Current status of tagging harbour porpoises - application to the Dutch North Sea

Knowledge base report

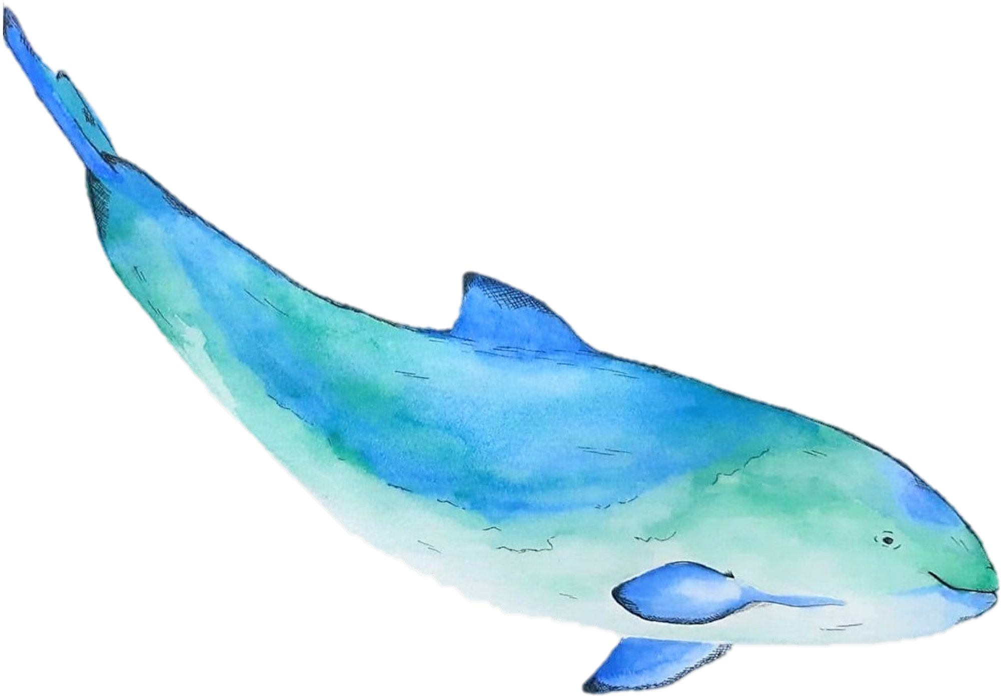
Author(s): Jip Vrooman, Steve C.V. Geelhoed, Meike Scheidat

Wageningen University &
Research report C017/22

Current status of tagging harbour porpoises - application to the Dutch North Sea

Knowledge base report

Authors:
Jip Vrooman, Steve C.V. Geelhoed, Meike Scheidat



This research project was carried out by Wageningen Marine Research and subsidized by the ministry of Agriculture, Nature and Food Quality for the purposes of Policy Support Research Theme 'Noordzee natuurbescherming en herstel' (project no. BO-43-116.01-010).

Wageningen Marine Research
IJmuiden, March 2022

CONFIDENTIAL ~~yes~~ / no

Wageningen Marine Research report C017/22

Wageningen University & Research

Keywords: harbour porpoise, telemetry, biologging, animal welfare, Dutch North Sea

Client: Ministerie van Landbouw, Natuur en Voedselkwaliteit
Attn.: Anne-Marie Svoboda
Bezuidenhoutseweg 73
2594 AC, Den Haag

BO-43-116.01-010

This report can be downloaded for free from https://doi.org/10.18174/567532
Wageningen Marine Research provides no printed copies of reports

Wageningen Marine Research is ISO 9001:2015 certified.

Photo cover: Steve Geelhoed
Figure cover: Jip Vrooman

Contents

Contents 3

Summary 5

1 Introduction 7

1.1 General background and scope 7
1.2 Workshops 2021 8

2 Research questions 9

2.1 Distribution 9
2.2 Foraging ecology 10
2.3 Habitat use 10
2.4 Cumulative noise impact 11
2.5 Cumulative effects 12
2.6 Other topics 13

3 Tag types and components 14

3.1 Transmission and archival tags 14
3.2 Tag attachment and release 14
3.2.1 Attachment through the skin 14
3.2.2 External attachment 15
3.2.3 Release mechanism and retrieval 15
3.3 Tag components 17
3.3.1 Location 17
3.3.2 Swimming behaviour 18
3.3.3 Acoustic data 18
3.3.4 Other components 19
3.3.5 Batteries 19
3.4 Current tag use on harbour porpoise 19
3.4.1 Wildlife Computers SPLASH/SPOT/MK10 or similar. 20
3.4.2 DTAG 20
3.4.3 Double attachment: V-tag/A-tag and ARGOS 21

4 Representative sampling 24

4.1 Sample size 24
4.2 Impact on behaviour 25
4.2.1 Behavioural reaction to tagging 26
4.2.2 Tag impact on natural behaviour 26
4.2.3 Using a rehabilitated animal 28

5 Collected data and link to research questions 29

5.1 Distribution 29
5.2 Foraging ecology 30
5.3 Habitat use 31
5.4 Cumulative noise impact 32
5.5 Cumulative effects 33
5.6 Other research questions 34
5.6.1 In human care 34
5.6.2 Rehabilitated animals 34

5.6.3 Other samples and information 34

6 Animal welfare and ethics **39**

6.1 Tagging phases 39
6.1.1 Catch 39
6.1.2 Restraint 40
6.1.3 Tag attachment 40
6.1.4 Post-tagging (deployment) 40
6.2 Adverse reactions / health risks 40
6.2.1 Skin and subcutaneous lesions 41
6.2.2 Stress 41
6.2.3 Aspiration pneumonia 41
6.2.4 Pulmonary oedema 41
6.2.5 Myopathy 42
6.2.6 Reaction to medication 42
6.2.7 Pain 42
6.2.8 Injury through tag attachment 42
6.2.9 Hydrodynamic drag 43
6.2.10 Decreased fitness 43

7 Conclusions and recommendations **44**

8 Quality Assurance **46**

Acknowledgements **47**

References **48**

Justification **59**

Annex 1 Report international workshop **60**

Annex 2 Report stakeholder workshop **65**

Annex 3 Aarhus University protocol when handling porpoises (Teilmann, 2021, *personal communication*) **69**

Summary

The recently updated Conservation Plan for the Harbour Porpoise (hereafter 'Conservation plan') identifies the research priorities that are currently considered most relevant for conservation of 'the Dutch' harbour porpoise (*Phocoena phocoena*). They include population abundance and distribution, (foraging) ecology and habitat requirements, analysis of strandings, effects of chemical pollution, incidental bycatch, and underwater noise. It also highlights the challenges of studying harbour porpoises in the wild, due to their small size, shyness, elusive nature and vast habitat. In lieu of concrete evidence from research, policy makers often have to rely on expert opinion or extrapolate information from studies in human care or from other marine species. To fill this gap the Conservation plan recommends to start a phased pilot study with tagging of harbour porpoises. To date, in the Netherlands, tagging has only been done in a limited number of studies on porpoises in human care, to assess certain effect of tags on harbour porpoises.

The aim of this report is to provide a comprehensive overview of the state of the art knowledge on tagging of harbour porpoises. To this end we discuss available tags and attachment methods, focussing on those that have been successfully applied in harbour porpoises, in order to answer the most eminent research questions for policy. Furthermore, this report discusses animal welfare and ethics, and the sampling of animals. This report builds upon a study by Scheidat et al. (2016) on the feasibility of tagging harbour porpoises in Dutch waters, and provides updates on the information therein, based on recently published literature. This report incorporates results from two workshops on the subject that were held in 2021. Finally, we provide a list of recommendations to consider.

In the future, tagging of harbour porpoises could help to fill knowledge gaps and complement current used methodologies to study aspects prioritised in the Conservation Plan, including distribution & abundance, foraging ecology, habitat requirements and use, cumulative acoustic impact of impulsive and continuous underwater noise and overall cumulative effects. We summarised the research priorities in the following overarching question: **How do harbour porpoises use the southern North Sea, and to what extent is this influenced by (anthropogenic) pressures?** This main question was further dissected into more specific research questions supporting the different research and conservation priorities.

There are various tag types available, the choice of which will depend mostly on the data required. Tags can be archival (often storing large amount or detailed data, but needing to be retrieved) or transmitting data (for example through satellite). Attachment can be external (e.g. with suction cups) or into body parts (fixed through the dorsal fin or anchored in the skin/dorsal fin). Additionally, there are various types of tag sensors and components, which can be combined in various configurations, depending on the research or monitoring questions. Those components can provide information on e.g. location, activity, diving and feeding behaviour, or acoustic and/or environmental data can be collected. The most used tag set-ups for harbour porpoise over the last years are the Wildlife Computers SPLASH and SPOT tags (satellite transmitters) and the acoustic DTAG or ATAG and the VTAG (archival tags). Depending on the research question, the one or the other is more suitable.

An important question to answer is "How many animals should be equipped with tags to acquire meaningful data?". This includes taking account of individual, but also temporal and spatial variation. To answer this question the representativeness and the statistical power of the collected data with regard to the research question should be taken into account. A single animal could provide valuable insights. However, to collect data that is representative for the population, more animals need to be tracked. Additionally, mortality of individuals, transmitter failure, and limited duration of batteries can result in a limited amount of data. Some research questions formulated in this report, such as those regarding distribution and habitat preferences, would require substantial numbers of tagged animals (10-100) and long term data-collection. Realistically, collecting and tagging enough animals will take several years.

The rationale for tracking harbour porpoises in Dutch waters is to obtain local data that will help to answer critical management and conservation questions. This method will, however, impact individual animals (by catching, handling and through tag attachment). It is thus necessary to weigh animal welfare issues against the potential conservation benefits of using this method. Harbour porpoise tagging consists of four phases. The first three involve humans' direct interaction with the animal through (1) the catch (not applicable to rehabilitated animals), (2) restraining and handling the animal, and (3) the tag attachment. The next phase (4) is the time the animal is at sea with the tag (deployment). In every phase animal welfare issues can occur, including stress, pain, tissue lacerations, aspiration pneumonia, reactions to medication and hydrodynamic drag. These effects can be minimised by working with experienced people and proceeding according to the newest insights, both in tag choice and protocols to follow. In the Netherlands there is no experience in capturing wild porpoises and hardly any in tagging harbour porpoises. Initial projects will necessitate help and training from experienced groups, to develop the required skills. We suggest starting by tagging rescued and rehabilitated animals, where animals can be followed in controlled conditions before release. It is likely that it will take several years before sufficient wild animals can be caught to fully answer many of the research questions formulated in the Conservation Plan.

Concluding, tagging of harbour porpoises is a valid approach to help answer some of the policy-related research questions prioritized in the porpoise Conservation Plan. Moreover, porpoises have been successfully tracked in other countries, such as Denmark. Learning from experiences such as these may help to limit potential welfare risks to the animals and carefully weigh the expected benefits. On the long term, tagging could provide valuable data on distribution, foraging ecology, and habitat use of harbour porpoises, as well as on anthropogenic impacts on harbour porpoises, while on the short term individual animals may provide first insight into movements, certain behaviour and physiological capacities specific to the shallow Dutch waters. Following animals in the southern North Sea could prove valuable in comparison to the other areas where porpoise have been tracked, such as Denmark. The use of telemetry is expected to substantially add to the knowledge on harbour porpoises in the area, which can be implemented in the protection or conservation of the animals.

We recommend to conduct tagging research in a phased approach, to ensure to have the lowest impact possible on animals and to leave room to decide on adjustment or even discontinuation of the tagging research. Various subjects should be considered during this phased approach, including clear research objectives, early involvement of experienced research teams, training of involved staff, regular assessment moments, risk assessment for animal welfare, use of most suitable tags, evaluation of effect of tag on porpoise behaviour and individual assessment of harbour porpoises.

1 Introduction

1.1 General background and scope

The recently updated Conservation Plan for the Harbour Porpoise (hereafter 'Conservation plan') identifies the research priorities for the conservation of 'the Dutch' harbour porpoise (*Phocoena phocoena*) (Ministry of Agriculture Nature and Food Quality, 2020). They include population abundance and distribution, (foraging) ecology and habitat requirements, strandings, and effects of chemical pollution, incidental bycatch, and underwater noise (impulsive and continuous). The plan also highlights the challenges of studying wild porpoises due to their small size, shyness, elusive nature and vast habitat. In lieu of concrete evidence from research, policy makers often have to rely on expert opinion or extrapolate information from captive studies or other marine species (Booth et al., 2016; Kastelein et al., 1997a). To fill some of the knowledge gaps related to distribution, habitat use, and (diving) behaviour the Conservation plan recommends to start a phased pilot tagging harbour porpoises. To date, in the Netherlands, tagging has only been done in a limited number of studies on rehabilitated animals several decades ago, to assess the effects of tags on harbour porpoises (Kastelein et al., 1997b). Two animals were released into the wild, but both tags stopped transmitting 16 hours after release, which suggested a technical (electronic) malfunction (Kastelein, 2022, *personal communication*). Also the effect of a transmitter was tested on a harbour porpoise in a floating pen (Geertsen et al., 2004); it was concluded that the increased drag due to the transmitter caused an increase in food intake of the animal.

The development of tagging as a method to study cetaceans has been reviewed in a large number of papers e.g. (Bograd et al., 2010; McIntyre, 2014). The suitability of tagging harbour porpoises in Dutch waters was reviewed in Scheidat et al. (2016). Tagging wild harbour porpoises at a large scale in Denmark, has provided information on distribution (Edrén et al., 2010; Mikkelsen et al., 2016; Nielsen et al., 2018; Sveegaard et al., 2012), habitat preferences (Sveegaard et al., 2011a), bycatch risk (Kindt-Larsen et al., 2016), foraging strategy (Pierpoint, 2008; Teilmann et al., 2007; Wisniewska et al., 2016), predator-prey relationships (Sveegaard et al., 2012), energy budgets (Pierpoint, 2008; Rojano-Donãte et al., 2018; Yasui et al., 1986), influences of environmental variability on movements (Stalder et al., 2020; van Beest et al., 2018b) and responses to (sound) disturbance (van Beest et al., 2018a; Wisniewska et al., 2018b). This information contributed to a better understanding of the ecology of the species, providing knowledge for the conservation of harbour porpoises. Furthermore, these studies have provided information on the effect of the tags on the tagged individuals (Berga et al., 2015; Geertsen et al., 2004; van Beest et al., 2018a). It should be kept in mind that some of these studies, specifically those on distribution and habitat preferences, involved substantial numbers of tagged animals (e.g. 39 (Edrén et al., 2010), 30 (Nielsen et al., 2018), 34 (Sveegaard et al., 2012), 64 (Sveegaard et al., 2011a). However, studies with fewer (<10) animals have also yielded valuable information, such as on foraging and responses to disturbance (Sørensen et al., 2018; van Beest et al., 2018a, 2018b; Wisniewska et al., 2016, 2018b).

Although telemetry and biologging studies provide for valuable information, they often come at a cost for individual animals – the handling of an animal and the attachment of the tag may cause pain and stress, and therefore be detrimental to the wellbeing and/or health of the tagged animal. It is therefore crucial to thoroughly explore and substantiate the need for such research, as well as to take precautionary measures to minimize negative effects to the animal if tagging research is conducted.

The aim of this report is to provide a comprehensive knowledge base on tagging of harbour porpoises. Based on the research priorities in the Conservation Plan a list of research questions to which tagging might contribute are formulated. Consecutively we discuss available tags and attachment methods, focussing on those that have been successfully applied in harbour porpoise, in order to answer those most eminent research questions for policy. Furthermore, this report discusses animal welfare and ethics of capturing, tagging and tracking these wild animals. We also discuss sampling representativity and required sample sizes depending on the data required to study different aspects. This report builds upon a study by Scheidat et al. (2016) on the feasibility of tagging harbour porpoises in Dutch waters, and provides updates on the information therein, based on recently published literature. This report also discusses results from two workshops on the tracking of porpoise that were held in 2021 (see section 1.2). Finally, we provide a list of recommendations to consider when tagging studies are to be carried out in the Netherlands.

This report aims to provide a knowledge basis for the development of a step-by-step action plan on how to proceed with tagging research on harbour porpoises in Dutch waters and potentially beyond. This work will be commissioned by the ministries of LNV (Agriculture, Nature and Food Quality) and EZK (Economic Affairs and Climate Policy), involving multiple stakeholders.

1.2 Workshops 2021

Two online workshops were held in 2021. The first (held in April) was an international workshop in which selected experts briefed Dutch science and government representatives on the current knowledge and options to tag harbour porpoises. An overview of (developments in) the currently available tags for harbour porpoises was given. Additionally, a telemetry scientist reflected on his experience with catching and tagging harbour porpoises, elaborating on stress, healing and behaviour. Lastly, an overview was provided of research questions which could be answered by tagging studies. The implications of all three presentations were further discussed. A good understanding was obtained on the benefits of tagging - it became clear that for certain information important for the conservation of harbour porpoises, no good alternative is available, and tagging is essential to fill these information gaps. Moreover, tagging can provide a connection between different types of studies (Figure 1.1). Furthermore, good understanding was achieved of the issues that should be solved and the capabilities needed before telemetry and biologging studies can be started. This included logistical challenges, but also specific attention should be paid to animal welfare. For a detailed report of the meeting see Annex 1.

A second workshop was held in May, in which the options for tagging were discussed with relevant stakeholders, mainly NGO’s. Government objectives were presented, and experiences with tagging of stranded cetaceans in the USA, including harbour porpoise, were shared. Furthermore, the potential use of a Dutch rehabilitation centre in a tagging pilot project was discussed. For a detailed report of the meeting see Annex 2.

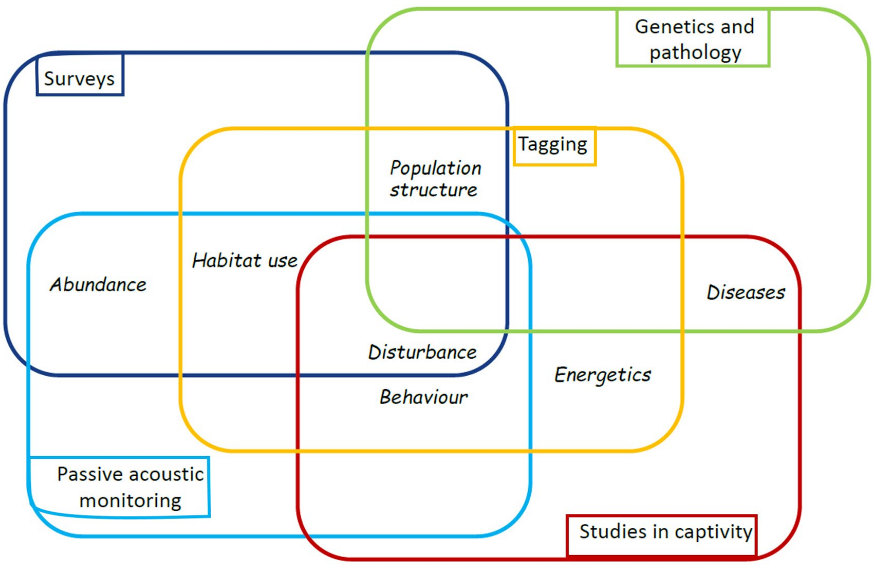


Figure 1.1. Figure on various type of studies and what kind of information they can provide/collate, adapted from Jakob Tougaard (Tougaard, 2021). Tagging, in combination with other surveys, can provide information on various aspects, such as habitat use, disturbance, behaviour, energetics and population structure.

2 Research questions

The Conservation Plan identifies a number of research and conservation priorities for harbour porpoise conservation in the southern North Sea, in order to provide information required for national and international agreements, such as the Habitats Directive, MSFD, ASCOBANS, OSPAR, CFP, CMS and IWC, as well as national permitting procedures, such as for offshore wind (Ministry of Agriculture Nature and Food Quality, 2020). Tagging of harbour porpoises can, on the long term, help to fill knowledge gaps and complement currently used methodologies for the following priority areas identified in the Conservation Plan: distribution and abundance, foraging ecology, habitat requirements and use, cumulative acoustic impact of impulsive and continuous underwater noise and overall cumulative effects (page 11 of the Conservation Plan). The use of telemetry is expected to substantially add to the knowledge on harbour porpoises in the area, which can be implemented in the protection or conservation of the animals.

We summarised the research priorities in the following overarching question:

- **How do harbour porpoises use the southern North Sea, and to what extent is this influenced by (anthropogenic) pressures?**

This main question can be further dissected into more specific research questions for the different research and conservation priorities (Table 2-1). In the next chapters the feasibility of tagging data to (help) answering these questions will be assessed.

Table 2-1. Research priorities and accompanying research questions

Priority	Research question
Distribution	1. What are the large-scale movements of porpoises in the southern North Sea?
	2. What is the home-range of harbour porpoises in the southern North Sea?
Foraging ecology	3. Where and how often do harbour porpoises forage?
	4. What kind of prey do porpoises feed on, how does it change over time?
Habitat requirements & use	5. What is the habitat use of porpoises in the North Sea? Are there important/key or preferred habitats?
	6. How much time and energy is spent on various behaviours?
	7. Is habitat use influenced by the presence of offshore and nearshore structures such as OWFs, marine energy devices and oil and gas platforms?
	8. Is habitat use influenced by other human activities such as fishing or shipping?
Cumulative noise impact	9. How do individual porpoises react to impulsive and continuous man-made sound?
	10. What is the noise exposure for harbour porpoises in the southern North Sea?
Cumulative effects	11. What is the impact of cumulative human effects on harbour porpoise in the North Sea?
Abundance	*No specific research question formulated but tagging can provide information.*

It is acknowledged that with small sample sizes the questions in the next sections can be answered for a few (potentially rehabilitated) *individual harbour porpoises* only. Though by doing so, we will be able to develop the method and possibly some insight into how the animals move in their environment. With larger sample sizes, in the future inferences could be made on a broader *population* level. Given the expected individual variation, differences between age classes or sex, seasonal and annual changes, large numbers of animals will have to be tracked over longer periods of time to fully answer many of the questions below. The issue of representative sampling and sample sizes will be discussed in more detail in chapters 4 and 5.

2.1 Distribution

1. **What are the large-scale movements of porpoises in the southern North Sea?**
   Although information is available about large-scale movements of harbour porpoises in Denmark and Greenland (Nielsen et al., 2018; Sveegaard et al., 2011a; van Beest et al., 2018b), little is known about their movements in the southern North Sea. The southern North

Sea is one of the busiest sea areas in the world (Emeis et al., 2015), with a wide array of human activities that can have a negative impact on porpoises. Providing a substantial sample is collected, information about distribution and large-scale movements of harbour porpoises in Dutch waters will shed light on connectivity between areas relevant for harbour porpoise within the North Sea, and aid in finetuning the relevant management scales for the conservation of harbour porpoises in this area.

2. **What is the home range of harbour porpoises in the southern North Sea?**
   Telemetry studies demonstrated that the extent of the home range of harbour porpoises tagged in Denmark (Inner Danish Waters, Kattegat, Skagerrak and North Sea) was entirely different from that of porpoises tagged in Greenland (Nielsen et al., 2018). Porpoises tagged in Denmark were limited to the continental shelf, while the porpoises tagged in Greenland spent a vast amount of time in the mid-Atlantic deep-water areas. In addition, there were large differences in the home ranges between individuals from the same region, for example in relation to gender or age (Sveegaard et al., 2011a). Some harbour porpoises tagged in Danish waters showed high site fidelity, while others ranged much further (Sveegaard et al., 2011a; Teilmann et al., 2008). Home range may also provide information on potential (sub)population delineation (Olsen et al., 2022; Sveegaard et al., 2015). Little is known about the home range of harbour porpoises in the southern North Sea.

2.2 Foraging ecology

3. **Where and how often do harbour porpoises forage?**
   Harbour porpoises have the highest metabolic rates of all studied toothed whales, and have been shown to forage at high rates (Booth, 2020; Hoekendijk et al., 2017; Kastelein et al., 1997a; Lockyer et al., 2003; Rojano-Donãte et al., 2018; Wisniewska et al., 2016, 2018a). Information on their diet in Dutch waters is available from stomach content analyses of stranded porpoises (Leopold, 2015) and to a lesser extent from analyses of stable isotopes in muscles and bones (Jansen et al., 2012). Though in aerial surveys there are sometimes patters in distribution suggesting areas may be of more or less interest for the porpoise, it is largely unknown where harbour porpoises forage in the (southern) North Sea. By tracking porpoises, insight could be gained on preferred feeding habitats.

4. **What kind of prey do porpoises feed on, how does it change over time?**
   Where harbour porpoises forage in the water column and how much time they spend foraging near the bottom or pelagic is only partly understood, but this information can be used as proxy for benthic or pelagic prey (Teilmann et al., 2007; Wisniewska et al., 2016, 2018a). Prey availability and choice in the southern North Sea could be different than in Danish waters. Changes in harbour porpoise foraging patterns could be linked to fishery activities, e.g. due to resource depletion, or changes in fish stocks due to, for example, climate change (Perry et al., 2005). In addition, human activities can disturb feeding behaviour of porpoises which may have consequences for the fitness of individuals (Wisniewska et al., 2018b). IJsseldijk et al. (2021a) demonstrated in stranded animals that high energy food might be essential for successful reproduction in harbour porpoises. Obtaining data on feeding behaviour in in relation to human activities would provide much needed information to quantify its effect (e.g. Wisniewska et al., 2018b).

2.3 Habitat use

5. **What is the habitat use of porpoises in the North Sea? Are there important/key or preferred habitats?**
   The North Sea provides various habitat types, with different characteristics like depth, sediment type, turbidity, currents and productivity. There are deeper and relatively muddy sediments on the Central Oyster grounds, shallower areas in the coastal zone, further North sand banks such

as the Dogger Bank, high-productivity areas such as the Frisian Front and (rocky) reef areas such as the Cleaver Bank region or the Borkum Reefground. While large-scale surveys and spatial modelling provide some insight in preferred habitat types, the underlying drivers are still poorly understood (Gilles, 2009; Gilles et al., 2011; van Beest et al. 2018; Stalder et al., 2020). Detailed data on habitat use of porpoises (e.g. time spent/ specific behaviour displayed in different habitats) in the southern North Sea would help understanding what key or important habitats are or which habitats could be important if undisturbed. This is vital information for marine spatial planning as well as for the management of marine protected areas in the region. It also provides input that allows more accurate predictive modelling of the impact of changing habitats.

6. **How much time and energy is spent on various behaviours?**
Harbour porpoises spend time on different behaviours, like resting, sleeping, feeding, and travelling which, when quantified, provide a time-energy budget (Teilmann et al., 2007, 2013; Wright et al., 2017). The time-energy budget can differ between gender, age, time of year, life stage (including pregnancy) or different areas. It can also be affected by human activities, disrupting specific behaviour. Time budgets and the influence of human activities thereon are also a vital component of modelling approaches to assess effects on populations.

7. **Is habitat use influenced by the presence of offshore and nearshore structures such as OWFs, marine energy devices and oil and gas platforms?**
The number of offshore wind farms in the southern North Sea is increasing. The primary concern for harbour porpoises is their disturbance due to the emission of impulsive noise during construction (Brandt et al., 2011, 2018; Geelhoed et al., 2018). However, the potential impact of operating OWF's is not well understood. An increase in local prey availability due to a "reef effect" could lead to a local attraction of porpoises. As operating OWFs are associated with increased vessel traffic for servicing, however, this could disturb porpoises and pose a barrier for porpoises moving throughout the North Sea (Teilmann et al., 2012). It is yet unknown to what extent distribution and habitat use are negatively or positively influenced by OWF's, or by other anthropogenic offshore and nearshore structures. Data on the behaviour and movement of harbour porpoises in and around these structures can help answering these questions and can be used for taking mitigation measures (Nabe-Nielsen et al., 2018).

8. **Is habitat use influenced by other human activities such as fishing or shipping?**
Data on harbour porpoise habitat use does not only inform on their habitat needs, but also on influences of human activities on these needs. As mentioned before, the southern North Sea is a very busy sea. Different types of vessels not only cause continuous noise which might affect porpoise behaviour (see section 2.4), but they also cause a risk of collision (Schoeman et al., 2020). In addition, there can be an overlap between fishing areas and porpoises when fishermen and porpoises exploit similar resources (Herr et al., 2009; Kindt-Larsen et al. 2016). With improved understanding on what habitat needs porpoises have and how human activities can impact them, targeted conservation actions can be developed for the region.

2.4 Cumulative noise impact

9. **How do individual porpoises react to impulsive and continuous man-made sound?**
Harbour porpoises use sound to navigate, forage and communicate. Hearing is their main sense, and one of the main concerns for harbour porpoises in the North Sea is their susceptibility to both impulsive and continuous noise (Lucke et al., 2009; Ruser et al., 2016). Studies using passive acoustic monitoring and aerial surveys have demonstrated that harbour porpoise activity was affected by pile driving up to around 25 km distance (Brandt et al., 2011; Dähne et al., 2013; Geelhoed et al., 2018). Seismic activity has also been shown to lead to a temporary decline in acoustic activity of harbour porpoises (Pirotta et al., 2014; Sarnocińska et al., 2020), and harbour porpoises have been shown to react negatively to acoustic harassment devices used against seals (Olesiuk et al., 2002). Additionally, shipping noise is a major source of noise in the North Sea that may impact porpoises (Hildebrand, 2009; Malakoff, 2010).

Tagging studies on larger species, e.g. Cuvier's beaked whale (*Ziphius cavirostris*), long-finned pilot whale (*Globicephala melas*), killer whale (*Orcinus orca*) and sperm whale (*Physeter macrocephalus*) show behavioural responses to impulsive noise (Deruiter et al., 2013; Isojunno et al., 2017; Miller et al., 2012). Telemetry studies with seals have indicated avoidance and different behavioural responses to pile-driving activities (Aarts et al., 2018; Russell et al., 2016). However, only limited studies exist on actual movements and behaviour of individual harbour porpoises in relation to impulsive or continuous noise (Nachtsheim et al., 2021; Schaffeld et al., 2020; van Beest et al., 2018a; Wisniewska et al., 2018b). Do porpoises go to other locations where they can forage? What does that look like in the Southern North Sea? Do they continue foraging after acoustic disturbance, or do they stop foraging for prolonged periods? Such information can, in combination with other types of data, shed light on how disturbances cumulatively change activity and energy budgets, and feeding efficiency.

10. **What is the noise exposure for harbour porpoises in the southern North Sea?**
    In relation to the question above, it remains largely unknown what the noise exposure of harbour porpoises in the North Sea is. Are they exposed to noise almost continuously, or only in certain areas or during some periods? How often are they exposed to noise above certain threshold levels? Combined with habitat use this can also shed light on the interaction between noise exposure and preferred habitats. Do porpoises (need to) select inferior areas to avoid noise, or conversely, endure noise to access better areas?

2.5 Cumulative effects

11. **What is the impact of cumulative human effects on harbour porpoise in the North Sea?**
    Also specified as a priority in the Conservation Plan, in the context of changing climate and other large-scale changes of the North Sea ecosystem, cumulative effects will become more relevant in the (near) future. Assessing the cumulative impacts from human activities on porpoises is challenging. Harbour porpoise distribution and abundance is driven by their environment, defined by the conditions (such as temperature), resources (e.g. food) and risks (predation, human activities) (van der Meer et al., 2020), and human-induced effects work through complex interaction between environmental conditions and resources as well as diverse risks.

    Different approaches have been discussed and applied to assess single or cumulative risks to harbour porpoises; all approaches have limitations (Scheidat et al., 2013; Heinis and de Jong, 2015; Aarts et al., 2016; Booth et al., 2016; Piet et al., 2017; Merchant et al., 2018; Nabe-Nielsen et al. 2018; von Benda-Beckmann et al., 2019; Harwood et al., 2020; RWS et al., 2020). It has recently been suggested that standardized modelling approaches that integrate individual behaviour with demographic frameworks are the best way forward (Johnston et al., 2019, and see Figure 2.1). Examples of this integration of Individual Based Models within a population model framework are studies on the influence of harbour porpoises movement strategy on the cumulative effect of underwater explosions (Aarts et al., 2016) and on the effect of pile-driving noise on the harbour porpoise in the North Sea (Nabe-Nielsen et al., 2014; van Beest et al., 2015) in the DEPONS (Disturbance Effects of Noise on the Harbour Porpoise Population in the North Sea) project.

    However, models are as good as their data input. Only with good data they are useful as a tool to simulate current or future scenarios. One of the shared challenges in all approaches is the lack of data regarding how porpoises interact with their environment. Porpoise tagging can potentially fill these data gaps.

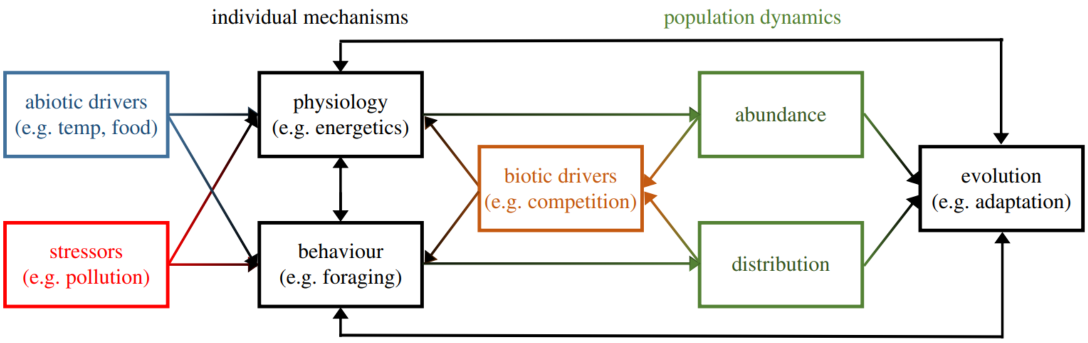


Figure 2.1 Conceptual standardized mechanistic approach for predicting animal population dynamics in response to spatially explicit abiotic drivers (blue) and multiple stressors (red). Data on individual mechanisms (black) is needed as they drive shifts in population abundance and distribution (green). In addition, biotic drivers (orange) cause feedbacks between population dynamics and individual mechanisms. Adapted from (Johnston et al., 2019).

2.6 Other topics

Harbour porpoise abundance is currently mainly inferred from aerial surveys. However, to obtain abundance estimates from aerial surveys correction factors for observer bias and availability of porpoises are needed (Buckland et al., 2015). Information on dive patterns from tagged animals can be used to validate and improve the accuracy of the so-called availability bias in such correction factors (Teilmann et al., 2013).

To derive absolute numbers of harbour porpoises from PAM recordings, another important type of information one can only obtain from tagging with acoustic recorders is the mean click production rate. This multiplier can be used to convert PAM measurements of click-rates to absolute numbers of animals per km^2, through application of distance sampling methods (Marques et al., 2013).

Other research questions that might not be a first priority for policy, but are relevant for optimizing any tagging study, can potentially be answered while or before investigating the questions in sections 2.1-2.5. These research questions include:

In human care:
- Is there a difference between the behaviour of tagged individuals compared to untagged animals, and how does this relate to tag type and tag placement?
- How long after the application of a tag does behaviour return to 'normal' or reference behaviour and how is this influenced by the type of tag and the tag placement?
- What is the impact of tag placement on the performance of the tag and (if applicable) data transfer (Mul et al., 2019)?
- What is the impact of tags on the health of a harbour porpoise?

In the wild:
- How representative are rehabilitated individuals compared to animals that have not gone through a rehabilitation trajectory?

3 Tag types and components

The term *tag* describes the device that is attached to the animal and can contain different types of components (e.g. sensors, GPS, transmitting device). There are different combinations of components possible, depending on the research question as well as limitations such as size, shape, weight, buoyancy, transmission capacity, memory size, sampling frequency and battery life.

Development of tag technologies and attachment are ongoing, such as the use of a silicon-printed "marine skin" with environmental sensors (depth, temperature, salinity) that is flexible, thin and stretchable (Karimi et al., 2019; Nassar et al., 2018). However, it does not seem likely that those kind of tags will be available for porpoises in the foreseeable future. In this report we focus on the most commonly used tag components for small cetaceans, that have been proven to provide reliable data and that have to some extent been investigated regarding their impact on porpoise behaviour, physiology and health.

3.1 Transmission and archival tags

There are two basic approaches to collect data from tagging cetaceans. The first is that data is transmitted while the tag is attached to the animal (Block, 2005). Data transmission can only be done during the short period that the tagged animal surfaces, and amount of data that can be sent is limited. There is currently a push to develop 'smart tags' that are long-duration, process data onboard and telemeter back summarized results (Heerah et al., 2015; Skubel et al., 2020). Tags can already do this to some extent, but with improved equipment and technology, this will allow for future studies to combine the benefits of high-resolution sampling with long duration attachments.

The second approach uses an archival tag which needs to be retrieved so the data can be extracted.
Usually the tag collects more information, that is more difficult to send. Often the tag releases as a result of weak attachment or a planned release mechanism. To prevent it from sinking it is made buoyant, and is therefore larger.

3.2 Tag attachment and release

There are different types of tag attachments, with definitions provided in Andrews et al. (2019) & IWC (2020). For harbour porpoises there are currently two forms of tag attachment used, one is using one or more pins through the dorsal fin (aiming at longer deployment) and the second one is using suction cups (tracking for a short time). The attachment type used depends on the tag itself and on how long it is meant to stay on the animal.

3.2.1 Attachment through the skin

This tag attachment intentionally pierces the skin, using either anchors or bolts to secure the tag to the animal, and is therefore considered invasive (Andrews et al., 2019). These tags are used for long-term studies and can stay on an animal for several months or years (e.g. Sveegaard et al., 2011; Nielsen et al., 2018).

Bolt-on tags are attached by piercing through tissue. This can be done as a "spider-leg" tag, where the tag is connected through several connection points on the body, or as one or more pins that go through the dorsal fin (Figure 3.1, Figure 3.3b and c). To attach these tags, animals need to be fixated during handling. The tags can be attached to the trailing edge (Figure 3.3c) or through the dorsal fin/dorsal ridge (Figure 3.3b) (Balmer et al., 2019; Nielsen et al., 2018). In all cases the position of the bolts should be carefully chosen, because the dorsal fin contains a large amount of nerves and blood vessels.

Moreover the tag needs to be attached securely to prevent it from migrating through the fin by hydrodynamic drag (also see section 6.2.9).

Figure 3.1. Examples of bolt-on tags, 'spider-leg' (left) and trailing edge of dorsal fin (middle) (Andrews et al., 2019) and mounted to the side (right) (Sonne et al., 2012).

Anchored tags are – as the name implies, anchored in the tissue under the skin, and are primarily attached remotely, such as via a crossbow, pneumatic gun or a pole. The electronic section of the tag can be outside of the skin, or in so-called consolidated tags, it is part of the anchor itself. The anchoring is typically done in the body or the dorsal fin. *Limpet* (Low Impact Minimally-Percutaneous External-electronics Transmitter) *tags* (Figure 3.3*a*) are a form of anchored tags that are attached remotely but do not penetrate deeply into the skin, generally not past the blubber layer. They are considered more suitable for medium-sized cetaceans (e.g. Reisinger, 2014; Olsen et al., 2018). For harbour porpoises anchored tags are currently not suitable, as the presently available anchors are so large that they would penetrate muscles.

3.2.2 External attachment

External tag attachments include devices that do not penetrate the skin, such as harnesses and suction cups (Figure 3.2, Figure 3.3d). They have been successfully applied to Yangtse finless porpoises (*Neophocaena asiaeorientalis asiaeorientalis*), Dall's porpoise (*Phocoenoides dalli*) and harbour porpoises (Akamatsu et al., 2005; Hanson et al., 1998; McDonald et al., 2021; Sørensen et al., 2018; Wisniewska et al., 2016, 2018b). Attachments can last for hours up to days (McDonald et al., 2021; Wisniewska et al., 2016).

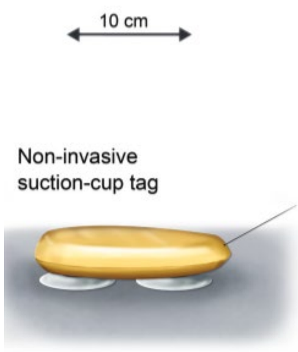


Figure 3.2. Non-invasive suction cup tag (Andrews et al., 2019)

Remotely deployed (e.g. through crossbow, pneumatic gun or a pole) external tags have been successfully used for a range of larger cetacean species (Davis et al., 2007; Mate et al., 2011; Tyack et al., 2011), and to a lesser extent for small species like Dall's porpoise (Hanson et al., 1998). They are not suitable for harbour porpoises yet, although some biopsy sampling with crossbows of porpoises at sea has been done in the 90s (Chivers et al., 2000). Future technological advances might therefore allow for use of remotely deployed tags on porpoises.

3.2.3 Release mechanism and retrieval

Tag release can be done remotely through a timer that can trigger a very small explosion (Berga et al., 2015), by timing a current through a corroding a wire, using magnesium as a corroding link or an acoustic trigger that can be used if the tag is in close enough range to receive an acoustic signal to trigger the release. The latter is only used on pinnipeds that rest on land.

For tags that are attached with pins, most commonly the release can be roughly planned through the use of corrodible nuts, or bolts that hold the pins of the tag in place (Hanson, 2001; van Beest et al., 2018b). One of the corrodible materials often used is magnesium. Suction cup tags can also be released by using metal wires that will corrode and disturb the vacuum so water will enter the suction cups. It is also possible to have no release mechanism in place or very slowly corroding materials like iron, in which case the tags will likely stay attached for a long time with data transmission being limited by battery power.

For harbour porpoises the retrieval of an archival tag is generally done by adding a satellite tag (or transmitter in part of the tag) that transmits its position. As the signal transmission frequency of the ARGOS system (see section 3.3.1.1) is generally too low for retrieval (once every 45 seconds), a VHF or UHF transmitter can be added. This radio beacon signal can be detected more accurately through a dedicated search in the area that is indicated by the ARGOS transmitted position (Mikkelsen et al., 2019; van Beest et al., 2018a, 2018b; Wisniewska et al., 2016). However, there is equipment to track the 45 second ARGOS signal, and some ARGOS tags can be programmed to transmit low level ARGOS signals every second, allowing for retrieval based on the ARGOS satellite signal. Either way, it should be underlined that retrieving a tag can be difficult (weather, current and terrain dependent), and is cost- and time intensive. This means that in some cases tags are lost and no data is collected.

Attachment of a(n anchored) limpet tag on a Blainville's beaked whale (Andrews et al., 2010) .

Multiple-pin attachment of two tags (on left and right side) on a Dall's porpoise (Hanson, 2001).

One-pin bullet tag attachment of a VHF transmitter (above) and a satellite tag (below) on the trailing edge of a bottlenose dolphin (Balmer et al., 2011).

A D-tag (see section 3.4.2) deployed at the base of a pilot whale's dorsal fin with the suction cups. Photo: Ari Friedlaender, https://phys.org/news/2014-10-law-sea-authorizes-animal-tagging.html

Figure 3.3. a-d Examples of a limpet, multiple pin, single-pin and suction cup attachment on small cetaceans.

3.3 Tag components

The various sensors and components of tags are summarized in Table 3-1 and discussed in detail in the next sections.

Table 3-1. Various tag sensors and components (full tag set-ups are discussed in Table 3-2).

Information	Component	Suitable for archival and/or transmission tags	Suitable for pinned and/or suction cup attachment
Location	ARGOS satellite transmitter	Both	Both
	Snapshot GPS	Both	Both
	VHF transmitters (relatively close range generally used for tag retrieval)	Archival	Both
Swimming and foraging behaviour	Time-depth/pressure recorders	Both	Both
	Accelerometers and magnetometers	Both (but with constraints on data rate in transmission tags)	Both
Acoustic data	Hydrophones	Archival (currently, transmission under development)	Suction cup
Other	Environmental data	Both	Both
	Video	Archival	Suction cup
	Heart function	Archival (because need for suction cup)	Suction cup

3.3.1 Location

Location sensors are always used in tags, since the geographical location of tagged animals is a basic data need. There are two main types; ARGOS and GPS.

3.3.1.1 ARGOS satellite transmitter

When the porpoise surfaces to breath, the ARGOS satellite transmitter attempts to send short transmissions to the ARGOS satellite system, usually every 45 sec when the animal is in water. Potentially several signals are received during each satellite pass and can then be used to calculate the location of the transmitter, a so-called location fix, using the doppler shift principle. Locations conveyed to the ARGOS centre can be downloaded in near-real-time, varying within five accuracy classes from 0 to a several kilometres. The accuracy varies from position to position and depends on the number of signals received. This can be influenced by inclination of the satellite pass, the number of messages received by the satellite, latitude, transmitter power, attachment on the animal and behaviour of the animal (and possibly also with weather conditions influencing wave height). The global coverage of the system makes it possible to track the tags anywhere in the world, but the system works better the higher the latitude as the satellites are polar orbiting (for an animation on the set-up of the ARGOS system see https://youtu.be/sP3oQxuz_gQ).

The transmitter only has to be in the air for 0.25 seconds to transmit the ID of the tag and sensor data. Satellite tags have a low power requirement, and are comparatively small, making them suitable for long-term tracking.

One disadvantage of the ARGOS system is that the location accuracy is variable and can range up to several kilometres, even with the application of models to improve the location assessment (Lopez et al., 2015). In general ARGOS locations are best suited for movements/migrations and home ranges, while the Snapshot GPS system (see section 3.2.1.2) is better for more precise locations necessary for fine scale analysis like movements within a wind farm or confined water systems (e.g. Costa et al., 2010; Dujon et al., 2014; Irvine et al., 2020).

In general, ARGOS satellite transmitters can be added to any type of tag, and can also be programmed to transmit low power signals that can aid in recovery, similar to VHF tracking (wildlifecomputers.com). The SPLASH tag (https://wildlifecomputers.com/our-tags/splash-archiving-tags/) is an example of a tag with an ARGOS satellite transmitter, that also allows the measurement of depth, temperature and light. The SPOT tag only provides locations (https://wildlifecomputers.com/our-tags/spot-ARGOS-satellite-tags/spot/). In Greenland, these tags were fin-mounted with a bolted, non-release attachment on porpoises, allowing them to be tracked for 1.5 years (SPLASH) and up to 3 years (SPOT) (Nielsen et al., 2018).

3.3.1.2 Snapshot GPS

The Snapshot GPS system (e.g. Fastloc GPS) is a receiving system, which means it has to receive signals simultaneously from several satellites to calculate a location fix. Snapshot GPS has a very high acquisition speed compared to normal GPS systems and needs much less than 1s and is thus suitable for harbour porpoises that surface only briefly. The accuracy depends on the number of satellite messages received, ranging from <30m (eight satellites) to <170m (five satellites) (Dujon et al., 2014).

The GPS data is stored in the tags memory and can either be transmitted or downloaded once the tag is retrieved (see section 3.1). In the former case, the GPS data can be directly relayed via an ARGOS transmission. However, the amount of data that can be transmitted is limited by the number of programmed daily ARGOS transmissions and how many GPS fixes are attempted, which means finding a balance between battery size and tag lifetime. On average one GPS location per hour is realistic (Irvine et al., 2020).

3.3.1.3 UHF and VHF transmitters

UHF and VHF transmitters/beacons can be added to archival tags to help locating them after release from the animal. They are not suitable for acquiring location fixes of tagged animals, instead they can be used to track an animal or a floating tag that has been released at a few kilometre range (van Beest et al., 2018b). Recent developments allow for ARGOS tags to be programmed to transmit low level ARGOS signals (UHF) every sec. This allows for recovery based on the ARGOS signal, without needing a separate UHF/VHF transmitter.

3.3.2 Swimming behaviour

3.3.2.1 Time-depth (or pressure) recorders

Time-depth recorders come in a variety of different shapes and sizes. They record the depth at a pre-programmed sampling rate. They are often used in combination with other sensors such as accelerometers and magnetometers providing high resolution data on how cetaceans dive (Nowacek et al., 2016). Most of them can be customized regarding data resolution, sampling rates and accuracies.

3.3.2.2 Accelerometers & magnetometers

Accelerometers in combination with magnetometers provide detailed information on how animals move under water, both in terms of 3D movements, feeding events (Wisniewska et al., 2016) and heading. They enable not only an interpretation of behaviour and energy expenditure, but, for example, also how this changes in response to noise, if noise data are available (Shepard et al., 2008; Williams et al., 2017a).

3.3.3 Acoustic data

3.3.3.1 Hydrophones

Hydrophones are used to record the sounds a tagged animal emits or is exposed to. Different types of hydrophones can be built into tags. The specifications depend on the aim of the study e.g. (Akamatsu et al., 2005; Blomqvist et al., 2005; Johnson et al., 2009, 2003; Lawson et al., 2015; Wisniewska et al., 2016), but can be used for:

- vocalisations from the tagged animal and conspecifics
- feeding buzzes and other foraging related sounds
- respiration rate from the tagged animal

- natural sounds in the sea, e.g. other animals and waves
- anthropogenic (background) sounds

Note however, that flow-noise generated by movement of the animal tends to mask ambient noise at lower frequencies.

3.3.4 Other components

3.3.4.1 Environmental data

Sensors can measure habitat characteristics such as temperature, light levels and salinity. This has been used not only to study habitat characteristics of marine animals, but also to provide hydrographic data e.g. (Roquet et al., 2013; Teilmann et al., 2020).

Another approach to understand the environment in which marine animals move is to have an AUV (autonomous underwater vehicle) follow animals that are satellite tagged and to sample the areas through which they moved (Wilmers, 2015). However, this is unlikely to work for porpoises, which are very shy and have an unpredictable movement pattern.

3.3.4.2 Video

Video cameras have been placed on a number of marine species to investigate their behaviour (e.g. crittercams, whale cam), but their use for small cetaceans had been limited due to their size. The new generations of underwater cameras are smaller in size, and have preliminary been used to monitor behaviour of porpoises in Denmark (Teilmann, 2021, *personal communication*). Their usefulness also depends on the water clarity.

3.3.4.3 Heart function

Suction cups have been used successfully on a number of cetacean species in human care to attach electrocardiogram (ECG) recorders (Aoki et al., 2021; Bickett et al., 2019). Two trained harbour porpoises in human care were equipped with an ECG-measuring sound-and-movement tag (DTAG-3, see section 3.4.2) providing data on how heart function was impacted by sound (Elmegaard et al., 2019). In a different study three trained harbour porpoises were equipped with a multi-sensor data logger to record heart rate while they were swimming and capturing prey (McDonald et al., 2018). In the wild these kinds of measurements have been done for blue whales (*Balaenoptera musculus*), narwhals (*Monodon monoceros*) and harbour porpoises (Goldbogen et al., 2019; McDonald et al., 2021; Williams et al., 2017b).

3.3.5 Batteries

Batteries are needed for the tags to function. The decision on what battery to use depends on the expected time of operation, sensors used and size and weight (Chung et al., 2021). Battery life expectancy is linked to size and weight, which could have a negative impact on the animal. Rechargeable batteries work well for archival tags, where the batteries can be charged before each deployment. Solar cells for recharging the batteries are not very efficient in cetaceans that spend little time at the surface. Trickle-charging is likely to become more topical, given the diversity of miniature energy harvesting systems available today, which range from mechano-harvesters through thermo-electric generators to radio-wave harvesters (Holton et al., 2021). Such recharging methods could potentially make the tag run forever on an animal.

3.4 Current tag use on harbour porpoise

The above-described tags consist of different components, including sensors, attachment and release mechanisms, batteries and housing. In this section we present a detailed description of three tag set-ups that have been applied to harbour porpoises. They are summarized in Table 3-2.

3.4.1 Wildlife Computers SPLASH/SPOT/MK10 or similar.

Wildlife Computers has various models of tags with ARGOS satellite transmitters, with various attachment configurations. Commonly used for harbour porpoise are the fin mounted SLASH or SPOT models. These were the main kind of tags that were used for the studies in Greenland and Denmark (Nielsen et al., 2018; Sveegaard et al., 2011a). The tags are bolted with one to three pins through the dorsal fin, either trailing or on the side of the fin (Figure 3.4).

The tags generally contain
- ARGOS satellite transmitter (SPLASH and SPOT)
- Time and pressure (depth) meter (SPLASH)
- Thermometer (SPLASH and more basic in SPOT)

In Denmark detachment occurred unaided through corroding bolts after 14 to 349 days, with a median duration of 98 days (Sveegaard et al., 2011a). In Greenland non-corrodible bolts were used, and one of the tags transmitted from the animal for almost 3 years (1047 days). Average transmission duration was 250 days (Nielsen et al., 2018).

Figure 3.4. Trailing (left) or side-mount attached (right) tags with ARGOS satellite transmitter, to be bolted onto the dorsal fin. Models SPLASH10 (left, https://wildlifecomputers.com/taxa/cetacean-finmount/) and SPOT4 (right, (Sonne et al., 2012)*).*

3.4.2 DTAG

The D-tag (digital audio and movement recording tag) was developed by (Johnson et al., 2003)(Figure 3.5, Figure 3.6). It was first applied on porpoises in human care providing high-resolution information on porpoise acoustic behaviour (Deruiter et al., 2009). Wild porpoises have been tagged with the DTAG3 which also provide data on swimming and hunting behaviour, allowing the assessment of both vocalisations, social interactions, heart rate and movement changes in relation to anthropogenic sounds (Wisniewska et al., 2016; Sørensen et al., 2018; Wisniewska et al., 2018b, McDonald et al. 2021). Meanwhile there is also a DTAG4, which is more compact than DTAG3 and has been applied to harbour porpoises, seals and sperm whales (Figure 3.6) (Ladegaard et al., 2019; Mikkelsen et al., 2019; Teilmann et al., 2019; Tønnesen et al., 2020). The tag is attached with three or four silicon suction cups. The casing consists of epoxy resin, and it has buoyancy through the use of syntactic foam floatation.

A DTAG generally contains the following components:
- Sound recording unit
- Pressure sensor
- Tri-axial accelerometer
- Magnetometer
- Snapshot GPS (DTAG4)
- VHF transmitter (for retrieval)
- ARGOS satellite transmitter (for retrieval, and usually outside of the DTAG)

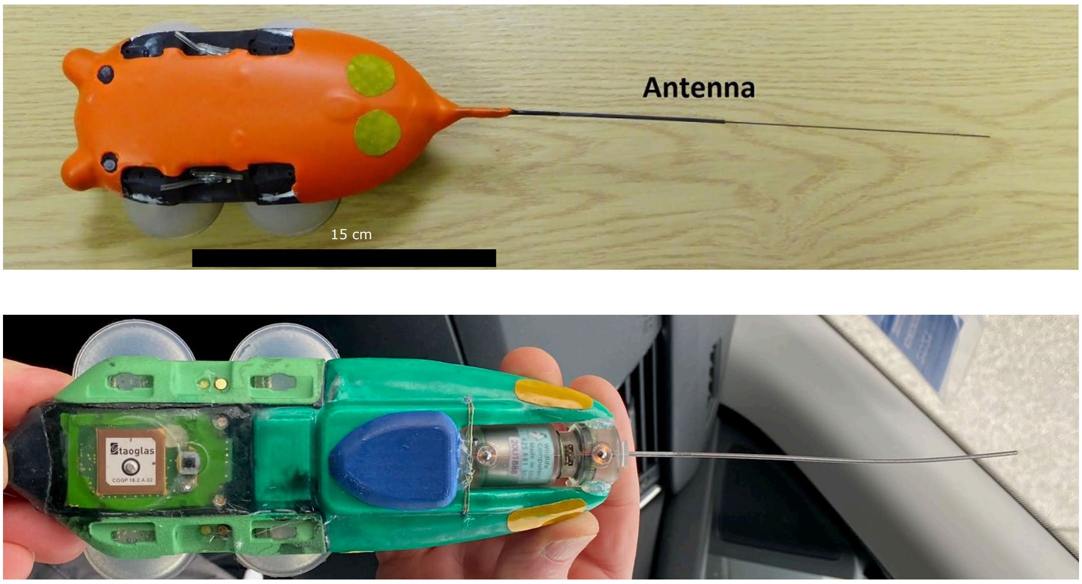


Figure 3.5. DTAG3 (above) and DTAG4 (below) from soundtags. Photo: https://www.soundtags.org/dtags/ (top) and Jonas Teilmann (below).

Detachment can be programmed to release through a clock circuit in the DTAG consisting of nickel-chromium wire (which corrodes rapidly in sea water when it becomes anodic) and release tubes (which are sealed by the wire and let the water in the suction cups when they open). If no release mechanism is used, deployment is possible for up to 55 hours until the suction cups detach (Teilmann, 2021, *personal communication*). After this the tag has to be retrieved.

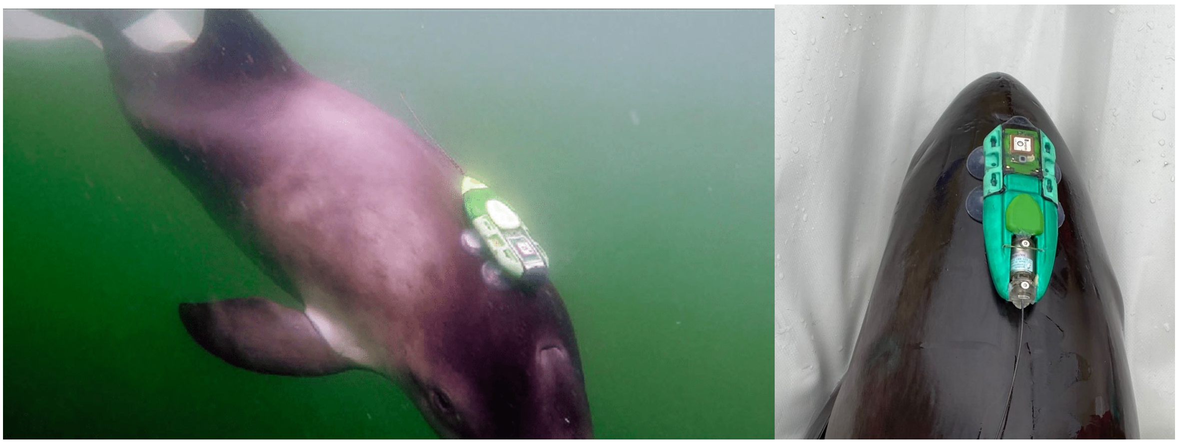


Figure 3.6. DTAG4 on porpoise. Photo: Florian Graner (left, (Teilmann et al., 2019) *& Jonas Teilmann (right).*

3.4.3 Double attachment: V-tag/A-tag and ARGOS

This double tag set-up was used on seven porpoises by Wright et al. (2017) and six animals by van Beest et al. (2018a) from the Kattegat/Skagerrak area that were either captured in pound nets or actively captured using floating gillnets (Figure 3.7). First a tag containing an ARGOS satellite transmitter (SPOT5, Wildlife Computers, Redmond, WA, USA) was attached to the left side of the dorsal fin using two 5mm pins. The tag weight was 55g. Iron nuts were used for long-term release. The second tag was a V-tag or an A-tag. It was held in place using a dissolving magnesium bolt on the front pin of the ARGOS tag, while the rear (delrin) pin of the ARGOS tag was used to stabilise its' orientation. The tag detached after 3 to 12 days.

V-tag and A-tag contain the following components:

- Fastloc GPS F5G 133A (Sirtrack, Havelock North, New Zealand) (only in the V-tag configuration)
- Hydrophone (ML200-AS2: Marine Micro Technology, Saitama, Japan) (only in the A-tag configuration)

- Time-Depth Recorder: TDR Lat1800ST (Lotek, Ontario, Canada), TDR DST F-milli (StarOddi, Reykjavik, Iceland) or D2GT: Little Leonardo, Tokyo, Japan
- VHF radio transmitter (ATS, Isanti, MN, USA) (for retrieval)
- ARGOS satellite transmitter (Wildlife Computers, Redmond, WA, USA) (for retrieval)

The electronics were enclosed in a closed cell pressure resistant foam package. The weight of the V- or A-tag is 135-230g (depending on the components used), and it has a slight buoyancy.

Figure 3.7. Attachment of the V-tag to the right side, and the additional ARGOS tag to the left side of the dorsal fin. (source: van Beest et al. (2018a).

Table 3-2. Three tag setups that have been applied successfully to harbour porpoises. NB These are the tags that are currently being used on harbour porpoises. However, tags can often be custom-made, with different types of components added or removed. There are more tag types available, which are not suitable yet for small cetaceans, but might become in the future.

Tag	Components	Information	Archival/ transmission	Duration	Attachment	Reusability	Release	Weight (in air)	Developer	Image
Wildlife Computer SPLASH/ SPOT (various models)	ARGOS satellite transmitter	Location	Transmission	Months/years	Bolt-on (limpet or anchored also possible)	Single-use	Unaided, corroding material or no detachment	57 - 86 g	Wildlife computers (https://wildlifecomputers.com/)	 
	Snapshot GPS (optional)	Location								
	Pressure sensor/time-depth recorder	Dive summary data (number of dives, max depth, mean duration)								
	Thermometer	Temperature								
	Light sensor	Light level								
DTAG	Snapshot GPS	Location	Archival	Hours/ days	Suction cups	Reusable	Unaided, corroding material, can be programmed	206 g (DTAG4) - 325 g (DTAG3)	SOUNDTAG Lab at Aarhus University (https://www.soundtags.org/, formerly at St. Andrews University)	
	ECG – recorder (optional)	Heart rate								
	VHF radio transmitter	Location (for retrieval)								
	Pressure sensor/ time-depth recorder	Dive data								
	Magnetometer	Dive and swimming data								
	Accelerometer	Dive and swimming data								
	Hydrophone	Acoustic data								
	Can be combined with ARGOS satellite transmitter	Location (for retrieval)								
V-tag or A-tag	Fastloc GPS (V-tag)	Location	Archival	Hours/ days	Bolt-on	Reusable	Unaided, corroding material	135 - 150 g	Custom-made by Mikkel Villum Jensen, Aarhus University	
	Hydrophone (A-tag)	Acoustics								
	ARGOS satellite transmitter	Location (for retrieval)								
	VHF radio transmitter	Location (for retrieval)								
	Pressure sensor/ time-depth recorder	Dive data								

4 Representative sampling

To answer the question "How many animals should tagged to acquire meaningful data?" it is important to consider the statistical power and the representativeness of the collected data in relation to the question to be answered. As described in Scheidat et al. (2016), tagging research on harbour porpoises is limited by two main constraints: sample size and impact on behaviour of the tagged individuals. In this chapter we will discuss these constraints and provide guidance to mitigate them. Animal welfare issues will be discussed in chapter 6.

4.1 Sample size

The population of harbour porpoises in the North Sea is estimated at roughly 350.000 animals (Gilles et al., 2016; Hammond et al., 2017). To collect data that is representative for the entire population, a suite of (potential) differences between porpoises needs to be considered. First of all, individuals within a population exhibit different behaviour (to a certain extent). In the southern North Sea, harbour porpoises show distinct differences between gender and age, examples are:

- stranded animals, which consist predominantly of young males (IJsseldijk et al., 2020);
- ontogenetic development in diet, with a switch from small prey, e.g., gobies, to larger prey like whiting while becoming mature (Leopold, 2015);
- contaminant loads, with adult females having the lowest PCB-load, and adult males the highest PCB-concentrations. Females offload PCBs to their offspring (van den Heuvel-Greve et al., 2021).

On top of these gender- and age-related differences, harbour porpoises show seasonal patterns in, for instance:

- reproduction cycle, with the main birth period during June-August after a gestation of ca 11 months (Hasselmeier et al., 2004; Lockyer, 2003);
- energy balance (the difference between energy intake via food and energy expenditure), with a positive balance from September to February, and a negative balance from April to July (Gallagher et al., 2021);
- distribution, with a north-south and/or inshore-offshore movement during different seasons of the year (Gilles et al., 2016).

Sequeira et al. (2019) reviewed a number of marine megafauna tagging studies (birds, turtles, sharks and pinnipeds) and summarized the importance of sample sizes to answer research questions. Their review provides a general overview of the possibilities and limitations of different sample sizes:

- Sample size 1; even one tagged individual can provide proof of concept, or discover new behaviour;
- Sample size < 10; can provide initial insights into individual variability, scale of movements, and drivers of movement and can be used to generate hypotheses for further targeted research;
- Sample size 10-100; can provide estimates of space-use, characterise spatio-temporal patterns and identify specific behaviours (e.g., sex and age differences);
- Sample size > 100; can quantify habitat use over large spatial scales, assess shifts in space-use with time, among sub-populations or with gender, age class and period (e.g., breeding cycles) and estimate susceptibility to interactions with human activities.

These sample sizes refer to the number of tagged individuals and can be used as a rule of thumb to determine the necessary effort. The sample size, however, does not refer to the so-called *sample size sufficiency* (Street et al., 2021). This includes duration and intensity of the tagging effort per individual, which are additionally important to acquire robust tagging results. For instance, tagging results from one individual that is followed for a year potentially differ from tagging results from several individuals that are tracked for (subsequent) parts of the year. These effort-related issues have been addressed in telemetry home-range studies on a variety of species. A minimum number of location fixes and a minimum sampling period is needed to acquire enough data to quantify home-ranges. Additionally, mortality of individuals, transmitter failure, and exhaustion of batteries can result in an *effective sample size* that is smaller than the number of originally tagged individuals. This has to be taken into account when deciding on a suitable sample size.

The sample sizes in existing harbour porpoise tagging studies vary. For example, with 5-7 animals that were tagged for hours to a few days, inferences have been made about click communication (Sørensen et al., 2018), fine-scale movements (van Beest et al., 2018b) and responses to (sound) disruption (van Beest et al., 2018a; Wisniewska et al., 2018b). Sample sizes of 10-20 animals provided valuable information on time allocation and diving behaviour (Nielsen et al., 2019; Teilmann et al., 2007), metabolic rates (Rojano-Donãte et al., 2018) and distribution compared to PAM results (Mikkelsen et al., 2016). Studies into home-ranges, distribution and predator-prey relationships base their conclusion generally on 30 – 70 animals and extended periods of data collection (~ 1 year per animal and over more years) (Edrén et al., 2010; Kindt-Larsen et al., 2016; Nielsen et al., 2018; Sveegaard et al., 2011a, 2012).

It should be emphasized that even a small sample size can provide important information and valuable insights to fill existing knowledge gaps (Johnson et al., 2004; Madsen et al., 2005; Sørensen et al., 2018; Wisniewska et al., 2018b). Increasing the sample size will strengthen the reliability of the acquired knowledge and insights, and will allow for more general conclusions. The currently available information does not allow for determining necessary samples sizes through a power analysis. Ideally, however, a power analysis should be done before and during a tagging study, with information that becomes available from the study. During analysis of the collected data, it is prudent to check if adding tagging data changes the results. For example, do home ranges reach an equilibrium when adding more location fixes or do depth profiles changes when adding data from new individuals or habitats? It should also be kept in mind that the North Sea is constantly changing, which may affect harbour porpoise behaviour and habitat use and complicates analysis and interpretation of the tagging data. In chapter 5 we provide some rule-of-thumb sample sizes.

In this report we are not able to provide detailed information on needed tagging and sampling periods, since it is unknown if and how many individual harbour porpoises can be tagged in a certain period. Depending on the number of tagged individual porpoises per year the lower limits of effectively needed sample sizes can probably be reached on the short term (< 5yr), but acquiring bigger effective sample sizes will be a long-term process that can even extend to decades.

4.2 Impact on behaviour

The aim of tagging is to collect data of an animal that behaves in the same way as if it was not tagged. It is important to assess if and to what extent both the tagging process and the tag itself change the behaviour of a porpoise. To cite Cooke (2008), "data derived from telemetry and logging studies would not be useful if the observations generated were not genuine".

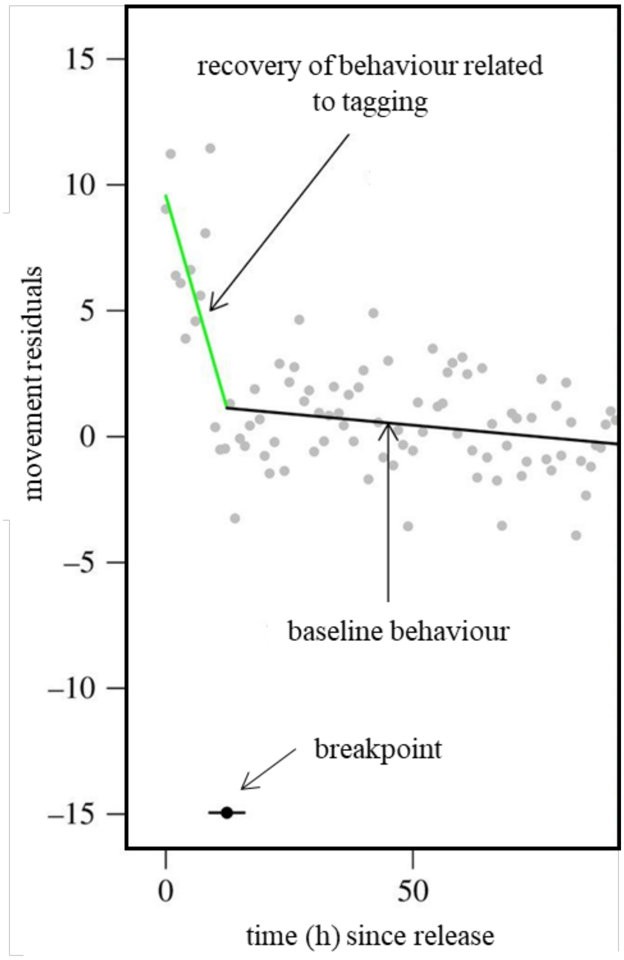


Figure 4.1. Assessing the behavioural response and recovery of a harbour porpoise to tagging. Adapted from van Beest et al. 2018b.

4.2.1 Behavioural reaction to tagging

In a study with five animals equipped with V-tags (see section 3.4.3) the behavioural response to tagging itself was assessed (van Beest et al., 2018b). The authors assumed that porpoises would change their behaviour as reaction to the catch, handling and tag attachment.

By fitting piecewise linear regression models to different movement parameters, such as speed, the best fitting model provided breakpoints in movement parameters which have been used to determine the time it took for animals to return to their original behaviour (Figure 4.1) (van Beest et al., 2018b). The five animals in this study responded to the tagging with site displacement and changes in both horizontal and vertical movement patterns. The behaviour reached the (assumed) baseline level within 24 hours after tagging (van Beest et al., 2018b). Disturbed behaviour, however, potentially results in a temporary decrease in foraging efficiency, which could lead to a decline in fitness (also see section 6.2.10).

4.2.2 Tag impact on natural behaviour

It is well understood that tags influence the hydrodynamics of small cetaceans, through their size, shape and buoyancy (Berga et al., 2015; Van Der Hoop et al., 2014). The additional hydrodynamic drag will increase the energetic costs of swimming and diving, potentially causing long-term effects on the fitness and behaviour of the animal (Scott and Chivers, 2009; Balmer et al., 2010b) and thereby influencing the data. Over the last decades tag design has been improved to reduce the impact on the tagged animal, but assessment of potential impact has primarily been based on theoretical models or on experiments with animals in human care (Balmer et al., 2014; Geertsen et al., 2004; Jones, 2013; Kay et al., 2019; Kyte et al., 2019; Pavlov et al., 2007; Van Der Hoop et al., 2014) (Figure 4.2).

An early study investigated the drag coefficients, loads, and proportional increase in drag for three tag designs that had been previously deployed on wild harbour porpoises: paired side-mounted, single side-mounted and front-mounted (Figure 4.6). Measurements conducted on a porpoise model in a wind tunnel showed that the single side-mounted and front-mounted tag designs produced the highest drag values (Hanson, 2001). Next to the additional drag, the stability of the tag attachment has been shown to influence the behaviour. A decrease in the stability leads to an increase in longer dives in bottlenose dolphins (Balmer et al., 2010). It is worth mentioning that those tags are not representative for the current designs, but the conclusions about drag and stability are still valid.

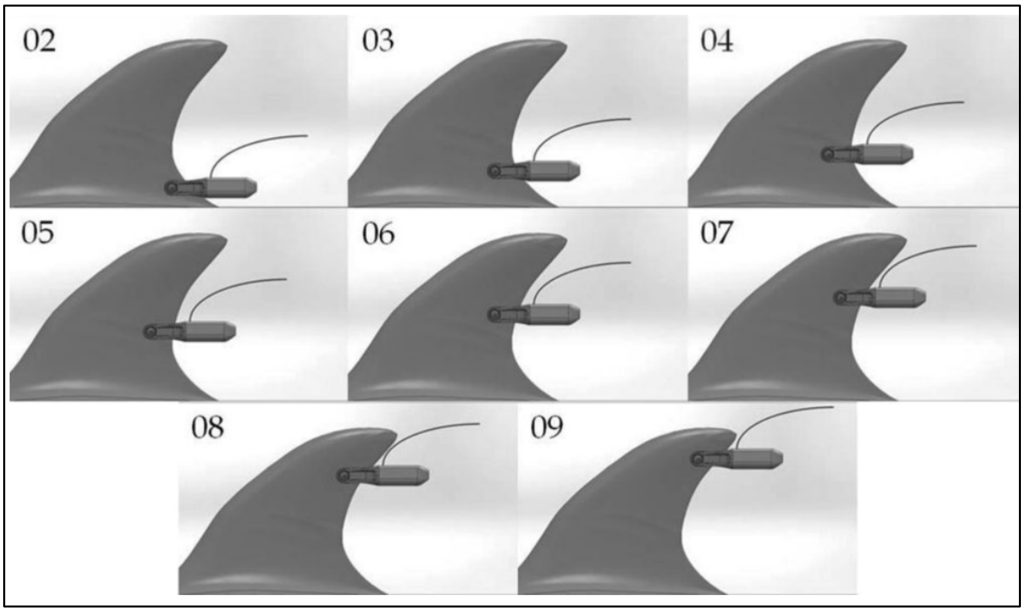


Figure 4.3. The drag of different tag placements on the trailing edge of a bottlenose dolphin dorsal fin were assessed using computational fluid dynamics (CFD). The 04 position (upper right image) incurred the least drag and position 09 had the greatest drag with an increase of 120% over position 04 (Balmer et al., 2014)*.*

Figure 4.2. Assessment of three satellite attachment designs for harbour porpoise: (a) paired side mounted (Telonics split board ST-10, left side and ATS Model 201, right side) (b) single side-mounted (Telonics split board ST-10) (c) front-mounted (Telonics ST-10). From (Hanson, 2001).

The main challenge is that assessing the impact of tags on porpoise behaviour requires the comparison of tagged and untagged animals. Unfortunately, there are only limited options to study behaviour above and below water unless tags are used. One study addressed this question by comparing the behaviour of porpoises that were tagged with either a satellite tag, or with a satellite tag and a data logger. The study showed that the combination of a satellite tag and data logger significantly reduced the average dive depth of porpoises, possibly due to the increased hydrodynamic drag and buoyancy (Berga et al., 2015).

In most studies the potential effect of tag design, weight and placement on drag and its relevance for the tagged animals is not considered (Kay et al., 2019). An evaluation of the added drag of a tag, either on captive animals or through modelling, is highly advisable. As a framework, the US Fisheries and Wildlife Service advises that tags (among other criteria) should not induce a drag of more than 10% to prevent a substantial impact on the animal (U.S. Fish and Wildlife Service, 2017). Guidelines on how to assess these parameters, however, are lacking.

It is also worthwhile to point out that there are continuous developments that will reduce the power needs and increase the storage capability of tags. Both of these developments will allow a reduction in size in tags in the future.

4.2.3 Using a rehabilitated animal

Harbour porpoises that strand alive and are rehabilitated in a care facility can potentially be used for tagging. The advantage of these animals is that there is no need to capture, and tagging can be done in a controlled environment and even days or weeks before the release to verify how the animal adapts to the tag. On the other hand, there is uncertainty if a rehabilitated porpoise will show natural behaviour. The main concern is that animals may have changed their natural behaviour while being rehabilitated. Before releasing a rehabilitated animal, however, it has to meet a set of criteria; it must be healthy without needing medication, have a normal growth, girth and weight for its age, show no abnormal behaviour, be old and experienced enough to survive at sea (~ 1 year or older (Teilmann, 2021, *personal communication)*) and not have been in captivity for too long (Kastelein, 2022, *personal communication*). These criteria limit the risk of an animal having reduced survival chances, and can be used to assess if an animal is fit for tagging (also see section 6.1.2). The question if a rehabilitated animal will show normal behaviour after release can only be answered when enough rehabilitated animals and animals caught in the wild have been tagged.

5 Collected data and link to research questions

In this chapter we link the research questions as defined in chapter 2 to the information presented in chapters 3 and 4, and discuss how and to what extent tagging data can answer each research question (summarized in Table 5-2). It is important to stress that tagging data alone cannot necessarily provide conclusive answers to many questions, but that it serves as an important technique in a multidisciplinary and multi-method approach (also see Figure 1.1). Together with other data sources it can provide information that is of relevance to the conservation of this species.

5.1 Distribution

1. **What are the large-scale movements of porpoises in the southern North Sea?** *and*
2. **What is the home-range of harbour porpoises in the southern North Sea?**

Tags on porpoises can provide information on the animals' location at regular intervals for up to a year or more (one tag lasted almost three years). This duration depends on tag type and attachment, but also on the survival of the animal (Holton et al., 2021; Nielsen et al., 2018). Bolt-on (ARGOS) tags are the smallest tags available suitable to investigate large-scale movements over longer periods of time. They can provide positioning data with a few hundred meters accuracy at regular interval, as well as optional summary of dive data (Johnson, 2021; Nicholls et al., 2007). This would allow for recording of locations of animals over at least several months, and provides information on positions in space and time (e.g. day of year and time of day) from which total distance travelled, radius of travelled area, potential hot spots within its home range and potential migration patterns could be inferred (Aarts et al., 2008; Block et al., 2011; Heide-Jørgensen et al., 2012; Nielsen et al., 2018; Read et al., 1997; Stalder et al., 2020; Sveegaard et al., 2011a; Teilmann et al., 2007). Kernel density of location data can be used to determine home-ranges (Calenge, 2019; Cumming et al., 2012; Heide-Jørgensen et al., 2012). Satellite tags are now often combined with Fastloc GPS receivers, allowing a higher precision in location data, but in some cases increasing size, weight and potentially drag of the tag.

Other methods for distribution
Information on large-scale shifts in distribution of porpoises can also be derived from aerial surveys, providing data on seasonal changes and trends over time (Gilles et al., 2016; Hammond et al., 2017). PAM studies can inform on how distribution patterns change over time in the monitored areas (Carlén et al., 2018; Verfuß et al., 2007). These methods, however, cannot provide details on *which* animals cause these patterns; e.g. is the early spring peak in the southern North Sea caused by porpoises from the Channel or from the northern North Sea? Nor can these methods be used to determine home-ranges.

Sampling considerations for distribution
Harbour porpoise spatio-temporal distribution in the North Sea likely differs between gender and age. The strandings of calf, juvenile and adult porpoises vary between regions as well as throughout the year (IJsseldijk et al., 2020) (Table 5-1). To collect statistically robust data tagging efforts should target both males and females, and young (but not too young, see section 6.1.2) and adult individuals. To account for seasonal differences tracking effort should be spread over the entire year. To provide *initial* insights into individual variability and scale of movements an *effective sample size* of 10 can suffice, provided animals from all different categories (gender,

age, season) are tagged (see section 4.1). To provide home range size estimates the number of sampled individuals, the number of location fixes per individual and the sampled period are important. As a rule of thumb estimates of individual home ranges should be based on at least 30 and preferably > 50 location fixes per individual (Seaman et al., 1999). Existing harbour porpoise studies into home-ranges and distribution base their conclusion generally on 30 – 70 animals and extended periods of data collection (Edrén et al., 2010; Kindt-Larsen et al., 2016; Nielsen et al., 2018; Sveegaard et al., 2011a). It should be noted that the resulting home range is only valid for the tagged individual during the sampled period and does not necessarily represent the home range during an entire year. An *effective sample size* between 10-100 individuals can characterise spatio-temporal distribution patterns of a population, providing animals from all different categories are tagged (see section 4.1). Depending on the number of 'effectively' tagged individual porpoises per year the lower limit of the sample size (10 animals) can probably be reached on the short term (< 5yr), but a bigger effective sample size will take a longer period.

5.2 Foraging ecology

3. **Where and how often do harbour porpoises forage?**
Location data can be used to model porpoise habitat in relation to prey, or proxies of prey occurrence (e.g. sandeel spawning grounds) (Arranz et al., 2011; Sveegaard et al., 2012; Witteveen et al., 2008). In addition, dive patterns (dive lengths and profiles, time at surface and at different depths, swim speed) can provide information on where animals are foraging, e.g. pelagic, benthic, and allow for a general idea on prey (Akamatsu et al., 2005; Arranz et al., 2011; Booth, 2020; Nielsen et al., 2019; Rasmussen et al., 2013; Sørensen et al., 2018; Teilmann et al., 2007; Wisniewska et al., 2016, 2018a). Information on dive patterns can be acquired over a longer period of time by telemetry tags, and in a higher resolution but over a shorter period of time by archival tags with multiple sensors.

Acoustic sensors – so far only used as archival short-term tags - can record harbour porpoise vocalizations associated with feeding activities (Johnson, 2021; Johnson et al., 2004; Madsen et al., 2005; Rasmussen et al., 2013; Sørensen et al., 2018; Wisniewska et al., 2016). This can be linked to habitat characteristics to model where foraging occurs (Arranz et al., 2011; Stalder et al., 2020).

4. **What kind of prey do porpoises feed on, how does it change over time?**
While porpoise tags cannot be used to determine prey species, foraging behaviour can be identified and linked to depth, thus allowing the assessment if feeding occurs in pelagic or benthic habitats. Analyses of echoes from prey as a result of harbour porpoise clicks also allow for the determination of approximate prey size and its movement, which may lead to species identification if detailed knowledge on fish distribution and behaviour is available (Wisniewska et al., 2016).

Other methods for foraging ecology
To enhance our knowledge on foraging ecology of harbour porpoises, information from diet analyses (Leopold, 2015) and analyses of stable isotopes in muscles and bones (Jansen et al., 2012), as well as data on prey distribution and porpoise distribution could be combined with tagging data on movements of porpoises. This could provide a framework to model harbour porpoise predator–prey relationship, as recently done by Ransijn et al. (2021).

Sampling considerations for foraging ecology
Feeding ecology of harbour porpoises in the southern North Sea is influenced by age, and possibly shows seasonal patterns (Table 5-1). Therefore, tagging effort needs to target both young and adult individuals to collect statistically robust data. To account for seasonal differences, tagging effort should be spread over the entire year. A sample size of 5-10 can provide initial insights into individual variability, provided both young and adult animals are tagged (see section 4.1). More generally valid info will be acquired by tagging data of both age

categories in different seasons, and different locations in the North Sea. This would increase the effective sample size to 10-100 individuals. Existing harbour porpoise tagging studies with 5-7 animals that were tagged for hours to a few days allowed for inferences about fine-scale movements and prey type (van Beest et al., 2018b; Wisniewska et al., 2016). Sample sizes of 10-20 animals provided valuable information on time allocation and diving behaviour (Nielsen et al., 2019; Teilmann et al., 2007) and metabolic rates (Rojano-Donãte et al., 2018). A study into predator-prey relationships based its conclusion on 34 animals and extended periods of data collection (Sveegaard et al., 2012). Again, depending on the number of 'effectively' tagged individual porpoises per year the lower limit of the sample size can probably be reached on the short term (< 5yr), but a bigger effective sample size will take a longer period.

5.3 Habitat use

5. **What is the habitat use of porpoises in the North Sea? Are there important/key or preferred habitats?**
   Locations and behaviour as derived from either telemetry or archival tags can be linked to habitat-specific biological and physical variables (e.g. depth, slope, primary production), as well as to factors like day of year and time of day and the presence of structures (Aarts et al., 2008; Nielsen et al., 2018; Stalder et al., 2020; Sveegaard et al., 2011a; van Beest et al., 2018b). Tagged animals can also collect environmental data, such as temperature, while they are moving through their habitat. Kernel density of location data can determine certain hot-spots within the home-range (Cumming et al., 2012; Fleming et al., 2016; Heide-Jørgensen et al., 2012; Sveegaard et al., 2011a). This provides information on highly used habitats or habitat characteristics. Preferred habitats can be assessed by comparing the available habitats with the location fixes per habitat (Aebischer et al., 1993). If hot spots identified by telemetry data can be confirmed to be stable over time by acoustic or visual surveys, this provides support to designate these areas as MPA's (Sveegaard et al., 2011b). Vice versa, whether and how current MPA's are used by harbour porpoises can be unveiled with tagging results.

6. **How much time and energy is spent on various behaviours?**
   Certain archival tags can provide detailed information on behaviour, including movement, swimming and dive data and sound production and reception. Sound data, in turn allows for characterisation of foraging behaviour, social interactions, and metabolic rate (Johnson, 2021; Sørensen et al., 2018; Wisniewska et al., 2016). Based on this a time-energy budget can be developed (Teilmann et al., 2007), which in turn can feed into models such as DEPONS (Nabe-Nielsen et al., 2018). Sound recording tags can record respiration rates allowing for an estimate of the field metabolic rate and the relative energy costs of different activities (Rojano-Donãte et al., 2018).

7. **Is habitat use influenced by the presence of offshore and nearshore structures such as OWFs, marine energy devices and oil and gas platforms?**
   Tagging data can be analysed in relation to data on offshore wind farm location and other structures (Nowacek et al., 2016; Rosenbaum et al., 2014). From large-scale movement patterns based on tagging studies it can be derived whether harbour porpoises generally avoid existing OWF's or OWF's development areas, something that has so far been done only for tagged seals (Chudzinska et al., 2021; Dietz et al., 2003; Russell et al., 2014; Tougaard et al., 2003). Smaller-scale data derived from archival tags can provide detailed information on actual movements and behaviour in and around OWF sites and other structures (Aarts et al., 2018; Hastie et al., 2014; Nowacek et al., 2016; Russell et al., 2016). These kinds of data can, again, ultimately feed into population models such as DEPONS, with which potential effects on the entire population can be modelled.

8. **Is habitat use influenced by other human activities such as fishing or shipping?**
   Tagging data can also be analysed in relation to data on other human activities, such as fishing or shipping (Mikkelsen et al., 2019; Nowacek et al., 2016; Rosenbaum et al., 2014). Most commercial vessels are obliged to record their position through AIS or VMS, and data on

important shipping lanes and areas with high vessel density can be compared to harbour porpoise location data, to investigate whether there is overlap, and whether there are certain attraction or deterrence patterns (Bedriñana-Romano et al., 2021; Guzman et al., 2020; Mikkelsen et al., 2019). This is especially interesting in light of operational OWF that have a regular occurrence of maintenance vessels. Additionally, detailed data from archival (sound) tags can shed light on the precise noise exposure from individual vessel passes and on any corresponding behavioural changes (Mikkelsen et al., 2019; Nowacek et al., 2004; Wisniewska et al., 2018b). Again, these data are needed for models that assess population effects.

Other methods for habitat requirements and use
Information on habitat requirements and habitat use of porpoises can also be derived from aerial surveys and PAM studies. For example, analysing patterns in distribution derived from aerial surveys can be used to quantify and model habitat preferences and drivers that shape these (Gilles et al., 2016). The impact of vessel activities can also be monitored through aerial surveys, however, this is limited to a snapshot in time. PAM networks can provide information on habitat requirements, provided they are placed in a representative way over the study area (Brinkkemper et al., 2021; Carlén et al., 2018; Geelhoed et al., 2018). PAM can also monitor changes in acoustic activity due to vessel noise, however, in the current set-up with single PAM devices used, it is not possible to distinguish individual reactions of animals. Understanding behaviour on different spatio-temporal scales will also allow the improvement of accuracy existing spatial models.

Sampling considerations for habitat requirements and use
Habitat requirements of and habitat use by harbour porpoises in the southern North Sea is influenced by gender and age, and shows seasonal patterns (Table 5-1). Therefore, tagging effort needs to target both males and females, and young and adult individuals to collect statistically robust data. To account for seasonal differences tagging effort should be spread over the entire year. To provide *initial* insights into habitat use and individual variability movements an *effective sample size* of 10 can suffice, provided animals from the four different age-gender categories are tagged (see section 4.1). To provide enough data on habitat use two things are important: 1) the number of sampled individuals and the number of location fixes per individual, and 2) the spatial coverage by the tagged individuals of the different North Sea habitats (Aebischer et al., 1993). An *effective sample size* between 10-100 individuals can characterise preferences in habitat, provided animals from all different categories are tagged on a wide enough spatial scale (see section 4.1). To provide *initial* sights into individual variability in time-budgets spent on different behaviours a sample size <10 tagged individuals is sufficient, provided animals from the four different age-gender categories are tagged (see section 4.1). For example, with 5-7 animals that were tagged for hours to a few days, inferences have been made about fine-scale movements and the effect of environmental drivers thereon (Stalder et al., 2020; van Beest et al., 2018b). Sample sizes of 10-20 animals provided valuable information on time allocation and diving behaviour (Nielsen et al., 2019; Teilmann et al., 2007). Studies into larger-scale distribution base their conclusion generally on 30 – 70 animals (Edrén et al., 2010; Kindt-Larsen et al., 2016; Nielsen et al., 2018; Sveegaard et al., 2011a). Again, depending on the number of 'effectively' tagged individual porpoises per year the lower limit of the sample size can probably be reached on the short term (< 5yr), but a bigger effective sample size will take a longer period.

5.4 Cumulative noise impact

9. How do individual porpoises react to impulsive and continuous man-made sound?
As mentioned above, archival tags can provide detailed information on behaviour in relation to certain human activities, such as pile-driving, operational wind parks, seismic activities or shipping (Friedlaender et al., 2016; Mikkelsen et al., 2019; Nowacek et al., 2016; Southall et al., 2019; van Beest et al., 2018a; Wisniewska et al., 2018b). Changes in dive patterns, swimming speed or behaviour (foraging clicks) can be investigated and compared to sound

exposures (e.g. a reduction in foraging dives has energetic consequences and can feed into population models on cumulative effects, such as DEPONS & iPCoD).

10. What is the noise exposure for harbour porpoises in the southern North Sea?
Archival harbour porpoise tags can provide data on (ambient) sound at sea as it reaches the animal (Johnson, 2021; Johnson et al., 2009; Madsen et al., 2006; Mikkelsen et al., 2019; Nowacek et al., 2004). However, in practice this has proven to be difficult due to the short deployment types of the current acoustic tags and issues with so-called flow-noise, caused by movement of the tagged animal, masking the lower frequencies of ambient noise (sounds with higher frequencies can however still be used).

Other methods for noise impact
Currently, studies on noise impact focus on sound exposure of harbour porpoises during the construction of offshore wind farms. These studies aim at finding relationships between acoustic activity of porpoises, measured by PAM, and pile driving noise. Only in the most recent studies simultaneous sound measurements and PAM research have been conducted to relate porpoise activity to actual sound exposure (Brandt et al., 2016; Brinkkemper et al., 2021; Dähne et al., 2017; Sarnocińska et al., 2020). A drawback of PAM is the unknown relation between measured acoustic activity and porpoise numbers, as well as the uncertainty on how animals further behave if they are disturbed and leave the area. Therefore the (piling) sound exposure of individual porpoises, and consequently the potential effect, cannot be determined with PAM. Furthermore, the impact of noise on harbour porpoises is affected by their movement patterns as shown by simulations of porpoise distribution in relation to noise exposure with different movement strategies (Aarts et al., 2016). Information on actual porpoise movements through tagging can potentially fill such knowledge gaps.

Sampling considerations for noise impact
It is currently unknown if noise impact on harbour porpoises differs by gender or age, or shows seasonal patterns (Table 5-1). Tagging effort, however, needs to be high to collect statistically robust data on the impact of (impulsive) noise on porpoises, since the likelihood that tagged animals will be swimming near an impulsive sound source and are exposed to emitted noise is diminutive. A sample size of > 100 tagged individuals would be optimal. On the other hand, *any* information on noise exposure of harbour porpoises at sea is relevant. An effective sample size 1-10 tagged individuals, irrespective of which age-gender categories are tagged, can already provide valuable insights into, for example, the behaviour of porpoises in response to impulsive noise (though one should be aware that behavioural reactions to sound are context dependent and vary per individual) (e.g. van Beest et al., 2018a; Wisniewska et al., 2018b). Possibilities for controlled sound exposure (in human care or in the wild) can be explored, although this is complicated and may require additional ethical considerations (Miller et al., 2011; van Beest et al., 2018a). Again, depending on the number of 'effectively' tagged individual porpoises per year the lower limit of the sample size can probably be reached on the short term (< 5yr), but a bigger effective sample size will take a longer period.

5.5 Cumulative effects

11. What is the impact of cumulative human effects on harbour porpoise in the North Sea?
Cumulative impact on a population is currently estimated with the use of models, such as DEPONS or iPCoD (e.g. Heinis et al., 2019; Harwood et al., 2020). These models need data input, and data on individual mechanisms is needed as they drive shifts in population abundance and distribution. As described in the sections above, tagging data can provide information on distribution, foraging behaviour, swimming behaviour, time-energy budgets and behavioural responses to disturbances. All these factors can feed into models on cumulative effects improving and validating them. Location fixes could also be used to refine spatial risk areas by overlaying human activity layers with harbour porpoise movement. Ideally these would be coupled with other data such as on prey availability, since the context is important in considering

the effect of human activities. For example: when there is high prey densities the predator might expose itself to disturbance longer than when prey density is low (Hastie et al., 2021).

Sampling considerations for cumulative effects
Since quantifying cumulative effects depends on data on different topics that interact with each other, it is difficult to provide guidelines on necessary sample sizes.

Table 5-1. Expected differences between gender- and age or seasons with respect to patterns in distribution, foraging ecology, habitat requirements and use, and noise impact based on the information in chapter 2 and section 4.1. ? = unknown, - = no difference, + = difference.

	Age	**Gender**	**Season**
Distribution	+	+	+
Foraging ecology	+	-/?	+/?
Habitat	+	+	+
Noise impact	?	?	+/?

5.6 Other research questions

In order to answer the priority research questions above, a step-by-step approach is desirable (Scheidat et al., 2016, also see workhop conclusions and reports). During these first steps, some of the questions mentioned under section 2.6 can potentially be answered along the way.

5.6.1 In human care

Some of the questions could be addressed through an experimental approach on the effect of tagging on porpoise in human care. In human care, the tagged animal can be carefully monitored and observed, providing (preliminary) information on tag performance and changes in behaviour, as well as enabling calibration of the output of the sensors with visually observed behaviour, thereby verifying it with independent information (e.g. Ydesen et al., 2014). Behavioural differences between tagged and untagged animals can be studied (preferably within individuals). It can also be recorded after how long the behaviour returns to the baseline situation. Effects of different tag types, attachments and locations on the body could be investigated. Measurements of behavioural impact should include changes in breathing patterns, swimming behaviour, swimming speed and social interactions.
Suction cups are considered to have less physical impact on porpoise behaviour and health than attachment methods through the skin. However, there are indications that tissue under suction cups can be damaged, potentially leading to tissue necrosis (Kastelein et al., 1997b), especially if stiff cups (i.e., with high vacuum force) are used on sensitive areas of the body. The question could be addressed through tests on captive animals and should consider the influence of temperature, type of suction cup, pressure of suction cup, location on the body and length of deployment.

5.6.2 Rehabilitated animals

It is likely that a tagging project will start with rehabilitated animals. Tagging rehabilitated animals can provide information on the success of rehabilitation. The overall goal and success of a rehabilitation procedure/strategy are achieved if an animal is able to live a natural life in the wild, including natural behaviour and successful reproduction (also see section 4.2.3). Otherwise a wild animal is considered non-releasable. The movements and behaviour of the animal can be studied after it is set free, and can potentially be compared to animals that were tagged directly after being caught in the wild.

5.6.3 Other samples and information

During the handling and tagging of an (free-living) animal, samples should be taken, such as blood or tissue samples and skin swabs to evaluate the health status of the tagged animal. In addition, those samples can provide important information on, for example, genetics, immune and reproductive status, stress level, infectious agents or contaminant load (Eskesen et al., 2009; Müller et al., 2013). If possible, ultrasound measurements can give valuable insights on the blubber thickness and reproduction status. The consequences for the animal of the extra handling time needed to acquire such health data must however be considered carefully.

As mentioned before, information on dive patterns from tagged animals can be used to validate and improve the accuracy of the so-called availability bias in the correction factors for abundance estimated based on aerial surveys (Teilmann et al., 2013). Additionally acoustic tagging data can provide information for a multiplier that can be used to convert PAM measurements of click-rates to absolute numbers of animals per km^2, through application of distance sampling methods (Marques et al., 2013).

Table 5-2. Research questions and the type of data tagging can provide to help answer them. Relevant components and suitable tag types per research question.

Priority	Research question	Short description of tagging data and potential information after analysis	Relevant tag components: Location	Swimming behaviour	Acoustic data	Other	Most suitable tag types(s)	Effective sample size
Distribution	1. What are the large-scale movements of porpoises in the southern North Sea?	• Recording of locations and for up to three years. • Positions in space and time (e.g. day of year and time of day), total distance travelled, radius of travelled area, potential hot spots in home range and potential migration patterns • Kernel density of location data can determine home-ranges	X				Wildlife Computer SPLASH/SPOT	10-100
	2. What is the home-range of harbour porpoises in the southern North Sea?		X				Wildlife Computer SPLASH/SPOT	10-100
Foraging ecology	3. Where and how often do harbour porpoises forage?	• Dive patterns (dive lengths and profiles, time at surface and different depths, swim speed) can inform on where animals are foraging, e.g. pelagic, benthic, and allow a general idea on prey. • Acoustic sensors can record the echo of the prey and interpret the size of the fish. • Acoustic sensors can record harbour porpoise vocalizations associated with feeding activities. This can be linked to habitat characteristics to model where feeding was successful. • Modelling of habitat use can be linked to prey, or proxies of prey occurrence (e.g. sandeel spawning grounds)	X	X			Wildlife Computer SPLASH/SPOT and DTAG	10-100
	4. What kind of prey do porpoises feed on, how does it change over time?		X	X	X	X	DTAG	10-100, and >100 to detect changes
Habitat requirements & use	5. What is the habitat use of porpoises in the North Sea? Are there important/key or preferred habitats?	• Locations and behaviour can be linked to habitat-specific biological and physical variables, as well as factors like day of year and time of day and the presence of structures. • Use tagging data in combination with habitat models. • Kernel or otherwise determined hot spots in home-range. • Use tagging data (location but also behaviour) in combination with OWF locations, other structures and shipping or fishing activity.	X	X			Wildlife Computer SPLASH/SPOT or DTAG/VTAG/ATAG	10-100
	6. How much time and energy is spent on various behaviours?			X	X		Wildlife Computer SPLASH/SPOT or DTAG	10-100
	7. Is habitat use influenced by the presence of offshore and nearshore structures such as OWFs, marine energy devices and oil and gas platforms?		X	X	X		Wildlife Computer SPLASH/SPOT or DTAG	>100

	8. Is habitat use influenced by other human activities such as fishing or shipping?		X	X	X		Wildlife Computer SPLASH/SPOT or DTAG	10-100
Cumulative (noise) impact	9. How do individual porpoises react to impulsive and continuous man-made sound?	• Acoustic tags can provide information regarding noise levels during tagged period • Changes in dive patterns, swimming speed, behaviour (foraging clicks) can be investigated together with sound (e.g. a reduction in foraging dives has energetic consequences and can feed into population models on cumulative effects).	X	X	X		DTAG	10-100
	10. What is the noise exposure for harbour porpoises in the southern North Sea?		X		X		DTAG	10-100
Cumulative effects	11. What is the impact of cumulative human effects on harbour porpoise in the North Sea?	• tagging data can provide information on distribution, foraging behaviour, swimming behaviour, time-energy budgets and behavioural responses to disturbances. All these factors can feed into models on cumulative effects improving and validating them.	X	X	X	X	Wildlife Computer SPLASH/SPOT or DTAG/VTAG/ATAG	>100
Abundance	•	• Dive patterns can be used to validate and improve the accuracy of correction factors used in abundance estimates. • Multiplier for calculating absolute porpoise density from PAM.	X	X			Wildlife Computer SPLASH/SPOT or DTAG/VTAG/ATAG	10-100

6 Animal welfare and ethics

The rationale for conducting tagging on harbour porpoises in Dutch waters is to obtain data that will help to answer critical management and conservation questions. This method will, however, impact individual animals and thus it is necessary to weigh animal welfare considerations against the potential conservation benefits that can be gained by using this method (Cooke, 2008). When considering the welfare of an individual animal there are three primary sources of impacts: the capture, the tag attachment, and the tag design and its effect on the animal during deployment (Figure 6.1). In this chapter we provide an overview of what activities take place during these different phases of the tagging of porpoises at sea. We also provide an overview of potential adverse effects that animals can experience based on current knowledge, and how to reduce them. The risk of these components of the tagging project should be evaluated, where possible through experimental evaluation.

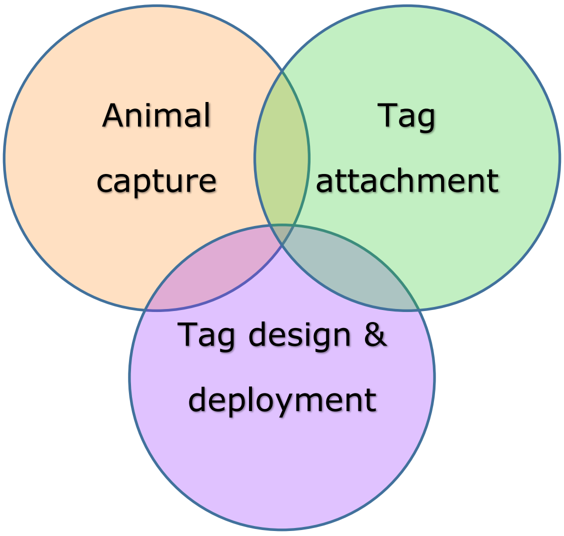


Figure 6.1. The three primary sources during a tagging project that can cause animal welfare concerns. Addressing any one of them reduces the overall health risk to the tagged animal.

6.1 Tagging phases

Harbour porpoise tagging, as it is currently done, consists of four phases. The first three phases involve humans directly interacting with the animal through (1) the catch, (2) it's restraint and (3) the tag attachment. The last phase (4) is the time the animal is at sea with the tag (deployment). The first phase of catching a harbour porpoise is not applicable when tagging rehabilitated animals. In this section we briefly describe each of these phases. Also see Annex 3 for some important considerations during the handling of porpoises.

6.1.1 Catch

Passive catching of living porpoises can occur in stationary fishing gear, such as weirs or pound nets (in Danish: Bundgarn). These nets are generally placed along the coastline to trap schools of fish. Porpoises can enter these nets and swim freely about until they are either released by the fishermen or removed by researchers for tagging. This has been done successfully in Canada and the inner waters of Denmark (Read et al., 1997; Teilmann et al., 2007). In the Netherlands the likelihood of passively catching animals is very low, as there are only very few fishermen that use this type of net (Scheidat et al., 2016). On rare occasions porpoises are caught alive in bottom-set gillnets if these are set in shallow waters allowing the entangled animals to breathe. As there is a high chance of injury for the animals, it is not a suitable method to obtain animals for tagging.

In Greenlandic and North Sea waters harbour porpoises have been actively caught at sea using drifting gillnets (Nielsen et al., 2018; van Beest et al., 2018b). Two vessels are used, with the launch vessel casting the net and the herd vessel chasing the porpoise towards the net, which lasts on average 15 to 20 minutes (Nielsen et al., 2018). When the animal swims into the net and is entangled both boats move towards the net, turn off their engines and remove the animal from the net (Nielsen et al., 2018). This method requires good weather conditions, calm sea (sea state 1 or 2 Beaufort) and an experienced crew. Where and to what extent this is possible in the Netherlands requires further investigation.

6.1.2 Restraint

Once animals are caught, they need to be restrained to allow further handling, for which there are different options. Animals can be placed on a stretcher that stays in the water, which is the least stress-inducing method, as long as the animal can breathe, but this can be challenging if seas are not calm. Animals can also be moved onto a vessel and placed for example on a foam pad where they are dosed with sea water (Nielsen et al., 2018). Depending on the type of vessel this can also be a porpoise transport box with a sling. Since noise can cause additional stress to the animal, the engine of the boat should be switched off, and speaking loudly should be avoided. Water should be used for cooling and keeping the animal wet (cautiously preventing water from entering the blowhole), this may also be fresh water. It is advisable to have different responsibilities and clear tasks for the different members involved, where, for example, one will be monitoring heart rate, where another will keep the animal wet, etc. Also see Annex 3. The presence of a veterinarian is highly recommended.

During this phase, it has to be assessed whether the animal is fit for tagging. As mentioned before, it must seem healthy, have normal girth and weight for its length (minimal 100 cm, (Teilmann, 2021; Siebert, 2022, *personal communication*), and be old and experienced enough to survive at sea (~ 1 year or older (Teilmann, 2021, *personal communication*)). There should be a strict protocol on animal selection criteria beforehand.

6.1.3 Tag attachment

Prior or during tag attachment, information on sex, mass and body length of the animal is collected (Nielsen et al., 2018). Blood should be taken to assess the health status of the animal. In some studies, additional measurements and sampling for other analyses (e.g. stress level, immune parameters), ultrasound examination or extraction of tissue samples is done (Rojas-Bracho et al., 2019).

The use of tags that are connected to the dorsal fin with pin(s) involves the process of disinfection, application of a local anaesthetic and the making holes for the pins (van Beest et al., 2018b). The handling time for Greenlandic porpoises during attachment of the tag, equipped with three pin tags on their dorsal fins, was on average 5 minutes (Nielsen et al., 2018). In a project on porpoises from the Kattegat, Skagerrak and the Wadden Sea the process took less than 30 minutes per animal (van Beest et al., 2018b).

6.1.4 Post-tagging (deployment)

The animal is released back to the sea where it should resume normal activities again. Tags differ in their attachment, size and release mechanism (see chapter 3). With this the chance for injury from the tag or impact through the increased hydrodynamic drag also varies. Some tags are designed to detach after hours or days, others to stay on the animals for months or have no mechanism for release. This should always be considered when choosing the appropriate tag. Issues related to carrying a tag (and to the other stages) are further discussed in section 6.2.

6.2 Adverse reactions / health risks

In this section we highlight a number of adverse reactions that have been documented for porpoises (*Phocoenidae*) related to the tagging procedure (Table 6-1). The order does not reflect the likelihood of occurrence or its' severity.

Table 6-1 Potential occurrence of adverse effects during each tagging phase.

	Catch	Restraint	Tag attachment	Post-tagging (deployment)
Skin and subcutaneous lesions	+			
Stress	+	+	+	+
Aspiration pneumonia	+	+	+	
Pulmonary oedema	+	+	+	
Myopathy	+	+	+	
Reaction to medication		+	+	
Pain	+	+	+	+
Injury through tag attachment			+	+
Hydrodynamic drag				+
Decreased fitness				+

6.2.1 Skin and subcutaneous lesions

Capture procedures, such as using a drifting gillnet, can cause skin and subcutaneous lesions in porpoises (Rojas-Bracho et al., 2019). Normally the wounds are small and bleeding stops quickly in the salt water. If, in rare cases, the bleeding is heavier it can be stopped by an anticoagulant.

6.2.2 Stress

The tagging process is stressful for a wild porpoise, and can lead to stress reactions which can consist of, e.g., changes in respiration and heart rate, pulmonary oedema (see section 6.2.4), increase in stress hormone levels, decrease in immune parameter and signs of shock (Geertsen et al., 2004; Norman et al., 2004). The reaction of individuals to handling and tagging is highly variable (Eskesen et al., 2009). If signs of stress are recognised, Eskesen et al. (2009) advise this may be reduced by pouring water over the handled animal and/or lowering it into water. With some porpoise the stress can be lowered very quickly by simply stopping all handling for a few minutes (no touching, not making the animal wet, etc.). When the animal's stress level is lowered the handlings may gently be picked up again. Despite all possible precautions, Norman et al. (2004) advise that handling a marine mammal outside the water always poses a risk. The effects of short-term stress on the long-term wellbeing of porpoises is not well understood. However, an animal can be lost very quickly, therefore if signs of stress persist, the animal should be released immediately. Taking into consideration the number of animals which have been successfully tagged in the past, the stress level can be considered as medium if an experienced team is handling the animal.

6.2.3 Aspiration pneumonia

During the capture and/or the handling of the animal there is a risk of water entering the blowhole and being inhaled (SOS Dolfijn, 2021, *personal communication*). Porpoises can deal with a little water in the airways and exhale it, but it is very important that the blowhole is free and protected to allow breathing during the entire handling time.

6.2.4 Pulmonary oedema

Pulmonary or lung oedema develops through a collapse of a certain cell type in the lungs, which frees a surfactant factor that mixes air and blood into a foamy substance (much like the functioning of detergent), resulting in foam exiting through the blow hole. This can occur in any stressful situation (bycatch, life stranding, human handling) and can sometimes be an agonal sign (Rojas-Bracho et al., 2019; IJsseldijk et al., 2021b). It is a clear sign of an acute stress response and immediate steps should be taken to lower or end the stress level of the animal. A moderate or severe pulmonary oedema should be avoided at any cost. In three cases (out of over 200) in Denmark animals have died due to stress leading to a severe pulmonary oedema, probably as a result of inexperience people handling the animals (Teilmann, 2021, *personal communication*).

6.2.5 Myopathy

The capture process, the removal from the water and the handling of the animal during the tag attachment leads to muscle damage (myopathy) which is a measure for the stress level of the animal. Myopathy is a metabolic syndrome that has been well documented for live stranded cetaceans (Câmara et al., 2020). It leads to a number of responses and a rapid degeneration of heart and skeletal muscle (Herráez et al., 2013).

One recently described case occurred during the capture of a female vaquita (*Phocoena sinus*), a highly endangered porpoise species that is endemic to the Gulf of California. Even though the research team consisted of highly experienced people the animal developed a profound stress response, ultimately leading to its death (Rojas-Bracho et al., 2019). The post-mortem examination showed that this was caused by capture myopathy. The authors suggest that the severe stress response was triggered during the chase and capture phase.

It is likely that there is a difference in susceptibility to capture myopathy between porpoise species and it is not clear to what degree the experience with the vaquita can be extrapolated to harbour porpoises. Porpoises likely also develop different stress responses based on their individual differences and any underlying health issues. As there is no cure for capture myopathy, it is very important to prevent it from happening. Apart from reducing stressors as much as possible it is imperative to use experienced staff.

6.2.6 Reaction to medication

Harbour porpoises, as all cetacean species, have voluntarily control over their breathing. This means that the use of anaesthesia can be dangerous as it can lead to death through asphyxiation (Higgins et al., 2013). Similarly, tranquilizers (Valium, benzodiazepines) used for sedation, may impact the well-being of the animal (Eskesen et al., 2009). In addition, as the overall goal is to release the harbour porpoise as quick as possible, it is not desired to tranquilize the animal and prolong the time of handling.

Anaesthetic ointments have been used locally on the places where the pin holes are made in the dorsal fin and no adverse effects have been noted.

In Denmark about 200 porpoises have been tagged since 1996. In one case a porpoise died during the procedure, probably caused by applying disinfection spray on a relatively deep injury (Teilmann, 2021, *personal communication*). In three other cases animals have died due to stress leading to a severe pulmonary oedema, probably as a result of inexperienced people handling the animals (Teilmann 2021 *pers. comm*).

6.2.7 Pain

It is not known what pain is experienced by the animal during the attachment procedure and if this is temporary or persistent during tag attachment or beyond. Measuring pain is challenging. However, short-term reactions such as changes in respiratory rate and body posture can be assessed (International Whaling Commission, 2020). Long-term impacts of pain in animals have been suggested, such as changes in body weight and steroid hormones, but these are much more difficult to document (Sneddon et al., 2014).

6.2.8 Injury through tag attachment

The making of holes into the dorsal fin may cause swelling of the tissue which can lead to pressure necrosis. To avoid this, holes may be drilled a millimetre larger than the diameter of the pins. Additionally, like mentioned before, the position of the bolts should be chosen to avoid the most sensitive and vascularised areas.

Pathogens can be inadvertently introduced into the animal during the tagging if the tag is contaminated through contact with sea water, the animals' skin or human skin. In one documented case a killer whale was tagged with an implanted tag that caused a fatal fungal infection (International Whaling Commission, 2020). During the tag attachment with pins measures should be taken to avoid any pathogen contamination of the tissue, through using only sterilized equipment (e.g. drill) and gloves, disinfection of the attachment site and using antibacterial cream.

Suction cup tags are attached to the animal only from the outside on the skin. However, through the negative pressure in the suction cup, they can cause blisters and necrosis of the skin, although there are very few reports of these (Kastelein et al., 1997b) and it has barely been studied. Therefore, only suction cups which are medically approved should be used for the attachment.

6.2.9 Hydrodynamic drag

Researchers need to make a compromise between the "ideal" tag designed to collect data for a long period and the harm it might do to an animal. Tag design, in particular its' drag and mass can affect the risk of increased energy demand, injury to the animal, and thermoregulation (International Whaling Commission, 2020). This is particularly relevant for the relatively small harbour porpoise.

The drag particularly depends on the size and form of the tag and the position of the attachment (Tudorache et al., 2014). Drag can cause bolts to move through the fin tissue, leading to subsequent out-migration of the pins over days or months (Chilvers et al., 2001; Irvine et al., 1982; Orr et al., 1998). This was documented in two harbour porpoises, where one was tagged with a less hydrodynamic tag than the other. The more hydrodynamic tag stayed in place and the holes healed up inside, while the other tag migrated 1 cm backwards in the dorsal fin (Heide-Jørgensen et al., 2017; Sonne et al., 2012). Current tag designs produce less drag, leading to a faster healing of the pin hole and reducing the risk of tag migration. However, as described in section 4.2.2. clear assessment of impacts on wild animals is still rare.

The recommendations from a recent joint workshop on cetacean tagging conducted by the US Naval Office, the IWC and the NMFS (International Whaling Commission, 2020) are to:

- Assess hydrodynamics of tags and all tag attachment types: initially using computer models and then transition to wind tunnel/water flumes (see for example Shorter et al., 2014).
- Evaluate increased energetic requirements of animal due to increased drag for all tag designs using computer simulations and captive animal experiments.

6.2.10 Decreased fitness

The tagging procedure, the accompanying stress or hydrodynamic drag can cause (temporary) disturbed behaviour that can potentially result in a decrease in foraging efficiency. Since harbour porpoises have high metabolic rates and need to forage at high rates (Booth, 2020; Hoekendijk et al., 2017; Kastelein et al., 1997a; Lockyer et al., 2003; Rojano-Donãte et al., 2018; Wisniewska et al., 2016, 2018a), a lower foraging efficiency could ultimately lead to a decline in fitness. Not only can the drag cause a potential decrease in foraging efficiency, but it can also cause a higher food intake requirement for the tagged animal.

A study on near-fasting for 24 hr periods (after which behaviour of a tagged porpoise returns to baseline, see section 4.2.2) with two animals in human care (Kastelein et al., 2019) showed decreases in blubber thickness (0-3 mm) and a loss of body mass (4%) during these near-fasting periods. Such mass losses are unlikely to result in declines in fitness of an animal in good condition. However, the effect of tagging on foraging efficiency and fitness is largely unknown.

7 Conclusions and recommendations

For several research questions that were identified as research priorities in the updated Conservation Plan, tagging of harbour porpoises using telemetry or biologging devices is a valid approach. Telemetry will prove most useful in studies concerning distribution, foraging ecology, and habitat use of harbour porpoises, and on anthropogenic impacts on harbour porpoises. Future results will permit comparison with other regions, especially Denmark, where multiple porpoise have been tracked, thus producing a better view of the North Sea population. As there is little experience in catching wild porpoises or tagging them in the Netherlands, starting up such a project and ultimately obtaining data that would be representative might take several years or even decades. However, initially data of single animals provide first insight into movements, certain behaviour and physiological capacities (dive depth/duration, swim speed, etc) specific to the shallow Dutch waters. Growing numbers will help indicate the scale of individual variation and differences between ages and sexes. So although every tagged animal can provide valuable information, some research questions formulated in this report, such as on distribution and habitat preferences, require substantial numbers of tagged animals (10-100) and long term data-collection.

The use of telemetry is expected to substantially add to the knowledge on harbour porpoises in the area, which can be implemented in the protection or conservation of the animals. However, there are (animal) ethical aspects to consider as wild animals need to be captured, handled and tags need to be attached after which the animals might be burdened with the instruments for at least the duration of the experiment. The pros and cons, therefore, need to be weighed carefully. Deliberations should include, for example, maximising the data collected with one animal (possibly leading to a heavier tag) or "spreading the load" and collecting less data (lighter tags) with more animals. Moreover, a tracking program should be aimed at ameliorating methods causing the least possible grief to the animals, coupled with a continuous search for less intrusive methods. Studies on wild animals may be cause for debate, even if this will profit the animals on the long run. Involvement of stakeholders in the process is essential.

Andrews et al. (2019) provide guidelines that help researchers, policy makers and other stakeholders to – through the evaluation of ethical and legal considerations – come to a decision on tagging of cetaceans. This work was further adapted during an IWC workshop (Andrews et al., 2019). Their framework can be condensed to a decision tree that consists of two phases, and includes an iterative third phase that will be used to evaluate the next steps (Figure 7.1). Following up on these suggestions we recommend to introduce the tagging of porpoise in the Netherlands in phases and to allow for evaluation after every phase ensuring public support and the best strategies to minimize impact to animals or to even refrain from continuing. The following subjects should be considered during this phased approach:

- **Clear definition of the (priority) research question(s)** and **realistic** research objectives, as well as **development of a plan** for data handling and analyses. An important part of this plan should be a description of tags, sample sizes and sampling duration needed to address the research topics and sketch realistic research goals (see Table 5-2). Prioritizing requires consideration of available time and resources – how many animals can realistically be caught and tagged in a certain amount of time, and which questions can be answered with this data?
- **Make sure every animal counts.** Since tagging porpoises will entrail a certain burden to the animals studied, it is important to ensure all data collected will be used at the advantage of the species (even when sample sizes are limited).
- **Early involvement of experienced research teams and training of involved staff.** Health risks to porpoises during capturing and tagging process should be minimised. This can be ensured by involving experienced personnel. In our case, we should cooperate closely with the Danish team that have captured and tagged multiple animals (Annex 3). Experienced researchers and

veterinarians can furthermore train the involved staff. Before tagging live porpoises, involved staff could for example practice on 'dummies' or on deceased stranded animals.

- **Regular assessment moments.** There should be regular assessment moments, in which risks, progress and necessity of further research should be evaluated and reconsidered. These could serve as so-called 'go/no-go' moments, and at any time during the research trajectory there must be the option to (temporarily) discontinue.
- **Risk assessment for animal welfare.** Prior to starting the tagging research a risk assessment should be done and repeated for different phases. This assessment should estimate the likelihood and severity of animal welfare issues, identify measures that can be taken to minimize risk and define acceptable risk levels.
- **Use of most suitable tags, considering both data collection quality and animal welfare.** Tag technology is a developing field. In the study of porpoises the best tags on the market should be used, both concerning data quality and animal welfare, but respecting the continuity of the study. There are various types of tag configuration, design and attachment, suitable for different kinds of information. Depending on the research question the most appropriate tag should be chosen (also see Table 5-2).
- **Evaluation of effect of tag on porpoise behaviour in human care.** Although quite some research has been done with tagging harbour porpoises, the effect of the tag on behaviour and energy consumption remains largely unknown. During the first phase of the research it is advised to study this in human care, where tagged and untagged individuals can be closely observed and compared.
- **Define clear health assessment requirements for study animals.** Before an individual porpoise can be tagged, it's general health and suitability for tagging should be assessed. Guidelines and protocols should also include selection criteria such as minimum size or animal status (i.e. pregnancy, age and nutritional stage).
- **Combine tagging data with data from other types of research.** In many cases data from tagging studies compliment data collected using other methods. Next to continuously evaluating the necessity of tagging if other data is available, the research team should ensure that both tracking data and other data are harmonised for optimal results. Such is the case for tracking data in relation to data obtained by PAM, strandings, aerial surveys etc. Additionally, opportunities should be sought to validate tracking results, for example by studying animals in captivity or in areas where porpoises occur in relatively predictable locations, to monitor tagged individuals visually and/or acoustically. This would allow for a better interpretation of the results.

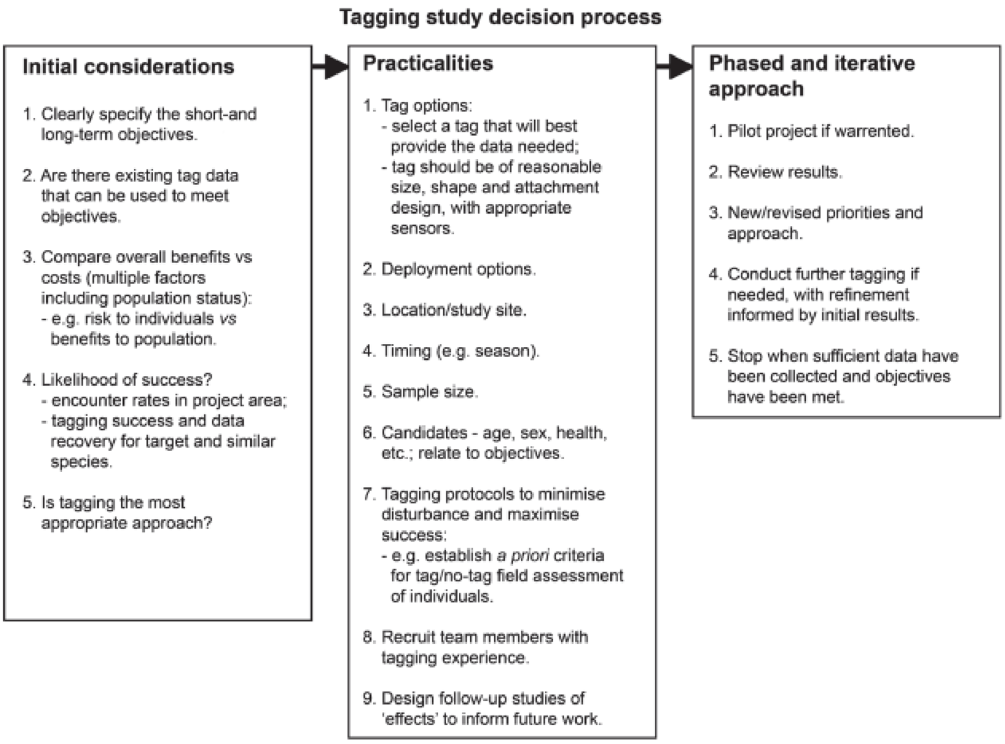


Figure 7.1. An example of a decision tree from IWC report, based on Andrews et al. 2019.

8 Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. This certificate is valid until 15 December 2021. The organisation has been certified since 27 February 2001. The certification was issued by DNV GL.

Acknowledgements

We would like to thank express our gratitude to the participants of the two workshops in 2021 that shared their experience with tagging and expressed their concerns; Jonas Teilmann, Mark Peter Johnson, Jakob Tougaard, René Dekeling & Brian Sharp. Members of the Dutch tagging project team were involved in the process of writing this report, and provided valuable input during different stages: Anne-Marie Svoboda, Annemarie van den Berg, Marije Siemensma, Floor Heinis, Niels Kinneging & Aylin Erkman. Furthermore we would like to thank the other national stakeholders and (inter)national experts that were present during the workshops and/or reviewed (sections of) this report; Ursula Siebert, Nathalie Houtman, Ron Kastelein, Frank Zanderink, Nynke Osinga, Patrick Miller, Sander von Benda-Beckmann, Christ de Jong & Sophie Brasseur, as well as Jaap van der Meer for his valuable remarks early in the process. Last but not least we would like to thank the Ministry of Agriculture, Nature and Food Quality (LNV) for enabling this study.

References

Aarts, G., MacKenzie, M., McConnell, B., Fedak, M., & Matthiopoulos, J. (2008). Estimating space-use and habitat preference from wildlife telemetry data. *Ecography*, *31*(1), 140–160. https://doi.org/10.1111/j.2007.0906-7590.05236.x

Aarts, G., Von Benda-Beckmann, A. M., Lucke, K., Sertlek, H. Ö., Van Bemmelen, R., Geelhoed, S. C. V., Brasseur, S., Scheidat, M., Lam, F.-P. A., Slabbekoorn, H., Slabbekoorn, H., & Kirkwood, R. (2016). Harbour porpoise movement strategy affects cumulative number of animals acoustically exposed to underwater explosions. *Marine Ecology Progress Series*, *557*, 261–275. https://doi.org/10.3354/meps11829

Aarts, G., Brasseur, S., & Kirkwood, R. (2018). *Behavioural response of grey seals to pile-driving.* (Report C006/18). Wageningen Marine Research. https://doi.org/10.18174/466039

Aebischer, N. J., Robertson, P. A., & Kenward, R. E. (1993). Compositional Analysis of Habitat Use From Animal Radio-Tracking Data. *Ecology*, *74*(5), 1313–1325. https://doi.org/10.2307/1940062

Akamatsu, T., Matsuda, A., Suzuki, S., Wang, D., Wang, K., Suzuki, M., Muramoto, H., Sugiyama, N., & Oota, K. (2005). New stereo acoustic data logger for free-ranging dolphins and porpoises. *Marine Technology Society Journal*, *39*(2). https://doi.org/10.4031/002533205787443980

Andrews, R. D., Baird, R. W., Calambokidis, J., Goertz, C. E., Gulland, F., Peter Heide-jørgensen, M., H Ooker, S. K., Johnson, M., Ate, B. M., Mitani, Y., N Owacek, D. P., Wen, K. O., Quakenbush, L. T., Averty, S. R., Robbins, J., S Chorr, G. S., Shpak, O. V, Townsend, F. I., Hart, M. U., Wells, R. S., & Lexandre Zerbini, A. N. (2019). Best practice guidelines for cetacean tagging. *Journal of Cetacean Research and Management*, *20*, 27–66. https://doi.org/10.47536/JCRM.V20I1.237

Aoki, K., Watanabe, Y., Inamori, D., Funasaka, N., & Sakamoto, K. Q. (2021). Towards non-invasive heart rate monitoring in free-ranging cetaceans: a unipolar suction cup tag measured the heart rate of trained Risso's dolphins. *Philosophical Transactions of the Royal Society B*, *376*(1831). https://doi.org/10.1098/RSTB.2020.0225

Arranz, P., de Soto, N. A., Madsen, P. T., Brito, A., Bordes, F., & Johnson, M. P. (2011). Following a Foraging Fish-Finder: Diel Habitat Use of Blainville's Beaked Whales Revealed by Echolocation. *PLOS ONE*, *6*(12), e28353. https://doi.org/10.1371/JOURNAL.PONE.0028353

Balmer, B., Watwood, S., Quigley, B., Speakman, T., Barry, K., Mullin, K., Rosel, P., Sinclair, C., Zolman, E., & Schwacke, L. (2019). Common bottlenose dolphin (Tursiops truncatus) abundance and distribution patterns in St Andrew Bay, Florida, USA. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *29*(3), 486–498. https://doi.org/10.1002/AQC.3001

Balmer, B. C., Schwacke, L. H., & Wells, R. S. (2010). Linking dive behavior to satellite-linked tag condition for a bottlenose dolphin (*Tursiops truncatus*) along florida's Northern gulf of Mexico coast. *Aquatic Mammals*, *36*(1). https://doi.org/10.1578/AM.36.1.2010.1

Balmer, B. C., Wells, R. S., Schwacke, L. H., Rowles, T. K., Hunter, C., Zolman, E. S., Townsend, F. I., Danielson, B., Westgate, A. J., McLellan, W. A., & Pabst, D. A. (2011). Evaluation of a single-pin, satellite-linked transmitter deployed on bottlenose dolphins (*Tursiops truncatus*) along the coast of Georgia, USA. *Aquatic Mammals*, *37*(2), 187–192. https://doi.org/10.1578/AM.37.2.2011.187

Balmer, B. C., Wells, R. S., Howle, L. E., Barleycorn, A. A., McLellan, W. A., Ann Pabst, D., Rowles, T. K., Schwacke, L. H., Townsend, F. I., Westgate, A. J., & Zolman, E. S. (2014). Advances in cetacean telemetry: A review of single-pin transmitter attachment techniques on small cetaceans and development of a new satellite-linked transmitter design. *Marine Mammal Science*, *30*(2), 656–673. https://doi.org/10.1111/MMS.12072

Bedriñana-Romano, L., Hucke-Gaete, R., Viddi, F. A., Johnson, D., Zerbini, A. N., Morales, J., Mate, B., & Palacios, D. M. (2021). Defining priority areas for blue whale conservation and investigating overlap with vessel traffic in Chilean Patagonia, using a fast-fitting movement model. *Scientific Reports*, *11*(1), 1–16. https://doi.org/10.1038/s41598-021-82220-5

Berga, A. S., Wright, A. J., Galatius, A., Sveegaard, S., & Teilmann, J. (2015). Do larger tag packages alter diving behavior in harbor porpoises? *Marine Mammal Science*, *31*(2), 756–763. https://doi.org/10.1111/mms.12179

Bickett, N. J., Tift, M. S., St. Leger, J., & Ponganis, P. J. (2019). Heart rates, heart rate profiles, and electrocardiograms in three killer whales, a beluga, and a pilot whale: An exploratory investigation. *Marine Mammal Science*, *35*(3), 1112–1132. https://doi.org/10.1111/MMS.12578/SUPPINFO

Block, B. A. (2005). Physiological ecology in the 21st century: Advancements in biologging science. *Integrative and Comparative Biology*, *45*(2), 305–320. https://doi.org/10.1093/ICB/45.2.305

Block, B. A., Jonsen, I. D., Jorgensen, S. J., Winship, A. J., Shaffer, S. A., Bograd, S. J., Hazen, E. L., Foley,

D. G., Breed, G. A., Harrison, A. L., Ganong, J. E., Swithenbank, A., Castleton, M., Dewar, H., Mate, B. R., Shillinger, G. L., Schaefer, K. M., Benson, S. R., Weise, M. J., Henry, R. W., & Costa, D. P. (2011). Tracking apex marine predator movements in a dynamic ocean. *Nature*, *475*(7354), 86–90. https://doi.org/10.1038/NATURE10082

Blomqvist, C., & Amundin, M. (2005). An Acoustic Tag for Recording Directional Pulsed Ultrasounds Aimed at Free-Swimming Bottlenose Dolphins (*Tursiops truncatus*) by Conspecifics. *Aquatic Mammals*, *30*(3), 345–356. https://doi.org/10.1578/am.30.3.2004.345

Bograd, S. J., Block, B. A., Costa, D. P., & Godley, B. J. (2010). Biologging technologies: New tools for conservation. Introduction. *Endangered Species Research*, *10*(1), 1–7. https://doi.org/10.3354/ESR00269

Booth, C. G., Harwood, J., Plunkett, R., Mendes, S., & Walker, R. (2016). *Using the "Interim PCoD" framework to assess the potential effects of planned offshore wind developments in Eastern English Waters on harbour porpoises in the North Sea* (Report Joint Publication JP024; Issue June). Natural England.

Booth, C. G. (2020). Food for thought: Harbor porpoise foraging behavior and diet inform vulnerability to disturbance. *Marine Mammal Science*, *36*(1). https://doi.org/10.1111/mms.12632

Brandt, M. J., Diederichs, A., Betke, K., & Nehls, G. (2011). Responses of harbour porpoises to pile driving at the Horns Rev II offshore wind farm in the Danish North Sea. *Marine Ecology Progress Series*, *421*, 205–216. https://doi.org/10.3354/MEPS08888

Brandt, M. J., Dragon, A.-C., Diederichs, A., Schubert, A., Kosarev, V., & Nehls, G. (2016). *Effects of offshore pile driving on harbour porpoise abundance in the German Bight. Final report* [Report]. IBL, IFAÖ & BioConsult.

Brandt, M. J., Dragon, A. C., Diederichs, A., Bellmann, M. A., Wahl, V., Piper, W., Nabe-Nielsen, J., & Nehls, G. (2018). Disturbance of harbour porpoises during construction of the first seven offshore wind farms in Germany. *Marine Ecology Progress Series*, *596*, 213–232. https://doi.org/10.3354/MEPS12560

Brinkkemper, J. A., Geelhoed, S. C. V., Bergès, B. J. P., Noort, C. A., Nieuwendijk, D. N., & Verdaat, J. P. (2021). *Underwater sound measurements - During the installation of the Borssele OWF Client: Rijkswaterstaat Water, Verkeer en Leefomgeving* (WP2019_1173_R9r1).

Buckland, S. T., Rexstad, E. A., Marques, T. A., & Oedekoven, C. S. (2015). *Methods in Statistical Ecology Distance Sampling: Methods and Applications* (S. T. Buckland et al. (eds.)). Springer International Publishing. https://doi.org/10.1007/978-3-319-19219-2

Calenge, C. (2019). *Home Range Estimation in R: the adehabitatHR Package*.

Câmara, N., Sierra, E., Fernández, A., Arbelo, M., de Quirós, Y. B., Arregui, M., Consoli, F., & Herráez, P. (2020). Capture Myopathy and Stress Cardiomyopathy in a Live-Stranded Risso's Dolphin (*Grampus griseus*) in Rehabilitation. *Animals 2020, Vol. 10, Page 220*, *10*(2), 220. https://doi.org/10.3390/ANI10020220

Carlén, I., Thomas, L., Carlström, J., Amundin, M., Teilmann, J., Tregenza, N., Tougaard, J., Koblitz, J. C., Sveegaard, S., Wennerberg, D., Loisa, O., Dähne, M., Brundiers, K., Kosecka, M., Kyhn, L. A., Ljungqvist, C. T., Pawliczka, I., Koza, R., Arciszewski, B., Galatius, A., Jabbusch, M., Laaksonlaita, J., Niemi, J., Lyytinen, S., Gallus, A., Benke, H., Blankett, P., Skóra, K. E., & Acevedo-Gutiérrez, A. (2018). Basin-scale distribution of harbour porpoises in the Baltic Sea provides basis for effective conservation actions. *Biological Conservation*, *226*, 42–53. https://doi.org/10.1016/J.BIOCON.2018.06.031

Chilvers, B., Corkeron, P. P. J., Blanshard, W. W. H., Long, T. T. R., & Martin, A. A. R. (2001). A new VHF tag and attachment technique for small cetaceans. *Aquatic Mammals*, *27*(1), 11–15. https://www.researchgate.net/publication/232271940_A_new_VHF_tag_and_attachment_technique_for_small_cetaceans

Chivers, S. J., Danil, K., & Dizon, A. E. (2000). Projectile biopsy sampling of cetacean species. In *International Whaling Commission, Scientific Committee paper SC/52/O*. International Whaling Commission.

Chudzinska, M., Nabe-Nielsen, J., Smout, S., Aarts, G., Brasseur, S., Graham, I., Thompson, P., & McConnell, B. (2021). AgentSeal: Agent-based model describing movement of marine central-place foragers. *Ecological Modelling*, *440*, 109397. https://doi.org/10.1016/J.ECOLMODEL.2020.109397

Chung, H., Lee, J., & Lee, W. Y. (2021). A Review: Marine Bio-logging of Animal Behaviour and Ocean Environments. *Ocean Science Journal*, *56*(2), 117–131. https://doi.org/10.1007/S12601-021-00015-1

Cooke, S. J. (2008). Biotelemetry and biologging in endangered species research and animal conservation: Relevance to regional, national, and IUCN Red List threat assessments. *Endangered Species Research*, *4*(1–2), 165–185. https://doi.org/10.3354/ESR00063

Costa, D. P., Robinson, P. W., Arnould, J. P. Y., Harrison, A. L., Simmons, S. E., Hassrick, J. L., Hoskins, A. J., Kirkman, S. P., Oosthuizen, H., Villegas-Amtmann, S., & Crocker, D. E. (2010). Accuracy of ARGOS locations of Pinnipeds at-Sea estimated using Fastloc GPS. *PLoS ONE.*, *5*(1), e8677. https://doi.org/10.1371/journal.pone.0008677

Cumming, G. S., & Cornélis, D. (2012). Quantitative comparison and selection of home range metrics for telemetry data. *Diversity and Distributions*, *18*(11), 1057–1065. https://doi.org/10.1111/J.1472-4642.2012.00908.X

Dähne, M., Gilles, A., Lucke, K., Peschko, V., Adler, S., Krügel, K., Sundermeyer, J., & Siebert, U. (2013). Effects of pile-driving on harbour porpoises (*Phocoena phocoena*) at the first offshore wind farm in Germany. *Environmental Research Letters*, *8*(2), 025002. https://doi.org/10.1088/1748-9326/8/2/025002

Dähne, M., Tougaard, J., Carstensen, J., Rose, A., & Nabe-Nielsen, J. (2017). Bubble curtains attenuate noise from offshore wind farm construction and reduce temporary habitat loss for harbour porpoises. *Marine Ecology Progress Series*, *580*, 221–237. https://doi.org/10.3354/MEPS12257

Davis, R., Jaquet, N., Gendron, D., Markaida, U., Bazzino, G., & Gilly, W. (2007). Diving behavior of sperm whales in relation to behavior of a major prey species, the jumbo squid, in the Gulf of California, Mexico. *Marine Ecology Progress Series*, *333*, 291–302. https://doi.org/10.3354/meps333291

Deruiter, S. L., Bahr, A., Blanchet, M. A., Hansen, S. F., Kristensen, J. H., Madsen, P. T., Tyack, P. L., & Wahlberg, M. (2009). Acoustic behaviour of echolocating porpoises during prey capture. *Journal of Experimental Biology*, *212*(19), 3100–3107. https://doi.org/10.1242/JEB.030825

Deruiter, S. L., Southall, B. L., Calambokidis, J., Zimmer, W. M. X., Sadykova, D., Falcone, E. A., Friedlaender, A. S., Joseph, J. E., Moretti, D., Schorr, G. S., Thomas, L., & Tyack, P. L. (2013). First direct measurements of behavioural responses by Cuvier's beaked whales to mid-frequency active sonar. *Biology Letters*, *9*(4). https://doi.org/10.1098/RSBL.2013.0223

Dietz, R., Teilmann, J., Henriksen, O., & Laidre, K. (2003). *Movements of seals from Rødsand seal sanctuary monitored by satellite telemetry Relative importance of the Nysted Offshore Wind Farm area to the seals* (Report No. 429). National Environmental Research Institute, Ministry of the Environment, Denmark. https://www.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/FR429.pdf

Dujon, A. M., Lindstrom, R. T., & Hays, G. C. (2014). The accuracy of Fastloc-GPS locations and implications for animal tracking. *Methods Ecol Evol*, *5*(11), 1162–1169. https://doi.org/10.1111/2041-210x.12286

Edrén, S. M. C., Wisz, M. S., Teilmann, J., Dietz, R., & Söderkvist, J. (2010). Modelling spatial patterns in harbour porpoise satellite telemetry data using maximum entropy. *Ecography*, *33*(4), 698–708.

Elmegaard, S. L., McDonald, B. I., & Madsen, P. T. (2019). Drivers of the dive response in trained harbour porpoises (*Phocoena phocoena*). *Journal of Experimental Biology*, *222*(19). https://doi.org/10.1242/JEB.208637

Emeis, K. C., van Beusekom, J., Callies, U., Ebinghaus, R., Kannen, A., Kraus, G., Kröncke, I., Lenhart, H., Lorkowski, I., Matthias, V., Möllmann, C., Pätsch, J., Scharfe, M., Thomas, H., Weisse, R., & Zorita, E. (2015). The North Sea — A shelf sea in the Anthropocene. *Journal of Marine Systems*, *141*, 18–33. https://doi.org/10.1016/J.JMARSYS.2014.03.012

Eskesen, I., Teilmann, J., Geertsen, B., & Desportes, G. (2009). Stress level in wild harbour porpoises (*Phocoena phocoena*) during satellite tagging measured by respiration, heart rate and cortisol. *Marine Biological Association of the United Kingdom*, *89*(5), 556–892.

Fleming, C., Evolution, J. C.-M. in E. and, & 2017, undefined. (2016). A new kernel density estimator for accurate home-range and species-range area estimation. *Wiley Online Library*, *8*(5), 571–579. https://doi.org/10.1111/2041-210X.12673

Friedlaender, A. S., Hazen, E. L., Goldbogen, J. A., Stimpert, A. K., Calambokidis, J., Southall, B. L., & Southall2', B. L. (2016). Prey-mediated behavioral responses of feeding blue whales in controlled sound exposure experiments. *Ecological Applications*, *26*(4), 1075–1085. https://doi.org/10.1002/15-0783

Gallagher, C. A., Grimm, V., Kyhn, L. A., Kinze, C. C., & Nabe-Nielsen, J. (2021). Movement and Seasonal Energetics Mediate Vulnerability to Disturbance in Marine Mammal Populations. *The American Naturalist*, *197*(3), 296–311. https://doi.org/10.1086/712798

Geelhoed, S., Friedrich, E., Joost, M., & Machiels, M. (2018). *Gemini Tc: aerial surveys and passive acoustic monitoring of harbour porpoises 2015* (Report C020/17). Wageningen Marine Research. https://doi.org/10.18174/410635

Geertsen, B. M., Teilmann, J., Kastelein, R. A., Vlemmix, H. N. J., & Miller, L. A. (2004). Behaviour and physiological effects of transmitter attachments on a captive harbour porpoise (*Phocoena phocoena*). *Journal of Cetacean Research and Management*, *6*(2), 139–146. https://doi.org/10.1071/WR10177

Gilles, A. (2009). *Characterisation of harbour porpoise (*Phocoena phocoena*) habitat in German waters* [Thesis, Christian-Albrechts-Universität zu Kiel]. Christian-Albrechts-Universität zu Kiel. https://macau.uni-kiel.de/servlets/MCRFileNodeServlet/dissertation_derivate_00002663/gilles_diss.pdf

Gilles, A., Adler, S., Kaschner, K., Scheidat, M., & Siebert, U. (2011). Modelling harbour porpoise seasonal density as a function of the German Bight environment: implications for management. *Endangered Species Research*, *14*(2), 157–169. https://doi.org/10.3354/ESR00344

Gilles, A., Viquerat, S., Becker, E. A., Forney, K. A., Geelhoed, S. C. V., Haelters, J., Nabe-Nielsen, J., Scheidat, M., Siebert, U., Sveegaard, S., Van Beest, F. M., Van Bemmelen, R., & Aarts, G. (2016). Seasonal habitat-based density models for a marine top predator, the harbor porpoise, in a dynamic environment. *Ecosphere*, *7*(6), e01367. https://doi.org/10.1002/ecs2.1367

Goldbogen, J. A., Cade, D. E., Calambokidis, J., Czapanskiy, M. F., Fahlbusch, J., Friedlaender, A. S., Gough, W. T., Kahane-Rapport, S. R., Savoca, M. S., Ponganis, K. V., & Ponganis, P. J. (2019). Extreme bradycardia and tachycardia in the world's largest animal. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(50), 25329–25332. https://doi.org/10.1073/PNAS.1914273116

Guzman, H. M., Capella, J. J., Valladares, C., Gibbons, J., & Condit, R. (2020). Humpback whale movements in a narrow and heavily-used shipping passage, Chile. *Marine Policy*, *118*, 103990. https://doi.org/10.1016/J.MARPOL.2020.103990

Hammond, P. S., Lacey, C., Gilles, A., Viquerat, S., Börjesson, P., Herr, H., McLeod, K., Ridoux, V., Santos, M., Scheidat, M., Teilmann, J., Vingada, J., & Øien, N. (2017). *Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys* [Report]. https://synergy.st-andrews.ac.uk/scans3/files/2017/04/SCANS-III-design-based-estimates-2017-04-28-final.pdf

Hanson, M. B., & Baird, R. W. (1998). Dall's Porpoise Reactions to Tagging Attempts Using A Remotely-Deployed Suction-Cup Tag. *Marine Technology Society Journal*, *32*(2).

Hanson, M. B. (2001). *An evaluation of the relationship between small cetacean tag design and attachment durations: a bioengineering approach.* [Thesis, University of Washington]. University of Washington. https://www.researchgate.net/publication/237120405_An_Evaluation_of_the_Relationship_Between_Small_Cetacean_Tag_Design_and_Attachment_Durations_A_Bioengineering_Approach

Harwood, J., Booth, C. G., Sinclair, R., & Hague, E. (2020). Developing marine mammal Dynamic Energy Budget models and their potential for integration into the iPCoD framework. *Scottish Marine and Freshwater Science*, *11*(11). https://doi.org/10.7489/12328-1

Hasselmeier, I., Abt, K. F., Adelung, D., & Siebert, U. (2004). Stranding patterns of harbour porpoises (*Phocoena phocoena*) in the German North and Baltic Seas; when does the birth period occur? *Journal of Cetacean Research and Management*, *6*(3), 259 to 263.

Hastie, G. D., Gillespie, D. M., Gordon, J. C. D., Macaulay, J. D. J., McConnell, B. J., & Sparling, C. E. (2014). Tracking Technologies for Quantifying Marine Mammal Interactions with Tidal Turbines: Pitfalls and Possibilities. In M. A. Shields et al. (Eds.), *Marine Renewable Energy Technology and Environmental Interactions* (pp. 127–139). Springer. https://doi.org/10.1007/978-94-017-8002-5_10

Hastie, G. D., Lepper, P., Mcknight, | J Chris, Milne, R., Russell, D. J. F., & Thompson, D. (2021). Acoustic risk balancing by marine mammals: anthropogenic noise can influence the foraging decisions by seals. *J Appl Ecol*, *00*, 1–10. https://doi.org/10.1111/1365-2664.13931

Heerah, K., Hindell, M., Guinet, C., & Charrassin, J.-B. (2015). From high-resolution to low-resolution dive datasets: a new index to quantify the foraging effort of marine predators. *Anim Biotelemetry*, *3*, 42. https://doi.org/10.1186/s40317-015-0074-3

Heide-Jørgensen, M. P., Laidre, K. L., Litovka, D., Villum Jensen, M., Grebmeier, J. M., & Sirenko, B. I. (2012). Identifying gray whale (*Eschrichtius robustus*) foraging grounds along the Chukotka Peninsula, Russia, using satellite telemetry. *Polar Biol*, *35*, 1035–1045. https://doi.org/10.1007/s00300-011-1151-6

Heide-Jørgensen, M. P., Nielsen, N. H., Teilmann, J., & Leifsson, P. S. (2017). Long-term tag retention on two species of small cetaceans. *Marine Mammal Science*, *33*(3), 713–725. https://doi.org/10.1111/mms.12394

Heinis, F., & de Jong, C. (2015). *Cumulative effects of impulsive underwater sound on marine mammals.* (Report No. R10335-A). TNO. https://tethys.pnnl.gov/sites/default/files/publications/TNO-2015.pdf

Heinis, F., de Jong, C. A. F., von Benda-Beckmann, S., & Binnerts, B. (2019). *Framework for Assessing Ecological and Cumulative Effects – 2018. Cumulative effects of offshore wind farm construction on harbour porpoises* (Report 18.153RWS_KEC2018). Heinis Waterbeheer en Ecologie, TNO. https://www.noordzeeloket.nl/publish/pages/165414/kec_update_3_0_part_b_cumulative_effects_on_harbour_porpoise.pdf

Herr, H., Fock, H. O., & Siebert, U. (2009). Spatio-temporal associations between harbour porpoise *Phocoena phocoena* and specific fisheries in the German Bight. *Biological Conservation*, *142*(12), 2962–2972. https://doi.org/10.1016/J.BIOCON.2009.07.025

Herráez, P., Espinosa de los Monteros, A., Fernández, A., Edwards, J. F., Sacchini, S., & Sierra, E. (2013). Capture myopathy in live-stranded cetaceans. *The Veterinary Journal*, *196*(2), 181–188. https://doi.org/10.1016/J.TVJL.2012.09.021

Higgins, J. L., & Hendrickson, D. A. (2013). Surgical procedures in pinniped and cetacean species. *Journal of Zoo and Wildlife Medicine*, *44*(4), 817–836. https://doi.org/10.1638/2012-0286R1.1

Hildebrand, J. A. (2009). Anthropogenic and natural sources of ambient noise in the ocean. *Marine Ecology Progress Series*, *395*, 5–20. https://doi.org/10.3354/MEPS08353

Hoekendijk, J. P., Spitz, J., Read, A. J., Leopold, M. F., & Fontaine, M. C. (2017). Resilience of harbor porpoises to anthropogenic disturbance: Must they really feed continuously? *Marine Mammal Science*, *34*(1), 258–264. https://doi.org/10.1111/mms.12446

Holton, M. D., Wilson, R. P., Teilmann, J., & Siebert, U. (2021). Animal tag technology keeps coming of age: an engineering perspective. *Philosophical Transactions of the Royal Society B*, *376*(1831). https://doi.org/10.1098/RSTB.2020.0229

IJsseldijk, L. L., ten Doeschate, M. T. I., Brownlow, A., Davison, N. J., Deaville, R., Galatius, A., Gilles, A., Haelters, J., Jepson, P. D., Keijl, G. O., Kinze, C. C., Olsen, M. T., Siebert, U., Thøstesen, C. B., van den Broek, J., Gröne, A., & Heesterbeek, H. (2020). Spatiotemporal mortality and demographic trends in a small cetacean: Strandings to inform conservation management. *Biological Conservation*, *249*, 108733. https://doi.org/10.1016/J.BIOCON.2020.108733

IJsseldijk, L. L., Hessing, S., Mairo, A., ten Doeschate, M. T. I., Treep, J., van den Broek, J., Keijl, G. O., Siebert, U., Heesterbeek, H., Gröne, A., & Leopold, M. F. (2021). Nutritional status and prey energy density govern reproductive success in a small cetacean. *Scientific Reports 2021 11:1*, *11*(1), 1–13. https://doi.org/10.1038/s41598-021-98629-x

International Whaling Commission. (2020). Report of the Joint US Office of Naval Research, International Whaling Commission and US National Oceanic and Atmospheric Administration Workshop on Cetacean Tag Development, Tag Follow-up and Tagging Best Practices. *Journal of Cetacean Research and Management (Supplement)*, *21*, 349–372. https://doi.org/10.25607/OBP-858

Irvine, A., Wells, R., & Scott, M. D. (1982). An evaluation of techniques for tagging small odontocete cetaceans. *Fishery Bulletin - National Oceanic and Atmospheric Administration*, *80*(1), 135–143. https://spo.nmfs.noaa.gov/sites/default/files/pdf-content/1982/801/irvine.pdf

Irvine, L. M., Winsor, M. H., Follett, T. M., Mate, B. R., & Palacios, D. M. (2020). An at-sea assessment of Argos location accuracy for three species of large whales, and the effect of deep-diving behavior on location error. *Animal Biotelemetry*, *8*(1), 1–17. https://doi.org/10.1186/S40317-020-00207-X/TABLES/4

Isojunno, S., Sadykova, D., Deruiter, S., Cure, C., Visser, F., Thomas, L., Miller, P. J. O., & Harris, C. M. (2017). Individual, ecological, and anthropogenic influences on activity budgets of long-finned pilot whales. *Ecosphere*, *8*(12), e02044. https://doi.org/10.1002/ECS2.2044

Jansen, O. E., Aarts, G. M., Das, K., Lepoint, G., Michel, L., & Reijnders, P. J. H. (2012). Feeding ecology of harbour porpoises: stable isotope analysis of carbon and nitrogen in muscle and bone. *Marine Biology Research*, *8*(9), 829–841. https://doi.org/10.1080/17451000.2012.692164

Johnson, M., Madsen, P. T., Zimmer, W. M. X., Aguilar De Soto, N., & Tyack, P. L. (2004). Beaked whales echolocate on prey. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *271*(SUPPL. 6). https://doi.org/10.1098/RSBL.2004.0208

Johnson, M., De Soto, N. A., & Madsen, P. T. (2009). Studying the behaviour and sensory ecology of marine mammals using acoustic recording tags: A review. *Marine Ecology Progress Series*, *395*, 55–73. https://doi.org/10.3354/meps08255

Johnson, M. (2021). Overview of, and development in, biologging tags for harbour porpoise. *International Workshop on Tagging of Harbour Porpoise in the Netherlands*, 8.

Johnson, M. P., & Tyack, P. L. (2003). A digital acoustic recording tag for measuring the response of wild marine mammals to sound. *IEEE Journal of Oceanic Engineering*, *28*(1), 3–12. https://doi.org/10.1109/JOE.2002.808212

Johnston, A. S. A., Boyd, R. J., Watson, J. W., Paul, A., Evans, L. C., Gardner, E. L., & Boult, V. L. (2019). *Predicting population responses to environmental change from individual-level mechanisms: towards a standardized mechanistic approach*. https://doi.org/10.1098/rspb.2019.1916

Jones, T. T. (2013). Calculating the ecological impacts of animal-borne instruments on aquatic organisms. *Methods Ecol. Evol.*, *4*(12), 1178–1186. https://doi.org/10.1111/2041-210x.12109

Karimi, M. A., Zhang, Q., Kuo, Y. H., Shaikh, S. F., Kaidarova, A., Geraldi, N., Hussain, M. M., Kosel, J., Duarte, C. M., & Shamim, A. (2019). Flexible tag design for semi-continuous wireless data acquisition from marine animals. *Flexible and Printed Electronics*, *4*(3). https://doi.org/10.1088/2058-8585/ab423f

Kastelein, R. A., Hardeman, J., & Boer, H. (1997a). Food consumption and body weight of harbour porpoises (*Phocoena phocoena*). In A. J. Read et al. (Eds.), *The Biology of the Harbour Porpoise*. De Spil Publishers.

Kastelein, R. A., Bakker, M. J., & Staal, C. (1997b). The rehabilitation and release of stranded harbour porpoises (*Phocoena phocoena*). In A. J. Read et al. (Eds.), *The biology of the harbour porpoise*. De Spill. https://www.researchgate.net/publication/280614662_The_rehabilitation_and_release_of_stranded_harbour_porpoises_Phocoena_phocoena

Kastelein, R. A. (2016). *Personal communication*.

Kastelein, R. A., Helder-Hoek, L., Jennings, N., van Kester, R., & Huisman, R. (2019). Reduction in body mass and blubber thickness of harbor porpoises (*Phocoena phocoena*) due to near-fasting for 24 hours in four seasons. *Aquatic Mammals*, *45*(1), 37–47. https://doi.org/10.1578/AM.45.1.2019.37

Kastelein, R. A. (2022). *Personal communication*.

Kay, W. P., Naumann, D. S., Bowen, H. J., Withers, S. J., Evans, B. J., Wilson, R. P., Stringell, T. B., Bull, J. C., Hopkins, P. W., & Börger, L. (2019). Minimizing the impact of biologging devices: Using computational fluid dynamics for optimizing tag design and positioning. *Methods in Ecology and Evolution*, *10*(8), 1222–1233. https://doi.org/10.1111/2041-210X.13216

Kindt-Larsen, L., Berg, C. W., Tougaard, J., Sørensen, T. K., Geitner, K., Northridge, S., Sveegaard, S., & Larsen, F. (2016). Identification of high-risk areas for harbour porpoise *Phocoena phocoena* bycatch using remote electronic monitoring and satellite telemetry data. *Marine Ecology Progress Series*, *555*, 261–271. https://doi.org/10.3354/meps11806

Kyte, A., Pass, C., Pemberton, R., Sharman, M., & McKnight, J. C. (2019). A computational fluid dynamics (CFD) based method for assessing the hydrodynamic impact of animal borne data loggers on host marine mammals. *Marine Mammal Science*, *35*(2), 364–394. https://doi.org/10.1111/MMS.12540

Ladegaard, M., & Madsen, P. T. (2019). Context-dependent biosonar adjustments during active target approaches in echolocating harbour porpoises. *Journal of Experimental Biology*, *222*(16). https://doi.org/10.1242/jeb.206169

Lawson, G. L., Hückstädt, L. A., Lavery, A. C., Jaffré, F. M., Wiebe, P. H., Fincke, J. R., Crocker, D. E., & Costa, D. P. (2015). Development of an animal-borne "sonar tag" for quantifying prey availability: Test deployments on northern elephant seals. *Animal Biotelemetry*, *3*(1). https://doi.org/10.1186/S40317-015-0054-7

Leopold, M. (2015). *Eat and be eaten: Porpoise diet studies* [Thesis, Wageningen University]. Wageningen University. https://library.wur.nl/WebQuery/wurpubs/fulltext/361729

Lockyer, C., Desportes, G., Hansen, K., Labberté, S., & Siebert, U. (2003). Monitoring growth and energy utilisation of the harbour porpoise (*Phocoena phocoena*) in human care. *NAMMCO Scientific Publications*. https://doi.org/10.7557/3.2743

Lockyer, C. (2003). Harbour porpoises (*Phocoena phocoena*) in the North Atlantic: Biological parameters. *NAMMCO Scientific Publications*, *5*, 71–89. https://doi.org/10.7557/3.2740

Lopez, R., Malardé, J. P., Danès, P., & Gaspar, P. (2015). Improving Argos Doppler location using multiple-model smoothing. *Animal Biotelemetry*, *3*(1), 1–9. https://doi.org/10.1186/S40317-015-0073-4/TABLES/3

Lucke, K., Siebert, U., Lepper, P. A., & Blanchet, M.-A. (2009). Temporary shift in masked hearing thresholds in a harbor porpoise (*Phocoena phocoena*) after exposure to seismic airgun stimuli. *The Journal of the Acoustical Society of America*, *125*(6), 4060. https://doi.org/10.1121/1.3117443

Madsen, P. T., Johnson, M., Aguilar De Soto, N., Zimmer, W. M. X., & Tyack, P. (2005). Biosonar performance of foraging beaked whales (*Mesoplodon densirostris*). *Journal of Experimental Biology*, *208*(2), 181–194. https://doi.org/10.1242/JEB.01327

Madsen, P. T., Johnson, M., Miller, P. J. O., Soto, N. A., Lynch, J., & Tyack, P. (2006). Quantitative measures of air-gun pulses recorded on sperm whales (*Physeter macrocephalus*) using acoustic tags during controlled exposure experiments. *The Journal of the Acoustical Society of America*, *120*(4), 2366. https://doi.org/10.1121/1.2229287

Malakoff, D. (2010). A push for quieter ships. *Science*, *328*(5985), 1502–1503. https://doi.org/10.1126/science.328.5985.1502

Marques, T. A., Thomas, L., Martin, S. W., Mellinger, D. K., Ward, J. A., Moretti, D. J., Harris, D., & Tyack, P. L. (2013). Estimating animal population density using passive acoustics. *Biological Reviews*, *88*(2), 287–309. https://doi.org/10.1111/BRV.12001

Mate, B. R., Best, P. B., Lagerquist, B. A., & Winsor, M. H. (2011). Coastal, offshore, and migratory movements of South African right whales revealed by satellite telemetry. *Marine Mammal Science*, *27*(3), 455–476. https://doi.org/10.1111/j.1748-7692.2010.00412.x

McDonald, B. I., Johnson, M., & Madsen, P. T. (2018). Dive heart rate in harbour porpoises is influenced by exercise and expectations. *Journal of Experimental Biology*, *221*(1). https://doi.org/10.1242/JEB.168740

McDonald, B. I., Elmegaard, S. L., Johnson, M., Wisniewska, D. M., Rojano-Doñate, L., Galatius, A., Siebert, U., Teilmann, J., & Madsen, P. T. (2021). High heart rates in hunting harbour porpoises. *Proceedings of the Royal Society B*, *288*(1962). https://doi.org/10.1098/RSPB.2021.1596

McIntyre, T. (2014). Trends in tagging of marine mammals: a review of marine mammal biologging studies. *African Journal of Marine Science*, *36*(4), 409–422. https://doi.org/10.2989/1814232X.2014.976655

Merchant, N. D., Faulkner, R. C. R. C., & Martinez, R. (2018). Marine Noise Budgets in Practice. *Conservation Letters*, *11*(3), 1–8. https://doi.org/10.1111/conl.12420

Mikkelsen, L., Rigét, F. F., Kyhn, L. A., Sveegaard, S., Dietz, R., Tougaard, J., Carlström, J. A. K., Carlén, I., Koblitz, J. C., & Teilmann, J. (2016). Comparing distribution of harbour porpoises (*Phocoena phocoena*) derived from satellite telemetry and passive acoustic monitoring. *Plos One*, *11*(7), e0158788.

Mikkelsen, L., Johnson, M., Wisniewska, D. M., van Neer, A., Siebert, U., Madsen, P. T., & Teilmann, J. (2019). Long-term sound and movement recording tags to study natural behavior and reaction to ship noise of seals. *Ecology and Evolution*, *9*(5), 2588–2601. https://doi.org/10.1002/ECE3.4923

Miller, P., Antunes, S., Alves, A. N., Wensveen, P., Kvadsheim, P. H., Kleivane, L., Nordlund, N., Lam, F. P. A., van IJsselmuide, S., Visser, F., & Tyack, P. (2011). *The 3S experiments: studying the behavioural effects of naval sonar on killer whales (*Orcinus orca*), sperm whales (*Physeter macrocephalus*), and long-finned pilot whales (*Globicephala melas*) in Norwegian waters.* (Report SOI-2011-001). Scottish Ocean Institute. file:///C:/Users/vroom009/AppData/Local/Temp/Milleretal.-20112.pdf

Miller, P., Kvadsheim, P., … F. L.-A., & 2012, U. (2012). The severity of behavioral changes observed during experimental exposures of killer (*Orcinus orca*), long-finned pilot (*Globicephala melas*), and Sperm (*Physeter macrocephalus*) whales to naval sonar. *Aquatic Mammals*, *38*(4), 362–401. https://doi.org/10.1578/AM.38.4.2012.362

Ministry of Agriculture Nature and Food Quality. (2020). *Updated Conservation Plan for the Harbour Porpoise* Phocoena phocoena *in the Netherlands: Maintaining a Favourable Conservation Status*. https://www.rijksoverheid.nl/documenten/rapporten/2020/11/16/updated-conservation-plan-for-the-harbour-porpoise-phocoena-phocoenain-the-netherlands

Mul, E., Blanchet, M. A., Biuw, M., & Rikardsen, A. (2019). Implications of tag positioning and performance on the analysis of cetacean movement. *Animal Biotelemetry*, *7*(1). https://doi.org/10.1186/S40317-019-0173-7/METRICS

Müller, S., Lehnert, K., Seibel, H., Driver, J., Ronnenberg, K., Teilmann, J., van Elk, C., Kristensen, J., Everaarts, E., & Siebert, U. (2013). Evaluation of immune and stress status in harbour porpoises (*Phocoena phocoena*): Can hormones and mRNA expression levels serve as indicators to assess stress? *BMC Veterinary Research*, *9*(1), 1–12. https://doi.org/10.1186/1746-6148-9-145/FIGURES/5

Nabe-Nielsen, J., Sibly, R. M., Tougaard, J., Teilmann, J., & Sveegaard, S. (2014). Effects of noise and by-catch on a Danish harbour porpoise population. *Ecological Modelling*, *272*, 242–251. https://doi.org/10.1016/J.ECOLMODEL.2013.09.025

Nabe-Nielsen, J., van Beest, F. M., Grimm, V., Sibly, R. M., Teilmann, J., & Thompson, P. M. (2018). Predicting the impacts of anthropogenic disturbances on marine populations. *Conservation Letters*, *11*(5), e12563. https://doi.org/10.1111/CONL.12563

Nachtsheim, D. A., Viquerat, S., Ramírez-Martínez, N. C., Unger, B., Siebert, U., & Gilles, A. (2021). Small Cetacean in a Human High-Use Area: Trends in Harbor Porpoise Abundance in the North Sea Over Two Decades. *Frontiers in Marine Science*, *7*. https://doi.org/10.3389/FMARS.2020.606609

Nassar, J. M., Khan, S. M., Velling, S. J., Diaz-Gaxiola, A., Shaikh, S. F., Geraldi, N. R., Torres Sevilla, G. A., Duarte, C. M., & Hussain, M. M. (2018). Compliant lightweight non-invasive standalone "Marine Skin" tagging system. *Npj Flexible Electronics 2018 2:1*, *2*(1), 1–9. https://doi.org/10.1038/s41528-018-0025-1

Nicholls, D., Robertson, C., & Murray, M. (2007). Measuring accuracy and precision for CLS: Argos satellite telemetry locations. *Notornis*. https://www.notornis.osnz.org.nz/system/files/Notornis_54_3_137.pdf

Nielsen, N. H., Teilmann, J., Sveegaard, S., Hansen, R. G., Sinding, M. H. S., Dietz, R., & Heide-Jørgensen, M. P. (2018). Oceanic movements, site fidelity and deep diving in harbour porpoises from Greenland show limited similarities to animals from the North Sea. *Marine Ecology Progress Series*, *597*, 259–272. https://doi.org/10.3354/meps12588

Nielsen, N. H., Teilmann, J., & Heide-Jørgensen, M. P. (2019). Indications of mesopelagic foraging by a small odontocete. *Marine Biology*, *166*, 78. https://doi.org/10.1007/s00227-019-3525-1

Norman, S., Hobbs, R., Foster, J., Schroeder, J., & Townsend, F. (2004). A review of animal and human health concerns during capture-release, handling and tagging of odontocetes. *Journal of Cetacean Research and Management*, *6*(1), 53–62. https://www.researchgate.net/publication/267787172_A_review_of_animal_and_human_health_concerns_during_capture-release_handling_and_tagging_of_odontocetes

Nowacek, D. P., Johnson, M. P., & Tyack, P. L. (2004). North Atlantic right whales (*Eubalaena glacialis*) ignore ships but respond to alerting stimuli. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *271*(1536), 227–231. https://doi.org/10.1098/RSPB.2003.2570

Nowacek, D. P., Christiansen, F., Bejder, L., Goldbogen, J. A., & Friedlaender, A. S. (2016). Studying cetacean behaviour: new technological approaches and conservation applications. *Animal Behaviour*, *120*, 235–244. https://doi.org/10.1016/J.ANBEHAV.2016.07.019

Olesiuk, P. F., Nichol, L. M., Sowden, M. J., & Ford, J. K. B. (2002). Effect of the sound generated by an acoustic harassment device on the relative abundance and distribution of harbor porpoises (*Phocoena phocoena*) in Retreat Passage, British Columbia. *Marine Mammal Science*, *18*(4), 843–862. https://doi.org/10.1111/J.1748-7692.2002.TB01077.X

Olsen, D. W., Matkin, C. O., Andrews, R. D., & Atkinson, S. (2018). Seasonal and pod-specific differences in core use areas by resident killer whales in the Northern Gulf of Alaska. *Deep-Sea Research Part II: Topical Studies in Oceanography*, *147*, 196–202. https://doi.org/10.1016/J.DSR2.2017.10.009

Olsen, M., Nielsen, N., Biard, V., Teilmann, J., Ngô, M., Víkingsson, G., Gunnlaugsson, T., Stenson, G., Lawson, J., Lah, L., Tiedemann, R., & Heide-Jørgensen, M. (2022). Genetic and behavioural data confirm the existence of a distinct harbour porpoise ecotype in West Greenland. *Ecological Genetics and Genomics*, *22*, 100108. https://doi.org/10.1016/j.egg.2021.100108

Orr, J. R., St. Aubin, D. J., Richard, P. R., & Heide-Jørgensen, M. P. (1998). Recapture of belugas, *Delphinapterus leucas* tagged in the Canadian Arctic. *Marine Mammal Science*, *14*(4), 829–834. https://doi.org/10.1111/J.1748-7692.1998.TB00766.X

Pavlov, V. V., Wilson, R. P., & Lucke, K. (2007). A new approach to tag design in dolphin telemetry: Computer simulations to minimise deleterious effects. *Deep Sea Research Part II: Topical Studies in Oceanography*, *54*(3–4), 404–414. https://doi.org/10.1016/J.DSR2.2006.11.010

Perry, A. L., Low, P. J., Ellis, J. R., & Reynolds, J. D. (2005). Ecology: Climate change and distribution shifts in marine fishes. *Science*, *308*(5730), 1912–1915. https://doi.org/0.1126/science.1111322

Pierpoint, C. (2008). Harbour porpoise (*Phocoena phocoena*) foraging strategy at a high energy, near-shore site in south-west Wales, UK. *Journal of the Marine Biological Association of the United Kingdom*, *88*(6), 1167–1173. https://doi.org/10.1017/S0025315408000507

Piet, G., Boon, A., Jongbloed, R., van der Meulen, M., Tamis, J., Teal, L., & van der Wal, J. T. (2017). *Cumulative effects assessment: proof of concept marine mammals*. https://doi.org/10.18174/403893

Pirotta, E., Brookes, K. L., Graham, I. M., & Thompson, P. M. (2014). Variation in harbour porpoise activity in response to seismic survey noise. *Biology Letters*, *10*(5). https://doi.org/10.1098/RSBL.2013.1090

Ransijn, J. M., Hammond, P. S., Leopold, M. F., Sveegaard, S., & Smout, S. C. (2021). Integrating disparate datasets to model the functional response of a marine predator: A case study of harbour porpoises in the southern North Sea. *Ecology and Evolution*, *11*(23), 17458–17470. https://doi.org/10.1002/ece3.8380

Rasmussen, M. H., Akamatsu, T., Teilmann, J., Vikingsson, G., & Miller, L. A. (2013). Biosonar, diving and movements of two tagged white-beaked dolphin in Icelandic waters. *Deep-Sea Research Part II: Topical Studies in Oceanography*, *88–89*, 97–105. https://doi.org/10.1016/j.dsr2.2012.07.011

Read, A. J., & Westgate, A. J. (1997). Monitoring the movements of harbour porpoises (*Phocoena phocoena*) with satellite telemetry. *Marine Biology*, *130*(2), 315–322. https://doi.org/10.1007/S002270050251

Reisinger, R., Oosthuizen, W., Péron, G., Toussaint, D., Andrews, R., & Bruyn, P. (2014). Satellite tagging and biopsy sampling of killer whales at subantarctic Marion Island: effectiveness, immediate reactions and long-term responses. *PLoS ONE*, *9*(11), e111835. https://doi.org/10.1371/journal.pone.0111835

Rojano-Donãte, L., McDonald, B. I., Wisniewska, D. M., Johnson, M., Teilmann, J., Wahlberg, M., Højer-Kristensen, J., & Madsen, P. T. (2018). High field metabolic rates of wild harbour porpoises. *Journal of Experimental Biology*, *221*(23). https://doi.org/10.1242/JEB.185827/20508

Rojas-Bracho, L., Gulland, F. M. D., Smith, C. R., Taylor, B., Wells, R. S., Thomas, P. O., Bauer, B., Heide-Jørgensen, M. P., Teilmann, J., Dietz, R., Balle, J. D., Jensen, M. V., Sinding, M. H. S., Jaramillo-Legorreta, A., Abel, G., Read, A. J., Westgate, A. J., Colegrove, K., Gomez, F., Martz, K., Rebolledo, R., Ridgway, S., Rowles, T., van Elk, C. E., Boehm, J., Cardenas-Hinojosa, G., Constandse, R., Nieto-Garcia, E., Phillips, W., Sabio, D., Sanchez, R., Sweeney, J., Townsend, F., Vivanco, J., Vivanco, J. C., & Walker, S. (2019). A field effort to capture critically endangered vaquitas *Phocoena sinus* for protection from entanglement in illegal gillnets. *Endangered Species Research*, *38*, 11–27. https://doi.org/10.3354/ESR00931

Roquet, F., Wunsch, C., Forget, G., Heimbach, P., Guinet, C., Reverdin, G., Charrassin, J., Bailleul, F., Costa, D. P., Huckstadt, L. A., Goetz, K. T., Kovacs, K. M., Lydersen, C., Biuw, M., Nøst, O. A., Bornemann, H., Ploetz, J., Bester, M. N., McIntyre, T., Muelbert, M. C., Hindell, M. A., McMahon, C. R., Williams, G., Harcourt, R., Field, I. C., Chafik, L., Nicholls, K. W., Boehme, L., & Fedak, M. A. (2013). Estimates of the Southern Ocean general circulation improved by animal-borne instruments. *Geophysical Research Letters*, *40*(23), 6176–6180. https://doi.org/10.1002/2013GL058304

Rosenbaum, H. C., Maxwell, S. M., Kershaw, F., & Mate, B. (2014). Long-Range Movement of Humpback Whales and Their Overlap with Anthropogenic Activity in the South Atlantic Ocean. *Conservation Biology*, *28*(2), 604–615. https://doi.org/10.1111/COBI.12225

Ruser, A., Dähne, M., Neer, A. van, Lucke, K., Sundermeyer, J., Siebert, U., Houser, D. S., Finneran, J. J., Everaarts, E., Meerbeek, J., Dietz, R., Sveegaard, S., & Teilmann, J. (2016). Assessing auditory evoked potentials of wild harbor porpoises (*Phocoena phocoena*). *The Journal of the Acoustical Society of America*, *140*(1), 442. https://doi.org/10.1121/1.4955306

Russell, D. J. F., Brasseur, S. M. J. M., Thompson, D., Hastie, G. D., Janik, V. M., Aarts, G., McClintock, B. T., Matthiopoulos, J., Moss, S. E. W., & McConnell, B. (2014). Marine mammals trace anthropogenic structures at sea. *Current Biology*, *24*(14), R638–R639. https://doi.org/10.1016/J.CUB.2014.06.033

Russell, D. J. F., Hastie, G. D., Thompson, D., Janik, V. M., Hammond, P. S., Scott-Hayward, L. A. S., Matthiopoulos, J., Jones, E. L., & McConnell, B. J. (2016). Avoidance of wind farms by harbour seals is limited to pile driving activities. *Journal of Applied Ecology*, *53*(6), 1642–1652. https://doi.org/10.1111/1365-2664.12678

Sarnocińska, J., Teilmann, J., Balle, J. D., van Beest, F. M., Delefosse, M., & Tougaard, J. (2020). Harbor Porpoise (*Phocoena phocoena*) Reaction to a 3D Seismic Airgun Survey in the North Sea. *Frontiers in Marine Science*, *6*. https://doi.org/10.3389/FMARS.2019.00824/FULL

Schaffeld, T., Schnitzler, J. G., Ruser, A., Woelfing, B., Baltzer, J., & Siebert, U. (2020). Effects of multiple exposures to pile driving noise on harbor porpoise hearing during simulated flights—An evaluation tool. *The Journal of the Acoustical Society of America*, *147*(2), 685–697. https://doi.org/10.1121/10.0000595

Scheidat, M., Leaper, R., Heuvel-Greve, M. Van Den, Winship, A., Scheidat, M., Leaper, R., Heuvel-Greve, M. Van Den, & Winship, A. (2013). Setting Maximum Mortality Limits for Harbour Porpoises in Dutch Waters to Achieve Conservation Objectives. *Open Journal of Marine Science*, *3*(3), 133–139.

https://doi.org/10.4236/OJMS.2013.33014
Scheidat, M., Bos, O. G., & Geelhoed, S. C. V. (2016). *The feasibility of tagging habour porpoises in Dutch waters* (Report C009/16). Wageningen Marine Research. https://edepot.wur.nl/370735
Schoeman, R. P., Patterson-Abrolat, C., & Plön, S. (2020). A Global Review of Vessel Collisions With Marine Animals. *Frontiers in Marine Science*, *7*. https://doi.org/10.3389/FMARS.2020.00292
Seaman, D. E., Millspaugh, J. J., Kernohan, B. J., Brundige, G. C., Raedeke, K. J., & Gitzen, R. A. (1999). Effects of Sample Size on Kernel Home Range Estimates. *The Journal of Wildlife Management*, *63*(2), 739–747. https://doi.org/3802664
Sequeira, A. M. M., Heupel, M. R., Lea, M. A., Eguíluz, V. M., Duarte, C. M., Meekan, M. G., Thums, M., Calich, H. J., Carmichael, R. H., Costa, D. P., Ferreira, L. C., Fernandéz-Gracia, J., Harcourt, R., Harrison, A. L., Jonsen, I., McMahon, C. R., Sims, D. W., Wilson, R. P., & Hays, G. C. (2019). The importance of sample size in marine megafauna tagging studies. *Ecological Applications*, *29*(6), e01947. https://doi.org/10.1002/EAP.1947
Shepard, E. L. C., Wilson, R. P., Quintana, F., Laich, A. G., Liebsch, N., Albareda, D. A., Halsey, L. G., Gleiss, A., Morgan, D. T., Myers, A. E., Newman, C., & Macdonald, D. W. (2008). Identification of animal movement patterns using tri-axial accelerometry. *Endanger Species Res*, *10*(1), 47–60. https://doi.org/10.3354/esr00084
Shorter, K., Murray, M., Johnson, M., Moore, M., & Howle, L. (2014). Drag of suction cup tags on swimming animals: modeling and measurement. *Mar. Mammal. Sci.*, *30*(2), 726–746. https://doi.org/10.1111/mms.12083
Siebert, U. (2022). *Personal communication*.
Skubel, R. A., Wilson, K., Papastamatiou, Y. P., Verkamp, H. J., Sulikowski, J. A., Benetti, D., & Hammerschlag, N. (2020). A scalable, satellite-transmitted data product for monitoring high-activity events in mobile aquatic animals. *Animal Biotelemetry*, *8*(1). https://doi.org/10.1186/S40317-020-00220-0
Sneddon, L. U., Elwood, R. W., Adamo, S. A., & Leach, M. C. (2014). Defining and assessing animal pain. *Animal Behaviour*, *97*, 201–212. https://doi.org/10.1016/J.ANBEHAV.2014.09.007
Sonne, C., Teilmann, J., Wright, A. J., Dietz, R., & Leifsson, P. S. (2012). Tissue healing in two harbor porpoises (*Phocoena phocoena*) following long-term satellite transmitter attachment. *Marine Mammal Science*, *28*(3), E316–E324. https://doi.org/10.1111/j.1748-7692.2011.00513.x
Sørensen, P. M., Wisniewska, D. M., Jensen, F. H., Johnson, M., Teilmann, J., & Madsen, P. T. (2018). Click communication in wild harbour porpoises (*Phocoena phocoena*). *Scientific Reports*, *8*(1), 1–11. https://doi.org/10.1038/s41598-018-28022-8
SOS Dolfijn. (2021). *Personal communication*.
Southall, B. L., Deruiter, S. L., Friedlaender, A., Stimpert, A. K., Goldbogen, J. A., Hazen, E., Casey, C., Fregosi, S., Cade, D. E., Allen, A. N., Harris, C. M., Schorr, G., Moretti, D., Guan, S., & Calambokidis, J. (2019). Behavioral responses of individual blue whales (Balaenoptera musculus) to mid-frequency military sonar. *Journal of Experimental Biology*, *222*(5). https://doi.org/10.1242/jeb.190637
Stalder, D., Van Beest, F. M., Sveegaard, S., Dietz, R., Teilmann, J., & Nabe-Nielsen, J. (2020). Influence of environmental variability on harbour porpoise movement. *Marine Ecology Progress Series*, *648*, 207–219. https://doi.org/10.3354/MEPS13412
Street, G. M., Potts, J. R., Börger, L., Beasley, J. C., Demarais, S., Fryxell, J. M., McLoughlin, P. D., Monteith, K. L., Prokopenko, C. M., Ribeiro, M. C., Rodgers, A. R., Strickland, B. K., Beest, F. M., Bernasconi, D. A., Beumer, L. T., Dharmarajan, G., Dwinnell, S. P., Keiter, D. A., Keuroghlian, A., Newediuk, L. J., Oshima, J. E. F., Rhodes, O., Schlichting, P. E., Schmidt, N. M., & Vander Wal, E. (2021). Solving the sample size problem for resource selection functions. *Methods in Ecology and Evolution*, *12*(12), 2421–2431. https://doi.org/10.1111/2041-210X.13701
Sveegaard, S., Teilmann, J., Tougaard, J., Dietz, R., Mouritsen, K. N., Desportes, G., & Siebert, U. (2011a). High-density areas for harbor porpoises (*Phocoena phocoena*) identified by satellite tracking. *Marine Mammal Science*, *27*(1), 230–246. https://doi.org/10.1111/J.1748-7692.2010.00379.X
Sveegaard, S., Teilmann, J., Berggren, P., Mouritsen, K. N., Gillespie, D., & Tougaard, J. (2011b). Acoustic surveys confirm the high-density areas of harbour porpoises found by satellite tracking. *ICES Journal of Marine Science*, *68*(5), 929–936. https://doi.org/10.1093/ICESJMS/FSR025
Sveegaard, S., Nabe-Nielsen, J., Stæhr, K.-J., Jensen, T. F., Mouritsen, K. N., & Teilmann, J. (2012). Spatial interactions between marine predators and their prey: herring abundance as a driver for the distributions of mackerel and harbour porpoise. *Marine Ecology Progress Series*, *468*, 245–253. https://doi.org/10.3354/meps09959
Sveegaard, S., Galatius, A., Dietz, R., Kyhn, L., Koblitz, J. C., Amundin, M., Nabe-Nielsen, J., Sinding, M. H. S., Andersen, L. W., & Teilmann, J. (2015). Defining management units for cetaceans by combining genetics, morphology, acoustics and satellite tracking. *Global Ecology and Conservation*, *3*, 839–850. https://doi.org/10.1016/J.GECCO.2015.04.002
Teilmann, J., Larsen, F., & Desportes, G. (2007). Time allocation and diving behaviour of harbour porpoises (*Phocoena phocoena*) in Danish and adjacent waters. *Journal of Cetacean Research and Management*,

9(3), 201–210. http://www.vliz.be/imisdocs/publications/294344.pdf

Teilmann, J., Sveegaard, S., Dietz, R., Petersen, K., Berggren, P., & Desportes, G. (2008). *High density areas for harbour porpoises in Danish waters* (Report No. 657, 2008). National Environmental Research Institute. https://www.ascobans.org/sites/default/files/document/AC16_40_HighDensityHPDenmark_1.pdf

Teilmann, J., & Carstensen, J. (2012). Negative long term effects on harbour porpoises from a large scale offshore wind farm in the Baltic—evidence of slow recovery. *Environmental Research Letters*, *7*(4), 045101. https://doi.org/10.1088/1748-9326/7/4/045101

Teilmann, J., Christiansen, C. T., Kjellerup, S., Dietz, R., & Nachman, G. (2013). Geographic, seasonal, and diurnal surface behavior of harbor porpoises. *Marine Mammal Science*, *29*(2). https://doi.org/10.1111/J.1748-7692.2012.00597.X

Teilmann, J., Sveegaard, S., & Teilmann, J. (2019). Porpoises the World Over: Diversity in Behavior and Ecology. *Ethology and Behavioural Ecology of Odontocetes*, 449–464. https://doi.org/10.1007/978-3-030-16663-2_21

Teilmann, J., Agersted, M. D., & Heide-Jørgensen, M. P. (2020). A comparison of CTD satellite-linked tags for large cetaceans - Bowhead whales as real-time autonomous sampling platforms. *Deep-Sea Research Part I: Oceanographic Research Papers*, *157*. https://doi.org/10.1016/J.DSR.2020.103213

Teilmann, J. (2021). *Personal communication*.

Tønnesen, P., Oliveira, C., Johnson, M., & Madsen, P. T. (2020). The long-range echo scene of the sperm whale biosonar. *Biology Letters*, *16*(8), 20200134. https://doi.org/10.1098/RSBL.2020.0134

Tougaard, J., Ebbesen, I., Tougaard, S., Jensen, T., & Teilmann, J. (2003). *Satellite tracking of Harbour Seals on Horns Reef Use of the Horns Reef wind farm area and the North Sea*.

Tougaard, J. (2021). *New insights by tagging* (p. 24). International workshop on tagging of Harbour Porpoise in the Netherlands.

Tudorache, C., Burgerhout, E., Brittijn, S., & van den Thillart, G. (2014). The Effect of Drag and Attachment Site of External Tags on Swimming Eels: Experimental Quantification and Evaluation Tool. *PLoS ONE*, *9*(11), e112280. https://doi.org/10.1371/journal.pone.0112280

Tyack, P. L., Zimmer, W. M. X., Moretti, D., Southall, B. L., Claridge, D. E., Durban, J. W., Clark, C. W., D'Amico, A., DiMarzio, N., Jarvis, S., McCarthy, E., Morrissey, R., Ward, J., & Boyd, I. L. (2011). Beaked whales respond to simulated and actual navy sonar. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0017009

U.S. Fish and Wildlife Service. (2017). *Federal Fish and Wildlife Permit Application OMB No. 1018-0093*. https://www.fws.gov/forms/3-200-37.pdf

van Beest, F. M., Nabe-Nielsen, J., Carstensen, J., Teilmann, J., & Tougaard, J. (2015). *Disturbance Effects on the Harbour Porpoise Population in the North Sea (DEPONS): Status report on model development.* (Report No. 140). Danish Centre for Environment and Energy. https://dce2.au.dk/pub/SR140.pdf

van Beest, F. M., Teilmann, J., Hermannsen, L., Galatius, A., Mikkelsen, L., Sveegaard, S., Balle, J. D., Dietz, R., Nabe-Nielsen, J., Beest, F. M. van, Teilmann, J., Hermannsen, L., Galatius, A., Mikkelsen, L., Sveegaard, S., Balle, J. D., Dietz, R., & Nabe-Nielsen, J. (2018a). Fine-scale movement responses of free-ranging harbour porpoises to capture, tagging and short-term noise pulses from a single airgun. *Royal Society Open Science*, *5*(1), 170110. https://doi.org/10.1098/rsos.170110

van Beest, F. M., Teilmann, J., Dietz, R., Galatius, A., Mikkelsen, L., Stalder, D., Sveegaard, S., Nabe-Nielsen, J., Rune Dietz, ·, Galatius, A., Mikkelsen, L., Stalder, D., Sveegaard, S., Nabe-Nielsen, J., Dietz, R., Galatius, A., Mikkelsen, L., Stalder, D., Sveegaard, S., & Nabe-Nielsen, J. (2018b). Environmental drivers of harbour porpoise fine-scale movements. *Marine Biology*, *165*(5), 95. https://doi.org/10.1007/s00227-018-3346-7

van den Heuvel-Greve, M. J., van den Brink, A. M., Kotterman, M. J. J., Kwadijk, C. J. A. F., Geelhoed, S. C. V., Murphy, S., van den Broek, J., Heesterbeek, H., Gröne, A., & IJsseldijk, L. L. (2021). Polluted porpoises: Generational transfer of organic contaminants in harbour porpoises from the southern North Sea. *Science of The Total Environment*, *796*, 148936. https://doi.org/10.1016/J.SCITOTENV.2021.148936

Van Der Hoop, J. M., Fahlman, A., Hurst, T., Rocho-Levine, J., Shorter, K. A., Petrov, V., & Moore, M. J. (2014). Bottlenose dolphins modify behavior to reduce metabolic effect of tag attachment. *Journal of Experimental Biology*, *217*(23). https://doi.org/10.1242/jeb.108225

van der Meer, J., & Aarts, G. M. (2020). *Individual-based modelling of seabird and marine mammal populations* [Report]. https://www.noordzeeloket.nl/publish/pages/190267/top-down-individual-based-modelling-of-seabird-and-marine-mammal-populations.pdf

Verfuß, U. K., Honnef, C. G., Meding, A., Dähne, M., Mundry, R., & Benke, H. (2007). Geographical and seasonal variation of harbour porpoise (*Phocoena phocoena*) presence in the German Baltic Sea revealed by passive acoustic monitoring. *Journal of the Marine Biological Association of the UK*, *87*(1), 165–176. https://doi.org/10.1017/s0025315407054938

von Benda-Beckmann, A. M., Wensveen, P. J., Prior, M., Ainslie, M. A., Hansen, R. R., Isojunno, S., Lam, F.-

P. A., Kvadsheim, P. H., & Miller, P. J. O. (2019). Predicting acoustic dose associated with marine mammal behavioural responses to sound as detected with fixed acoustic recorders and satellite tags. *The Journal of the Acoustical Society of America*, *145*(3), 1401–1416. https://doi.org/10.1121/1.5093543

von Benda-Beckmann, S., Geelhoed, S. C. V., Kinneging, N., Kuijk, B., Scheidat, M., & Versteeg, S. (2020). *Assessment methodology for impulse noise. A case study on three species in the North Sea* (Report D10014710:28). ARCADIS. https://edepot.wur.nl/531594

Williams, H. J., Holton, M. D., Shepard, E. L. C., Largey, N., Norman, B., Ryan, P. G., Duriez, O., Scantlebury, M., Quintana, F., Magowan, E. A., Marks, N. J., Alagaili, A. N., Bennett, N. C., & Wilson, R. P. (2017a). Identification of animal movement patterns using tri-axial magnetometry. *Movement Ecology*, *5*(1), 1–14. https://doi.org/10.1186/S40462-017-0097-X/FIGURES/10

Williams, T. M., Blackwell, S. B., Richter, B., Sinding, M. H. S., & Heide-Jørgensen, M. P. (2017b). Paradoxical escape responses by narwhals (Monodon monoceros). *Science*, *358*(6368), 1328–1331. https://doi.org/10.1126/SCIENCE.AAO2740

Wilmers, C. (2015). The golden age of bio-logging: how animal-borne sensors are advancing the frontiers of ecology. *Ecology*, *96*(7), 1741–1753. https://doi.org/10.1890/14-1401.1

Wisniewska, D. M., Johnson, M., Teilmann, J., Rojano-Doñate, L., Shearer, J., Sveegaard, S., Miller, L. A. A., Siebert, U., & Madsen, P. T. T. (2016). Ultra-High Foraging Rates of Harbor Porpoises Make Them Vulnerable to Anthropogenic Disturbance. *Current Biology*, *26*(11), 1441–1446. https://doi.org/10.1016/J.CUB.2016.03.069

Wisniewska, D. M., Johnson, M., Teilmann, J., Rojano-Doñate, L., Shearer, J., Sveegaard, S., Miller, L. A., Siebert, U., & Madsen, P. T. (2018a). Response to "Resilience of harbor porpoises to anthropogenic disturbance: Must they really feed continuously?" *Marine Mammal Science*, *34*(1), 265–270. https://doi.org/10.1111/mms.12463

Wisniewska, D. M., Johnson, M., Teilmann, J., Siebert, U., Galatius, A., Dietz, R., & Madsen, P. T. (2018b). High rates of vessel noise disrupt foraging in wild harbour porpoises (*Phocoena phocoena*). *Proceedings of the Royal Society B: Biological Sciences*, *285*(1872). https://doi.org/10.1098/RSPB.2017.2314

Witteveen, B. H., Foy, R. J., Wynne, K. M., & Tremblay, Y. (2008). Investigation of foraging habits and prey selection by humpback whales (*Megaptera novaeangliae*) using acoustic tags and concurrent fish surveys. *Marine Mammal Science*, *24*(3), 516–534. https://doi.org/10.1111/J.1748-7692.2008.00193.X

Wright, A. J., Akamatsu, T., Mouritsen, K. N., Sveegaard, S., Dietz, R., & Teilmann, J. (2017). Silent porpoise: potential sleeping behaviour identified in wild harbour porpoises. *Animal Behaviour*, *133*, 211–222. https://doi.org/10.1016/J.ANBEHAV.2017.09.015

Yasui, W., & Gaskin, D. (1986). Energy budget of a small cetacean, the harbour porpoise, *Phocoena phocoena* (L.). *Ophelia*, *25*(3), 183–197. https://doi.org/10.1080/00785326.1986.10429749

Ydesen, K. S., Wisniewska, D. M., Hansen, J. D., Beedholm, K., Johnson, M., & Madsen, P. T. (2014). What a jerk: Prey engulfment revealed by high-rate, super-cranial accelerometry on a harbour seal (*Phoca vitulina*). *Journal of Experimental Biology*, *217*(13), 2239–2243. https://doi.org/10.1242/JEB.100016/VIDEO-1

Justification

Report C017/22
Project Number: 4318100379

The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

Approved: Sophie Brasseur
Onderzoeker

Signature:

Date: 31 maart 2022

Approved: Jakob Asjes
Manager Integratie

Signature:

Date: 31 maart 2022

Annex 1 Report international workshop

International workshop on tagging of harbour porpoises in the Netherlands
14th April 2021 – online (Teams)

Programme

9.30	Welcome	René Dekeling
9.45	Introduction (background, objectives)	Anne-Marie Svoboda
10.05	Capture and tagging harbour porpoises – stress, healing and behaviour	Jonas Teilmann
10.35	Overview of, and development in, biologging tags for harbour porpoises	Mark Johnson
11.05	Break	
11.15	New insights by tagging	Jakob Tougaard
11.50	Discussion on way to proceed	René Dekeling
12.30	END	

Take home messages, questions (and answers) raised by presentations and summary of discussion
Introduction
Anne-Marie Svoboda (Ministry of Agriculture, Nature & Food Quality)

Main question: <u>information</u> on habitat use and improved <u>understanding</u> how much porpoises are impacted by pressures

- What are their largescale movements (in space and time)?
    - Are there differences in day and night behaviour and between seasons?
    - What are depth profiles of their diving behaviour?
- How do they respond to specific pressures?
- Can habitat use/responses be related to foraging behaviour?

<u>Timeline:</u>

- International expert workshop: 14th April 2021
- Determine options for tagging in NL: May
- Stakeholder workshop: 27th May
- Develop plan of action: April – July
- Preparing materials: July – Oct
- Start of pilot: early 2022

<u>Q and A:</u>
Q: Timing is quite fast, taking into account international initiatives such as CEAF (that probably move more slowly)?
A: NL will put effort in aligning activities with international initiatives
Q: What is meant by 'high risk' areas?
A: Areas that are of special importance for HP and where the risks on affecting them by human activities are highest.

<u>Q in chat:</u>
Q: Can presentations be shared?
A: yes, provided that external use is only allowed after contacting, and permission by the author.

Capture and tagging harbour porpoises – stress, healing and behaviour
<u>Jonas Teilmann (Aarhus University)</u>

<u>Main messages for the Netherlands:</u>

- Catching porpoises can best be done with drifting gillnets in calm weather; driftline should be seen all the time, because you have only a few minutes to release the animal. The use of pound nets is not an option because of the relatively strong currents in NL waters. We'll probably need a mother ship for guiding and two smaller boats (Zodiacs).

- Never try to catch the same individual again; they learn!
- To minimize risk for the animals, experience in handling is needed.
- Be aware of stress responses (see presentation) and put animal on the stretcher back in the water if that occurs or release it if stress responses continue (there is a large individual variation in how they react).
- Two ways of tagging:
  - suction cup (high resolution data for max. 2 days); these tags can give (painful, according to Ron Kastelein) blisters when they come off. By these tags data can be collected for knowing foraging behaviour, sounds, individual response to disturbance and playback experiments (see example in Wisniewska's 2016 paper).
  - tags attached by a pin through the dorsal fin; gives low resolution data (more or less real time through ARGOS system) as well as high resolution data (archival) for a much longer period. The dorsal fin consists of very dense fibrous tissue (see pictures in presentation). The hole that is pierced into this will stay open. The dorsal fin is used for thermo regulation. Normally the blood stops very fast and often you don't even see it because when the animal is not overheating the animal does not use this circulation. When the tag comes off the wound heals very fast, but there might be a scar afterwards.

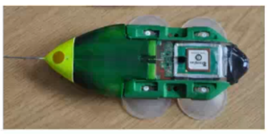
<u>Q and A:</u>
Q: How did the work with the fishermen go, as it can be imagined that bycatch is a sensitive issue?
A: We never had any problems working with them. The pound net fishery is different from the gillnet fishery. When porpoises are in the pound net that we don't want, the fishermen just release them. None of them want this bycatch, also in gillnets. They are eager to solve the problem and I have seen no conflict. The active catching is done by us, but not in Greenland where hunters for porpoises (and fishermen) help with this. They are extremely skilled.
Q: What kind of gillnets did you use?
A: Mono filament nets were used as they give the least reflection from the echo of the animal.

Overview of, and development in, biologging tags for harbour porpoises
Mark Johnson (Aarhus University)

<u>Summary of trade-offs in tag selection:</u>

Telemetry tags:
- month-scale.
- bolt on to fin, single-use tag.
- low-resolution movement and dive summary data.
- data on home range, habitat utilisation.
- limited inferences on behaviour and conservation threats.

Archival tags:
- 1-2 day scale.
- suction cup attachment, re-usable tag.
- high-resolution multi-sensor data.
- detailed quantification of behaviour, energetics and disturbance.
- limited context: is short-term behaviour representative?



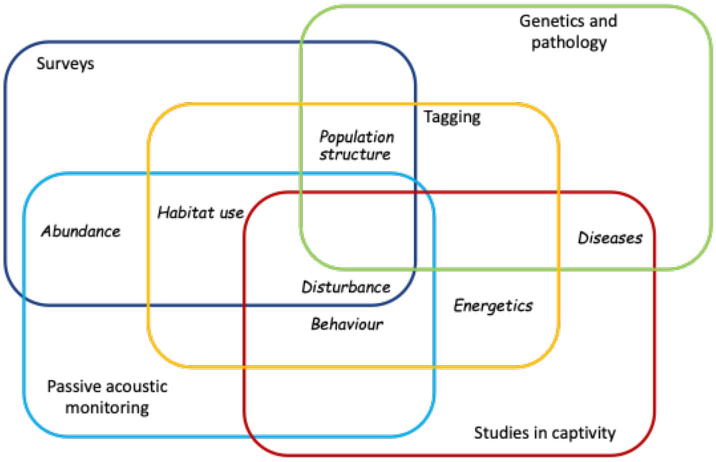
Hybrid tags:
- long-term high-resolution archival tags are being developed.
- currently too large for fin mounting.
- physical recovery is a major difficulty.

<u>Notes:</u>
- Tags should be as hydrodynamic as possible for small species, such as HP. All tags affect the animal.
- Tags should generate representative data; for archival tags there is a post-tagging period where data are not representative because of stress by the procedure. For archival tags with a limited duration this means that a relatively long part of the recording has limited value.
- By collecting data on dive behaviour only you still do not know how that is related to feeding behaviour.

<u>Q and A:</u>
Q: Is the D-tag an archival tag and does it, therefore, need to be recovered?

A: Yes, it is. You could pin a Dtag to the other side of an already existing long-term tag. Because a lot of equipment is loaded on a relatively small surface, there needs to a be good justification for the use of a large tag in combination with an invasive method.
Also, a 'V-tag' can be used: the GPS is attached to the one side and the dive and accelometry to the other side of the pin tag. Magnesium nuts are used for release. They are not 100 percent predictable for release, but generally dissolve within a few days. The longer it stays on, the further away the animal might be making recovery harder.
Q: if you have ARGOS in a tag, can more data be uploaded if there is a constant link to satellites?
A: Unfortunately, not out at full sea. The satellite system can only be used to collect limited data. If you would like to collect more data, you need to be close to the tag and then you can use other connections to upload data. Needs link of 6 to 7 seconds. Option of pop-up design is use on other species, such as sharks. That is a consideration, but for porpoises it would be difficult to apply.
Q: Are VHS tags still followed by boat?
A: You could use the VHS radio signal to track the animals. Following animals with vessels is not really done anymore because positions are quite accurate. Better to let the animals be than impacting the animals by following them. Getting rough positions from ARGOS when the tags are floating at sea is sufficient to then search for the VHS signal.

New insights by tagging
Jakob Tougaard (Aarhus University)



Notes:

- Various data sources provide insight in ecology of harbour porpoises: surveys, passive acoustic monitoring, genetics and pathology, studies in human care and tagging. Information from multiple data sources, if consistent, can complete the puzzle.
- Tagging gives information about behaviour of individuals. A sufficient number of animals is needed to see a pattern (e.g. subdivisions of a population).
- Information from tagged animals in the Dutch North Sea could also be used to validate (Danish) models about habitat suitability.
- With respect to assessing the impact of stressors, energy is the common currency of indirect effects on vital rates. Tagging data give insight in energy intake by foraging activities.
- Tagging is the only way to get high resolution data on the behaviour of individual harbour porpoises.

General discussion
Facilitated by René Dekeling

Paper of ONR-project on tagging and animal welfare (Andrews et al. 2019): https://journal.iwc.int/index.php/jcrm/article/view/237

Due to time limitations, the discussion mainly focused on handling of animals, animal welfare and bias.

Summary:

- When starting a pilot in NL, experienced people should be invited to help and teach. This will minimize stress for the animals and reduce the probability of casualties.

- There are large differences between individuals. Bringing animals on board will always result in stress, but some animals are more relaxed than others. It is almost impossible to treat the animals in the water because of swell and waves. Big pool on board would also be a possibility, but in that case, you need a big ship.
- Prepare for very robust protocols when it is decided to tag wild animals caught at sea. It is a risky procedure to handle wild animals in boats. Know what to do if something happens. Minimize the time the animal is out of the water. Focus on the essentials. Central: one person in charge who has the responsibility and who makes the decision (in time) to let an animal go. The priority is the safety of the animals, even if that means time is lost.
- Animal welfare is an important issue in NL. How many casualties in DK of app 120 animals tagged? Many years ago, an animal that was injured with an open wound on tail died, after disinfection was put on by a vet. They think it fainted from the pain, which is lethal in cetaceans. There have been two cases where inexperienced people did not notice the foam around the blow hole and oedema, and the animals died. This highlights the importance of monitoring the animals all the time and having experienced people, who can recognize small signs.
- In research centres in NL we often see smaller injuries in stranded animals. Is that the same for animals caught in nets? Lifting animals in nets is a cause for injuries. They should, therefore, be lifted out of the water by hand. The injuries are not severe, though, and recover quickly.
- Suction cups can cause painful blisters which could be more harmful than pinhole tags. Wound of pins heals quickly (within 2 days). A suction cup cannot be considered as a passive device. Impact of suction cup depends on the pressure that is applied.
- Drag caused by transmitters is a real problem and affects the behaviour for at least a day. It is not the weight of satellite tag that causes the non-typical behaviour; in water they weigh app 10-15 g (50 – 100 g in air)
- Before drilling the hole in the dorsal fin anaesthetic cream is applied to the skin by DK; this appears to be effective as not much of a reaction by the animals when drilling the hole.
- About catching animals in the wild: baiting the porpoises instead of guiding them into a gillnet has been tried but did not work. The same holds for attracting them by porpoise sounds.
- In NL we will have the possibility of tagging stranded animals that are rehabilitated. This gives us the opportunity to study the behaviour of an animal in the pool with and without a tag.
- There is some concern about the representativity of the behaviour of a rehabilitated and subsequently released animal with a tag.

Questions in chat:
Q: How do you weigh the potential individual impact from long detachment that could have energetic consequences and possibly impact the survival of an animal, vs a shorter detachment? Is there a process that has been used to weigh e.g. research questions vs animal welfare questions?
A: There is a little about research vs. ethics in the Andrews et al. 2019 paper (link above). It generally refers back to the Bateson Cube.
Q: There have been multiple studies on drag and potential increase on energetic needs for other species. Has there anything done on porpoises, e.g. with tag changes in oxygen needs?
A: Not enough work has been done on energetic consequences of tags. There has been some work on captive dolphins, but the results are not easy to interpret. The speeds and movements that are studied in human care are difficult to make ecologically relevant.

Questions in chat that were not answered:
- What is the average success rate or the active capture (given good weather) - is it in the order of one/multiple animals per day or multiple days per tagged animal?
- Is there a formal protocol available that can be shared?
- How much would it cost (order of magnitude estimate) to organise a tagging study on porpoises in the Southern North Sea (aiming at ~20 tagged individuals – with long-term position tags)? Assuming local vessels can be provided free of cost. This is just to get an initial rough idea.

Take home message/conclusions after the presentations and discussion:
We obtained a good common understanding of tagging, tag types and application of the new information. We identified a number of relevant issues that need to be addressed related to animal welfare, we understand the different types of data we can get with different tags and we have seen what we can learn from these data. It is also clear that for a number of information needs, notably the habitat use of (individual) harbour porpoises, tagging is the only way to obtain the information needed for management decisions, there is (currently) no other alternative that can provide high resolution, complete data. However, a lot of expertise is needed to make data collection and analysis operational, and it may take several years to build this capacity. Continuing international cooperation is needed, and a phased plan of action, potentially initially building experience with rehabilitated porpoises, is needed.

The phased action plan should (at least) cover the following issues:

- Best options for initial tagging experiences (e.g. making use of rehabilitated animals);
- Choices for specific tags based on data needs, including pros and cons of different tag types;
- Processing of tag data and recovery of archival tags;
- Catching techniques that could be useful for the Dutch situation;
- An inventory of resources and personnel that is needed for catching;
- Handling techniques during catching and tagging, including the required expertise.

Annex 2 Report stakeholder workshop

Stakeholder workshop: responsible tagging of Harbour Porpoises in the Netherlands

27th May 2021 – online (Teams)

Programme

14.00	1. Welcome	René Dekeling (NL Defence Materiel Organisation)	Including brief introduction of participants & results of the international workshop
14.15	2. Introduction	Anne-Marie Svoboda (Ministry of Agriculture, Nature & Food Quality)	Questions to be answered for NL, goals of NGO workshop
14.35	3. Questions		
14.40	4. Experiences of tagging harbour porpoises in US	Brian Sharp (IFAW)	Background Experiences Harbour porpoises Advice
15.05	5. Potential for use of rehabilitation centre in tagging pilot	Annemarie van den Berg (SOS Dolfijn)	Reflection on international experiences Dutch stranding network Stranded animals and their fitness Research opportunities
15.30	6. Discussion		

Summary of presentations, questions and answers, summary of discussion

1. <u>Introduction and results of earlier workshop</u>
René Dekeling (NL Defence Materiel Organisation)

The in 2020 updated NL Harbour Porpoise Conservation Plan identified the need to explore different tagging methods and use existing expertise from available tagging studies and invest in dialogue with stakeholders.
An international expert workshop was held in April 2021 to learn from experiences of scientists in other countries. The main results were:

- A good common understanding of tagging, tag types and application of the new information was obtained, including:
    - Identifying main issues and best practices related to animal welfare
    - Understanding the different types of data that can be obtained by using different types of tags, there are two main categories:
        1. Long term use, invasive type tags (typically making use of satellites; normally not recovered)
        2. Short term use, often non-invasive tags ('archival' tags that need to be recovered to obtain the data)
    - Understanding of what can be learned from these data
- It has become clear that for a number of information needs, notably for understanding habitat use and severity of impact by human stressors, tagging is the only way to obtain the information.
- Expertise is needed to make data collection and analysis operational, and it is realized that it takes time and effort to build this capacity, learning from the expertise in Denmark.
- A phased plan of action, including international cooperation, is needed; a practical and safe approach would be to initially start building experience with stranded animals for tag attachment practices, and rehabilitated porpoises.

2. <u>Government objectives and specific goals of the second workshop</u>
(Anne Marie Svoboda, Ministry of Agriculture, Nature & Food Quality)

For the NL government to be able to take appropriate management measures, information on habitat use and improved understanding how much porpoises are impacted by pressures is needed. Detailed research question include:

- What are their largescale movements (in space and time)?
    - Are there differences in day and night behaviour and between seasons?
    - What are depth profiles of their diving behaviour?
- How do they respond to specific pressures?
- Can habitat use/responses be related to foraging behaviour?

If tagging is undertaken, this will be regulated by the Nature Conservaton Act and the Animals Act, and permitting procedures will be overseen by the the Dutch Enterprise Agency (RVO) and the Dutch Central Committee for Animal Testing (Centrale Commissie Dierproeven, CCD).

Various issues to ensure responsible tagging were identified in the scientific experts meeting. In this second meeting for stakeholders the focus was on issues and concern related to animal welfare; experiences with rehabilitated porpoises in the USA have been presented, linking this with the potential of a new NL rehabilitation centre for small cetaceans. Based on the results of the two workshops, the Ministry of Agriculture, Nature & Food Quality will further develop the phased plan of action.

The initial focus will likely be to obtain information on habitat use and to understand how this relates to anthropogenic pressures, including the development of offshore wind energy. Habitat use of NL Harbour porpoises is currently not well understood, and to develop and validate models to assess impact of anthropogenic activities this understanding is essential. At this stage it is not clear how many animals need to be tagged on the longer term, the experiences in Denmark suggest an order of magnitude of 10-100 animals. In the phased approach, experiences with single tagged animals may already provide useful information. Knowledge will be used that was developed in areas where some form of porpoise monitoring is already established (Oosterschelde) and cooperation with institutes in Belgium will be addressed.

3. Discussion about research questions

Important that research questions will be as detailed as possible to justify time and effort in tagging harbour porpoises. What extra information can be obtained by tagging results? It was suggested to combine results of photo-id work in the Eastern Scheldt with tagging data. See summary of general discussion below for more elaborate notions on this topic.

4. Experiences with tagging harbour porpoises in the USA

(Brian Sharp, International Fund for Animal Welfare)

In the Cape Cod area many strandings take place (25% of all the strandings in the USA territory in the period 2010-2019); the unique geographical features with a peninsula and large tidal variations (3-4 meters) function as a 'cetecean trap'; most strandings occur during the months December – April.
To obtain better insight whether animals are fit enough to survive and thus can be released, post-release monitoring was started in 2010.
The type of tag mostly used (Wildlife computers) can be equipped with a time-depth recorder (TDR) but these make the tag a little larger. Tags can, however, be trimmed to make them as small as possible. Dtags are able to record sound, which is not possible with the ARGOS tags.
The current practice is to release stranded animals as soon as possible in a safe location. Tagging can be done very quickly (+/- 10 minutes), and monitoring animals condition and tagging preparation can start during the transport to the release location.
Tagging (on porpoises) is done by drilling a 8 mm hole in the dorsal fin. Over time (30 - 90 days) tags will release. The last porpoise tag was attached 40 days ago and was still transmitting. The tag showed that the stranded and released animal directly moved to the continental shelf edge which is a favourable feeding area. Another porpoise that was tagged earlier was in a borderline condition. This tag transmitted for 9 days and then stopped, the cause is not clear.
Only two porpoises have been tagged now; the policy is to tag only one animal of a group (in the case of a multiple stranding). This data is still limited at this stage but it is clear that tagging rehabilitated animals can provide information on the succes of rehabilitation. Tagging may cause some post-tagging effects (by stress) but animals that were tagged moved to a usual habitat upon release which is an indication of normal behaviour post-tagging.

Q and A:
Q: Did the results contribute to conservation of marine mammal species?
A: It caused more discussion about habitat use; oil and gas exploration was (temporarily) banned in favour of windenergy.
Q: New information about harbour porpoise swimming directly to edge of continental shelf?
A: Yes, first time it was seen.
Q: Why did you tag only one of the two stranded propoises?
A: Not enough funding to employ 2 tags. Financial resources are limited. Therefore, policy is to tag only one animal after a mass stranding in order to be able to tag other animals/species too.
Q: Can stress by application of tag be the cause for observed behaviour in minke whale?
A: Not likely, because animal headed to well-known habitat

5. Potential for use of rehabilitation centre in tagging pilot
(Annemarie van den Berg, SOS Dolfijn)

SOS Dolfijn is a Dutch rescue organization for cetaceans, specialized in rehabilitation of harbour porpoises. From 2004 – 2017 it was located in Harderwijk; a new educational dolphin and porpoise rehab centre and whale rescue centre will open near the end of 2021, some months before the expected peak in harbour porpoise strandings (100 – 900 stranded animals per year, dead or alive). They work in close cooperation with the Veterinary Department of the University of Utrecht and the Dutch stranding network. The new centre offers unique opportunities for combining rescue with research. Large potential for tagging research; animals can be tagged weeks before releasing them and animals are healthy when they are released. Tagging of rehabiltated animals can give information about behaviour of animals in the wild and their response to (increasing) human stressors, but also about the success of rehabilitation. The conservation of harbour porpoises will, therefore, greatly benefit from tagging data.

Q and A:
Q: Does the rehabilitation of harbour porpoises always take 3 – 6 months?
A: Yes, three months is usually the minimum duration, even for animals that appear to be relatively healthy. Most rescued animals do have some kind of infection, such as lung worms.

6. General discussion:
The Ministry is thinking of executing a tagging pilot in phases: (1) tagging rehabilitated animals and releasing them, (2) catching, tagging and following animals in a relatively sheltered area, such as the Eastern Scheldt (and compare tagging data with photo ids) or the Marsdiep near Texel, (3) catch, tag & release in open sea, if possible in cooperation with other North Sea countries.

The partcipants generally like the idea of the three phases, but first (zero) phase should consist of an in-depth definition of the research questions and should describe how tagging data could contribute to conservation goals:

- Why do we need tagging data from the North Sea (to justify time and effort in tagging porpoises)?
  Q: Do we expect patterns in 'our' part of the North Sea that are different from the Danish waters and don't we know enough about impact of human stressors?
  A 1: We don't know. When you look at the differences between patterns near Greenland and Denmark, you can see it is not possible to extrapolate information from one area directly to another area. For conservation purposes in the Dutch part of the North Sea, it is important to know what the home range is.
  A 2: Data about reponse of harbour porpoises to windfarm construction do not tell us what the impact is on the fitness of animals.
- Explanation of the relationship between tagging data and conservation goals.
- Link detailed research questions to phases 1 – 3 of the pilot (*e.g.* which questions could be answered by tagging harbour porpoises in the Eastern Scheldt?)

Several participants state that they would like to contribute to the specifying of the questions.

Apart from the above mentioned research questions, other issues that should be included in the action plan:

- Conclusions and discussion points of two workshops (14^{th} April 2021 & 27^{th} May 2021)
- Overview of recent literature, including results form the WMR paper comparing and combining various methods to get a more complete picture

- Number of animals needed to answer the questions; large intraspecific variation in harbour porpoises, as seen in eastern Scheldt and Denmark
- Tag types and questions that can be answered by different types
- Possibilities of following animals staying close to the coast and look at fine scale behaviour (vocal following with a hydrophone)
- Practical issues about gaining experience, for instance first practice on dead animals to get familiar with tools (UU can collect samples)
- Institutions that will be involved, role of Harbour porpoise Scientific Advisory Committee to review research proposal
- Locations to release rehabilitated and tagged animals and locations to catch and tag animals (Eastern Scheldt, Marsdiep?)

Annex 3 Aarhus University protocol when handling porpoises (Teilmann, 2021, *personal communication*)

Important points to consider when catching, handling and tagging porpoises

This list of procedure should be laminated and always given to all participants in the procedure

1) **Distribute tasks in advance**: Person A) responsible for the operation and decides who does what (must be very experienced), Person B) monitors breathing rate with a stopwatch, Person C) monitors the pulse with a heart rate monitor, Person D) responsible for watering the animal, taking notes and photos of the animal.
2) **All participants will wear gloves** during the entire procedure to prevent mutual infections.
3) **At least one person have a GoPro** or similar video camera attached to his/her head to be able to evaluate the procedure afterwards.
4) **When the animal is on the boat**, check the condition, gender and take measurement.
5) **The pulse** should not drop below 50 or be above 200 beat/min for more than a few seconds before the animal have to be back in the stretcher and lifted back into with water. The pulse should be said out loud by person C frequently.
6) **Breaks in the breathing** should not exceed 30 sec without there carefully being poured water over the animal towards the blowhole and at the same time the blowhole is being protected with the hand from the water. The hand should never cover the blowhole and the animal should never get water in the blowhole. Superficial breathing can give limited oxygen and it will increase the risk for pulmonary edema. The breathing frequency and time interval needs to be said out loud frequently. If the animal have been prevented to breathe freely for more than 1 minute before it can be collected, then the animal have to stay in the stretcher in the water and ensure regular strong breathing with no foam by the blowhole before it can be brought up on the boat.
7) If **foam forms around the blowhole**, there needs to be a thorough evaluation if the animal needs to be stabilized in the water, the stretcher or if it needs to be released.
8) **Talk quietly and stay calm**. This will reduce the risk for stress and accidents.
9) **Avoid motor noise if possible**, which means turning off the engine or minimum motor use and low rotations. Never use echo sounder at any time.

Wageningen Marine Research
T +31 (0)317 48 7000
E: marine-research@wur.nl
www.wur.eu/marine-research

Visitors' address

- Ankerpark 27 1781 AG Den Helder
- Korringaweg 7, 4401 NT Yerseke
- Haringkade 1, 1976 CP IJmuiden

With knowledge, independent scientific research and advice, **Wageningen Marine Research** substantially contributes to more sustainable and more careful management, use and protection of natural riches in marine, coastal and freshwater areas.

Wageningen Marine Research is part of Wageningen University & Research. Wageningen University & Research is the collaboration between Wageningen University and the Wageningen Research Foundation and its mission is: 'To explore the potential for improving the quality of life'