Review of telemetry technologies in relation to the marine renewable energy sector and seabirds

Elizabeth Masden
Environmental Research Institute
North Highland College – UHI
University of the Highlands and Islands
Thurso, KW14 7EE

University of the Highlands and Islands
Oilthigh na Gàidhealtachd agus nan Eilean

North Highland College
University of the Highlands and Islands

eri environmental research institute

Table of Contents

Summary

Telemetry solutions are available for tracking seabirds in relation to marine renewable energy developments. Technologies currently used include satellite transmitters, GPS-enabled devices, accelerometers, and temperature depth recorders. However, these tags to date have not provided the data quality or quantity required by the industry to fully assess the potential environmental impacts. The size of tags, extended deployment time and remote data download capability have been raised as the key constraints for many species. Combining sensors within a single tag may provide a way forward. With increasing numbers of seabird tagging projects it is also important that there is a suitable register of these projects to guard against duplication of effort.

Background

Marine renewable energy projects are developing at an unprecedented rate. Understanding how birds interact with marine renewable energy devices is vital to assessing the potential for proposed developments to negatively impact populations of concern, either via collision with tidal stream turbines, or displacement from development sites. The collection of data on interactions between birds and marine renewables has focused on surveys of birds at sea and the deployment of telemetry tags. However, due to data collection costs or accuracy/precision, the spatial and temporal resolution of these data is generally low, and the ability of the data to answer the questions of interest can be poor.

Tagging and tracking of seabirds has provided important information about the spatial ecology of many seabird species which would be impossible to obtain through other techniques. Radio, satellite and GPS telemetry are commonly used to track seabirds in two dimensions above seawater, but despite recent developments transmitters can be heavy and/or expensive. These have often been used in the context of wind turbine developments, but greater resolution on flight heights is needed to improve collision risk assessments. Depth loggers have been used to record diving depths of some seabirds, but must often be retrieved from the birds in order to access recorded data.

At present, a number of different tagging and tracking technologies are available to be used to assess the spatial ecology to diving seabirds in relation to offshore renewable energy activities. These include satellite transmitters, GPS data loggers, geo-locators, radio-telemetry, time-depth recorders and GSM phone tags, with acoustic tags offering another possibility. Each technique has both advantages and disadvantages, and currently there is little convergence in technology. No single technology directly addresses the environmental knowledge needs of the renewable energy sector, and more specifically, it is not yet possible for a single technology to track birds in three dimensions both underwater and above water.

There are a number of aspects that should be considered when determining which, if any, tagging technologies are suitable for a given project. These include the types of movement to be recorded (vertical and/or horizontal) and the scale of these movements, as different technologies have varying degrees of accuracy. Also, the duration over which data are to be collected should be considered as different technologies and tags have different life spans, dependent on battery life/size. In addition, there are also constraints on the tag size, shape and weight due to the morphology of the seabird which is to be tracked. It is recommended that a tag does not exceed 3% of the body weight of the bird. When tagging European shags (approx. 1.9kg) this may not be

restrictive because the tag can weigh up to 57g, however for a black guillemot (approx. 380g) this is reduced to 11g. In addition it is necessary to consider the shape of the tag when working with diving seabirds as drag can be an important factor affecting their movement.

There is good potential to commercialise newly developed tags, as these techniques are used in many contexts beyond the renewables industry and by researchers internationally. However, information about current technologies is difficult to access and unconsolidated. Without a solid knowledge base, it is difficult to determine which needs of the renewables sector are currently met by already existing telemetry options and which are yet to be realised. There is therefore a need for the identification and synthesis of the specifications of telemetry technologies currently available for use on seabirds that would provide data for the assessment of impacts of marine renewables.

Project description

The overall aim of the knowledge exchange activity is to review the existing telelmetry technologies available for use on seabirds, and that could provide data for the renewable energy sector.

Tag and tracking technology manufacturers as well as seabird researchers and ornithologists working in the renewable energy sector will be contacted globally to acquire information about,

- Currently available seabird tracking options
- Technologies suitable for seabirds in the R and D phase
- Technologies currently used for species other than seabirds but with modification and development could be suitable for seabird tracking.
- Opinions on the pros and cons of different technologies/methods

Using the opinions collected on the pros and cons of different technologies, a preliminary gap analysis shall be performed to highlight where development and innovation may be required. Subsequently these data could form the basis of a discussion workshop with the objective of discussing telemetry requirements of the marine renewables sector and aligning them with currently available technologies, else further developing new technologies.

Methods

To obtain information about different tagging options, 60 people were contacted including seabird researchers and ornithologists working on seabird tracking and also those in the renewable energy sector, as well as tag manufacturers. In addition, marine mammal and fish ecologists were also contacted to determine whether technologies available for these groups could be suitable for deployment on seabirds.

The following questions were asked to determine whether the tagging technologies had been used successfully on seabirds and whether these might be applicable to use in relation to marine renewables.

- Which telemetry or tracking technologies have you used and on which species?
- What was the method of attachment?
- Did you use the device in combination with another?

- Did these technologies successfully record data and what types of data?
- Did the data require large amounts of post-processing?
- If the telemetry device was not used on a seabird, do you think it would be suitable for use on a seabird?
- Was the tracking conducted in relation to marine renewable energy development?

Of the 60 people contacted, 25 responded and provided information. Using the responses collated, tagging options were explored further from information available for products on the internet, and where information was not available, companies contacted directly. Once data were collated, a preliminary gap analysis was undertaken to determine whether the technologies highlighted are able to meet the needs of the marine renewable energy sector.

Tagging technologies

There is a range of tagging technologies that can be used to track the movements of animals. These include archival tags, otherwise known as data storage tags or loggers which must be retrieved if the data are to be downloaded. There are also transmitting tags which can transmit data back via a communications network. Not only the type of technology but the weight, size and shape of the tag can also vary greatly depending on the components of the tag, for example batteries and sensors. The variety of tags which have been used on seabirds is outlined below. In addition, tags that have been used on other groups of species such as fish but which potentially could be used for seabirds are also listed, along with technologies that may have increased suitability after additional development. The cost of tags has been excluded from this review as it is constantly changing.

Tags used on seabirds

Geolocators

Geolocation tags measure and store data on light levels. Light level geolocation is a method of using solar irradiance to establish geographical location. Longitude can be determined because the Earth spins in its orbit around the Sun and latitude can be determined because the axis of the Earth is tilted in relation to its orbit around the Sun. Using the measured ambient light level, algorithms can determine geographical location. Light level geolocation is possible whenever there are periods of night and day and therefore, close to the poles, the method cannot be used all year around. Latitude accuracy also decreases near the equator and close to equinox due to the lack of variation in day length. Geolocators are therefore most suitable for tracking movements of seabirds with a large range e.g. during migration or for seabirds which conduct long-distance foraging trips. They would be able to provide information on the use of distant sites over an annual cycle, for example if a seabird was using areas in the Pentland Firth and also the Bay of Fundy. Such information would be required in the assessment of transboundary cumulative effects.

Geolocators have been used on a range of seabird species including puffin and black-legged kittiwake and are available with a minimum weight of approximately 0.3g. Geolocators are data storage loggers and therefore must be retrieved to download the data. Geolocation tags can also be designed to record immersion i.e. wet/dry information and sea surface temperature. The immersion data can be used to indicate the activity of the birds, and the temperature information, when correlated with satellite data, can be used to improve the location estimate.

Examples of companies which currently supply geolocation tags include Biotrack (including the British Antarctic Survey tags) http://www.biotrack.co.uk and http://www.birdtracker.co.uk, and Migrate Technology Ltd http://www.migratetech.co.uk.

Radio tags

VHF radio tags have long been used for tracking animals and through pulsed signals are able to provide presentence, as well as identification data for an individual. The individual can be tracked manually in real time or using a data logging receiver, the presence of an individual can be recorded. If triangulation is possible, information on location can be obtained. Radio tags have been used on small birds and ultra-lightweight VHF transmitters are available down to a weight of 0.19g. However, radio tags can only be operated in air and not water and are therefore unlikely to be suitable for diving seabirds.

Several companies manufacture radio tags for bird tracking and these are supplied by Biotrack http://www.biotrack.co.uk

Satellite transmitters

Satellite transmitters are tags that transmit a signal to the Argos satellite system which determines the position of the tag, providing near real-time tracking of the animal's movements which can be accessed remotely, therefore removing the need to re-trap the animal. As well as location, satellite transmitters can also be configured with a pressure transducer to enable depth of a dive, profile of a single dive and percentage of time in defined depth layers to be recorded and transmitted, however these increase the tag weight. Satellite transmitters have been used on larger seabirds such as northern gannet and are available with a minimum size of approximately 30g.

Examples of companies which currently supply satellite tags include Biotrack http://www.biotrack.co.uk, Microwave telemetry http://www.microwavetelemetry.com, and Telonics http://www.telonics.com.

GPS

GPS tracking uses the global positioning system of satellites to determine the precise location of the animal. Locations are stored on the GPS-enabled device and can later be downloaded in various ways. GPS-enabled devices are now being used to track small birds and are available down to a weight of 1g for example nanoFix from PathTrack http://www.pathtrack.co.uk/Site/nanoFix.html though more generally devices are greater than 10g. Additionally power solutions are being devised to prolong the tracking lifespan. When weight is not a limiting factor, it is possible to use a GPS tag which has a solar panel incorporated to recharge the battery, thus extending the lifespan of the tag. An example is the University of Amsterdam bird tracking system http://www.uva-bits.nl/system/. In addition, and due to the fact that GPS receivers are now ubiquitous, it is possible to purchase off-the-shelf GPS loggers such as i-gotU 120 http://www.i-gotu.com/ designed for a purpose other than seabird tracking and adapt them, at little cost.

GPS-enabled tagging devices are data storage tags and therefore they must be retrieved to download the recorded data. However, there are technologies which can be incorporated into tags to enable remote download of data such as ultra high frequency (UHF) radio and Global System for Mobile Communications, originally Groupe Spécial Mobile (GSM). Using these technologies data can

be downloaded without recapture of the bird; this therefore removes an element of risk from the project.

When considering marine applications of GPS-enabled devices Fastloc GPS can be used. Waves, submersion and poor antenna orientation are all problems that can prevent a traditional GPS receiver from maintaining signal reception and providing location information. Fastloc is able to operate in environments where only brief periods of satellite signal are available, as is often the case for diving seabirds during a diving bout.

The size of GPS-enabled devices is continually decreasing and they are consequently becoming a realistic solution for an increasing number of species. In addition, and due to the reduced size and weight it is now possible to combine GPS with additional sensors. Companies are now starting to create modular systems that can combine GPS, pressure sensors, light sensors and accelerometers at weights suitable for deployment on seabirds. Examples are the CATS Diary http://cats.is and Mataki tags http://mataki.org/.

Examples of companies that currently supply GPS tags are PathTrack http://www.pathtrack.co.uk, Ecotone http://www.ecotone-telemetry.com, Customised Animal Tracking Solutions (CATS) http://cats.is, and TechnoSmart http://www.technosmart.eu.

Accelerometers

Tri-axial accelerometers measure movement in 3 perpendicular axes and allow for the characterisation of different behavioural patterns as well as animal movement through dead-reckoning. Accelerometers can be used both above (in flight) and below (diving) the water surface. Accelerometer data requires large amounts of post-processing however some manufacturers provide the suitable software, such as the Daily Diary from Wildbyte Technologies. Accelerometers are often used in combination with other sensors such as GPS, temperature or depth sensors. The GPS data allows for the use of GPS-enabled dead-reckoning to determine an animal's location accounting for any drift in the movement data. This will be particularly in areas of high tidal flow. Standalone accelerometers are available with a minimum weight of approximately 1g.

Accelerometers (in combination with GPS) have been used to track razorbills and common guillemots to observe their behaviour in the different phases of their foraging event, with the aim to use these data to parameterise movement models investigating the potential effects of the presence of marine renewable devices on seabird foraging activities.

Examples of companies which currently supply accelerometers for animal tracking are Wildbyte Technologies http://www.wildbyte-technologies.com, E-Obs GmbH http://www.e-obs.de and TechnoSmart http://www.technosmart.eu

Temperature Depth Recorders (TDRs)

TDR tags offer a means of gathering data on temperature and water pressure/depth and are therefore able to collect data on seabird diving behaviour, though originally designed for fish species.

TDRs have been used for a range of diving seabird species including black guillemots and are available with a minimum weight of approximately 3g. TDRs are data storage loggers and therefore must be retrieved to download the data. Some models of TDR such as the Cefas G5 have options

which are more applicable to seabirds such as a dive switch which deactivates the tag by removal from water or return to the sea surface and fast logging which is activated by entry into water and initiates logging at rates down to 0.1 seconds. TDRs have been used in combination with GPS tags for larger species of seabird such as European shag to provide not only dive profile data but a geographical location for the dives.

Examples of companies which currently supply TDRs are Cefas http://www.cefastechnology.co.uk, Biotrack http://www.biotrack.co.uk, Star Oddi http://www.star-oddi.com and Wildlife Computers http://wildlifecomputers.com.

Tags used on other species

Acoustic tags

Acoustic telemetry uses sound waves to track fish and other wildlife including crocodiles and seals. It is useful in situations where radio telemetry is not appropriate for example in deep or highly conductive water, i.e. the marine environment. The acoustic tags transmit signals or 'pings' which are detected by an acoustic receiver and indicate the presence of the animal. If receivers are arranged in an array it is possible to determine the location of the transmitter. Additional data such as a unique identification number or depth can be coded into the transmitted signal and due to the fact that acoustic tags transmit data, there is no requirement for recapture of the animal. However, in general a signal is only transmitted every 60 seconds, therefore the depth data available would not be of the same temporal scale as would be collected from a TDR. It may be possible to create an acoustic tag that transmits depth data every second however the power requirement and therefore the size of such a tag would likely make it prohibitive for use on seabirds. Alternatively, it is possible to deploy acoustic receivers at different depths. With a large number of receivers deployed and using a tag that transmits a pulse every few seconds, it could be possible to reconstruct a dive profile of a diving bird. Such tags are available from Hydroacoustic Technology, Inc. http://www.htisonar.com/acoustic_tags.htm. Sonotronics experimented using acoustic tags on seabirds however the results are not available.

Examples of companies which currently supply acoustic tags are Vemco http://www.vemco.com, Sonotronics http://www.sonotronics.com, and Hydroacoustic Technology, Inc. http://www.htisonar.com.

Gap analysis

To determine whether the tagging technologies available are able to meet the needs to the marine renewable energy sector, specifically tidal steam turbine developments, several questions have been posed below along with an initial assessment of whether these could be adequately answered using currently available tags.

1. Which population or breeding colony are the birds using/passing through a particular site associated with?

Telemetry and tagging technologies are able to provide information about space use by an individual. However, by observing a tagged animal at a specific site, for example a tidal energy lease site, it will not provide information about where it came from, unless there is a mark on the tag that

can be read. However, colour ringing or marking of birds can provide such information. Colour rings provide a unique identifier which can be associated with the colony at which it was ringed. The disadvantages of colour ringing are however that the ring must be visible, and at tidal sites, the birds' legs are frequently under the water. Also, it requires large amounts of re-sighting effort. There are however other methods of marking birds which the British Trust for Ornithology will permit, such as colour dying, which may be applicable and suitable to answer such questions.

2. Are birds from a particular colony using or passing through a specific site?

The technology is available to determine where a bird from a particular colony is going. GPS tags are becoming miniaturized and suitable for an increasing number of small seabird species and have been deployed successfully on auk species including black guillemots. Collection of data requires re-trapping of birds if the tags do not have a remote download capability. This may be more of a consideration for smaller birds where tag size and weight is a constraint, as these additional components usually increase the overall weight of the tag, however companies such as PathTrack seem to be overcoming these challenges.

3. What are birds from a specific colony doing i.e. foraging, transiting, resting within a site of interest?

Understanding and interpreting the activities birds may be performing at particular locations can be inferred at a course level from GPS data such as flight speed. However, to obtain more information requires technologies such as accelerometers which are able to detect the movements of the animal. It is then possible to associate these movements with specific behaviours. The University of Aberdeen currently have a project using GPS tags in combination with accelerometers to observe the behaviour of diving seabirds in the different phases of a foraging event. It is intended that these data will then be used to parameterise movement models investigating potential effects of the presence of marine renewable devices on diving seabirds foraging activities. Technologies such as wet-dry immersion sensors can also determine whether a bird is in the air or in contact with the water. TDRs can also provide information about dive profiles if the birds are diving. Size and combined weight of tags is again a constraint when working with smaller seabirds. However, above all, it relies on the fact and assumption that the majority of birds from a specific colony are using the site of interest and a large number of birds may need to be tagged to collect sufficient data.

4. What are the dive profiles of a specific species and how do these vary within/ between seasons, activities, weather conditions, location (e.g. distance from shore/colony), sex, age class, etc.?

TDRs have been used successfully on seabirds to gain dive profile data. However, unlike GPS tags, there is as yet, no option to remotely download data. Therefore, a greater number of tags must be deployed to ensure adequate data, and this is a constraint, not least due to the cost of the tags but also the amount of field effort required. If it is of interest how the dive profile may vary with season or weather conditions for example, this also requires that the tag can remain on the bird for the required duration and that the lifespan of the tag is adequate. Although TDRs have been attached to leg rings for some of the larger seabirds, this may not be possible for smaller species. The other typical method of attachment is to use Tesa tape and using the method, the tag is likely to be lost after several weeks.

5. Do dive profiles vary with proximity to renewable energy devices?

To determine whether dive profiles vary with distance from a renewable energy device requires both information on dive profile and location and so in essence requires a GPS device and a TDR or pressure sensor to be attached to the animal at the same time. This is possible for larger seabirds and a GPS tag and TDR have been used in combination effectively for European shags however for smaller seabirds, this is not possible due to the combined weight of the tags. However, if a GPS receiver and a pressure sensor could be combined into a single tag this would be very attractive, especially if the weight could be minimised to <15g, as this would become a possibility for even the smaller species of auk in the UK i.e. black guillemot. Companies such as Customised Animal Tracking Solutions and Mataki might have the ability to produce such a tag. Currently RSPB are running trials on tags which they are developing using circuit boards from Mataki and these tags include accelerometer, temperature and pressure sensors, GPS, and light sensor and remote download via radio. The configuration being tested weighs approximately 15g and has the capabilities to record data for up to one week. The board without battery and housing weighs 7g therefore it is possible to reduce the weight by altering the battery size.

6. Do dive profiles, dive speed or direction change on approach to renewables devices, and at what distance?

Information regarding dive profiles and vertical dive speed are available using TDRs. However, to acquire data on dive direction and change of direction under the water would require the addition of accelerometer data. To determine at what distance diving seabirds might change their dive direction would require a GPS-enabled device to provide location at the surface and then this would allow for dead reckoning from that known point. This is necessary in areas of high tidal flow where drift may occur. Such calculations are possible using software available with tags such as the daily diary from Wildbyte Technologies however these tags are currently used on larger animals such as turtles and penguins and therefore weight would likely be a consideration for use on seabirds in the UK.

7. What are the avoidance rates for a given species for the renewable energy technology under consideration?

To answer this question requires data collected both above and below the sea surface. A seabird could exhibit macro-avoidance to a renewable development and avoid the whole area, or it could show micro-avoidance or evasion and only change its movement trajectory if an underwater collision was imminent. As for the previous question, information about the orientation of the bird under the water would also be required to determine its horizontal movement under the water as this may be equally important in terms of avoidance. Such data collection would likely require GPS, TDR and accelerometer tags.

Conclusion

The marine renewable energy sector requires data on the movements of seabirds to determine potential impacts on populations, but despite increasing miniaturisation, tags are not yet suitable for all purposes and all species of seabird. The main constraints raised are the size and weight of tags that can be attached to seabirds i.e. <3% of body mass, which limits the amount of data that can be collected for a species. It is possible to deploy single sensors for example a TDR or a GPS tag and

remain under the recommended weight but combining tags is not always possible on smaller species. The weight limitation also limits the size of the battery and therefore the longevity of the tag, thus quantity of data that can be recorded and also the ability to include remote download capabilities. The ability to remotely download TDR data is also missing from the current array of tag possibilities and this may be due to the quantity of data that is recorded and also due to the fact that historically TDRs were developed for fish species. Another observation that was made during the collection of opinions on tagging was that there is presently not a register of seabird tracking projects that is available and readily accessible. If increasing numbers of seabird tagging projects are to be undertaken, it is only sensible that there is a searchable register to ensure that there is not duplication of tagging effort.

Acknowledgements

This review was funded by the NERC Marine Renewable Energy Knowledge Exchange Programme. Many thanks to all those who participated and provided information on tags and tracking technologies.