a population, the delineation of stock structure is essential. Furthermore such information is useful in understanding disease epidemiology. Recent effort has been made to obtain skin and blood samples for DNA analysis from seals captured for telemetry research in southwest Ireland. It is suggested that such efforts be continued in future tagging studies and from dead by-caught and stranded animals.

2.10 National Aerial Survey Details

- 10 one-day aerial surveys using (1) hired commercial helicopter or (2) an Air Corps helicopter;
- All 229 distinct moult haul-out sites discovered in 2003 to be covered in the survey programme;
- The coastline between haul-out sites will be searched for 'new' sites or sites 'missed' in 2003;
- Teams of 2 experienced surveyors (1 Scientific Researcher + 1 NPWS staff) envisaged for each aerial survey;
- NPWS staff to conduct a series of ground-counts at key haul-outs during the aerial survey day and on two to three other days to obtain replicate counts;
- Use of thermal imager as primary aerial search and detection tool;
- Haul-out identification and counts of harbour and grey seals carried out in real time, as in 2003;
- High-resolution digital photography to be conducted at all sites for count verification purposes;
- Recording based on GIS-based map systems developed for the 2003 (harbour seal) and 2005 (grey seal) population assessments;
- Image and Data Analysis to be carried out by scientific researcher via systems developed in 2003 and 2005;
- Estimates of time required for image analysis based on 2003 and 2005 data.

2.11 Regional Aerial Survey Details

- 4-6 one-day aerial surveys using (1) hired commercial fixed-wing aircraft or (2) an Air Corps fixed-wing or helicopter;
- Significant moult haul-out sites in regional areas to be surveyd;
- The coastline between haul-out sites within the regional areas will be searched for 'new' sites;
- Teams of 2 experienced surveyors (1 Scientific Researcher + 1 NPWS staff) envisaged for each aerial survey;

- NPWS staff to conduct a series of ground-counts at key haul-outs during the aerial survey day and on two to three other days to obtain replicate counts;
- High-resolution digital photography of haul-outs to be conducted at all sites;
- Recording based on GIS-based map systems developed for the 2003 (harbour seal) and 2005 (grey seal) population assessments;
- Image and Data Analysis to be carried out by scientific researcher via systems developed in 2003 and 2005;
- Estimates of time required for image analysis based on 2003 and 2005 data.

2.12 Reporting

Data analysis would include an evaluation of ground-truthing data, trends in annual moult population size and habitat use. A concise annual status report would be provided highlighting these results. The annual report will be due on **31st December** of the year following survey.

2.13 Timescale

The monitoring programme is envisaged to require 6 months full-time, covering

- preparation - 1 month (July)
- data acquisition - 1 month (August)
- image and data analysis - 3 months (September to November)
- reporting - 1 month (December)

[* *Target time for aerial surveys may span the month of August, depending on weather conditions*].

3. GREY SEAL POPULATION MONITORING

3.1 Current knowledge of the grey seal population in the Republic of Ireland

The population of grey seals (*Halichoerus grypus*) inhabiting the Irish coastline is part of a larger western European stock centred in northern Britain and stretching to western France, the eastern North Sea, the Faroe Islands, Iceland, Norway and the northwest coast of Russia (Bonner, 1972). Other genetically- and morphologically-distinct stocks inhabit the Baltic Sea, where they breed on winter sea ice, while a western Atlantic stock breeds along the northeast coasts and offshore islands of the U.S. and Canada (Bonner, 1990).

Knowledge of Ireland's grey seal population has historically been sparse and much of the species' natural history in Ireland can only be inferred from the results of long-term studies in the UK and elsewhere. Recent efforts have begun to address some of the deficit, however, building on experience and knowledge of local grey seal sites first explored by R.M. Lockley (1966) and the Forestry & Wildlife Service (1978-1985; P.J. Warner, NPWS, *unpubl*.).

Table 1. Summary of research into local or regional grey seal populations in the Republic of Ireland: 1994-2004.

YEAR(S)	REFERENCES	SEASONS	LOCATIONS	ASSESSMENT TYPE
1994	BIM, 1997	Breeding	Inishkea Group	Pup through-count
1994	Kiely, 1998	Breeding	Inishkea Group	Reconnaissance
1995-97	Kiely, 1998 Kiely & Myers, 1998	All	Inishkea Group Blasket Islands Saltee Islands	Pup through-count Haul-out abundance Photo-ID Mark-recapture
1997-99	Kiely *et al*., 2000 Lidgard *et al*., 2001	All	Saltee Islands Irish Sea Eastern Celtic Sea	Pup through-count Haul-out abundance Photo-ID Mark-recapture
1997-99	BIM, 2001	Breeding	Inishkea Group Southwest Mayo Northwest Galway Donegal coast	Pup through-count Reconnaissance
2002	Ó Cadhla & Strong, 2003	Breeding	Inishkea Group	Pup through-count
2003	Cronin *et al*., 2004 Cronin *et al*., 2007a	Summer	Republin of Ireland	National haul-out count
2003	Cronin & Ó Cadhla, 2004 Cronin *et al*., 2007b	Breeding	Blasket Islands	Aerial population assessment
2003	Cronin & Ó Cadhla, 2004 Cronin *et al*., 2007b	Breeding	Inishkea Group Donegal coast	Single aerial count Reconnaissance
2003-04	D. Strong & G. O'Donnell, NPWS, *unpubl.*	Breeding	North Galway	Single aerial count Reconnaissance
2004	Ó Cadhla *et al*., 2005	Breeding	Slyne Head islands Hen Island	Pup through-count
2004	Ó Cadhla *et al*., 2006	Breeding Moult	Southwest Mayo Northwest Galway	Single ground count Reconnaissance Aerial scoping survey

The paucity of information and persistent interactions with commercial fisheries culminated in studies at several colonies between 1994 and 2004 (Table 1) and a nationwide summer count in August 2003 (Cronin *et al*., 2007a). Thereafter, the Republic of Ireland's first comprehensive assessment of grey seal population size was carried out in 2005 (*see* Ó Cadhla *et al*., 2007). This study delivered a definitive minimum population estimate of 5,509-7,083 grey seals of all ages. It also noted that breeding numbers had increased at a number of nationally-important colonies since dedicated surveys first began in 1995.

The 2005 breeding population estimate was followed up with a secondary moult season assessment which recorded 5,343 grey seals along the coastline of the Republic of Ireland over the course of 6 successive survey days in early March 2007 (Ó Cadhla & Strong, 2007). The latter survey highlighted the potential of surveys during the moult season as a further population assessment and monitoring tool.

Knowledge of the population, its distribution and natural history garnered up to mid-2007 was then used to report to the European Commission on the conservation status of grey seals in the Republic of Ireland. This detailed report, which is currently in press, concluded that the current conservation status was favourable overall given certain assumptions and information gaps which remain.

3.2 Rationale for establishing a grey seal population monitoring program

Grey seal population data are a necessary component to fulfilling Ireland's conservation obligations under the European Union's Habitats Directive (92/43/EEC). This requires member states to: (1) maintain listed species and habitats at a 'favourable' conservation status and (2) report comprehensively on this matter to the European Commission every 6 years. As an Annex II protected species under the Directive, grey seals are afforded the designation of Special Areas of Conservation (SAC) within which the species and its habitat are given optimal protection. There are currently ten such sites in the Republic of Ireland (Ó Cadhla *et al*., 2007).

Member states are further obliged to develop monitoring programs to evaluate the ongoing status of species protected under the Directive, taking into account their known **Range**, **Habitat** and **Population Status**. In dealing with the latter component alone, the minimum grey seal population estimate of 5,509-7,083 grey seals (Ó Cadhla *et al*., 2007) which currently represents the *Favourable Reference Population* (EC, 2006) for the Republic of Ireland, is already two years out of date. No coordinated system of population monitoring or data collation exists that would better inform the authorities as to the ongoing status of the population. Thus the purpose of this document is to assess the available methodological and budgetary options, providing a recommended framework for future effective population monitoring.

3.3 International grey seal population monitoring

Accurate estimates of grey seal population size are needed to determine appropriate monitoring and management policies for the grey seal species throughout its international

range. To date, international efforts to estimate and monitor grey seal populations have varied considerably in scale and substance. They have also lacked an element of methodological co-ordination, naturally depending on factors such as the national requirements for assessment, the population size and trends, its distribution and availability for counting, its habitat use and the survey resources available. International research into grey seal population status and dynamics over the last five decades have complemented one another, however, by their predominant focus on breeding season assessments. This convergence is due to the species' annual requirement for suitable terrestrial habitat on which pups are born and remain ashore for 3-4 weeks (Bonner, 1990), thus delivering a defined cohort that can be counted annually to determine the overall population size and trajectory (Ward *et al*., 1987). An exception occurs in the Baltic Sea, where co-ordinated international grey seal counts are now carried out annually during the moult season, producing a minimum population estimate. A similar ancillary moult population assessment was carried out for the first time in Ireland in 2007 (Ó Cadhla & Strong, 2007).

Today it is known that Canada holds the largest proportion (c.45-50%) of the global grey seal population, numbering approximately 190,000-230,000 seals of all ages. This is based on an estimated 47,600 pups born during the 2000 and 2004 breeding seasons (SCOS, 2007). The second largest population is found in the UK, producing an estimated 45,100 pups in the 2006 season, over 90% of which are associated with breeding colonies in Scotland. Thereafter, estimated pup production in the Baltic Sea population was 4,000 in 2003 while pup productions in Norway, Russia, Iceland and Ireland may approximate one another in size, consisting of c.800-1600 pups in the most recent year of survey (SCOS, 2007; Ó Cadhla *et al*., 2007). The smallest known breeding population (200 pups) occurs in the Wadden Sea area of the Netherlands (SCOS, 2007).

While the eastern and western North Atlantic populations are shown to be currently increasing (SCOS, 2007), the empirical determination of international population trends has relied principally on data obtained in Canada and the UK whose breeding populations (i.e. pup production) are monitored on an annual basis. In both cases, the core method of pup production and hence population estimation is via a set of extensive aerial surveys carried out at intervals over the breeding season. Consistent yearly research in the UK using a standard aerial survey methodology (Hiby *et al*., 1988; C.Duck *et al*., SMRU, *unpubl.*) has yielded a very effective monitoring platform, augmenting data that first described exponential increases since 1962 to currently show that the annual rate of grey seal population increase has declined from approximately 6% to 1.1% over the last 10 years (SCOS, 2007). Annual results since 1984 also indicate that the rate of increase differs significantly between regional colonies in the western isles of Scotland and those off the northern and eastern coasts.

As seen across many of the smaller European grey seal populations (e.g. France, Netherlands, SW Britain, Norway), research efforts in the Republic of Ireland commenced with infrequent ground-based methods to assess minimum population size (e.g. Lockley, 1966; Summers, 1980; Summers, 1983). As knowledge was acquired these progressed to more standard survey methodologies (e.g. Kiely & Myers, 1998; Ó Cadhla & Strong, 2002) and began to involve international and inter-seasonal dimensions (e.g.

Kiely, 1998; Kiely *et al*., 2000) in order to address issues of regional population distribution and movement. Yet the infrequent research effort in Ireland fell short of providing a population total from which a coherent monitoring programme could be established (Ó Cadhla & Mackey, 2002). This is now no longer the case.

Given the consistent operational and statistical methodologies applied in Britain, its proximity to the island of Ireland, knowledge of individual grey seal movements from photo-identification (Hiby & Lovell, 1990; Kiely *et al*., 2000), tagging (A.Hall, SMRU, *unpubl*.) and telemetry studies (e.g. McConnell *et al*., 1992; Hammond *et al.,* 1993), and the success of an Irish aerial survey trial (Cronin *et al*., 2007b) it was decided that Ireland's first comprehensive assessment of breeding population size should occur in 2005, following closely the methods applied annually by the UK's Sea Mammal Research Unit (SMRU) (Ó Cadhla *et al*., 2007).

The SMRU's collaboration, advice and assistance contributed greatly to the acquisition of Irish pup production estimates: 1,574 pups for the Republic of Ireland and approximately 100 pups for Northern Ireland (SCOS, 2007). The corresponding population estimate for the island of Ireland now approximates 5,859-7,533 grey seals of all ages, based on the ratio of newborn pups to an increasing all-age population (Harwood & Prime, 1978). This has been the standard method applied previously in Ireland, given the absence of additional life history data and the lack of a time-series of pup production estimates from the key breeding colonies (Ó Cadhla *et al*., 2007). It is against these baseline figures that effective population monitoring in both the Republic of Ireland and Northern Ireland should be compared.

3.4 Scientific rigour of methodologies used

There are two possible strategies for estimating the number of grey seals in a population or sub-population: (1) systematic sampling (e.g. mark-recapture estimation) or (2) direct counting of a definable population cohort and extrapolation to population size based on the age-structure of the population and age-specific fecundity rates (Harwood & Prime, 1978). But at no time is the entire population, or even a random sample of it, available for counting. Even where a component of the population is ashore and visible, as occurs with grey seal pups during the breeding season, if the population is geographically dispersed it is clearly not practical or economical to deploy the manpower necessary to accurately count all newborn pups through the entire season. Thus even the direct counting process must introduce potential sources of error and make a number of assumptions in the interests of obtaining wider survey coverage and an acceptable proportion of the total population.

In Britain, which currently provides the best comparative framework into which Irish data can be drawn, the SMRU's annual survey and statistical modelling programme produce a population estimate accounting for approximately 85% of the overall pup production (SCOS, 2007). The additional c.15% of its population data are provided by more infrequent survey data as and when these are acquired from Wales, England and Northern Ireland.

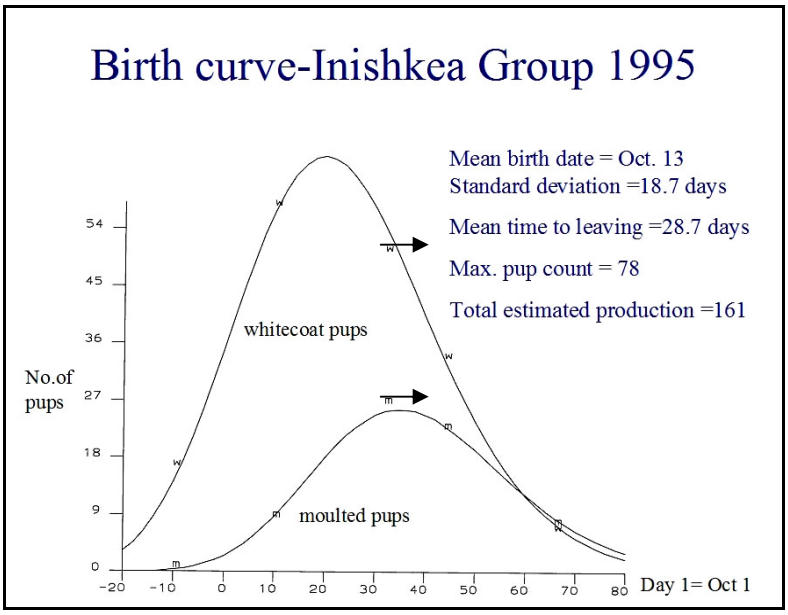
In examining the rigour of population monitoring methods, it should first be remembered that both in the UK and Canada, which provide the best examples of consistent grey seal population monitoring, pup counts used in the estimation process are conducted from aerial still images. This introduces the first potential source of error (i.e. false positives or pups missed). Ground-truthing studies on Sable Island, Nova Scotia (Bowen *et al*., 2003) determined that the proportion of pups seen on the imagery was 0.96, requiring a correction factor to be applied to aerial counts; But ground/imagery count comparisons did not differ significantly by habitat or according to the experience of the image analyst.

The adoption of a ground-truthing element in the 2005 Irish study also suggested that reliance on aerial imagery may have led to a slight under-recording of the true number of pups present (median difference = 0; mean & s.d.= -1.304 ± 4.363; n=25; Ó Cadhla *et al*., 2007). However no statistically significant difference was detected between pup numbers recorded from the ground and from the air in this case. The authors concluded that greater differences between ground counts and aerial counts at a few sites could be explained by topographic obstructions, variation in ground survey methodology and the movement of pups from designated ground-truthing areas. This underlined the need for a continued ground-survey element in any future Irish monitoring programme.

Another significant factor potentially affecting the estimate of pup production is the loss of dead pups from the breeding colony. While records of dead pups from matching Irish ground and aerial counts agreed closely with one another in 2005 (92.0% within ±1 pup; Ó Cadhla *et al*., 2007), the limitation of population-level surveys to just five or six replicates at each breeding site introduces the possibility of pups being born, dying and being removed or indistinguishable between survey flights. The potential error associated with this occurrence is complex since pup mortality and the availability of dead pups for counting can depend on a range of factors (Anderson *et al*., 1979) including pup densities on the ground and location ashore, topography, exposure, body condition, etc. The solutions are to model on-site pup mortality and losses over the season (e.g. SCOS, 2003) or to carry out dedicated ground-level censuses throughout the breeding colony (Bowen *et al*., 2003).

Once reliable pup count data are available the estimation of total pup production then depends on modelling the observed birth rate against an established statistical framework that describes how the numbers of whitecoat and moulted pups vary over the season (Fig. 1; Hiby *et al*., 1988; Myers *et al*., 1997). The production estimation model (*PEST*) designed for this process has been used for UK grey seal pup production estimation since 1984, delivering pup production estimates and associated 95% Confidence Intervals (C. Duck *et al*., SMRU, *unpubl*.).

The model allows various parameters (e.g. degree of pup misclassification, time to moulting, time to leaving the breeding site) to be fixed or freed in order to deliver the most accurate model fit to the observed counts, thereby reducing the error (i.e. coefficient of variation or CV) of each production estimate. Time-series data from the UK indicate that the CV of grey seal pup production estimates in Britain approximates 7% (SCOS, 2004). However the CV would be expected to be significantly higher for estimates from colonies that are not surveyed annually.



(*from* Kiely *et al.,* 1997)

Figure 1. Example of *PEST* model output showing sample pup datapoints (arrows) and an acceptable maximum likelihood best fit to the data points (smooth lines).

The *PEST* model assumes that the parameters defining the distribution of birth dates are variable from colony to colony and from year to year, but that those defining the time to moult and the time to leave the colony remain constant. In an Irish context, the absence of such data from breeding colonies precludes any independent assessment of the model's accuracy and an assumption must be made that grey seal pups born at Irish colonies behave the same as their counterparts in Britain (Ó Cadhla *et al*., 2007). While there was no alternative to this approach in 2005, new on-site investigations from a number of key Irish breeding colonies would help to ascertain if the assumption will remain valid, particularly since the pup production estimate delivered by the model is particularly sensitive to the time-to-leaving covariate (SCOS, 2004).

The use of photo-identification for mark-recapture estimation of population size has also proven itself a useful monitoring tool and one which could be used to independently assess pup production-based estimates. In a study of Irish and Welsh grey seal stocks conducted across the Irish Sea (Kiely *et al*., 2000) it was found that population estimates based on breeding season counts and those from photo-identification compared very favourably with one another (5,198-6,976 and 5,613 respectively), lending some support to its hypothesis that Irish and Welsh stocks could form part of a discrete sub-population. While the photo-ID method does not readily lend itself to population surveys across an expansive geographic area, being somewhat labour-intensive, the CVs attached to derived estimates can be notably lower than those produced by the *PEST* model (e.g. 0.2% - Kiely *et al*., 2000), adding value to regional monitoring programmes.

Other useful grey seal population monitoring methods include point counts of animals hauled out ashore outside the breeding season, such as that performed around Ireland in the summer 2003 (Cronin *et al*., 2004) and during the 2007 moult (Ó Cadhla & Strong, 2007). While the data generated give an indication of the seasonal distribution and

relative abundance of grey seals utilising Irish haul-out sites outside the breeding season, their value as long-term monitoring tools will depend on the accumulation of data from telemetry and other sources to determine the relationship between numbers and age-structure of grey seal sub-group(s) counted ashore and the population at large. In the context of significant numbers of grey seals recorded on six back-to-back surveys during the 2007 moult (5,343 – Ó Cadhla & Strong, 2007), determining (i) the proportion of the population ashore during sampling and (ii) the duration of the moult in wild grey seals, are key questions that must be addressed.

3.5 Ground surveys Vs Aerial surveys

The selection of survey method, whether aerial or ground-based, for monitoring Ireland's grey seal population depends on a number of factors, not least the cost-benefit trade-off and the financial resources available. Surveys in smaller populations like the Netherlands (Reijnders *et al*., 1995; Abt *et al*., 2002) and France (Vincent *et al*., 2005) are naturally on the lower-cost end of the scale, the distribution of haul-out groups being confined to a few discrete sites easily accessed by boat and on the ground. This was also the case in an Irish Sea study carried out between 1997-1999, which determined population size, distribution and relative abundance via ground-based photo-ID, pup through-counting and haul-out counts (Kiely *et al*., 2000).

However, in a national context, where more than 80% of pup production occurs on seven exposed colonies that are difficult to access, in some cases each colony consisting of several islands or complex storm beach systems (Ó Cadhla *et al*., 2007), the use of ground-survey methods fall short of providing a readily-repeatable, safe and statistically sound option. Furthermore, allowing for changes in personnel and vessels year on year, the training and health & safety requirements to implement coordinated ground survey methods on a national scale would introduce a significant yearly financial and logistical cost to the funding body. It is therefore considered that ground-survey methods should address local and interregional research questions (e.g. site fidelity, inter-site movement) while minimising disturbance at the haul-out site or breeding colony and protecting the species' habitat.

3.6 Natural fluctuations in grey seal populations

Unperturbed grey seal populations generally are described in the literature as having annual growth rates of 3-6%, though at individual breeding colonies they may exceed 10% (e.g. Stobo & Zwanenburg, 1990; Mohn & Bowen, 1996; SCOS, 2007). Although the overall national population trend may be one of exponential increase (e.g. Bowen *et al*., 2003), growth rates are generally unstable year on year (e.g. Hammill *et al*., 1998). In this manner, for example, in Britain total pup production at annually monitored colonies increased by 7.4% in 2003, following a decline of 3.2% the previous year (SCOS, 2004). In 2006, total production increased by 3.7% in contrast to a 3.0% decrease in 2005 (SCOS, 2007). Such natural fluctuations underline the inadequacy of single-year population estimates when trying to determine the species' true population status.
There are indications, however, that overall pup production in the UK has recently been stabilizing, having maintained high rates of increase of over 6% per annum through the

late 1980s and early 1990s. Between 2001 and 2005, total production for all annually monitored colonies has increased at a more modest 1.1% per annum, although newer individual breeding colonies may vary in size at rates far greater (e.g. Orkney – down 7.4% in 2004-2005, up 9.6% in 2005-06; SCOS, 2007).

Grey seal population trends in Ireland are not determinable at present, though there are now clear indications of significant increases in pup production at key colonies (Ó Cadhla *et al*., 2007). Numbers of grey seals recorded during the moult have also exceeded expectations based on background data (Ó Cadhla & Strong, 2007). A coherent population monitoring programme would address this issue, whether regionally or nationally and allow the better assessment of natural population fluctuations in an Irish context, framed against consistent population data available in Britain.

3.7 Survey replication and inter-annual frequency of surveys

Determining whether a sub-population or regional population of grey seals has a "favourable conservation status" may be an effective means of protecting its viability since it considers not just the population status in numerical terms but also its range and the availability of unperturbed habitat for the species. For Irish-breeding grey seals, only one of these features has been possible to assess to date, and then on the basis of a single nationwide breeding survey (i.e. population status in 2005). In Canada, an examination of historically infrequent and incomplete survey effort showed unequivocally that such censuses significantly underestimated total pup production values (Zwanenburg & Bowen, 1990). Annual monitoring of key breeding colonies in the UK has taken place since 1984. The research effort has delivered continuous assessments of population size and trajectory for approximately 85% of its breeding grey seals, demonstrating the variability of yearly pup production figures, which may be due to extrinsic (e.g. food availability) and intrinsic factors (e.g. density-dependence). It is advised that hereafter surveys in Ireland should replicate methods employed in 2005 (Ó Cadhla *et al*., 2007) to cover a significant majority proportion of the breeding population on a regular basis. This will allow for the improved definition of grey seal "favourable conservation status", better meeting the statutory Habitats Directive requirements.

3.8 Summary of appropriate monitoring strategies, national and regional

As shown, there are critical factors to take into account when devising the appropriate regime for monitoring a grey seal population. The ability to accurately detect changes in population size is a further issue for consideration. Yet analyses of statistical power to detect trends in grey seal populations are almost absent in the current scientific literature, though they have been conducted for harbour seals (*see 2.7 above*). A recent analysis of data for the Baltic Sea grey seal population concluded that it would take nine years to detect a decline from 1.075 to 1.027 (4.8%) in the rate of population increase (Harding *et al*., 2007). This was based on maximum annual count data and associated variances from surveys carried out over 14 years. If the mean rate of increase was 0.02, it would take 25 years to detect the same change. Although changes in seal population size may be detectable with more sparse data (e.g. Lonergan *et al*., 2007), in the case of the grey seal the significant analysis needs to be done and many unknowns remain (Table 2).

Table 2. Summary of methods appropriate for monitoring grey seal population size in Ireland, their scales and deliverables, based on information available. Indicative Cost estimates given are for the options considered most cost-effective. More details are given in detail in Sections 4.3 and 4.4 below.

Code	Target Season	Survey Mode	Scale	Assessment Type	Survey Interval	No. of Surveys (per year)	Result	CV 95% C.I.	Statistical Power (to detect trends)	Indicative Cost € with air corps (Commercial aircraft)
A-1	Breeding	Aerial	National	Pup count	10-15 days	12-18	Population estimate	Yes	unknown	66.0K (136.6K)
A-2	Moult	Aerial	National	Haul-out count	consecutive days	6, up to 18	Minimum count	No	unknown	26.5K (49.7K)
A-3	Summer	Aerial	National	Haul-out count	consecutive days	6, up to 18	Minimum count	No	unknown	26.5K (49.7K)
B-1	Breeding	Aerial	Regional	Pup count	10-15 days	6	Population estimate	Yes	unknown	26.5K (49.7K)
B-2	Moult	Aerial	Regional	Haul-out count	1 month	3	Minimum count	No	unknown	26.5K (37.9K)
B-3	Summer	Aerial	Regional	Haul-out count	1 month	3	Minimum count	No	unknown	26.5K (37.9K)
C-1	Breeding	Photo-ID	Regional	Mark-recapture	10-15 days	8	Population estimate	Yes	unknown	34.5K
C-2	Moult	Photo-ID	Regional	Mark-recapture	10-15 days	8	Population estimate	Yes	unknown	34.5K
C-3	Summer	Photo-ID	Regional	Mark-recapture	10-15 days	8	Population estimate	Yes	unknown	34.5K
D-1	Breeding	Ground count	Regional	Pup count	10-15 days	8	Population estimate	Yes	unknown	34.5K
D-2	Moult	Ground count	Regional	Haul-out count	10-15 days	8	Minimum count	No	unknown	34.5K
D-3	Summer	Ground count	Regional	Haul-out count	10-15 days	8	Minimum count	No	unknown	34.5K

Notes:

A-1 Details given below and are based on survey methods & results in Ó Cadhla *et al*., 2007.

A-2 Details given in Ó Cadhla & Strong, 2007. Provision may be needed for 3 or more nationwide replicates, however, due to the length of the season.

A-3 Details similar to those given in Ó Cadhla & Strong, 2007. Provision may be needed for 3 or more replicates, due to the length of the season.

B-1 Coverage of 1 Region per year only. Details given below and are based on survey methods & results in Ó Cadhla *et al*., 2007

B-2 Coverage of 1 Region per year only. Based on methods in Ó Cadhla & Strong, 2007. Provision given for 3 replicates due to the length of the season.

B-3 Coverage of 1 Region per year only. Based on methods in Ó Cadhla & Strong, 2007. Provision given for 3 replicates, due to the length of the season.

C Coverage of 1 Region per year only. Boat-hire included. Based on survey methods & results in Kiely, 1998 and Kiely *et al*., 2000.

D-1 Coverage of 1 Region per year only. Boat-hire included. Based on survey methods & results in Ó Cadhla & Strong, 2003 and Kiely & Myers, 1998.

D-2/3 Coverage of 1 Region per year only. Boat-hire included. Based on survey methods & results in Kiely, 1998.

3.9 Design recommendations for grey seal population monitoring in Ireland

Considering international best practice, published and unpublished documents, and discussions with the leaders of monitoring programmes of various scales in the UK (SMRU, Countryside Council for Wales, West Wales Wildlife Trust, Cornish Wildlife Trust, The National Trust, Environment & Heritage Service [EHS] Northern Ireland), US (NOAA), Canada (DFO), Sweden (University of Stockholm) and France (Laboratoire des Mammifères Marins), the following are specific design recommendations (a) for monitoring the Irish grey seal population and (b) for delivering coherent scientific data on population trends that can adequately meet current Irish obligations under the Habitats Directive:

A. **Monitor on an All-Ireland basis:** [**Defining the Irish population as that breeding on the island of Ireland*] Proper co-ordination of work schedules between NPWS and the Environment & Heritage Service, Northern Ireland would facilitate the assessment of breeding population size on the island of Ireland as a whole and take better account of seasonal or inter-annual movements of animals between local and regional colonies.

B. **Monitor annually:** It is clearly better and scientifically more robust to monitor a selection of key representative sites on an annual basis, making reliable inferences with respect to overall population trends and natural fluctuation, than it is to survey the entire island once every 5-6 years. The recommended methods detailed below allow for such an arrangement via the most cost- and operationally-effective means. If this can not be achieved annually, then biennial monitoring is recommended as an alternative if less robust option.

C. **Monitor at intervals through the season:** While breeding season surveys are undoubtedly the method of best practice, the power to reliably estimate pup production, and hence population size, is dependent on the ability of pup count data to fit the expected pattern of births over the season. For this purpose a single or two sporadic counts during the season will not suffice to achieve a good model fit. A minimum of four replicate surveys are required and a target of 4-6 replicates per breeding colony is recommended at c. two-week intervals, allowing for survey anomalies and inter-annual variation in the timing of pupping at breeding locations.

D. **Aerial survey – the principal data collection method:** Conducting pup surveys via aerial photography is the established international best practice for populations of several thousand grey seals or more. It has now been proven in an Irish context using a range of aircraft from single-engine *Cessna* aircraft to modern advanced helicopters. Atlantic weather conditions in Ireland's autumn are more conducive to and safer for flying during breaks in poor weather than they are to boat-based work. Spatial coverage is far greater in the same time-frame and can be achieved or modified more opportunistically. In addition, scientists and pilots now exist in Ireland that are familiar with the entire coastline, its seal habitats and the appropriate survey approaches, something no boat survey team can yet be sure of when going to sea, which carries with it an additional risk.

E. **Digital photography and data analysis:** High resolution digital photography and aerial survey methods used in recent Irish studies have proven very effective. Image analysis and pup counting in the laboratory allow maximisation of data collection in the air, reduce observer error in the field and optimise use of the aircraft. Where possible, images should be geo-referenced in real-time using an on-board GPS and geo-referencing software to improve data and metadata management.

F. **Ground surveys and data-truthing:** There are commonly constraints on the number, experience-levels and availability of personnel to carry out opportunistic boat-based grey seal surveys during the breeding season. However, the collection of data on the ground is critical to the assessment of breeding habitat, site use or on-site pup mortality, for example. It also provides the opportunity for concurrent aerial-count and ground-count data to be examined statistically for sources of analytical error or potential bias. Thus it is recommended that where possible 2 ground-surveys are conducted each year at a selection of readily accessible ground-truthing sites (*see below; also* Ó Cadhla *et al*., 2007). Ground surveys should be co-ordinated to coincide with the peak breeding season and within 1-2 days of a parallel aerial survey, closely following methods established in 2005.

G. **Pup production and population modelling:** Methods by which pup production and population size are estimated should closely follow those already established in the UK. While new statistical models are currently in development and testing at SMRU, its *PEST* pup production model is available for collaborative use and has proven itself remarkably adept at simulating the birth-curve function even at smaller Irish breeding colonies. Determining total population size from pup production data, however, relies on a number of assumptions as to the trajectory of the Irish grey seal population, its reproductive and survivorship characteristics. The necessary data are not currently available from grey seals in the Irish population and must currently be inferred from UK data held by SMRU.

H. **Personnel for population monitoring:** Members of NPWS are now trained in aerial- and ground-based grey seal survey methods and could perform most of the required tasks for a grey seal population monitoring programme. The roles of chief scientist, co-ordinator and aerial photographer, however, are critical to the success of the programme and should be performed by a dedicated, highly experienced marine mammal scientist. Image analysis and pup-counting could be performed by either a postgraduate student/research assistant, or NPWS staff with guidance from the chief scientist.

I. **Additional monitoring approaches:** In undertaking a coordinated population monitoring programme it is recommended that five further considerations are made:

(i) A full nationwide assessment every 6 years is factored into the schedule;
(ii) Population monitoring during the moult season is explored further;
(iii) Cave-breeding by grey seals is investigated on a nationwide basis;
(iv) Ground-level research at key sites is encouraged (e.g. PhotoID, mortality);

(v) Habitat use is investigated, whether marine or terrestrial, centred on key Irish breeding and non-breeding haul-out sites.

All of the above would address population-level issues not immediately answerable by the monitoring programme below, delivering key ancillary assessment data.

3.10 Details of the recommended monitoring programme

The 2005 grey seal population assessment established a firm methodological and informational baseline for the Republic of Ireland and furthered collaboration between NPWS and other bodies (e.g. CMRC, SMRU, Irish Air Corps). The survey programme determined that 84% of grey seal pups were born among seven key breeding colonies along the east, southeast and Atlantic west and northwest coasts. Many secondary breeding locations were also recorded including many newly-discovered sites.

It is recommended that the population monitoring programme for grey seals annually investigates population status at the seven principal Irish breeding colonies, using methods employed in 2005 with improvements via geo-positioning of aerial imagery. Secondary sites should be incorporated in a wider-scope survey every 5-6 years, thereby assessing population development at sites with lower pup production. Annual survey effort should be co-ordinated as much as possible with surveys carried out by EHS each year.

Targets:

- 15 aerial surveys: 3 survey areas (i.e. NW, W, E) x 5 replicates through the season:

  10 surveys (W & E) carried out by fixed-wing plane (e.g. Aer Árann Islands or Air Corps)
  + 5 surveys (NW) using an Air Corps helicopter

- Principal Irish breeding colonies (total current production > 50 pups) to be covered:

  Northwest - *Glen Head to Maghera*
  West - *Blasket Islands, Slyne Head Is., Inishshark, Inishgort, Inishkea Group*
  East - *Lambay Island, Saltee Islands*

- Minimum of 2 skilled surveyors (Chief scientist + 1) for each aerial survey;
- NPWS staff to conduct 1-2 counts at ground-truthing sites during peak season;
- High-resolution digital photography to be conducted at all sites;
- Recording based on GIS-based map system developed for the 2005 assessment;
- Image and Data Analysis to be carried out via appropriate datalogging system;
- Pup production modelling carried out at the SMRU, University of St. Andrews;

** Estimates of time required for image analysis based on 2005 and 2007 data.*
** Estimates of time required for image analysis based on employment of a research assistant.*

3.11 Timescale

The monitoring programme is envisaged to require 8 months full-time, covering

(a) preparation - 1 month (August)
(b) data acquisition - 2 months (mid-September to mid-November)
(c) image and data analysis - 4 months (December to March)
(d) reporting - 1 month (April)

[* *Target time for aerial surveys would span the months of September to November inclusive*].

3.12 Reporting

Data analysis is recommended to include an evaluation of ground-truthing data, trends in annual population size, pup mortality and site use. A concise annual report is recommended to highlight results and population trends. This could be due as early as **30th April** of the year after survey, depending on staffing, time commitments and the analysis strategy chosen.

4. ESTIMATED COSTS OF POPULATION MONITORING

4.1 Harbour seal population monitoring – Notes on estimated costs

a) All itemised costs below were estimated **in October 2007**.

b) Research costs are estimated via expenditure and time required under the 2003 project, revised to the present.

c) Costs of equipment hire are based on the UK-based Barr & Shroud thermal imager used in the 2003 national harbour seal survey.

d) An alternative would be for NPWS to purchase a similar high-resolution thermal imager. Estimated capital costs at present are approx. € 85,000. The thermal imager could potentially be used for surveying other species e.g. deer. Further evaluation and device testing are needed to explore this option.

e) No other equipment costs will be incurred. Research Group/NPWS will supply camera and optics equipment as necessary.

f) For effective comprehensive national coverage a helicopter is recommended for aerial surveying known and potential haul-out sites. Hire of a commercial helicopter would facilitate a back-to-back survey approach by co-ordination with the company's mobile fuel bowser. This method was used effectively in 2003 to reduce the overall survey time.

g) The use of an Air Corps helicopter (*see Option 2 below*) may require operations to be based in Baldonnel and refuelling to be carried out at recognised airfields. This method would also be appropriate, although it could extend the survey period by 2-3 days or more due to aircraft availability and transit times to/from Baldonnel.

h) Aerial survey costs of regional sites (as alternative survey options) are calculated on the basis of coverage by high-wing twin-engine plane or twin-engine helicopter. A Britten-Norman *Islander*, as hired from Aer Árann Islands in 2005 and 2007, is the ideal plane for this task and a set of windows was specifically modified for aerial photography. There are currently no other twin-engine plane options, except via international hire at a greater cost.

i) Costs of regional surveys are estimated on approximations of the amount of time that would be required to conduct the surveys using a fixed-wing aircraft. A feasability study would confirm the effectiveness and the length of time needed to survey the selected areas and therefore effectively establish the projected costs involved.

j) Air Corps fixed-wing planes that could be made available to conduct regional surveys are from the *Cessna 172* squadron. While these single-engine planes are high-wing and have been used for grey seal aerial surveys they are less safe and

less stable than the twin-engine aircraft. Passengers must wear drysuits when flying over coastal waters. The current planes also require window modifications to allow for more effective aerial photography, a feature which has been suggested by NPWS. The Air Corps may be buying 1-2 larger fixed-wing aircraft suitable for aerial survey work within 5 years.

k) Costs of Travel & Subsistence, Air-time and Airport Charges incurred during aerial survey operations, in particular, are approximations calculated on information currently available and experience in 2003 and 2005.

l) Individual aerial surveys are currently estimated to be of 5.5 hrs total duration. It must be remembered that this element will be flexible in order to avail of weather windows and work around changes in weather conditions.

m) All efforts will be made to reduce expenditure wherever possible (e.g. on aircraft flying-time).

4.2. Harbour seal population monitoring – Budget details

4.2.1 Aerial Survey Budget – National Survey Code A-1& A-2	**Total €**
PART 1. SURVEY COSTS	
HELICOPTER COSTS	
Hire for aerial survey (10 days requiring 5.5 hours hire @ € 1,250 per hour)	68,750.00
Fuel Bowser costs (Mobilisation for 10 days @ € 400 per day)	4,000.00
T & S for Pilot and Fuel Bowser driver (2 persons x 10 days @ € 125 per day)	2,500.00
Subtotal	75,250.00
** Option 2: Surveys with an Air Corps helicopter, by arrangement*	*0*
EQUIPMENT HIRE	
Camera, mounting & pan head (2 weeks @ € 4,000 per week)	8,000.00
Pure air compressor (2 weeks @ € 2,000 per week)	4,000.00
AIRPORT CHARGES	
Up to a maximum of 2 landings per day @ € 120 per landing (dependent on use of Fuel Bowser)	2,400.00
**Option 2: Landing and Parking Charges with Air Corps*	*0*
1.1 SUB- TOTAL SURVEY COSTS USING HIRED HELICOPTER	**89,650.00**
1.2. SUB- TOTAL SURVEY COSTS USING AIR CORPS HELICOPTER	***12,000.00***
PART 2. RESEARCH COSTS	
STAFF COSTS [including employer's PRSI (10.75%) and pension contribution (13.5%)] Postdoctoral Researcher for 6 months, full-time (Senior Postdoctoral Level 2, point 1 on CHIU salary scale - @ € 48, 210 gross salary p.a.)	29,950.50
TRAVEL & SUBSISTENCE	
12 survey days @ € 125 per day (August)	1,500.00
5 months @ € 250 per month (July, September-December)	1,250.00
CONSUMABLES	
Office costs, stationery, telephone (6 months @ €300 per month)	1,800.00
OVERHEADS @ 20%	*6,782.70*
2.1 SUB- TOTAL RESEARCH COSTS *(Exclusive of VAT)*	**41,400.60**
TOTAL COSTS (1.1+ 2.1)	**131,050.60**
***TOTAL COSTS WITH USE OF AIR CORPS HELICOPTER* (1.2 + 2.1)** *(Exclusive of VAT on staff-related costs)*	***52,400.60***

4.2.2 Aerial Survey Budget – Regional Surveys Code B-1	**Total €**
PART 1. SURVEY COSTS	
AERIAL COSTS Hire of commercial fixed-wing aircraft for aerial survey (5 days requiring 5.5 hours hire @ € 650 per hour)	17,875.00
** Option 2: Surveys with an Air Corps helicopter, by arrangement*	*0*
AIRPORT CHARGES Up to a maximum of 2 landings per day @ € 120 per landing	1,200.00
**Option 2: Landing and Parking Charges with Air Corps*	*0*
1.1 SUB- TOTAL SURVEY COSTS USING COMMERCIAL FIXED WING	**19,075.00**
1.2. SUB- TOTAL SURVEY COSTS USING AIR CORPS HELICOPTER	***0***
PART 2. RESEARCH COSTS	
STAFF COSTS [including employer's PRSI (10.75%) and pension contribution (13.5%)] Postdoctoral Researcher for 6 months, full-time (Senior Postdoctoral Level 2, point 1 on CHIU salary scale - @ € 48, 210 gross salary p.a.)	29,950.50
TRAVEL & SUBSISTENCE 5 survey days @ € 125 per day (August) 5 months @ € 250 per month (July, September-December)	625.00 1,250.00
CONSUMABLES Office costs, stationery, telephone (6 months @ €300 per month)	1,800.00
OVERHEADS @ 20%	
2.1 SUB- TOTAL RESEARCH COSTS *(Exclusive of VAT)*	**40,350.60**
TOTAL COSTS (1.1+ 2.1)	**59,425.60**
***TOTAL COSTS WITH USE OF AIR CORPS HELICOPTER* (1.2 + 2.1)** *(Exclusive of VAT on staff-related costs)*	***40,350.60***

4.3 Grey seal population monitoring – Notes on estimated costs

a) All itemised costs below were estimated **on 1st December 2007**.

b) Some costs (e.g. travel) are estimated via expenditure during 2005 & 2007 surveys.

c) **Equipment costs** of c. €10,000 (i.e. camera gear, GPS, computers) and **Boat purchase costs** are not included in the budget details below. The assumption is that the necessary resources would be supplied by NPWS and/or the Contractor(s) as appropriate.

d) **Aerial survey costs** are calculated on the basis of coverage by high-wing twin-engine plane or twin-engine helicopter. A Britten-Norman *Islander*, as hired from Aer Árann Islands in 2005 and 2007, is the ideal plane for this task and a set of windows was specifically modified for aerial photography. There are currently no other twin-engine plane options, except via international hire at a greater cost.

e) **Air Corps fixed-wing planes** that could be made available are from the *Cessna 172* squadron. While these single-engine planes are high-wing and have been used for grey seal aerial surveys they are less safe and less stable than the twin-engine aircraft. Passengers must wear drysuits when flying over coastal waters. The current planes also require window modifications to allow for more effective aerial photography, a feature which has been suggested by NPWS. The Air Corps may be buying 1-2 larger fixed-wing aircraft suitable for aerial survey work within 5 years.

f) One survey region (NW) should be covered using an **Air Corps helicopter** due to very difficult flying conditions in County Donegal. This service was made available to NPWS in 2005 and 2007 for grey seal aerial surveying and it worked very well.

g) Individual aerial surveys are estimated to be of **5.0-5.5 hours** total duration. It must be remembered that this element will be flexible in order to avail of weather windows and to work around changes in weather conditions on the survey day.

h) **Airport Charges** vary depending on the chosen pick-up/landing/fuelling points. No charges are incurred by Aer Árann Islands at Inverin. The Air Corps covers its own.

i) **Staff-related cost estimates** take account of the current need for assistance from outside Contractor(s) (e.g. Chief Scientist, Research Assistant), while factoring in NPWS staff wherever possible for aerial- & boat-based survey work.

j) Costs of Travel & Subsistence, air-time and airport charges incurred during aerial survey operations are also approximations calculated on information currently available and experience in 2005 and 2007.

k) Costs of **alternative survey options** (e.g. regional surveys) are estimated using figures given in the detailed cost breakdown below. These are approximations and do not include equipment or capital costs which may be incurred, depending on the technique and resources chosen.

l) **Boat costs** for Photo-ID surveys or Ground counts (Option Codes C, D) are assumed not to be covered by NPWS, thus boat-hire costs are included in estimates.

4.4 Grey seal population monitoring – Budget details

4.4.1 Aerial Survey Budget – National Survey Code A-1

AERIAL SURVEY OPTIONS & COSTS	**Total €**
FIXED-WING AIRCRAFT HIRE	
10 surveys requiring 5.5 hours with an Air Corps fixed-wing plane	0
** Option 2: 10 surveys of 5.5 hours commercial hire @ € 650 per hr inc.VAT*	*35,750.00*
HELICOPTER HIRE	
5 surveys requiring 5 hours with an Air Corps helicopter, by arrangement	0
** Option 2: Commercial hire (5 days of 5 hours hire @ € 1,250 per hr)*	*31,250.00*
AIRPORT CHARGES	
Landing and Parking Charges to Air Corps	0
** Option 2: Average charge of € 120 x 10 commercial flights x 2 landings (includes fuel stops; no charge for use of Inverin airport by Aer Árann)*	*2,400.00*
** Option 2: Average charges for hired helicopter (5 flights x 2 landings)*	*1,200.00*
TOTAL AIRCRAFT COSTS WITH FULL AIR CORPS ASSISTANCE	**0**
** OPTION: TOTAL COSTS WITH NO ASSISTANCE BY AIR CORPS*	*70,600.00*

4.4.2 Aerial Survey Budget – Codes A-2, A-3, B-1

AERIAL SURVEY OPTIONS & COSTS - 6 surveys only	**Total €**
TOTAL AIRCRAFT COSTS WITH FULL AIR CORPS ASSISTANCE	**0**
** OPTION: TOTAL COSTS WITH NO ASSISTANCE BY AIR CORPS*	*22,890.00*

4.4.3 Aerial Survey Budget – Codes B-2, B-3

AERIAL SURVEY OPTIONS & COSTS - 3 surveys only	**Total €**
TOTAL AIRCRAFT COSTS WITH FULL AIR CORPS ASSISTANCE	**0**
** OPTION: TOTAL COSTS WITH NO ASSISTANCE BY AIR CORPS*	*11,445.00*

4.4.4 Staff-related Budget -- National Survey Code A-1

STAFF-RELATED COSTS	**Total €**
PERSONNEL [incl. employer's PRSI (10.75%) + pension contribution (13.5%)]	
Chief Scientist for 8 months, full-time (*Senior Postdoc Level 2, point 1 on CHIU scale - @ €48,210 gross salary p.a.*)	39,933.95
Research Assistant for image analysis - 3 months, full-time (*BSc. Hons. Level 5 on CHIU scale - @ €29,980 gross salary p.a.*)	9,312.54
SUBTOTAL-1	49,246.49
TRAVEL & SUBSISTENCE	
Ireland	
2 months @ € 600 per month (mid Sept-mid Nov)	1,200.00
6 months @ € 250 per month (Aug, Dec-Apr)	1,500.00
UK	
Air, Bus & Train travel to/from St. Andrews, Scotland	300.00
Accommodation and subsistence in St. Andrews (3 days @ €125 per day)	375.00
CONSUMABLES	
Office costs, stationery, telephone (8 months @ €300 per month)	2,400.00
SUBTOTAL-2	***55,021.49***
OVERHEADS *(On Subtotal-2 costs @ 20%)*	*11,004.30*
TOTAL STAFF-RELATED COSTS (*Exclusive of VAT*)	**66,025.79**

4.4.5 Staff-related Budget – Codes A-2, A-3 (national) and B (one region only)

STAFF-RELATED COSTS (4 months' fulltime, T&S, Consumables, OH)	**Total €**
TOTAL STAFF-RELATED COSTS (*Exclusive of VAT*)	**26,480.38**

4.4.6 Ground-Survey Budget – One region only: Codes C and D

GROUND-SURVEY COSTS	**Total €**
STAFF-RELATED COSTS (4 months' fulltime, T&S, Consumables, OH) [*Exclusive of VAT*]	26,480.38
COST OF BOAT-HIRE (8 surveys of 2-3 locations per region @ €500 per day)	8,000.00
TOTAL GROUND-SURVEY COSTS (*Exclusive of VAT on staff-related costs*)	**34,480.38**

4.4.7 Total Budget – Options for National Survey Code A-1

ANNUAL BUDGET OPTIONS (*Exclusive of VAT on staff-related costs*)	**Total €**
OPTION 1: Air Corps aircraft only + Staff-related costs	**66,025.79**
OPTION 2: Commercial plane hire + Air Corps helicopter + Staff-related costs	**105,375.79**
OPTION 3: Commercial plane hire + helicopter hire + Staff-related costs	**136,625.79**

4.4.8 Total Budget – Options for National Survey Codes A-2, A-3 Options for One Region only Codes B, C and D

ANNUAL BUDGET OPTIONS (*Exclusive of VAT on staff-related costs*)	**Total €**
OPTION 1: A-2, A-3, B-1: Air Corps aircraft only + Staff-related costs	**26,480.38**
OPTION 2: A-2, A-3, B-1: Commercial plane / helicopter hire + Staff-related costs	**49,370.38**
OPTION 3: B-2, B-3: Air Corps aircraft only + Staff-related costs	**26,480.38**
OPTION 4: B-2, B-3: Commercial plane / helicopter hire + Staff-related costs	**37,925.38**
OPTION 5: C, D: Ground-Survey costs	**34,480.38**

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