Monitoring harbour porpoise abundance and distribution in Dutch waters

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Summary

European legislation (Habitats Directive and Marine Strategy Framework Directive) requires monitoring of harbour porpoise (*Phocoena phocoena*) abundance and distribution, as well as changes thereof, in Dutch North Sea waters. The primary objective of the monitoring in The Netherlands is to report on the status of harbour porpoise in Dutch waters every six years, and determine a trend over 12 years.

This document provides an overview of present monitoring efforts for harbour porpoise abundance and distribution in the Dutch North Sea as well as in other European countries. It describes the current methods used and –based on scientific value and feasibility- it gives recommendations on the best monitoring method available to fulfil the obligations. These recommendations reflect discussions of an expert panel of national and international scientists and representatives of Dutch ministries that were involved via email as well as during workshops.

The advised method to obtain robust unbiased abundance estimates is the use of line transect surveys applying distance sampling technology. For Dutch North Sea waters aerial surveys have been shown to be the most effective as they allow for using the short time periods of good survey conditions. A representative coverage of the study area through pre-determined track lines, provides robust absolute densities and robust absolute abundance estimates. New methods are developing, such as the use of high-definition (hi-def) cameras in airplanes, which could potentially allow simultaneous surveys of different species groups (birds and marine mammals). Currently however, these hi-def-methods are more expensive than visual surveys. No studies are available yet to show the effectiveness of hi-def-methods to study porpoises, but it is important to investigate this further.

While the monitoring obligations require local monitoring, it is recognized that population wide surveys are required as well. Porpoises are wide ranging migratory animals and therefore it is recommended that The Netherlands continue their commitment to the SCANS-type decadal surveys of the North Sea and adjacent waters.

Measuring changes in the abundance or the distribution of populations is challenging. It is important to consider the statistical power of any method used to make sure the survey design can answer the questions asked. The probability that aerial surveys would detect trends over a time period of 12 years was analysed.

Based on the fore mentioned points, the following recommendations are made:

1. Continue to clearly and precisely define the monitoring objectives, to be able to adapt the monitoring program if necessary.
2. Cooperate with other international monitoring programs and schemes and work in international fora (such as ICES, OSPAR, ASCOBANS) to streamline future programs (see 2.4.4; 2.6.3).
3. Conduct visual surveys on the scale of the North Sea or, or at least, of the Dutch Continental Shelf (see 2.3).
4. Include North Sea wide (SCANS-type) surveys (see 2.3; 2.4.3).
5. Conduct DCS wide surveys in the same season annually (see 2.4.2; 2.6.1).
6. Conduct visual surveys by airplane instead of by ship (see 2.5.5).
7. To obtain robust abundance estimates that are comparable to abundance estimates in other North Sea countries, conduct visual surveys applying line transect distance sampling technology instead of strip transect methods (see 2.4.4; 2.5.4).
8. To obtain 'absolute' abundance estimates, correction factors for availability and detection biases (g(0) value) are necessary. Use state of the art methodology to obtain these correction factors and continue investigating more efficient methods and options to obtain a g(0) value (see 2.5.4).
9. Determine the best timing of the survey in relation to the objectives on North Sea wide and DCS scale (see 2.6.2).
10. Adjust the methodology of the bird monitoring surveys in order to increase the efficiency of these surveys by obtaining data on harbour porpoises that are less biased and could provide relative trends in other seasons than the proposed season(s) for harbour porpoise monitoring (see 2.4.1; 2.5.4; 2.5.6; Appendix II).
11. Investigate alternative methods to the one currently used, including scenarios of using high definition cameras allowing combined bird and marine mammal surveys (see 2.5.7).

Furthermore a monitoring program should:
- Use the most cost-effective survey frequency that would still provide the best detectable trend.
- Conduct annual surveys during the same season every year to get the best chance of detecting trends.
- Conduct decadal SCANS surveys to provide abundance estimates for the whole North Sea.

This advice is elaborated in nine different scenarios (see 4.2) that were evaluated against the monitoring requirements (see 4.3).
Scenario III allows reaching the monitoring aims with the lowest survey effort. This scenario provides a trend detection of 6% or more annual change, corresponding to a change of 50% after 12 years. As the highest densities in The Netherlands are seen in spring, surveys in this period have the highest power to detect trends. If doing only spring surveys however, coordination with neighbouring countries is not possible, as surveys in these countries are conducted in summer.

To improve the information output of the surveys we advise to
- conduct additional surveys in more than one season

Scenario II (annual), Scenario VII (tri-annual) and Scenario VIII (tri-annual) meet this advice since they contain DCS wide surveys in two seasons: spring (annual) and summer ((tri-)annual). The summer surveys should enable a comparison with neighbouring countries and provide inter SCANS-type survey trend information. These scenarios provide a framework to bridge the gap between annual DCS wide spring surveys and internationally co-ordinated summer surveys of the entire North Sea.

Furthermore, we recommend
- to explore if future adjusted MWTL-surveys (primarily aimed at seabirds) have an added value for monitoring of harbour porpoise and to use bird surveys to additionally obtain annual seasonal information on occurrence of harbour porpoise.

Scenario VIII meets this advice in combining surveys in spring and summer with the MWTL-data.

In conclusion, one of these four scenarios (II, III, VII and VIII) is best to use as scheme for monitoring harbour porpoise abundance and distribution in Dutch waters.

1. Introduction

The conservation of harbour porpoise (*Phocoena phocoena*) and monitoring of the species is an obligation under European legislation, such as the Habitats Directive and the Marine Strategy Framework Directive. The monitoring of the distribution (1), trends in abundance (2) and (3) by-catch rate of harbour porpoise and other cetaceans is needed in order to meet management objectives under the Habitats Directive (HD, Habitatrichtlijn) and the Marine Strategy Framework Directive (MSFD, Kaderrichtlijn Marien):

1. "Distributional range of cetacean species regularly present and distributional pattern at the relevant temporal scale of cetacean species regularly present."
2. "Abundance, at the relevant temporal scale, of cetacean species regularly present".
3. "By-catch rate in relation to population size"

Currently the indicators and monitoring of these indicators are discussed within the framework of the MSFD and HD at different levels. In this document we propose a scheme for monitoring the distribution and abundance of porpoises in the Dutch Continental Shelf, while considering the statistical strength of different scenarios and considering different costs.

In this document we are determining the best:

- Method to estimate abundance of harbour porpoises in Dutch waters
- Method to estimate changes of abundance of harbour porpoises in Dutch waters (trends)
- Spatial coverage of the study area to investigate distribution and abundance
- Temporal coverage of the study area to investigate changes in distribution and abundance

In order to obtain

- The largest statistical strength/power to detect changes in abundance
- The largest statistical strength/power to detect changes in distribution
- The most cost efficient monitoring

This monitoring advice is based on a discussion paper that has been discussed by a number of stakeholders during a workshop on 21 February 2013, that focussed on methodology, and during meetings on 2 April 2013 and 9 July 2013, that focussed on monitoring objectives and scenarios. Aside from these sessions, several experts on aerial surveys of seabirds and of marine mammals have reviewed this document. Floor Arts (Delta Project Management, MWTL), Geneviève Desportes (GDnatur Denmark), Folchert van Dijken (Ministry of Economic Affairs), Ruben Fijn (Bureau Waardenburg), Jan Haelters (Royal Belgian Institute of Natural Sciences), Robin Hamerlinck (Ministry of Infrastructure and the Environment), Vincent van der Meij (Ministry of Economic Affairs), Marc van Roomen (SOVON Dutch Centre for Field Ornithology), Mervyn Roos (Ministry of Infrastructure and the Environment), Hans Ruiter (Ministry of Infrastructure and the Environment), Leo Soldaat (CBS Statistics Netherlands), Suzanne Stuijfzand (Ministry of Infrastructure and the Environment) and Jeroen Vis (Ministry of Economic Affairs) are kindly acknowledged for their contributions to this document.

2. Background

2.1 Legal framework

The conservation of harbour porpoise is an obligation under several international conventions and agreements. This species is protected under the UNEP Convention on the Conservation of Migratory Species of Wild Animals (commonly known as CMS or Bonn Convention) concluded in 1979, where the species is listed in Appendix II "Migratory species requiring international cooperation". In 1992 the Convention for the protection of the marine environment in the North-East Atlantic (OSPAR) was adopted, which defines ecological quality objectives (EcoQO) for human impacts, among those the by-catch of harbour porpoises, in order to achieve sustainable use of ecosystem goods. Under the CMS the regional agreement ASCOBANS (Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas) came into force in 1994. All cetaceans in European waters are also protected under the European Union Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (commonly known as Habitats Directive), where they are listed in Annex IV covering species in need of strict protection. In addition harbour porpoise is also listed in Annex II of the Habitats Directive: "animal and plant species of community interest whose conservation requires the designation of Special Areas of Conservation (SACs)". SACs will form part of a coherent European network of protected areas named the Natura 2000 network in which a so-called Favourable Conservation Status has to be achieved. Last but not least, the European Marine Strategy Framework Directive (MSFD) adopted in 2008 is also applicable. The MSFD is a legislative framework for an ecosystem based approach to management of human activities which supports sustainable use of goods and services. It strives to achieve Good Environmental Status (GES) described by a set of eleven quality descriptors and underlying indicators that should be operative in July 2014. For harbour porpoises in Dutch waters biodiversity (Descriptor 1), and underwater noise (Descriptor 11) will be most relevant. Underwater noise will not be addressed in this report. The MSFD will be implemented by the Dutch Marine Strategy (MS).
As cetaceans are taken up under the Habitats Directive, which is the leading legislation, their abundance and distribution comprise a key aspect for securing and achieving GES according to the MSFD. Target of the Marine Strategy is the same as the national target under the Habitats Directive which is described as:
"*Maintain populations in a healthy state, with no decrease in population size with regard to the baseline (beyond natural variability) and restore populations, where deteriorated due to anthropogenic influences, to a healthy state*".
Indicators to assess whether this target is achieved for the harbour porpoise still have to be decided upon in the framework of Dutch Harbour porpoise conservation plan (Camphuysen & Siemensma 2011). An appropriate tool to assess this is monitoring. The objective of this monitoring should be to detect trends, in particular negative ones, in abundance as well as in distributional range and pattern. The Netherlands is obliged to report every six years on the trend during the previous 12 year-period.
Additionally, EU member states will have to consider and to define safe by-catch limits (possibly on a national level). Assessing whether by-catch rates (e.g. OSPAR EcoQO) can be considered safe in terms of meeting the specified conservation objective, requires knowing the size of the harbour porpoise population (robust unbiased or 'absolute' abundance estimates).

2.2 Ecological framework: harbour porpoise occurrence in the North Sea

Nowadays harbour porpoises in The Netherlands show a consistent seasonal pattern in occurrence. As shown by land-based observations of seabird migration and marine mammals along the Dutch coast (see 0) harbour porpoises are present in coastal waters throughout the year. Peak numbers are observed in December-March, after which the numbers drop. Observations in June are relatively scarce, but the numbers slightly increase from July onwards (Camphuysen, 2004 & 2011).
Observations in the North Sea suggest a northward summer migration from the Channel, Belgium and The Netherlands to Danish and British waters and a southward migration in autumn. In the Belgian part of the North Sea, harbour porpoises are most abundant from February to April, whereas lower numbers tend to occur offshore in the rest of the year (Haelters et al., 2011a). In the German North Sea bordering Dutch waters the highest densities are found in spring. Further north along the German coast

numbers peak in May and June (Gilles et al., 2009). Still further north, along the Danish west coast, porpoise densities are highest from April to August, with a peak in August (data for Jun-Jul are lacking however; Teilmann et al., 2008). In the western North Sea porpoise numbers peak in April off south-eastern England, and further north they peak in August (Evans et al., 2003).

2.3 Monitoring target: North Sea population vs. local population

As sketched in §2.2 the harbour porpoise is a wide ranging and highly mobile species with populations that transcend national boundaries. The ultimate aim is to monitor and eventually protect the overall population. However, presently, most monitoring efforts are carried out within a national context, although national waters clearly do not represent biologically meaningful management units.

The population structure of the harbour porpoise in the North Sea remains unclear. Using mainly Danish telemetry data (Sveegaard et al., 2011) as well as other information, and adopting a precautionary approach, the ASCOBANS-HELCOM Small Cetacean Population Structure Workshop (Evans et al., 2009) proposed that the North Sea be divided into two Management Units (MU) along a line running NNW–SSE from northern Scotland to Germany/Denmark. The Dutch porpoises would belong to the management unit south of this line: the south-western North Sea and the Eastern Channel MU. In 2010, the ICES Working Group on Marine Mammal Ecology endorsed these proposed MUs (ICES, 2010), but more recently the same Working Group reconsidered its position and rejected splitting the North Sea into two MUs (ICES, 2012), proposing instead a single MU for the entire North Sea covering the ICES areas IV, VIId and the northern part of IIIa.

Under both these scenarios, however, national waters are much smaller entities than the MU(s).

2.4 Existing ‘monitoring’ schemes

Systematically collected data on abundance and distribution of harbour porpoise in Dutch waters are scarce. Most data are a by-product of studies primarily aimed at seabirds, like the land-based sea watching scheme as well as ESAS ship-based and MWTL aerial surveys on the Dutch Continental Shelf (DCS). The results of these ship-based and aerial surveys were published in two atlases (Baptist & Wolf, 1993; Camphuysen & Leopold, 1994). After publication of these atlases the aerial monitoring program continued to the present day. These MWTL-surveys gave a reasonable indication of offshore distribution in space and time, but they did not provide abundance estimates for porpoises (see 0). In 2008 IMARES started dedicated aerial surveys to estimate the abundance for harbour porpoises on the DCS (see 0). These surveys have been conducted on a year to year project base. In 1994 and 2005, two large scale surveys of the North Sea and adjacent waters SCANS and SCANS-II (see 0) provided abundance estimates for the harbour porpoise population of the entire North Sea. The different survey schemes will be described in more detail in the next paragraphs. A more detailed description of the used methods will be presented in §2.5.

2.4.1 MWTL monitoring in The Netherlands

In the early 1990s the “Monitoring van de Waterstaatkundige Toestand des Lands” (MWTL) program started (e.g. Arts, 2010). This monitoring scheme was commissioned by Rijkswaterstaat Waterdienst/Ministry of Infrastructure and the Environment and aims at the monitoring of trends in distribution and numbers of seabirds and marine mammals of the total Dutch North Sea. To be able to accommodate the different species in one survey, the choice has been made to conduct aerial surveys using strip transect sampling. The transect design was chosen in a way to cover the total area in a limited amount of time (to use good weather windows efficiently) and to have coverage throughout the range of the Dutch North Sea (Figure 1). Surveys are conducted bi-monthly.

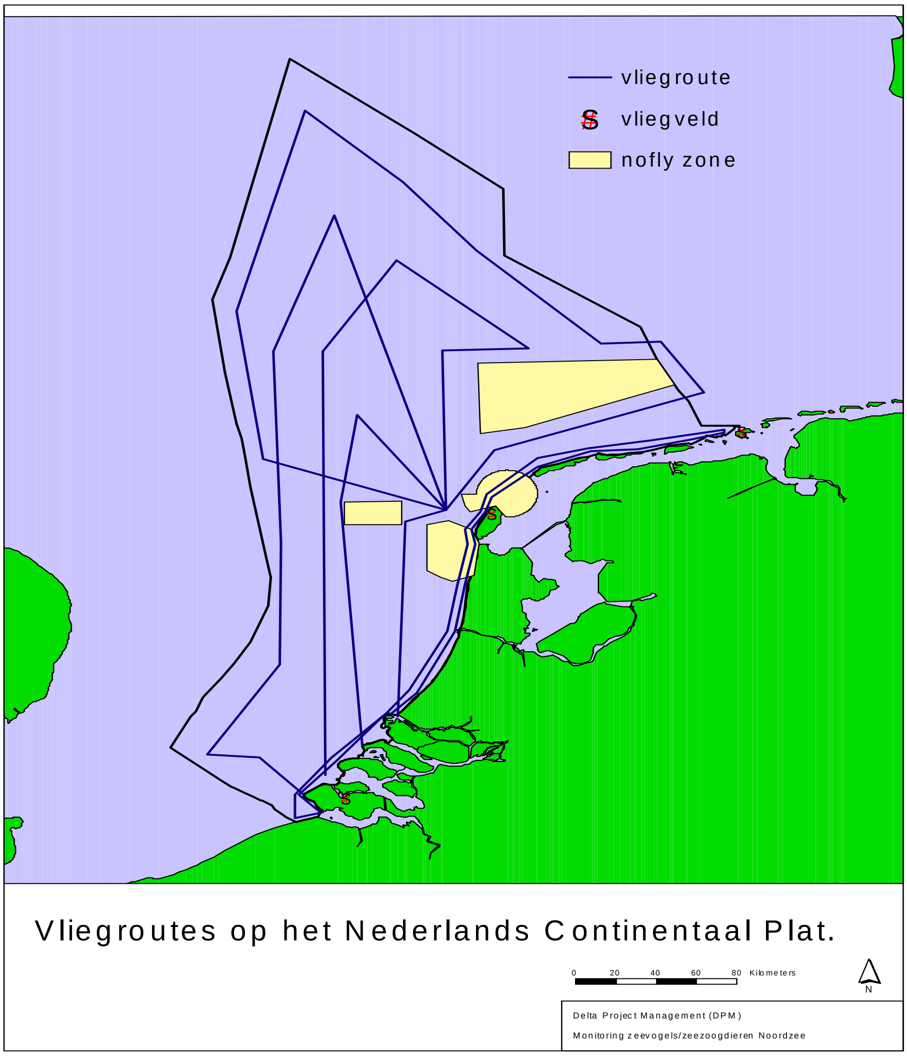

Figure 1. MWTL transects on the Dutch Continental Shelf: vliegroute = track line; vliegveld = airfield.

Survey flights are conducted with a two-engine airplane for long offshore flights and a one-engine airplane for the coastal flights. Flight altitude during the surveys is 500 ft (165 m). Observations are made by two observers, each on one side of the plane, and recorded in fixed strips, which are specific for each combination of airplane and observer. Strips are determined based on position of the eye relative to the window as dependent on the size of the observer. A more detailed comparison of MWTL- and IMARES-surveys is presented in Appendix II.

The current MWTL scheme is under review and several scenarios have been formulated to improve the delivery of information for present day policy and management needs (Van Roomen et al., 2013).

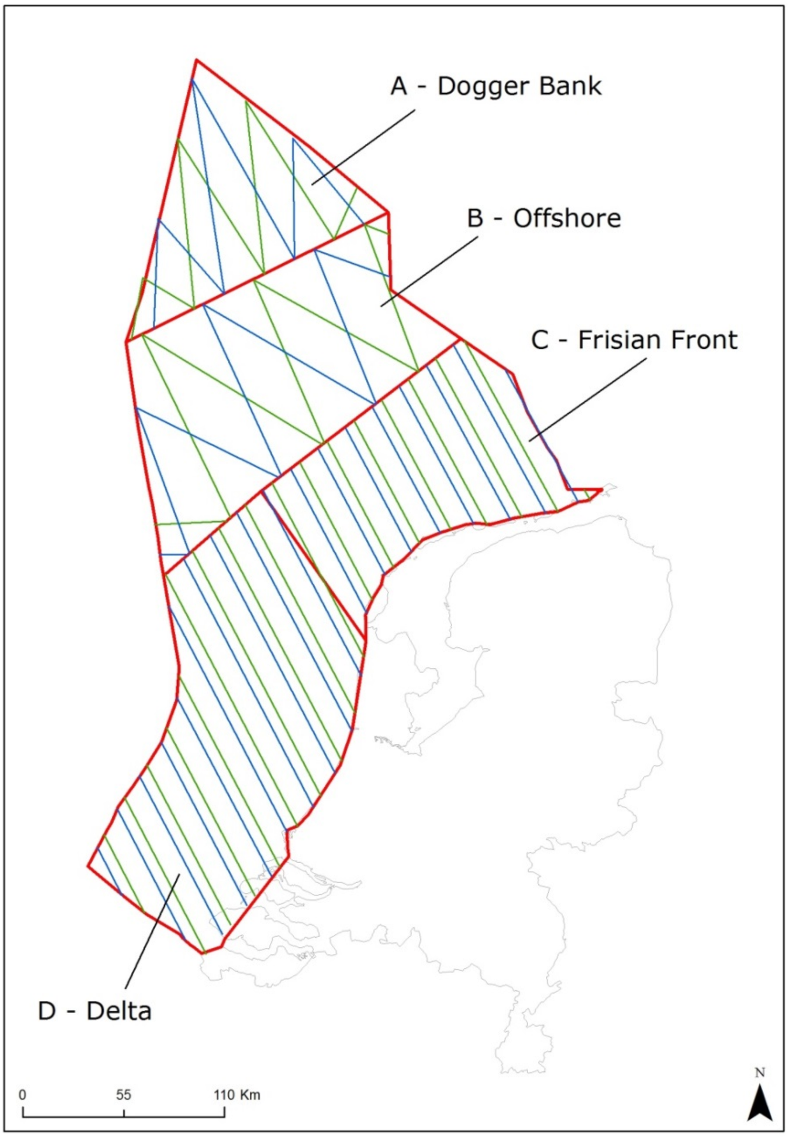

Figure 2. Map of the Dutch Continental Shelf with the planned track lines in study areas A ("Dogger Bank"), B ("Offshore"), C ("Frisian Front") & D ("Delta"). Two surveys are designed per study area (shown in blue and green).

2.4.2 IMARES porpoise surveys in The Netherlands

IMARES has been conducting aerial surveys using line transect distance sampling methods in Dutch waters since May 2008. Until March 2013, 27,878 km were covered on effort during 61 survey days in three different periods: March, July and October/November (Scheidat et al., 2012). The Dutch Continental Shelf is divided in four survey areas (Figure 2). Until 2010 the emphasis of the surveys was on areas C and D and abundance estimates for the entire Dutch Continental Shelf were lacking.

From July 2010 to March 2011, under the umbrella of the Shortlist Masterplan Wind program, dedicated aerial surveys of the entire DCS were conducted for the first time (Geelhoed et al., 2011 & 2013b). Also, additional funding was available within the Beleidsondersteunend Onderzoek (BO) program of the Ministry of Economic Affairs, enabling the completion of DCS wide surveys in three seasons between July 2010-November 2011, in March 2012 and in March 2013 (Geelhoed et al., 2013a, c).

These surveys resulted both in distribution maps and in robust unbiased or 'absolute' abundance estimates of harbour porpoises for the DCS, corrected for detectability (availability bias from diving animals, and perception bias for animal missed by observers). Thus these surveys initiated a trend series allowing to examine whether the distribution and number of harbour porpoises show annual variation in Dutch waters.

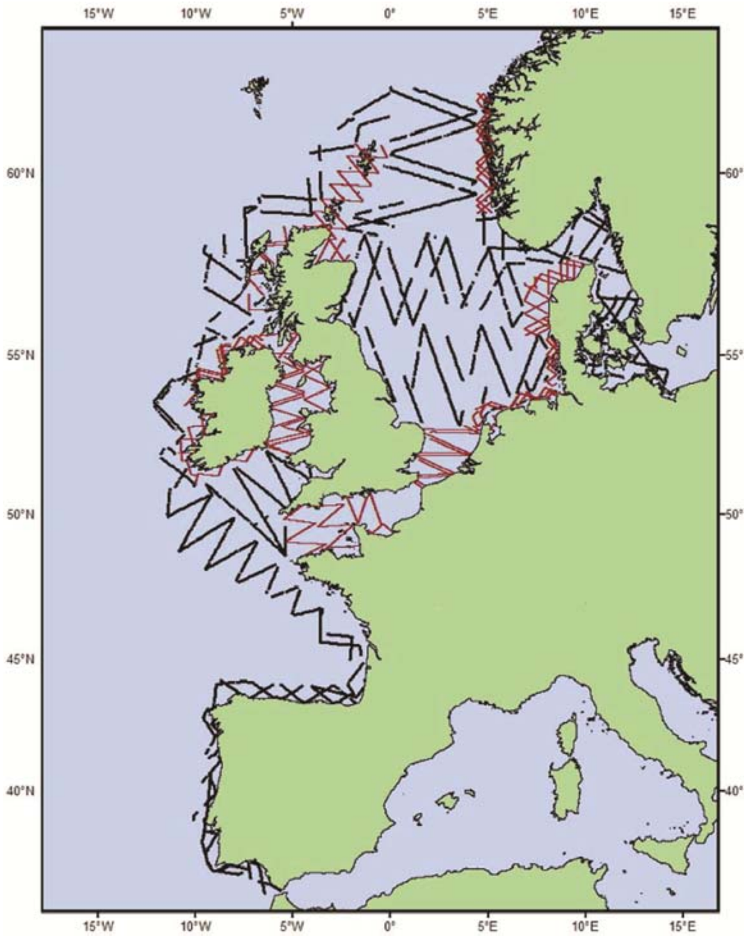

Figure 3. Realised survey effort for both ship-based (black lines, Beaufort sea state 0-4) and aerial (red lines, good and moderate conditions) surveys during SCANS II, summer 2005.

2.4.3 SCANS surveys in the North Sea

In 1994 the Small Cetacean Abundance in the North Sea and adjacent waters (SCANS) project provided the first estimates of abundance for harbour porpoises and other cetacean species in this area (Hammond et al 1995, 2002). In 2004 a second project, SCANS II began with support from the EU LIFE-Nature program and 12 European governments. SCANS II surveyed the European Atlantic continental shelf and the North Sea in July 2005 (Figure 3, SCANS 2008, Hammond et al 2013), thus initiating a series of large decadal surveys in the North Sea. Aim of the SCANS surveys is to provide robust estimates of abundance for the harbour porpoise population(s) in the North Sea and adjacent waters. A third survey is planned for July 2016 (SCANS III), but funding still needs to be secured.
Both SCANS surveys were conducted from ships and airplanes and provide a robust unbiased or 'absolute' population estimate for the North Sea harbour porpoise (Hammond et al., 1995 & 2002, SCANS 2008), corrected for detectability (availability bias from diving animals, and perception bias for animal missed by observers) and responsiveness to the survey platform. However, it is not possible to use this data to calculate national densities (e.g. just for the DCS). As Figure 3 shows, the actual

coverage of the SCANS II survey in Dutch waters was fairly low and the spatial modelling performed was not detailed enough to provide a reliable estimate for the DCS.
SCANS II also compared and recommended different methods that can be used to monitor cetacean populations in between large scale decadal surveys. The project also developed a computer-based tool to determine safe limits to by-catch for a given species in the face of the considerable uncertainty about our knowledge of these animals and the marine environment in which they live.

2.4.4 Monitoring in other North Sea countries

Belgium
In Belgian waters (BPNS – Belgium Part of the North Sea) a series of dedicated aerial line transect surveys started in April 2008. Surveys are conducted on average four times per year, taking advantage of good weather windows. Until now, monitoring has been conducted mostly in the period February to April (Haelters, 2009; Haelters et al., 2011ab, 2012). Surveys are conducted by the Royal Belgian Institute of Natural Sciences (RBINS) and use a method similar to the one used by IMARES. The surveys are planned to continue for at least the period 2013-2015 (Appendix 3 in Desportes, 2013).

Germany
Dedicated aerial surveys for assessing the distribution and density of harbour porpoise in the German part of the North Sea (GPNS) started in 2002 in the framework of the construction of offshore windmill parks, and to investigate potential areas for implementing Natura 2000 (Scheidat et al., 2004). The surveys have continued since then in spring and/or summer (Scheidat et al., 2007, Gilles & Siebert, 2009, 2010, Gilles et al., 2009, 2011, 2012), as part of the German monitoring program of Natura 2000 sites, funded by the Federal Agency for Nature Conservation (BfN). From May 2011 onwards these surveys have been conducted by the Institute of Terrestrial and Aquatic Wildlife Research (ITAW). The surveys normally focus on a single of the four GPNS survey areas at a time. Complete surveys of the GPNS are conducted every three years in the summer (2009, 2012 and next 2015), although they were also conducted in spring, summer and autumn in 2012.

These surveys use an identical type of plane and the same methodology as the IMARES surveys. The frequency and timing of the surveys should remain the same for at least the period 2013-2015 (appendix 3 in Desportes, 2013).

United Kingdom
There is no large scale monitoring effort directed at harbour porpoises in the UK waters of the North Sea. Some small scale recurrent surveys are conducted off the east coast from the Moray Firth down to the Yorkshire, thus in waters not contiguous to the DCS (Evans et al., 2007). A number of ferry-based surveys across various areas of the North Sea and Northern Isles of Scotland are undertaken on a regular basis by NGOs but are very little if at all entering Dutch waters. In relation to offshore renewable energy development, there are regular aerial surveys targeting primarily the coastal sector for marine megafauna, focussing mainly on birds but also on cetaceans.

In addition, the Joint Cetacean Protocol (JCP) collaborative project aiming at the long term surveillance and monitoring of cetaceans in UK waters and the wider northeast Atlantic is collating as much of the effort related data as possible for various cetacean species including harbour porpoises. This includes data from research institutes, developers and NGOs, including SCANS, CODA, European Seabirds at Sea (ESAS) data and Sea Watch data. The work aims to produce robust estimates of cetacean density, distribution and population trends, and the output includes density surface plots, an analysis of trends over time, and the power to detect those trends. The final report is due to be published online in 2013. For further details see http://jncc.defra.gov.uk/page-5657). At this point, however, the database does not include any eastern North Sea and Channel survey data.

2.5 Monitoring techniques

Monitoring spatial and temporal variation in harbour porpoise abundance involves a variety of approaches, which differ in terms of scope of information provided and necessary resources, thus presenting different strengths and limitations as well as cost-effectiveness in answering the questions the monitoring is intended to address.
Reviews of the approaches used to monitor cetaceans in European waters are provided by Evans & Hammond (2004) and SCANS (2008, appendix D2.1 & D2.4) and new developments have been made since. In the next paragraphs we review the most common approaches which are applicable to harbour porpoises and are relevant to Dutch waters.

2.5.1 Incidental sightings, strandings and by-catch information

Sightings of cetaceans that are not associated with effort data (e.g. hour observed, km travelled) can give a first impression on occurrence of a species. This type of data is often collected by the general public, for example from sailing vessels (Cooke et al., 2006). In areas of extremely low densities, such as the Baltic Sea, this type of information can be very valuable. The drawbacks are that the number of sightings recorded is not necessarily related to the density of animals. An increase in observer effort or a change in weather condition can have a direct (and not quantifiable) impact on the number of recorded sightings. Additionally, it can be difficult to assess or validate the quality of the data collected, in particular in regard to species identification, group size or behaviour observed.
In Europe a number of countries have stranding networks that collect information on cetaceans found on the beaches (alive or dead). Similarly fishermen often report when they have had an incidental catch of a cetacean. The analyses of stranding and by-catch data can provide information on a range of relevant biological and other parameters (e.g. age, reproductive rates, causes of death, prey choice, contaminant loads). The number of animals stranding is related to a number of factors that are again difficult to quantify. Effort changes by season (e.g. summer vs. winter) and area (e.g. public beaches vs. remote sandbanks), thus impacting the numbers of animals found. An increase in numbers could indicate an increase in local abundance and/or an increase in mortality and/or a change in distribution.
Thus, these type of data sources cannot be reliably used to monitor absolute abundance, distribution patterns or temporal changes in abundance and distribution (see a more detailed review in Evans & Hammond, 2004).

2.5.2 Acoustic monitoring

Acoustic methods use the echolocation signals cetaceans produce to detect the presence of these animals. The main advantage of acoustic methods is that they can record continuously, are independent of light conditions and are also less susceptible to bad weather than visual survey methods. In principle there are two approaches, the deployment of static (stationary) data loggers, such as C-PODs and ship surveys using towed hydrophones.
Static acoustic systems have low spatial resolution, but have high temporal resolution because continuous data on porpoise click activity can be collected. They are a valuable tool for obtaining information on seasonal presence and relative abundance in smaller defined areas, including narrow straits or areas where long term monitoring of presence, migration or time trends is needed, such as in offshore wind farms. Methods have now been developed for obtaining robust density estimates for porpoises by passive acoustic monitoring (e.g. Kyhn et al., 2012). The project SAMBAH in the Baltic Sea is currently further developing these (http://www.sambah.org/). In the southern North Sea strong tidal currents and high effort in trawling pose considerable logistical challenges, as the secure anchoring of static systems is difficult (and expensive). To ensure an adequate coverage of the DCS at least several hundred devices should be deployed. Static acoustic methods are particularly suitable for monitoring in areas with densities too low for visual surveys to be practically feasible.

Acoustic surveys with a towed hydrophone have a spatial resolution for the detection of harbour porpoises similar to shipboard visual surveys. Their temporal resolution is greater as they can continue in weather that is not good enough for visual observations and at night. The performance of this method greatly depends on the noise generated by the vessels. As during line-transect visual surveys, to obtain unbiased density estimates for harbour porpoises the survey vessel needs to follow a pre-designed representative grid of transects and the distance of the animal to the transect needs to be estimated. In most cases towed arrays are used in combination with a visual survey platform, also allowing the calculation of a correction factor for missed animals (see 0 and 0). A more detailed review of the strengths and weaknesses of using acoustic data from towed hydrophones and stationary click detectors can be found in SCANS (2008, appendix D2.1).

Although acoustic methods can provide detailed information on habitat use, they cannot provide robust abundance estimates of harbour porpoises occurring in the DCS.

2.5.3 Land-based observations

Dedicated sea watches following a standardized protocol are conducted by volunteers since the 1970s along the Dutch coast. The counts basically occur year-round, but with slightly increased intensity during periods of bird migration in spring (March-May) and autumn (August-October). Observations are made from vantage points (dune-tops, piers, dikes), with observatories normally at a height of 5-15 m above sea level, to provide views over the near shore strip (up to 5-10 km distance) of coastal sea. Porpoises are normally detected only within 2 km from the observers. Observers record date, duration of the observation period (start and end time), and weather characteristics and log their sightings usually per hour of observation. The observers are well-trained and experienced in cetacean identification. The database for the land-based observations is currently not sufficiently designed to correct for differences in sighting rates due to wind and other weather conditions.
The main limitation with using fixed-point sampling is that this method only provides information on seasonal occurrence (animals or sightings per hour) in the near shore area (<2km depending on weather conditions, detection method used and height above sea level). Although the method is in principle an inexpensive way of collecting data, it can only generate temporal data on distribution in the near shore area and cannot be used to estimate abundance of porpoises occurring in the DCS.

2.5.4 Strip transect versus line transect distance sampling

For both strip and distance sampling methods observers travel along a line, recording all detected animals. The major difference between strip transect and line transect distance sampling is that strip transect sampling assumes that all animals within the strip are detected. The only way to know if this is true is to actually measure the distances and check if they are evenly distributed within the strip. Line-transect distance sampling on the other hand is based on the assumption that the chance of detecting an animal decreases with distance to the track line. By measuring the distance to all sightings the so-called effective (half-)strip width (ESW) can be calculated, taking into account a number of parameters that could impact the sighting probability (e.g. sea state, turbidity, observer).

One of the assumptions of line-transect distance sampling is that all animals are detected on the track line, which would mean that the chance to see all animals at a distance of 0 m from the track line is 1 (100%). For most animals, but in particular for cetaceans, this assumption is not true and a correction factor, called g(0), needs to be obtained to correct for the proportion of animals missed on the track line. For aerials surveys for harbour porpoise the so-called racetrack method is used which allows the estimation of g(0) under different sighting conditions (see appendix I for more detailed explanations).
Another important assumption is that the survey coverage is representative of the study area. Track lines need to be placed while considering 1. replication (multiple lines that can be used as representative samples of the study area), 2. randomization (lines need to be placed randomly), 3. sampling coverage (all areas should have an equal probability of coverage, or if that is not the case, coverage probability needs to be known; see DISTANCE software: Thomas et al., 2002), 4. spatial stratification (to increase precision the study area is divided into smaller areas) and finally 5. sampling geometry (e.g. make sure the track lines follow gradients) (Buckland et al., 2001). The most common designs are parallel lines or zigzag patterns, either one starting from a random point.

Combining the ESW and the g(0) value, and assuming good survey design, line transect distance sampling allows for obtaining absolute densities, i.c. the number of animals/km² with the associated

95% confidence interval (C.I.) and coefficient of variation (C.V.; Buckland et al., 2001). These values are needed for an analysis of trends in abundance estimates.
Certain & Bretagnolle (2008) provide a good overview of strip transect vs. line transect sampling. And Burnham et al. (1985) give an overview over the trade-offs of bias and efficiency between strip and line transects. We reiterate their main conclusion that that line transect distance sampling allows for obtaining unbiased absolute abundance estimates, whereas strip transect methods provide relative abundance estimates.

2.5.5 Ship-based versus aerial surveys

Both ship-based and aerial visual surveys will provide robust and unbiased data on harbour porpoise abundance and distribution following standardized methods like line transect distance sampling. They will also provide additional information on group size and group composition, e.g. presence of calves, and to some extent on behaviour. However, depending on the study site and the research questions, there are advantages and disadvantages associated with both methods.

For the Dutch Continental Shelf the main advantage of using aerial surveys vs. ship-based surveys is that large areas can be covered in less time and that it is easier to react quickly to "good" weather conditions. A plane can be hired on a short-term basis, while a boat survey (normally) needs to be planned some time ahead. Weather conditions in the southern North Sea are often sub-optimal for porpoise surveys, which require good visibility (no fog, rain) and a Beaufort sea state of less than 4. Following the SCANS and SCANS II methodology, aerial survey flights are conducted with a two-engine airplane with bubble windows, allowing free observations on the track line below the airplane, which is important for the estimation for ESW. The team is constituted, apart from the pilot, of three observers. One acts as navigator and records environmental and sightings data while the two others sit at bubble windows on each sides of the plane. This allows the observers to keep their focus on the water and not have to remove their eyes from the search area to note down sightings.

A limitation of the aerial surveys is the "endurance" of the plane, which ranges from 3-4 hours to 6-7 hours. Especially offshore areas such as the Dogger Bank can pose a logistical challenge as the transit to the area is quite long (about an hour), and it is difficult to accurately predict the weather and sighting conditions that far offshore. Besides, contrary to ship-based surveys it is not possible (or only in a limited way) to collect biotic and abiotic data at the same time (e.g. salinity, sea surface temperature etc.). Such data can be valuable for spatial models of porpoise distribution.

One of the assumptions of line transect distance sampling is that animals do not move prior to detection. A large disadvantage of boat surveys is that porpoises have been shown to change their swimming directions in reaction to the survey vessel noise (Palka & Hammond, 2001), although analytical methods have been developed to address this (Borchers et al., 1998). Responsive movement of porpoises is not a problem for aerial surveys conducted at a flying height of 600 ft.

Accurately determining g(0) on a shipboard survey for harbour porpoise requires using a double platform methodology (see 0), the number of observers needed on a boat will then range between 8 to 10 people. The SCANS methodology for porpoise aerial surveys applies the racetrack method for determining g(0), which will increase survey time but not the number of observers (see Appendix I). Finally, the hourly rate for a plane is higher than for a survey vessel. However, a plane can cover an area about ten times as fast and is thus actually more cost-effective.

To conclude, aerial surveys provide unbiased abundance estimates and is the cost-effective of both survey methods.

2.5.6 Mega fauna surveys

Most surveys have target species or taxa (e.g. small cetaceans, large cetaceans) and are optimised to get the best possible data on these. In some cases so called mega fauna surveys are conducted, which aim to obtain information on a range of taxa simultaneously, such as all cetaceans, birds, turtles,

jellyfish and fish. Additionally they could also record the presence of marine debris, vessels and fishing sets. The main advantage of this approach is that information on different targets is obtained at the same time, thus diluting the cost over several required monitoring programs (e.g. Ridoux et al., 2010). Mega fauna surveys, however, have many drawbacks, as they inevitably have to compromise on some aspects of data collection.
For Dutch waters it would be ideal to combine bird and porpoise surveys as there is overlap in study areas and the survey methods are comparable. However, this situation is not applicable at the moment as the methods differ in important details (see 0 and 0). Aerial surveys for birds are typically conducted at 250 or 300 feet of survey height (Poot et al., 2011). This allows the identification of most bird sightings on a species level, but even then identification of all individuals to species level for divers, small gulls and auks is not possible. The standard survey height for porpoises is 600 feet. This is the best height to monitor porpoises and to obtain the highest possible sighting rate, which means using the largest possible search area in which animals must still be detectable. Therefore at this height porpoises can still be detected and the area that can be observed (and thus the resulting ESW) is as large as possible. If the sighting rate is reduced, monitoring in times of or areas of lower density will make survey work highly ineffective.

Another difficulty in combining bird and marine mammal surveys, is that bird surveys use strip sampling while distance sampling is used for harbour porpoises (see 0). The occurrence of birds is counted per strip, and the distance to every bird (or group of birds) is not measured, because seabirds can occur in very high densities as well as in very large group sizes. Having to measure distances to porpoises while counting birds, would compromise one of the two methods, especially in areas of high bird densities or high porpoise densities, when the search effort would need to focus on one of the two target taxa, thus reducing the effort for the other one.

Finally, another issue is that the timing of bird surveys do not necessarily match the times when porpoises are ideally surveyed. For porpoises (in Dutch waters) two seasons have been identified of highest interest, the early spring with high densities, and the late summer when porpoise calves can be recorded. The future bird surveys in The Netherlands will probably focus on two main groups: wintering birds (divers, grebes, auks) in November-February and breeding birds (gulls, terns) in summer (probably Aug). Thus potentially providing additional data on harbour porpoises in other seasons.

One needs to carefully consider what kind of additional information can be collected without compromising the quality of the data collected for the target species. IMARES has decided to record the occurrence of any floating debris associated with fishing (e.g. nets, buoys) as well as set net flags and all vessels, while conducting harbour porpoise surveys. However, these are recorded in a pre-determined strip, so it is not necessary to measure any distances. The frequency of these recordings is low and it is found that they can aid in keeping the observers alert in areas of low porpoise density.

In summary, a combination of bird and marine mammal surveys in Dutch waters, where both birds and harbour porpoises may occur in high densities, using current survey methods, would reduce the quality of the monitoring data for marine mammals.

2.5.7 High Definition Digital imagery versus visual aerial surveys

In recent years more and more seabird and marine mammal surveys are performed using new digital imagery techniques (Thaxter & Burton, 2009; Buckland et al., 2012). Nowadays, in the UK high definition digital imagery (Hi-def) from airplanes is widely used to survey seabirds and marine mammals. Similarly to visual ship-based and aerial surveys described in section 0, predefined transects are flown within the study area. The sea surface is either photographed or filmed with multiple cameras, providing images of a predefined sector along the transect. Often an extra camera can be used by a dedicated observer to zoom in on phenomena (like an activity of wildlife behind a fishing vessel or natural concentrations of animals e.g. along front lines) outside the transect to gather additional information. All footage is stored digitally to be analysed afterwards in the lab by observers. In digital surveys it is assumed that within

the field of view of the cameras all birds and marine mammals that are visible will be recorded (no perception bias).
The resolution of the cameras (1 pixel < 3 cm with a flight altitude of 300 m upwards) allows the survey planes to fly at a much higher altitude than during standard visual surveys. By doing so the disturbance effect of the observation platform is much smaller or absent than during visual surveys (in particular for birds as those surveys are generally taking place at 250 or 300ft). The actual "detection process" of sightings is done in the lab afterwards, with the advantage that data can be reviewed and re-analysed by others and observer effects that normally impact sighting probability are eliminated. Estimates of species as well as the size of groups of animals (at least for non-diving birds) are more precise than during visual aerial surveys. Also, detection and species identification is potentially less affected by weather and sea state compared to visual methods. Similarly to other types of survey techniques diving animals are still missed. The equipment makes it possible to see whether a marine mammal is breaking the sea surface or just below and the 'availability bias' can be accounted for by applying surfacing rates for marine mammals, as it is done for visual aerial surveys. More complex methods, involving double platforms, can be employed to derive 'absolute' abundance estimates of marine mammals, which use surfacing and sub-surface records from the video material. Some more general descriptions of digital aerial survey techniques and results were given in the reports of Mellor et al. (2007 & 2008) and in Buckland et al. (2012).

Several companies in the UK (HiDef, APEM) and one in Scandinavia (BLOM) offer these digital survey techniques in The Netherlands. The costs are higher than a standard visual aerial survey but for bird surveys the quality of data is potentially better. For harbour porpoise no comparisons between digital and standard visual survey techniques have been published so far. The main advantage of digital imagery is that it would, at the moment theoretically, allowed combining bird and marine mammal monitoring in the Dutch North Sea without compromising the quality of any of them.

2.6 Frequency and timing of monitoring surveys

2.6.1 Statistical power to detect change

Measuring population change in abundance involves comparing two or more estimates, made at different times. One can look at changes throughout the year, e.g. seasonal trends, or determine changes between years, by comparing estimates that were taken in the same month in different years. It is important to note that, in the case of the DCS which covers a small part of the distribution range of the North Sea harbour porpoise population, trends in abundance in time and space in whatever direction will not necessarily reflect an actual trend in the size of the overall population. They could also indicate a change in distribution pattern of harbour porpoises over a larger area (e.g. North Sea, as seen between SCANS and SCANS II). One of the main challenges is that any results obtained from surveys for wide-ranging cetaceans such as the harbour porpoise are associated with a degree of uncertainty. When comparing abundance estimates one needs to consider the precision of the estimates, as well as the power of the test used to show if a trend is statistically significant or not. There are several methods used to do this. Power analysis can be used to assess how often surveys need to be conducted to be able to detect a defined change (e.g. Wilson et al., 1999).

The statistical power of the trend in harbour porpoise density depends on three factors: (1) the reliability of the yearly density estimates, (2) the magnitude of yearly fluctuations in harbour porpoise density and (3) the number of years in the time series. As the statistical power is a complex interplay between these factors, Leo Soldaat (CBS) tested whether a trend in harbour porpoise density can be assessed under a previously estimated combination of coefficients of variation (CV) of within- and between-year densities. These CV-estimates were taken from table 7 of the report with the results of the 2012 DCS survey by IMARES (Geelhoed et al., 2013a). Only density-estimates in March were used, as the number of surveys in other months (Jul- Oct/Nov) is not enough to calculate 'robust' between-year CVs. Table 1 shows the densities and within-year CV's, as well as two different estimates of the between-year CV.

The best estimate of the within-year CV is the overall mean CV (0.38). A raw estimate of the between-year CV can be derived in two ways: (1) the mean of the between-year CV's of the separate areas (CV=0.33) or (2) the CV of all yearly density estimates (CV=0.46).

Table 1. Densities and CV estimates of harbour porpoises in four areas on the Dutch Continental Shelf (source: Geelhoed et al., 2013a).

Area	density	within year CV	between year CV
Area A			
2011	1.03	0.39	0.23
2012	1.44	0.36	
Area B			
2011	0.91	0.31	0.18
2012	0.7	0.42	
Area C			
2010	1.11	0.44	0.68
2011	2.98	0.33	
2012	0.94	0.48	
Area D			
2009	1.47	0.33	0.23
2010	2.01	0.39	
2011	1.17	0.34	
2012	1.42	0.35	
overall mean	1.38	**0.38**	
overall SD	0.64		
overall CV	**0.46**		**0.33**

Simulating harbour porpoise densities

The power analysis consists of Monte Carlo simulations (in R) of data sets and subsequent trend analysis. In more detail this analysis consists of:

1. 44 density estimates per year were simulated (44 'plots'), which corresponds to the number of more or less independent estimates made each year in the future monitoring program.
2. Densities were simulated for 12 consecutive years, as this is the shortest period to report under the European Habitats Directive.
3. For the first year 44 densities (X) were drawn from a normal (N(μ, σ)) distribution:

N(ln(μ1), CVw), with:

μ1 = mean density in year 1
CVw = within-year CV

(Note: the standard deviation of a naturally log-transformed variable is the coefficient of variation on the original scale).

4. This procedure is repeated for each year, with μ for each year again drawn from a normal (N(μ, σ)) distribution:

N(ln(μt), CVb), with:

μt = μ1*trend^(t-1)
CVb = between year CV (assumed to be the same in each year)

'trend' is the relative year-to-year change in density, for instance 1.05 means a 5% increase as compared to the previous year, 0.95 a 5% decrease. Trend 1.05 was used in the simulations.

5. A trend was calculated using simple linear regression of the simulated densities against year (on the natural log scale).
6. Steps 3-5 were repeated 1000 times. The mean of the 1000 trend values and their standard deviation reveal (by subtracting or adding 1.96*SD to the trend) whether a significant trend in density can be detected, given the combination of CVb and CVw.

Results

As an illustration, the results of the analysis of annual surveys are presented in Figure 4, which shows that smaller trends can be detected when CVb decreases. With the values of CVb and CVw from table 1 (0.33 and 0.38) trends of ca. 6% yearly change can be detected when surveying 12 consecutive years, or in other words a decline of 50% can be detected after 12 years. The results of analysis of multi-annual surveys are presented in the description of the different scenarios (see §4).
Trend detection (as derived from the standard deviation of the 1000 trends) was much more sensitive to CVb than CVw. Therefore, only results for CVw=0.38 (the overall mean from the table are shown in Figure 4.)

- Trend detection was highly insensitive to the number of 'plots'. However, there undoubtedly is a strong effect of the number of 'plots' on CVw. The message for the monitoring program from this is to keep the CVw as low as reasonable possible.
- The standard deviation of the 1000 trends was independent of the trend value used to simulate the data: the graph would be practically the same using a trend value of 1.10 in the simulations.

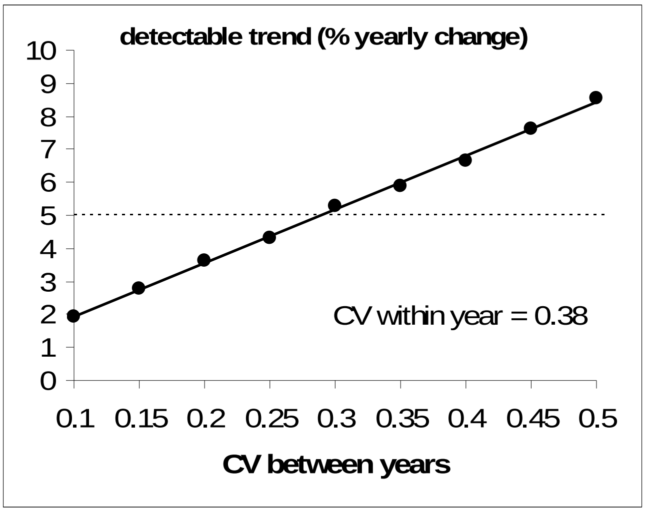

Figure 4. Relation between CV between years vs. detectable trend.

Table 2. Overview over five simulations for a 12 year monitoring scheme on an annual, bi-annual and tri-annual basis.

				Annual		Bi-annual		Tri-annual	
CVw	CVb	nPLOT	nSIM	Mean	SD	Mean	SD	Mean	SD
0.38	0.35	44	1000	1.050	0.032	1.048	0.039	1.045	0.046
0.38	0.35	44	1000	1.049	0.031	1.047	0.037	1.045	0.046
0.38	0.35	44	1000	1.050	0.031	1.048	0.036	1.045	0.043
0.38	0.35	44	1000	1.050	0.030	1.048	0.035	1.045	0.043
0.38	0.35	44	1000	1.050	0.032	1.049	0.039	1.045	0.046
			mean	1.050	0.031	1.048	0.037	1.045	0.045
Detectable annual change after 12 yrs				6%		7.5%		9%	
Detectable change after 12 yrs				-50%		-58%		-65%	

Additionally Leo Soldaat investigated what kind of trend could be detected when conducting annual, bi-annual or tri-annual surveys in a 12 year period. Table 2 shows the results for the described scenarios that were repeated five times. The mean annual change that can be detected after 12 years increases (from 6 to 9%), while the precision decreases. This means that a decrease of 50% is detectable with annual surveys after 12 years, and that reducing the frequency to bi-annual or tri-annual surveys leads to a (strong) decrease in the power of the trend detection.

These simulations demonstrate that the detectability of short-term trends (the 12 year reporting period required by the Habitats Directive) is especially sensitive to the magnitude of yearly density fluctuations and to the number of years in the time series, but less to the reliability of the density estimates. The conclusions of the simulations are:

- The conclusion of the simulations is only indicative for the power of the trend detection of the harbour porpoise monitoring. The power depends mainly on the CV between years, but the estimate of CVb is based on very few data, coming from different areas within the DCS. CV estimates would probably have been lower when based on more data. Thus, the power of the monitoring program to detect trends will probably be somewhat larger than estimated here. If annual surveys will be conducted in March after 12 years a mean annual change of 6% can be detected, corresponding to a decline of 50% after 12 years.
- The approach followed here using 'CV between years' produces a raw estimate of the yearly variation in harbour porpoise density in March, uncorrected for a possible trend in density. A first glance, however, shows no trend in the short time series in Table 1.
- There is a decrease in the trend that can be detected after 12 years of surveying when comparing annual, bi-annual and tri-annual surveys (50, 58 and 65% decline detectable after 12 yrs). The obtained uncertainties increase at the same time.
- The results of the provided IMARES surveys, assuming the current CV values remain the same, can be used to effectively monitor trends over a time period of 12 year.
- The approach followed here using 'CV between years' was not applicable for the survey data in other months (Jul and Nov). During the SMW surveys in 2010-2011 (Geelhoed et al., 2013b) the CVs in these months, however, were higher than in March. Thus, the power to detect trends will be lower with surveys in these months than with surveys in March.

For the monitoring program the main conclusions are:

- As yearly fluctuations cannot be influenced by the monitoring program, the easiest way to influence the reliability of trend detection is by changing the number of years the densities of harbour porpoises is estimated. Halving the number of years in the program (i.c. bi-annual surveys) will lead to a loss of 25% in statistical power (smallest detectable trend goes from 6% to 7.5% yearly change), and thus seems not advisable.
- The main reason to increase the number of transect lines would be to increase the spatial coverage of the program. In addition, the density estimates may become more reliable (although this is not sure). The power of trend detection, however, is rather insensitive to this reliability.

2.6.2 Seasonality

Harbour porpoise occurrence in Dutch waters changes not only between years, but also within a year. The current information is showing a strong seasonal pattern in both distribution and density. From a management perspective it can be important to know when porpoises occur in what area. This will inform where and when certain human activities, such as seismic exploration, offshore construction or set-net fishery could potentially be the most harmful to harbour porpoises. The occurrence of high densities of animals in specific areas or the presence of calves needs to be considered when designing mitigation measures.
Along the same lines, implementing conservation measures and monitoring their effect, e.g. monitoring existing protected areas, requires understanding the distribution pattern of porpoises in Dutch waters and the changes in this pattern throughout the year as well as between years.

2.6.3 International coordination

As described in 0, neighbouring countries Belgium and Germany are conducting investigations in harbour porpoise distribution and abundance using standard survey techniques. In some cases monitoring programs are already established, in other cases surveys are conducted on smaller scales (e.g. limited to protected areas) or only have funding for a short time. Since harbour porpoises are wide ranging and transcend national borders, it would be advisable to coordinate any, or at least some, survey efforts on an international level. Indeed, as already mentioned, any national waters in the North Sea cover only a small part of the distribution range of the harbour porpoise and a trend in abundance in time and space in any of those will not necessarily reflect an actual trend in abundance of the overall North Sea population. They could easily indicate a change in distribution pattern of harbour porpoises over a larger area (Hammond et al., 2013). As noted by SCANS (2008), if too small areas are covered it is possible that changes in movement patterns caused by variations in environment (e.g. prey availability) could have a large impact on local abundance estimates and consequently on estimates of trend.

Ideally, especially if similar methods are used, the collected data from different countries could be collated in a common database to provide more insight on porpoise distribution and abundance on a population level or at least for a larger area. However, as harbour porpoises show a seasonal pattern of movements between national waters, with peaks of abundance varying in time between areas, only surveys conducted in similar periods can be additive. This might mean that one needs to compromise on the timing of the survey to allow a common analysis of surveys conducted in different countries. In the DCS, the March dedicated aerial surveys have shown the highest densities of porpoises. The results are of special interest due to potential conflicts with some human activities at that time (sand supply vessels, fishery). However, other countries (e.g. Germany) survey mainly in summer months as weather and light conditions are generally more favourable and the presence of calves can indicate areas important for reproduction.

It might be possible to conceive a monitoring scheme over several years, where focus on national interest alternate with focus with providing abundance estimate over a larger, more biologically meaningful, area. This could be done for example every three-four years in cooperation with neighbouring countries also conducting monitoring programs, e.g. Germany, Belgium and the UK, assuming that designated monitoring schemes are in place.

Also, as mentioned, until now the July SCANS decadal surveys provide robust abundance estimate of harbour porpoises at the North Sea level, but do not provide estimates at the national level. Monitoring performed in Germany, The Netherlands and Belgium covers from time to time their entire respective EEZs. It would therefore be interesting to investigate whether SCANS survey blocks could be designed for covering, not national waters that are too small an area for such a survey, but combined national areas, as for example Belgium, Dutch and German waters. One could then design a monitoring pattern in these three countries, in which an internationally co-ordinated larger July survey would be performed every three-four years, and included every nine-ten years in the overall population survey (SCANS). In other years, national monitoring interests would be given priority.

3. Advice on monitoring methods

In order to implement a monitoring program for harbour porpoises delivering the information needed within the relevant legal framework as outlined in 2.1. These information needs are translated to the following monitoring objectives:

A. Obtain robust and unbiased abundance estimates on harbour porpoises on a relevant ecological scale within Dutch jurisdiction: the Dutch Continental Shelf (obtained directly by national surveys, or indirectly by international surveys) – as basis for management plans and permits under the Nature Protection act (Natuurbeschermingswet) and the Dutch Marine Strategy
B. Obtain trends in abundance on the Dutch Continental Shelf for short (12 yrs) and long time periods (24 yrs) - in order to report under the HD and MSFD
C. Obtain trends in temporal and spatial distribution on the Dutch Continental Shelf for short (12 yrs) and long time periods (24 yrs) - in order to report under the HD and MSFD
D. Obtain trends in abundance and distribution in relation to the objectives of HD site management plans

Based on the information provided in the previous chapter our advice on monitoring of harbour porpoises in the Dutch Continental Shelf is (between brackets relevant paragraphs):

1. Continue to clearly and precisely define the monitoring objectives, to be able to adapt the monitoring program if necessary.
2. cooperate with other international monitoring programs and schemes and work in international fora (such as ICES, OSPAR, ASCOBANS) to streamline future programs (see 2.4.4; 2.6.3).
3. Conduct visual surveys on the scale of the North Sea or, or at least, of the Dutch Continental Shelf (see 2.3).
4. Focus on North Sea wide (SCANS-type) surveys (see 2.3; 2.4.3).
5. Conduct DCS wide surveys in the same season annually (see 2.4.2; 2.6.1).
6. Conduct visual surveys by airplane instead of by ship (see 2.5.5).
7. to obtain robust abundance estimates that are comparable to abundance estimates in other North Sea countries, conduct visual surveys applying line transect distance sampling technology instead of strip transect methods(see 2.4.4; 2.5.4).
8. To obtain 'absolute' abundance estimates, correction factors for availability and detection biases (g(0) value) are necessary. Use state of the art methodology to obtain these correction factors and continue investigating new more efficient methods and options to obtain a g(0) value (see 2.5.4).
9. Determine the best timing of the survey in relation to the objectives on North Sea wide and DCS scale (see 2.6.2).
10. Adjust the methodology of the bird monitoring surveys in order to increase the efficiency of these surveys by obtaining data on harbour porpoises that are less biased and could provide relative trends in other seasons than the proposed season for harbour porpoise monitoring (see 2.4.1; 2.5.4; 2.5.6; Appendix II).
11. Investigate alternative methods to the one currently used, including scenarios of using high definition cameras allowing combined bird and marine mammal surveys (see 2.5.7).

In the next chapter our advice will be elaborated in different scenarios for monitoring of harbour porpoise on the Dutch Continental Shelf.

4. Scenarios for monitoring of harbour porpoise on the Dutch Continental Shelf

4.1 Requirements for monitoring scenarios

The following advice on monitoring methods and frequency is based on the review of the available and relevant methods, the received feedback from the experts involved as well as the analysis to determine the detectable trend in population changes based on previously conducted line transect aerial surveys in the DCS.

A. Concerning the "best" choice in terms of monitoring methods we advise to use: aerial surveys applying line transect distance sampling. To determine the correction factor g(0) we advise the application of the racetrack method.
B. Currently the main aim is to conduct monitoring on DCS scale. However, as population estimates for harbour porpoises in the North Sea are also needed, The Netherlands should continue to be actively involved in more frequent SCANS surveys.
C. The analysis of the DCS wide surveys under section 0 has shown that a reduction in CV of surveys conducted between years will greatly improve the chance to detect trends. The number of track lines (effort) used should be similar to what has been used during the simulation exercise, and what has been achieved previously (which is about 1% DCS coverage, 44 track lines).
D. Concerning spatial coverage, the density estimates may become more reliable (although this is not sure) with a denser coverage. The power of trend detection, however, is rather insensitive to this reliability. Therefore, effort should be directed to increasing temporal coverage instead of increasing spatial coverage.
E. Concerning survey frequency, the statistical analysis has shown that if annual DCS surveys are conducted in March for a period of 12 years, the results will allow the detection of a trend in population size of around 6% annual change, or in other words a decline of 50% after 12 years. The power to detect trends will decrease when bi- or tri-annual surveys are conducted (to 7.5 and 9% annual mean decline respectively and a decline > 50% after 12 yrs), with an increase in the associated uncertainty.
F. Concerning the seasonal timing the statistical analysis has indicated that the power to detect trends in July and November is lower than in March.
G. Concerning the seasonal timing, specific Dutch interests (highest abundance of porpoises and highest anthropogenic impacts in early spring,) point to a monitoring carried out in spring (Mar/Apr). However if international coordination is important, a survey could be conducted in other periods (e.g. Jul/Aug). Ideally monitoring effort should also encompass some investigation of seasonal changes (within year variation).

Based on these requirements, we have made an overview of different scenarios (Tables 3a to 3i). These take into account the timing and frequency of surveys, the expected probability of detecting a trend after 12 years and predicted costs. We have included options for DCS wide surveys (line transect distance sampling) in combination with decadal SCANS North Sea wide surveys (thus, once in the 12 years) and a mix of DCS wide surveys and future bird surveys (MWTL-plus; scenario D1 in Van Roomen et al., 2013). The proposed MWTL-plus surveys will be concentrated in the winter period November-February (3 surveys), and in April, June and August. Surveys will be restricted to the coastal zone in April and June. In the other months a complete DCS survey is proposed (Van Roomen et al., 2013). In the proposed scenarios different seasons are described: spring March-April, with a preference for March (highest densities on DCS); summer July-August with a preference for July (presence of calves, connection with SCANS surveys and Belgian and German surveys) and autumn October/November.
To make comparison of the costs of the scenarios easier we presented the average annual costs for a 12 year period, and assumed the costs for a complete DCS survey 80 k€ (subject to change). Furthermore, the costs of a SCANS-type survey are dependent on additional EU funding. The SCANS II survey cost about 3.5 Million Euros, we are estimating a minimum of 250 k€ funding needed for The Netherlands to match potential EU funding. It should be noted that this amount can also consist of "in kind" funding

(e.g. vessel time, personnel time), so the actual funding needed might be much lower. Costs for MWTL-plus survey are estimated 5 k€ for validation and analysis of the data.
To reduce the number of possible scenarios we assume that during a "SCANS-year" no DCS wide summer surveys will take place.

4.2 Description of scenarios

4.2.1 Scenario I

For Dutch waters two seasons are of particular importance – the early spring and the (late) summer. Ideally a monitoring scheme would allow annual surveys of both seasons. To determine the changes in seasonal distribution, it would also be good to obtain additional information on a third (or fourth) season. However, for the main aim of the monitoring scheme (trend analysis), such high seasonal coverage is not needed. The decadal SCANS-type survey is included to obtain a population estimate for the North Sea harbour porpoise. This scenario provides adequate information for the monitoring requirements A-D as sketched in chapter 3.

Table 3a: scenario I.

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
DCS survey spring	80	80	80	80	80	80	80	80	80	80	80	80
DCS survey summer	80	80	80	80	80	80	80	80	80		80	80
DCS survey autumn			80			80			80			80
SCANS type survey										250		
Monitoring requirement		A	++	B	+++	C	++	D	++			

+ detailed information on seasonal occurrence (three seasons) every three years
+ detailed information on national porpoise numbers in spring and summer every year
+ North Sea population estimate every 10 years
+ two annual estimates available for trend analyses
+ coordination with Belgium and Germany
- moderate costs

Detectable trend: 6 % or less annual change or decrease of 50% or more after 12 years
Annual cost: 200.8 k€

4.2.2 *Scenario II*

For Dutch waters two seasons are of particular importance – the early spring and the (late) summer. Ideally a monitoring scheme would allow annual surveys of both seasons. However, for the main aim of the monitoring scheme (trend analysis), one annual survey would be sufficient. The decadal SCANS-type survey is included to obtain a population estimate for the North Sea harbour porpoise. This scenario provides adequate information for the monitoring requirements A-D as sketched in chapter 3.

Table 3b: scenario II.

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
DCS survey spring	80	80	80	80	80	80	80	80	80	80	80	80
DCS survey summer	80	80	80	80	80	80	80	80	80		80	80
SCANS type survey										250		
Monitoring requirement	A	++	B	+++	C	++	D	++				

+ detailed information on seasonal occurrence (two season) every year
+ detailed information on national porpoise numbers in spring and summer every year
+ North Sea population estimate every 10 years
+ two annual estimates available for trend analyses
+ coordination with Belgium and Germany
- moderate costs

Detectable trend: 6% or less annual change or decrease of 50% or more after 12 years
Annual cost: 174.2 k€

4.2.3 *Scenario III*

One annual DCS wide survey in the spring or summer would provide the minimum data needed for the 12 year trend analysis with the highest probability of detecting trends. The decadal SCANS-type survey is included to obtain a population estimate for the North Sea harbour porpoise.
By only surveying one season, either information on the times of highest density (early spring) or the occurrence of calves (summer) will be lost. Surveys in spring have the highest power to detect trends. Summer surveys are most likely better when it comes to coordinating with neighbouring countries and their survey efforts. This scenario provides adequate information for the monitoring requirements A-D as sketched in chapter 3.

4.2.4 *Scenario IV*

One bi-annual DCS wide survey in the spring would not provide enough data for the 12 year trend analysis with the highest probability of detecting trends. The decadal SCANS-type survey is included to obtain a population estimate for the North Sea harbour porpoise. This scenario provides adequate information for the monitoring requirements A, C and D as sketched in chapter 3, whereas the information provided for monitoring requirement B is limited.

Table 3c: scenario III.												
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**1 1**	**1 2**
DCS survey spring or summer	80	80	80	80	80	80	80	80	80		80	80
SCANS type survey										250		
Monitoring requirement	A	+	B	++ +	C	+ +	D	+ +				

+ North Sea population estimate every 10 years
+ one annual estimate available for trend analysis
+ low costs
- timing of survey not coordinated with neighbouring countries (if in spring)
- will miss information either on spring or summer distribution and abundance

Detectable trend: around 6% annual change or decrease of 50% or more after 12 years
Annual cost: 94.2 k€

Table 3d: scenario IV.												
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
DCS survey spring	80		80		80		80		80		80	
SCANS type survey										250		
Monitoring requirement	A	+	B	+/-	C	+	D	+				

+ North Sea population estimate every 10 years
+ low costs
- only information during spring
- no annual estimates available for trend analysis
- no coordination with Belgium or Germany

Detectable trend: 7.5% annual change or decrease of 58% or more after 12 years
Annual cost: 60.8 k€

4.2.5 Scenario V

The variability of abundance of porpoises in Dutch waters is very high in the different seasons. Thus surveying twice a year will most likely not increase the chances of detecting trends. This option will provide information on two seasons every three years. The lower frequency of monitoring will reduce the probability to detect a trend and increase the uncertainty associated with the trend analysis. This scenario provides adequate information for the monitoring requirements A, C and D as sketched in chapter 3, whereas the information provided for monitoring requirement B is limited.

4.2.6 Scenario VI

The variability of abundance of porpoises in Dutch waters is very high in the different seasons. Thus surveying three times a year will most likely not increase the chances of detecting trends. This option will provide information on three seasons every three years. The lower frequency of monitoring will reduce the probability to detect a trend and increase the uncertainty associated with the trend analysis. This scenario provides adequate information for the monitoring requirements A, C and D as sketched in chapter 3, whereas the information provided for monitoring requirement B is limited.

Table 3e: scenario V.												
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
DCS survey spring		80			80			80			80	
DCS survey summer		80			80			80			80	
SCANS type survey										250		
Monitoring requirement	A	++	B	+/-	C	+	D	+				

+ information on two seasons
+ North Sea population estimate every 10 years
+ low costs
+ coordination with Belgium and Germany
- no annual estimates available for trend analysis

Detectable trend: 9% or less annual change or decrease of 65% or more after 12 years
Annual cost: 74.2 k€

Table 3f: scenario VI.												
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
DCS survey spring		80			80			80			80	
DCS survey summer		80			80			80			80	
DCS survey autumn		80			80			80			80	
SCANS type survey										250		
Monitoring requirement	A	+++	B	+/-	C	+	D	+				

+ information on three seasons
+ North Sea population estimate every 10 years
+ coordination with Belgium and Germany
+ low costs
- no annual estimates available for trend analysis

Detectable trend: 9% or less annual change or decrease of 65% or more after 12 years
Annual Cost: 100.8 k€

4.2.7 Scenario VII

One annual DCS wide survey in spring would provide the minimum data needed for the 12 year trend analysis with the highest probability of detecting trends. For Dutch waters two seasons are of particular importance – the early spring and the (late) summer. Ideally a monitoring scheme would allow annual surveys of both seasons. However, for the main aim of the monitoring scheme (trend analysis), one annual survey would be sufficient. As a compromise this scenario proposes an additional summer survey every three years. This would allow the coordination of that survey with neighbouring countries, and would provide additional trend data between the decadal SCANS-type surveys. The decadal SCANS-type survey is included to obtain a population estimate for the North Sea harbour porpoise. This scenario provides adequate information for the monitoring requirements A-D as sketched in chapter 3.

Table 3g: scenario VII.

Year	1	2	3	4	5	6	7	8	9	10	11	12
DCS survey spring	80	80	80	80	80	80	80	80	80	80	80	80
DCS survey summer			80			80			80		80	
SCANS type survey										250		
Monitoring requirement	A	++	B	+++	C	++	D	++				

+ information on two seasons every three years
+ North Sea population estimate every 10 years
+ one annual estimate available for trend analysis
+ coordination with Belgium and Germany
+ North Sea population estimate every 10 years
+ low costs

Detectable trend: 6% or less annual change or decrease of 50% or more after 12 years
Annual cost: 127.5 k€

Adjustments to MWTL-method to provide an additional index of porpoise occurrence

To optimize the monitoring scheme of harbour porpoises it is recommended using MWTL-plus surveys to provide additional data in seasons and years dedicated harbour porpoises surveys are not conducted. However, as sketched in 2.4 and Appendix II the MWTL-method and the IMARES-method differ in a number of ways, which makes a direct comparison of survey results difficult. For example, the flying heights of the planes differ. In order to compare these two survey methods, the following information would be needed from MWTL: distance of the porpoise sightings to the track line (e.g. measured with inclinometer), continuous environmental conditions on the track line during time of survey (e.g. sea state, glare, turbidity) and general flight information (height, observer, position of observer, speed of plane). We strongly support the SOVON advice to use distance sampling methods during MWTL surveys which will reduce a number of methodological differences.
During MWTL flights no correction factor g(0) will be estimated. But if an estimation of ESW (from the distances taken to the porpoise sightings) is possible, a minimum density can be obtained and compared with the uncorrected as well as corrected estimates from the dedicated porpoise flights.

4.2.8 Scenario VIII

One annual DCS wide survey in spring would provide the minimum data needed for the 12 year trend analysis with the highest probability of detecting trends. For Dutch waters two seasons are of particular importance – the early spring and the (late) summer. Ideally a monitoring scheme would allow annual surveys of both seasons. However, for the main aim of the monitoring scheme (trend analysis), one annual survey would be sufficient. As a compromise this scenario proposes an additional summer survey every three years. This would allow the coordination of that survey with neighbouring countries. Also, the newly designed bird surveys (MWTL-plus) could be used for an additional index of porpoise occurrence in other months *providing the method can be adjusted* (see textbox). The additional summer surveys (Jul/Aug) could be used to calibrate the two survey types, thus effectively increasing the information on seasonal distribution. The decadal SCANS-type survey is included to obtain a population estimate for the North Sea harbour porpoise. This scenario provides adequate information for the monitoring requirements A-D as sketched in chapter 3.

Table 3h: scenario VIII.												
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**1 1**	**1 2**
DCS survey spring	80	80	80	80	80	80	80	80	80	80	80	80
DCS survey summer			80			80			80			80
MWTL-plus data summer	5	5	5	5	5	5	5	5	5	5	5	5
MWTL-plus data winter	5	5	5	5	5	5	5	5	5	5	5	5
SCANS type survey										250		
Monitoring requirement	A	+ +	B	++ +	C	+ +	D	+ +				

+ North Sea population estimate every 10 years
+ information on abundance in two seasons every three years
+ one annual estimate available for trend analysis
+ coordination with Belgium and Germany
+ use of MWTL-plus (with adjustments)
+ low costs

Detectable trend: 6% or less annual change or decrease of 50% or more after 12 years
Annual cost: 137.5 k€

Table 3i: scenario IX.												
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
DCS survey spring	80	80		80	80		80	80		80	80	
DCS survey summer			80			80			80		80	
MWTL-plus data summer	5	5	5	5	5	5	5	5	5	5	5	5
MWTL-plus data winter	5	5	5	5	5	5	5	5	5	5	5	5
SCANS type survey										250		
Monitoring requirement	A	+ +	B	+ +	C	+	D	+				

+ North Sea population estimate every 10 years
+ coordination with Belgium and Germany
+ use of MWTL-plus (with adjustments)
+ low costs
- no annual estimates available for trend analyses
- very low power to detect trend

Detectable trend: between 6 and 7.5% annual change or decrease of 50-58% or more after 12 years
Annual cost: 110.8 k€

4.2.9 Scenario IX

This scenario provides a compromise to survey during spring for two years, then during summer for one year. Reducing the number of surveys in one season in the 12 year period will impact the probability of detecting a trend. The summer surveys would allow the coordination with neighbouring countries. Also, the newly designed bird surveys (MWTL-plus) could be used for an additional index of porpoise occurrence in other months *providing the method can be adjusted* (see textbox). The summer surveys

(Jul/Aug) could be used to calibrate the two survey types, thus effectively increasing the information on seasonal distribution. The decadal SCANS-type survey is included to obtain a population estimate for the North Sea harbour porpoise. This scenario provides adequate information for the monitoring requirements A-D as sketched in chapter 3.

4.3 Advice on scenarios

An overview of the scenarios in relation to the monitoring requirements (see chapter 3) is presented in table 4. Six out of nine scenarios, provide adequate information on monitoring requirements A-D. Scenarios IV, V and VI have a lower power to detect trends in abundance (monitoring requirement B) than the other scenarios, but they provide adequate information on monitoring requirements A, C and D.

Table 4. Overview of scenarios in relation to monitoring requirements (see chapter 3).

		Monitoring requirements				Trend within	Trend detection	Estimated costs
		A	B	C	D	year	12 years %	(k€)
Scenarios	I	++	+++	++	++	+*	50	200.8
	II	++	+++	++	++	-	50	174.2
	III	+	+++	++	+	-	50	94.2
	IV	+	+/-	+	+	-	58	60.8
	V	++	+/-	+	+	-	65	74.2
	VI	+++	+/-	+	+	+*	65	100.8
	VII	++	+++	++	+	-	50	127.5
	VIII	++	+++	++	+	+*	50	137.5
	IX	++	++	+	+	+*	50-58	110.8

*considered successful if surveying at least three seasons within one year

Based on the information in the previous chapters we advise to

- use the most cost-effective survey frequency that would still provide the best detectable trend
- conduct annual surveys during the same season every year to get the best chance of detecting trends (6% or more annual change, corresponding to a change of 50% after 12 years).
- conduct decadal SCANS-type surveys to provide abundance estimates for the North Sea

Scenario III combines the minimum survey effort to achieve this. This scenario provides a trend detection when a change of 50% or more after 12 years occurs. By only surveying one season, either information on the times of highest density (early spring) or the occurrence of calves (summer) will be lost. Surveys in spring have the highest power to detect trends. Summer surveys are most likely better when it comes to coordinating with neighbouring countries and their survey efforts.

To improve the information output of the monitoring program we advise to

- conduct additional surveys in more than one season

Scenario II (annual), **Scenario VII** (tri-annual) and **Scenario VIII** (tri-annual) meet this advice since they contain DCS wide surveys in two seasons: spring (annual) and summer ((tri-)annual). The summer surveys should enable a comparison with neighbouring countries and provide inter SCANS-type survey trend information. These scenarios provide a framework to bridge the gap between annual DCS wide spring surveys and internationally co-ordinated summer surveys of the entire North Sea.

Furthermore, we recommend

- to explore if MWTL-plus surveys have an added value for monitoring of harbour porpoise and to use bird surveys to additionally obtain annual seasonal information on occurrence of harbour porpoise.

Scenario VIII meets this advice in combining surveys in spring and summer with the MWTL-plus data.

All in all, we advise to choose one of the four scenarios **II, III, VII** and **VIII** to use as scheme for monitoring harbour porpoise abundance and distribution in Dutch waters.

5. Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2017 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

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Justification

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The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

Approved: S.M.J.M. Brasseur
Researcher

Signature:

Date: 24 October 2013

Approved: Drs. J. Asjes
Head of department Ecosystems

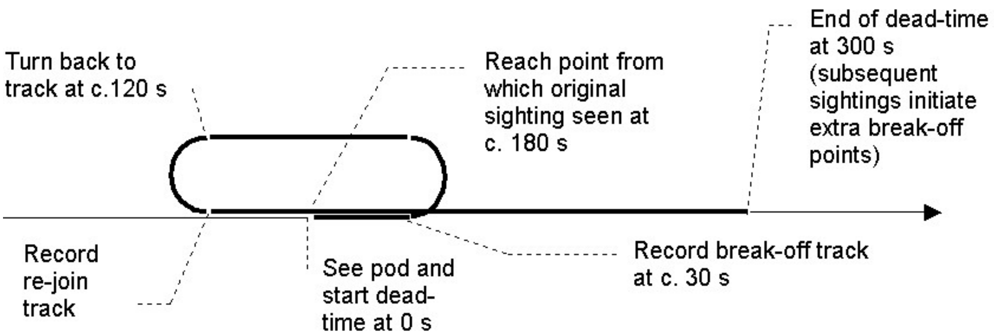
Signature:

Date: 24 October 2013

Appendix I. Details on the 'racetrack' method

As described in 2.4.4, during line-transect surveys a proportion of animals will not be seen. There are two reasons animals are not detected: 1. the availability bias and 2. the perception bias. The availability bias describes the chance that an animal is not visible to the observer, e.g. because it is diving. The perception bias describes the chance that the observer has missed the animal. To quantify the proportion of animals that are not seen directly on the track line (even though they are present), at the distance 0m, one needs to estimate the so-called g(0) value.

For aerial surveys several methods have been used to estimate the g(0) value, including using a combination of mark-recapture and dive data (e.g. Thomsen et al., 2006), a combination of land based observations and aerial surveys (Laake et al., 1997) as well as tandem flights with two planes or racetracks (circle back) (SCANS & SCANS-II). The tandem method was used during the SCANS survey in 1994 and evolved into the racetrack method. The main advantage hereby was that the logistics are much easier, as it only involves one airplane. This method has been successfully used during the SCANS II survey in 2005.



Flight path used to provide duplicate sighting effort over selected track line sections. The section from the recorded re-join point to the recorded break-off point is assigned to duplicate effort by the database management system.

The racetrack method

The racetrack method involves some doubling-back to re-survey previously flown transect segments with the same speed. The synchronous recording of GPS data, abeam times and declination angles allows the positions of pods sighted on the first and second sweeps of the plane (over flights) to be calculated. When deciding which of the pods seen on the first and second over flights are duplicates, the likelihood of the observed positions can be maximised with respect to (1) the parameters of models for the distribution of intervals between successive pods; (2) the succession of a pod's near-surface and diving phases; (3) its horizontal displacement between the times it comes abeam of the first and second over flights; and (4) the probability of it being detected as a function of its perpendicular distance from the aircraft. However, as it is impossible to determine which pod sightings on the first and second over flights are duplicates, it is necessary to sum the likelihood over all possible pairings. Some of the sighting times from the 2 over flights are too far apart to be duplicates. The remaining sightings form groups within which pairs of sightings from the first and second over flights may or may not be of the same pod. A recursive code is used to generate all possible pairings of sightings within each group (including the special case of no duplicates at all). These arrangements form an exhaustive set of mutually exclusive events so that the probability for the observed sighting positions equals the sum of the probabilities for each possible arrangement. In this way the likelihood for the data on each section of the survey conducted under consistent conditions is calculated; the log likelihood for the entire survey is obtained as the sum of the log likelihood for each section. Further details of the racetrack method and the analysis are described in Hiby & Lovell (1998) and Hiby (1999).

Some of the problems of this method are:

- knowledge that porpoises are there, thus the observers are more alert during over flight
- need between 50 and 100 circle backs and can only do this in areas with not too many porpoises;
- it is hard logistically to use this method in far offshore regions or during short survey days (e.g. winter) as the flight time is limited

Currently, however, the racetrack method is the best available method to obtain g(0) values.

Appendix II. Comparison of MWTL and IMARES surveys

As sketched in 2.4 the MWTL- and IMARES-surveys use different methods; strip transect and line transect distance sampling respectively. Apart from differences due the used methods there are some other inconsistencies which do not allow for a direct comparison of survey data. The main differences are summarized in table 1. These inconsistencies have to be addressed in the proposed bird monitoring surveys (Van Roomen et al., 2013) to facilitate obtaining additional data on harbour porpoise trends by means of a relative index.
Despite the methodological differences (Table 1), different survey dates and different weather conditions a rough comparison shows that the effort corrected numbers of observed harbour porpoises are highest during the IMARES survey in all periods (Table 2). The differences are smallest in June/July when the IMARES surveys have a 2.3 times higher sighting rate than the MWTL surveys and highest in February/March when the IMARES sighting rate is 62.5 times higher. Thus indicating that the IMARES surveys are more efficient in detecting harbour porpoises.

Table 1. Characteristics of the current IMARES and MWTL surveys and the proposed MWTL-plus surveys as far as determined yet.

	IMARES	MWTL	MWTL-plus
Method	Line transect distance sampling	Strip transect	Line transect distance sampling
Count strip	Calculated	Fixed strip of ca 100 m (observer dependent)	Fixed strip
Visibility below airplane	Animals from track line to ca 300 m	Animals below plane missed	Animals below plane missed
Distance of animals	Measured perpendicular to track line	Recorded in distance bins	Recorded in distance bins
Flying height	600 ft (183 m)	500 ft (165 m)	300 ft (92 m) or 500 ft (165 m) depending on season
Velocity	186 km/hr	163 km//hr coastal zone 225 km/hr offshore	Ca 180 km/hr
Suitable seastate surveys	≤ 4 Beaufort	≤ 5 Beaufort	≤ 5 Beaufort
Environmental conditions	Recorded whenever they change	Limited set recorded at fixed times	Recorded
Observation conditions	Four classes recorded whenever they change	Not recorded	Recorded

Table 2. Comparison of MWTL and IMARES surveys in 2010-2011 (adjusted from Geelhoed et al., 2011). The actual sightings are presented, corrected for survey effort.

Period	Survey	Survey dates	Effort (km)	Sightings (n)	n/km
Jun/Jul 2010	IMARES	5,6; 8-11; 18-20 Jul	6040	330	0.055
	MWTL	21, 23, 26 Jun	3006	71	0.024
Oct/Nov 2010	IMARES	12-14 Oct; 19, 21, 24 Nov	4028	163	0.040
	MWTL	26 Oct, 6, 6 Nov	2925	14	0.005
Feb/Mar 2011	IMARES	18, 19, 21-27 Mar	5945	743	0.125
	MWTL	28 Feb; 1, 7 Mar	4866	10	0.002