Risks and benefits of telemetry techniques in investigating harbour seal and wind generator construction interactions

Sea Mammal Research Unit
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1 Summary

1. In response to a request from the Dutch Ministry of Economic Affairs, Directorate-General for Nature and Regional Affairs, Regional Affairs and Spatial Economic Policy Department, this report briefly reviews aspects of the risks and benefits of telemetry techniques in investigating harbour seal and wind generator construction interactions.
2. The challenge is to quantify the magnitude of any telemetry effect with an appropriate metric, and then to predict the consequences of such an effect the validity of the investigation.
3. Seals spend much of their lives underwater any away from ready visual observation. Also it is at-sea that seals are acoustically coupled to effects of piling noise. Thus some form of telemetry is essential for both baseline and manipulative applied studies. There is no alternative method.
4. Whilst necessary for such applied studies, telemetry is unlikely to be sufficient on its own. It should certainly be undertaken as a compliment to population counts (and other biological stress-related studies). In this way causal linkages may be inferred / negated from changes in population trajectory. Also the synergy of these two techniques will permit absolute population estimates as well as the absolute density of at-sea usage.
5. During the last five years 105 peer-reviewed papers have been published whose data were obtained using seal telemetry; of these 22 papers were on harbour seals.
6. Harbour seal are difficult to re-catch and so tag data must be relayed ashore by satellite or GSM (mobile phone) systems. Tags vary greatly in their functionality – and thus also in size. The functionality must be matched to the question posed. Also, the sample of tagged individuals must be sufficient to support robust population behavioural responses.
7. Capture risks (chronic disturbance, collision trauma and drowning) are reduced to acceptable levels primarily by the availability of a skilled and experienced catching team. Such a team may take many years to assemble.
8. Seal handling (with or without anaesthesia) is unlikely to have significant long-term effects on individuals.
9. In the past, the excessive use of epoxy glue to attach tags to seals fur occasionally caused burns. However nowadays the use of minimal glue prevents any such exothermic build up. Also, the use of flexible edging to the edge of the tag reduces edge abrasion.
10. Seals are well streamlined and so external attachment will have some hydrodynamic effect. However it should be noted that, as capital breeders, harbour seals (particularly adult females) naturally undergo rapid and large changes in size and shape every breeding season.
11. Whilst some studies on penguins have shown significant tag effects, two empirical studies of Antarctic fur seals and elephants seals suggested minimal tag effects. However, caution must be used in extrapolating to other species and types of tag.
12. Computer Flow Dynamics (CFD) can simulate water flow and predict hydrodynamic parameters. In one CFD study the addition of a telemetry tag to a harbour seal caused a 12% increase in the coefficient of drag (C_d). However there were no data to assess the crucial link between this parameter and the real increase in drag in relation to seal activity / energy budget and the behavioural and fitness consequences.
13. The effect of carrying a tag of the thermal balance of a seal is unlikely to be significant.

14. The effect of telemetry on harbour seal individual welfare and reproductive fitness is difficult to estimate with a high degree of certainty. Certainly, more studies are needed. However an over-zealous application of the precautionary principle would be a dis-service to the conservation of a species currently facing threats from a variety of anthropogenic sources.

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3 Introduction

This report reviews the benefits and potential effects of using telemetry systems to investigate the effect of wind farm construction on harbour seals (*Phoca vitulina*). Specifically, the remit is to review and assess:

1. *The latest scientific international insights, possible effects of tagging devices on seals (including the possible effect of hydrodynamic disturbance),*
2. *Why this method is selected and used for research on possible disturbance effects due to construction works.*
3. *Alternative methodology*

Telemetry is an observation, or measurement, tool. We start with the premise that measurement in all fields of scientific investigation is imperfect. Such imperfection may be manifested in the measurement itself and / or in unwanted effect on the target. For example, a good voltmeter can both measure potential difference with precision and (due to its high internal resistance) **and** have minimal effect on the true potential difference in the circuit. In such cases the effect is sufficiently trivial that it is of no consequence. Thus the challenge is not to observe that there is effect, but

1. to *quantify* the magnitude of the effect with an appropriate metric, and then
2. predict the *consequences* of such an effect the validity of the investigation.

In this brief review we first describe the telemetry systems (Section 4), specifically their functionality and design constraints. In Section 5 we consider the potential risk to seals; this includes capture, handling and the effect of carrying a telemetry device. In Section 6 we consider the role of telemetry in investigating interactions between harbour seals and piling noise due to offshore wind energy construction piling. In the Discussion (Section 7) we synthesise these issues.

The brevity of this document precludes a comprehensive treatise; it also limits the depth of discussion. However we hope that it provides an initial framework, and a common currency, within which the role of telemetry in seal studies may be rationally debated.

Declaration of Interests

The author is a long-serving biologist within the Sea Mammal Research Unit (SMRU). In addition to its primary goal of biological investigation, SMRU also designs and sells telemetry tags. Other organisations also manufacture telemetry tags. This review is based on tag generic function and effect and does not advocate specific models or manufacturers.

4 Seal telemetry systems

Seals spend much of their lives underwater, and frequently far from land. Their behaviour at sea is thus seldom directly observable. It is for this reason that telemetry has become such an important and essential tool in marine mammal science (McConnell *et al.* 2010). During the last five years 105 peer-reviewed papers have been published whose data were obtained using seal telemetry; of these 22 papers were on harbour seals[1].

North Sea harbour seals breed in June/July and then moult in August / September. The standard telemetry attachment method for seals is to glue the tag glue to the fur (Field *et al.* 2012). Thus tags will detach from harbour seals at the moult in August / September. However mean tag longevity for harbour seal tags is 3-4 month, and so the tag may fail before the moult. Attempting to catch the same animal twice in order to retrieve an archival tag[2] is not practicable. Thus data must be relayed ashore from tags. Two types of data relay systems are available:

	Argos satellite	GSM mobile phone
Coverage	Global	=< 35 km from coast. Thus data store and forward required
Location determination	Inbuilt, but inaccurate and infrequent	None[3]. Fastloc GPS used: accurate and frequent
Data transfer rates (Kbytes.day^{-1})	1	50-100

[1]Based on a search of Web of Science on 'seal and (telemetry or Argos)' or 'seal and (harbor or harbour or vitulina) and (telemetry or Argos)', and manually deselecting inappropriate matches.
[2]Where data are just stored in memory.
[3] Location through base transceiver station (BTS) triangulation is not practicable at sea.

A balance must be achieved between tag functionality and size. The battery is usually the largest component in a marine mammal tag. Its size can be reduced by maximising energy storage capacity and minimising use:

maximising storage	minimising use
Use high energy density chemistry cells (e.g. Li-$SOCl_2$)	Duty cycling of operation
Scavenge energy (e.g. solar cells)	Intelligent on board processing of raw data
	Efficient data coding
	Efficient data relay
	Low power hardware

The user can further reduce energy use by reducing tag functionality:

- Shortening tag life. For a typical GSM tag on a harbour seal tag attachment seldom exceeds six months.
- Reducing rate of location fix attempts. Note that is will impair the ability to interpolate true tracks (Lonergan, Fedak & McConnell 2009).
- Omitting behavioural data: e.g. dive & haulout events. That is, 'location only' tags.

In summary, there is a variety of different telemetry systems, with a variety of functionality and form. As a guide, the weights of tags currently available may vary from 100 to 370 g. However within this range there is a large variation in functionality. The functionality (and thus size) of the tag chosen depends entirely upon the biological question posed. It is universally agreed that intervention in any wild population under study should be minimised. Thus it would be unacceptable to fit captured animals with tags that then could not actually provide the both the quality and quantity of information required for the study.

5 Potential risks

We consider here the potential risks to harbour seals during the capture, attachment and subsequent carrying of telemetry tags.

5.1 Capture

Unless it is an essential part of the scientific design, harbour seal capture tends to avoid the breeding periods. The moult follows soon afterwards and thus tag attachment would be brief. Avoiding the breeding season also minimises interference to nursing pups.

There are no methods available to remotely attach a tag without physical capture. Capture may be undertaken on shore with hand-held nets. The approach can either be from a fast boat landing, or covertly overland. Alternatively nets can be shot / set offshore from a haulout site, and act as either a barrier or a tangling device. Netted seals are then moved into hand held nets and onto land or a mother boat. If large numbers of seals are caught in one session, seals may remain in a hand net for up to two hours before tag attachment.

The following table shows risks associated with harbour seal capture:

	risk	comments
Chronic disturbance	Repeated capture attempts at the same site may lead to colony movement to alternative sites.	>30 years' experience indicates that hauled out colonies are robust to revisits. Individual seals disturbed into the water may haulout out again within 30 minutes and within 50 m of tagging operations.
Collision trauma	Fast manoeuvring of boats poses a risk of collision with hull or propeller.	
Drowning	Unattended nets in the water pose drowning risk.	

The principal risk reduction strategy is to develop a skilled and experienced catching team. Such a team may take many years to assemble. International coloration is a key to transferring these skills.

5.2 Handling

For tag attachment, a seal may either be physically restrained or chemically anaesthetised. Opinions differ on the preferred method. Restraint is a simpler process, but the seal is fully aware of the attachment process. However it may be argued that the short (20 min) period of tag attachment is no more stressful that the longer capture and holding phase. Harcourt et al. (2010) showed that Weddell seals (*Leptonychotes weddellii*) had elevated cortisol during handling, and that his could be reduced with application of diazepam.

Baker et al. (2002) compared the fate of 549 Hawaiian monk seals (*Monachus schauinslandi*) that had been handled against a control group. Handling had no effect on mortality in subsequent years. Hawaiian monk seals are highly endangered and Baker et al. stated:

> *'conservative selection procedures and careful handling techniques have no deleterious effects on Hawaiian monk seals.'*

Anesthetisation has the advantage that the seals are oblivious to the attachment process, but requires appropriate veterinary skills. As with all veterinary procedures, it carries a very small (< 1%) risk of an adverse reaction. When such rare reactions do occur > 95% can be successfully managed.

5.3 Attachment

Gluing to the seal fur is the preferred attachment method when moult detachment is acceptable (Field *et al.* 2012). This technique was first practically demonstrated in 1983 (Fedak, Anderson & Curry 1983). A variety of glues may be used. Whilst simple to use in the field, epoxy resins cure exothermically. Avoiding excess use of resin avoids the risk of heat build-up and burning. In a study of resighted elephant (*Mirounga leonina*) and Weddell seals, Field et al. (2012) state :

> *'Four of the 508 seals had lesions under the footprint of the instrument that we suspect were caused by the epoxy getting too hot. All of these deployments occurred in 1999, and all involved the epoxy being heated (in a water bath*

between 20°C and 30°C) prior to mixing. The practice of preheating the epoxy has been abandoned.'

5.4 Tag carrying

Tags are attached to harbour seals by gluing to the fur. Thus a seal will only carry the tag up to a maximum of the next annual moult. We consider here three risks to carrying a tag: abrasion, hydrodynamic drag and thermal balance.

5.4.1 Abrasion

In the study quoted above, Field et al. (2012) observed wounds from the edges of tag attachment on 7% of all animals. However they observed that 'All the abrasions observed in this study were healed following the first molt after'. It is now common practice to surround the edge of a tag with a silicone rubber bead to remove concentrated flexure at the edge of the tag.

5.4.2 Hydrodynamic modification

Seals are well adapted to an aquatic lifestyle. Therefore it is likely that any external attachment will have some hydrodynamic affect. The fact that any effect (e.g. drag) will have an energetic consequence of the individual is not in debate. What is important though is to **quantify** the energetic cost, and to do so within in the **context** of the life history of the individual.

In relation to drag, Wilson et al. (Wilson & McMahon 2006) stated that two measurements were required: the increased power (energy per time) output required to move, and the percentage of time spent moving. In fact, since drag is related exponentially to velocity, these two parameters should be considered over a range of velocities.

Drag (and other hydrodynamic forces) can either be estimated empirically or by simulation using Computer Flow Dynamics (CFD).

5.4.2.1 Empirical studies

McMahon et al (2008) demonstrated that elephants seals that were fitted with data-loggers showed no difference in mass gain during their at-sea foraging bouts compared with un-instrumented controls. They showed that this finding held in years of contrasting prey availability.

Boyd et al. (1997) studied the effect of tag drag on Antarctic fur seals (*Arctocephalus gazella*). They glued additional false tags (cross sectional area of 21 cm^2) onto lactating females and compared these with a control group. Whilst there was a reduction in the mean swimming speed (from 1.23 to 0.98 m/s) the experimental females used no extra body reserves in foraging and there was no difference in the pup growth rate compared with the control group.

However in laboratory experiments on a model, Wilson et al. (2004) suggested that the rigid antennae of some types of penguin tag can lead to a five-fold decrease in penguin foraging efficiency. The effect was reduced when the rigid antennae were replaced with (more modern) flexible types.

It is unwise to generalise too much from theses empirical findings. Different species (indeed different age classes) will respond differently to carrying a telemetry tag of a given absolute (or relative) size. A small, fast-moving animal will be effected more than a large slow-moving one.

5.4.2.2 Computer simulation

Pavlov (2007) used CFD to model the flow of water past a dolphin dorsal fin and then modified a tag design to minimise drag. Hazencamp et al. (2010) used CFD to model the change in coefficient of drag (C_d)[4] of a satellite relay data logger tag on a grey seal. C_d is a dimensionless quantity that is used to quantify the drag of an object in a fluid environment. They concluded that the increase in C_d was about 12%. But, crucially, they did not relate this to increase in power requirements and swimming budgets (Wilson & McMahon 2006). Their discussion of the biological consequences is thus speculation. Furthermore we note that the tag model used in this study has now been superseded by a smaller version.

5.4.3 Thermal balance

McCafferty et al. (2007) raised the possibility of tag attachment affecting thermal balance. However from their studies on grey seal (*Halichoerus grypus*) they concluded that tags 'will produce localised effects on heat transfer in air but will not significantly change the total heat exchange of grey seals on land or at sea'.

6 Wind farm construction and harbour seal interaction

The proliferation of offshore wind farms raises the possibility of deleterious interactions with marine life (Gill 2005). Whilst it is unlikely that the operational phase has significant effect on local harbour seal behaviour (Edren *et al.* 2010; McConnell 2012), the acoustic energy generated by piling operations during construction may have significant effect (Diederichs *et al.* 2008; Skeate, Perrow & Gilroy 2012).

6.1 Telemetry techniques

For there to be any interactions it is necessary, though not sufficient, for disturbance and seals to overlap both temporally and spatially. The intrinsic spatial basis of telemetry makes it the only available tool.

Studies in relation to offshore wind energy are on-going in the UK. The importance of both detecting biological effect and the development of appropriate mitigation systems is recognised by the UK Department of Energy and Climate Change (DECC[5]) who have commissioned (2012) a major harbour seal telemetry / audiometry study during nearby piling operations. In the past five years DECC has also commissioned the tagging over 80 UK seals as an essential part of its maritime Strategic Environmental Assessment[6]. Data from these seals filled in region al gaps in an extensive UK telemetry database (> 200 seals) to estimate at-sea usage (Matthiopoulos *et al.* 2004) for grey and harbour seals.

[4] Coefficients of lift and pitching moment were also calculated. Comments of the consequence of C_d apply also to these parameters.
[5] https://www.gov.uk/government/organisations/department-of-energy-climate-change
[6] http://www.offshore-sea.org.uk/consultations/Offshore_Energy_SEA_2/index.php

Telemetry techniques compliment other measurements. Seal population numbers are usually assessed through a time series of aerial counts of seals hauled out on land. In this way trends of population and abundance can be assessed. However, such techniques must be seen as a *compliment*, rather than an *alternative* to the study of individual behaviour from telemetry studies for the following reasons:

1. There may be a many drivers of population change (e.g. climate, prey availability, disturbance and disease) and so attributing change to, say, renewable energy construction is difficult. The use of space at sea by seals can indicate whether there is spatial overlap between animals and the extent of a stressor. The extent of such overlap will aid acceptance or rejection of a causal relationship. Note that the limited visibility of seals' heads at sea, and thus low sighting rate, precludes ship-borne 'distance' survey methods to quantitatively assess at-sea usage.

2. To assess the population size from haulout counts we need to know the proportion of time spend hauled out ashore – the correction factor. This is usually derived from telemetry studies (for example Ries, Hiby & Reijnders 1998).

3. If there are biological effects of construction noise, then the problem is then, which haulout sites would we expect to be affected? Where would the signal appear? Telemetry provides the crucial link between onshore abundance and off-shore distribution (Matthiopoulos *et al.* 2004).

6.2 Study types

In relation to offshore renewables there are two types of information that are generally required to fulfil licencing requirements:

1. Baseline information on the presence, movements and behaviour of seals in the region of interest.

2. Model changes in behaviour to relation to potential construction / operation stressors.

McConnell et al. (2012) provide an example of a telemetry study that investigated harbour seal behaviour in relation to wind turbine activity in Denmark.

For baseline studies (1) it important that there is minimal effect of tagging on the parameters of interest. However for the detection <u>change</u> ((2) before/after, or gradient) this assumption is not strictly required since it is very unlikely any <u>change</u> of behaviour would be influenced by whether a seal bears a tag. For example, it is unlikely that the degree to which an individual may react (e.g. suspend its foraging activity) to nearby piling activity is affected by a tag.

For most telemetry studies the aim is to detect change in the behaviour in the *population* of animals. We thus require a sufficient sample size of tagged individuals to provide statistical power. Tagging an insufficient number of individual results in data which are anecdotal. The power analysis depends upon the biological question posed, the variability between individuals, and the degree of *a priori* knowledge.

7 Discussion

Seal telemetry has developed and matured since its first use in the mid 1980's. Capture and handling techniques have become less invasive and more efficient – driven mainly by the cultivation of experienced field teams. In parallel, telemetry tags themselves have reduced in size, whilst functionality has increased. Whilst it is likely that these trends will continue, both physics and information theory ultimately limit how much information can be obtained from a given size of tag.

Telemetry has a scientifically justified and established role in investigating both the natural history of seals, and also interactions with potential anthropogenic stressors. To investigate the consequences of renewable offshore developments – there is no alternative.

However, this does not absolve the researcher from their moral, scientific, and frequently legal, obligation to minimise any threat to the target species. This obligation entails *active* responsibility to quantify any credible telemetry effect. As such, there is a need for more published studies that investigate the biological consequences (not just the physical consequences) of carrying a tag. Indeed these studies should extend from proximate consequences through to individual fitness and population consequences. However it would be misleading to suggest that the scientific community is either unaware of, or unconcerned with, these issues (for example: Wilson & McMahon 2006; McMahon *et al.* 2012; McMahon, Hindell & Harcourt 2012).

There is a growing scientific literature on the effects of tagging a variety of aquatic species. This has been illustrated above with three examples. The two seal studies suggested minimal effect. Yet the penguin study showed a significant effect. But it is not surprising that there is no one single result since the studies encompass a large range of

- species sizes and swimming speeds,
- tag weights, shapes and attachment techniques, and
- measurement metrics

Therefore the study should be based as closely as possible on the target species and tag. To this extent the simulation study of Hazekamp et al (2010) is a valuable contribution. However their extrapolation from physical drag coefficients to biological effects is unjustified. In summary, whilst more studies should be encouraged, currently there is no evidence that tag devices on seals have significant biological consequences.

It is important to be aware that the body shape of harbour seals changes seasonally. Being 'capital feeders' they spend most of the year foraging to attain sufficient condition to give birth to a viable pup and/or mate. During the breeding season, foraging is greatly reduced, and adults' fat reserves are rapidly depleted. Over a three week period a lactating female may lose 33 % (30 kg) of mass, 17% (16 kg) of its body fat (with consequential changes in density and thus buoyancy lift) and 32% (92 cm^2) of its cross-sectional area (Bowen, Oftedal & Boness 1992). A typical seal tag weighs between 100 and 370 g and has a cross sectional area of 28 cm^2. Typical figures for an adult pre-partum harbour seal are 87kg and 295 cm^2 respectively (Bowen, Oftedal & Boness 1992). It would be naïve and misleading to infer just from these facts alone that the effect of a tag is within the natural seasonal variation of an individual adult seal. For example, the drag effects are influenced by far more than just cross sectional area. However these figures do put the morphological alteration due to tag attachment into a realistic perspective.

Biological systems are invariably complex. They are also often data sparse. Thus effects and consequences are difficult to estimate with a reasonable degree of certainty. In terms of practical wildlife science, a balance thus has to be achieved in an 'uncertain' world. On one hand, effort must be (and is) directed to estimating the magnitude and consequences of tag effects. In an ideal world this would precede large-scale data collection. In practice the two may continue in parallel and the data obtained must carry any caveats regarding the effect of tagging, until such time as the issues are clarified.

The issue is well articulated by McMahon et al. (2012) whose final paragraph is copied below:

> *'At a time when science in general is being subject to unprecedented levels of public scepticism, it is clear that as a society, we have moved beyond accepting that the scientists/researchers know best. Now society demands that scientists use evidence-based approaches when informing conservation and animal welfare authorities about research methods. Ensuring that animal research is allowed to continue is important because we are currently experiencing a biodiversity crisis whereby species are being lost at alarmingly high rates. Without research we cannot conserve the animals or the ecosystems on which we all rely for our wellbeing. The challenge then is to bring the biological, ethical and legal components of biodiversity conservation into some form of jurisdictional harmony before the initiation of research projects that attempt to address species declines. Providing the basic information to inform this debate and to stimulate this debate publically must necessarily be a priority for wildlife researchers'.*

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