Project	AtlantOS – 633211
Deliverable number	D3.10
Deliverable title	ETN Technical Standards Report
Description	Development of technical standards for specific European lines and tagging projects in the form of a report.
Work Package number	WP3
Work Package title	Enhancement of autonomous observing networks
Lead beneficiary	IMAR
Lead authors	Andre Steckenreuter, Jan Reubens, Pedro Afonso
Contributors	Lenore Bajona, Frederick Whoriskey
Submission data	
Due date	31 March 2018, PU36
Comments	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement nº 633211.

Last updated: 16 April 2018

Stakeholder engagement relating to this task*

WHO are your most important stakeholders?	☒ Private company If yes, is it an SME ☒ or a large company ☐? ☒ National governmental body ☒ International organization ☒ NGO ☒ others Please give the name(s) of the stakeholder(s): Individual researchers
WHERE is/are the company(ies) or organization(s) from?	☒ Your own country ☒ Another country in the EU ☒ Another country outside the EU Please name the country(ies): Potential countries that would like to adopt ETN Technical Standards to cooperate with the network
Is this deliverable a success story? If yes, why? **If not, why?**	☒ Yes, because the Technical Standards have been developed according to plan and because they represent an increase in the network's capacity to operate at a higher level. ☐ No, because …
Will this deliverable be used? **If yes, who will use it?** **If not, why will it not be used?**	☒ Yes, the Technical Standards are already used as part of the ETN data management platform. They will be used by participants of the network and potentially third parties involved in acoustic telemetry worldwide. ☐ No, because …

NOTE: This information is being collected for the following purposes:

1. To make a list of all companies/organizations with which AtlantOS partners have had contact. This is important to demonstrate the extent of industry and public-sector collaboration in the observation community. Please note that we will only publish one aggregated list of companies and not mention specific partnerships.
2. To better report success stories from the AtlantOS community on how observing delivers concrete value to society.

*For ideas about relations with stakeholders you are invited to consult D10.5 Best Practices in Stakeholder Engagement, Data Dissemination and Exploitation.

Summary

The emerging European Tracking Network provides researchers with an opportunity to acquire and collate data on the movements of aquatic animals over large spatial and temporal scales, to better understand the spatial ecology of key (ecologically and commercially) aquatic species. This knowledge will enhance their sustainable management and conservation, especially that requiring concerted actions at the trans-national scale. Here, we develop the technical standards and best practices to orientate ETN members when designing new acoustic telemetry studies, carrying out the deployment and maintenance of acoustic telemetry infrastructures and tagging studies, and implementing the necessary data curation.

Introduction

A large and growing number of researchers of the emerging European Tracking Network (ETN) are using acoustic telemetry as one of the prime tools to study aquatic animals. The stationary acoustic receivers log data that documents the temporal and spatial patterns of movements and habitat use of aquatic animals over small (hundreds of meters) to large (hundreds of kilometres) scales (Heupel et al. 2006). These movement patterns are essential to understand the spatial ecology of key species, a knowledge that is expected to significantly enhance their sustainable management and conservation (Steckenreuter et al. 2014, McGowan et al. 2017, Ogburn et al. 2017). In recent years, acoustic telemetry studies in European waters evolved from addressing purely animal behaviour (e.g. home ranges, residencies and movement patterns) into more holistic approaches addressing management related issues, particularly with a focus on the design and assessment of marine protected areas (Steckenreuter et al. in review).

For each specific research question in acoustic telemetry-based studies, a proper experimental design needs to be developed taking the relevant species, as well as environmental and logistical variables into account. A number of flagship sites and species were identified by ETN to foster the establishment of future studies, including network expansion by deployment of new acoustic receiver lines in key areas (i.e. estuaries, narrow continental shelves, seamounts and the open ocean), cross-boundary studies and inter-research group collaborations (Steckenreuter et al. in review).

The ETN data management platform (http://www.lifewatch.be/etn/) hosted by the Flanders Marine Institute is the central data portal of ETN. It is a repository for data and metadata from receiver arrays, associated tagging studies and from research infrastructure provided by ETN and regional partners in universities, fishery agencies and non-governmental institutions (Abecasis et al. in review).

In order to achieve efficient and homogeneous data collections, standards and best practices for designing and developing acoustic telemetry studies, including the maintenance of acoustic telemetry infrastructure and data curation, are outlined in this report. This is of importance, as coordinated research efforts have been proven to increase data capture and quality and generate new knowledge useful to policy makers, managers, and the public (Steckenreuter et al. 2016, Hoenner et al. 2018). The integration of European scientists and research infrastructure into a pan-European network will provide a basis to address priority societal challenges such as the impacts of climate change upon valued species and the conservation of commercial and endangered species in the EU, consistent with the needs of the EU Maritime Policy and Blue Growth agenda (Steckenreuter et al. in review).

Designing and deploying acoustic telemetry studies

The careful planning and development of acoustic telemetry studies are crucial for these studies' successes. The equipment, logistics and duration of a planned study, the targeted species and the environment of the study site are important components that need to be considered and that will determine which acoustic telemetry setup is used. Furthermore, the research question dictates the layout of the acoustic telemetry array, i.e. a high-density or residency study needs a different setup than a study aiming to detect highly migratory species along entire coastlines or across ocean basins. In recent years, the models of acoustic receivers and tags on the market have increased steadily. The majority of acoustic telemetrists worldwide have adopted technologies from the Canadian manufacturer Vemco but other companies on the market offer products with similar capabilities (e.g. Lotek, Thelma). However, a considerable and increasing challenge that scientists face is that not all products are compatible (e.g., operate on different frequencies, use different coding schemes or have uncoordinated use of the same coding scheme, etc.), resulting in tag code duplication or detection losses.

Receiver models

Acoustic arrays (i.e., lines or ensembles of acoustic receivers) can use different receiver models, each with different capabilities and hence better for certain applications. Some receivers detect only one frequency, e.g. 69kHz, but some models can detect two frequencies or more. Basic models and those ubiquitously deployed such as the VR2W serve a diverse range of applications with a battery life of a minimum of twelve months. Other receivers now include different features such as acoustic releases for remote retrieval and integrated transmitters for improved fine scale 3D positioning (e.g. VPS) studies, or modems where the data can be uploaded remotely via a hydrophone. The modem-equipped models have the advantage for long-term deployments as the battery life can last for multiple years and that 69 and 180kHz frequencies can be detected simultaneously.

Transmitter models

Rapid technological advancements in electronic transmitters over the last three decades have allowed scientists to monitor a wide range of species and animal sizes from small salmon smolts (10cm length) to blue whales (29m) (Steckenreuter et al. in review). The transmitters have evolved from detecting purely the location of the tagged individual, to new models capable of incorporating a suite of sensors that can report data on the animal's 3D acceleration, physiology (e.g. heart rate, stomach pH), or chemo-physical parameters of the surrounding environment (e.g. depth, salinity, temperature, dissolved oxygen) (Cooke et al. 2004).

Tags will transmit at intervals that can be set by the tag owner. Normally, transmission is intermittent to conserve battery life, to preserve the memory of acoustic receivers, and to reduce collision with the signals from other tags on other animals in the area. To maximise the detection of a particular animal within a given acoustic array, a specific nominal delay of emitted code transmissions needs to be configured in accordance with the manufacturer's recommendations (see example in Fig. 1). Additionally, the total number of tagged individuals in a study area needs to be taken into account to avoid code collision and false detections that can hamper the detection efficiency of an acoustic telemetry study (Simpfendorfer et al. 2015). When designing a study, it is important to understand these effects; a higher number of transmitters in an area and shorter transmission delays cause more collisions (e.g. https://vemco.com/collision-calculator/).

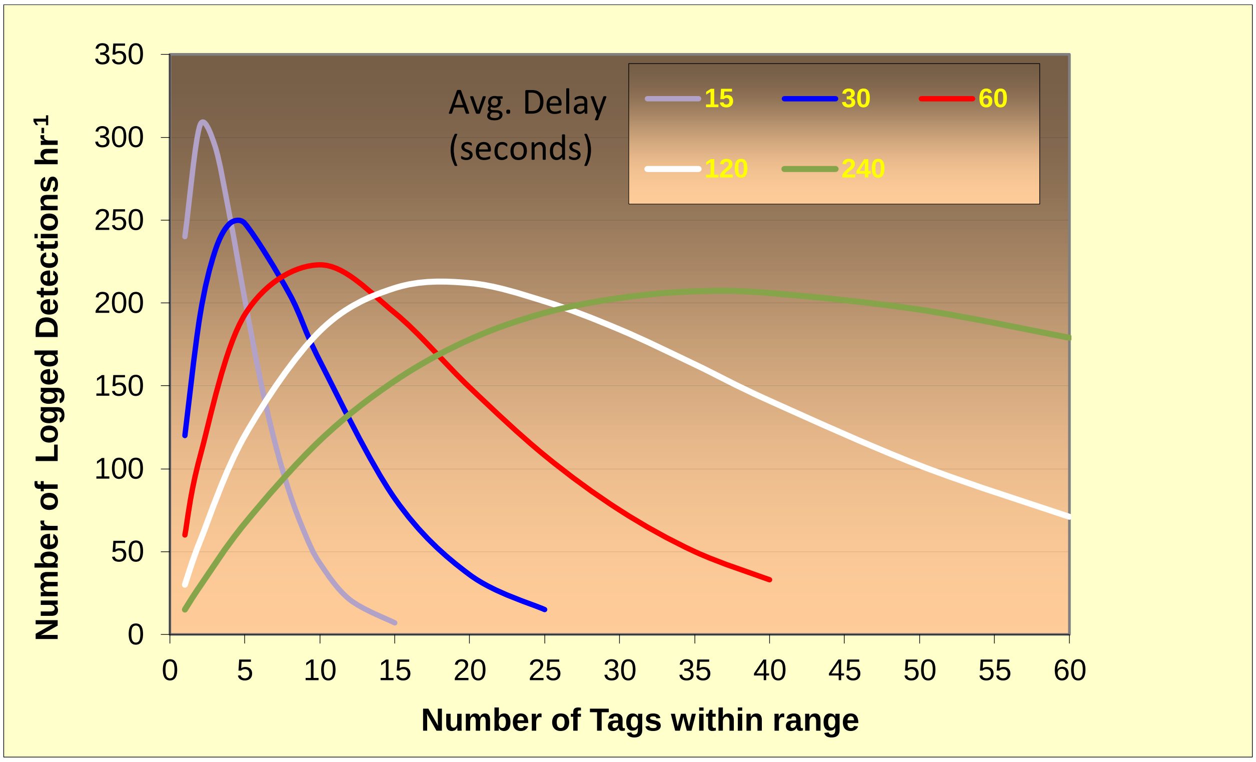

Fig. 1: An example of the calculation to maximize the amount of detections in a study on ten fish, resulting in an optimal nominal delay of sixty seconds or higher (Pederson 2016).

Range testing

For the design of an acoustic array, it is crucial to determine the detection ability of the array, which in turn depends on transmitter power, receiver spacing, and environmental conditions within the study area. In acoustic telemetry, noise is the most limiting factor. Environmental noise can be generated from different sources such as wind, waves, rain, substrate movements due to currents and tides, anthropogenic factors including boats and sonars as well as biological sources such as snapping shrimp. Furthermore, telemetry equipment uses relatively high frequencies that are prone to absorption (losses in excess of normal spreading losses) that varies with conductivity, depth and water temperature. It is possible and advisable to have a notion of the detection probability as a function of these variables beforehand. A number of different tools are available to assist investigators with this (e.g. https://vemco.com/range-calculator/).

However, it is also imperative to perform range testing in a representative location within the proposed array, preferably prior to the establishment of the study. The detection performance analysis can either be receiver- or transmitter-based, and should ideally be conducted over longer periods, i.e. months, to allow evaluating the impacts of variations in weather and oceanographic conditions (Webber 2009). A typical range test setup may consist of a certain number of stationary acoustic receivers with built-in transmitters. These should be placed at known distance intervals on mooring types that will be used in the actual study (Fig. 2). The detection analysis will determine the maximum distance that acoustic receiver moorings should be spaced apart in order to secure an efficient detection of tagged species. For a detailed overview on how to perform range tests and how to analyse related data, refer to Reubens et al. (2018), and Huveneers at al. (2016).

Manufacturers also provide guidance (e.g. Vemco's New User Guide (Webber 2009) and their Range Test Software (https://vemco.com/vemco-range-test-software/)).

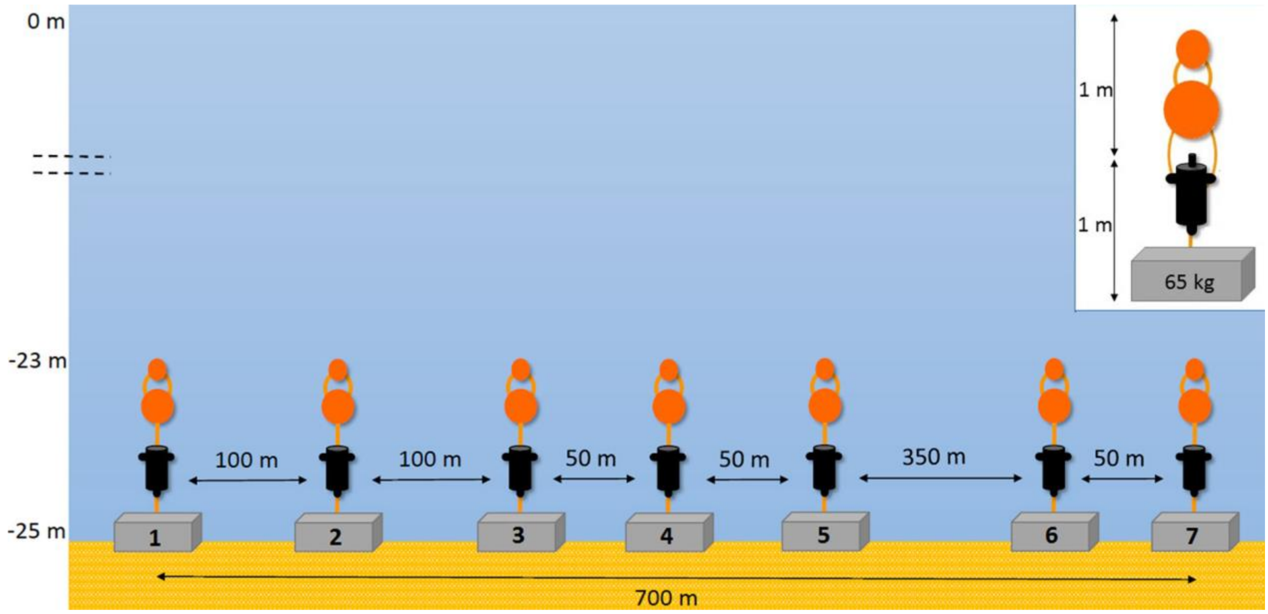

Fig. 2: Range test comprised of seven acoustic receivers with built-in transmitters spaced at distances of 0-700 m (Reubens et al. 2018).

Mooring and array design

In field deployments, each acoustic receiver will typically be attached to some sort of a mooring. The mooring setup needs to be designed to cope with site-specific environmental conditions, with special emphasis on the level of prevailing currents, tides and swell, the habitat/substrate, and avoiding excessive tilt of the receiver. However, the duration of a study, associated costs for deployments and maintenance, and servicing resources need to be considered as well. Thus, the mooring design can range from rather simple arrangements where an acoustic receiver is attached to a post or a roped buoy that is secured to the substrate by a simple anchor, to more elaborate deep-water moorings including potential acoustic releases (Fig. 3). As general rules when building your mooring, it is advisable 1) to keep moving parts working against rigid pieces to the minimum; 2) to reduce the use of metallic parts more prone to corrosion or replace them by non-corrodible material (e.g. resistant dynema rope, nylon shackles, etc.); 3) to maintain the integrity of your desired flotation (e.g., use more than one buoy in case one fails); 4) use non-pollutant materials, especially when using sacrificial weights. For advice on specific mooring designs, you can contact ETN via the portal service.

Regarding maintenance intervals, it is important to not only consider the factors directly affecting the receiver performance, such as the battery life of the receiver (when the battery is dead it will no longer detect any transmissions) or the level of bio-fouling and sediment transport (which can also reduce the detection probability), but also the increasing probability of interaction with fishing gear and consequent loss of equipment/data. Generally, the deeper the mooring, the less bio-fouling. In shallower areas corrosion may accelerate due to higher light and oxygen levels which is particularly relevant for moorings using metal pieces. These are also the areas of higher hydrodynamism and gear interaction probability, which calls for more frequent servicing and data retrievals (every 6-12 months). Thus, deep water moorings coupled with long-life receivers can be an option for long-term deployments where you also can have long intervals between servicing (1-

5 years, depending on receiver battery). The initial higher expenses for those mooring-receiver combinations can be offset by the savings resulting from by lower maintenance costs.

The most widely used array designs are laid out as grids or gates. Gate designs are generally conducted to monitor the passage of animals to define timing and routes of migration, or to determine the survival of juveniles, for example. This technique is used when equipment availability and local logistics and geography make it possible to monitor several potentially distant points, ideally with receivers spaced less than the estimated listening range. Good examples are across migration routes such as rivers and coast lines. Gates can be designed as single gates or double gates, the latter having the advantages of providing better detection of passing animals during periods when acoustic conditions become poorer, and of indicating directional movement of individuals (Pederson 2016). By contrast, grid studies are used to collect as much data as possible in areas where populations are known to more or less continuously inhabit a site for a portion of its life history, e.g. monitoring behaviour around man-made structures, fish homing and relocation, spawning and mating behaviour, stock mixing, etc. (Heupel et al. 2006, Webber 2009).

Appropriate metadata need to be recorded at each deployment of acoustic receiver arrays. Sample csv files of such metadata are located on the ETN data management platform (http://www.lifewatch.be/etn/dataimport).

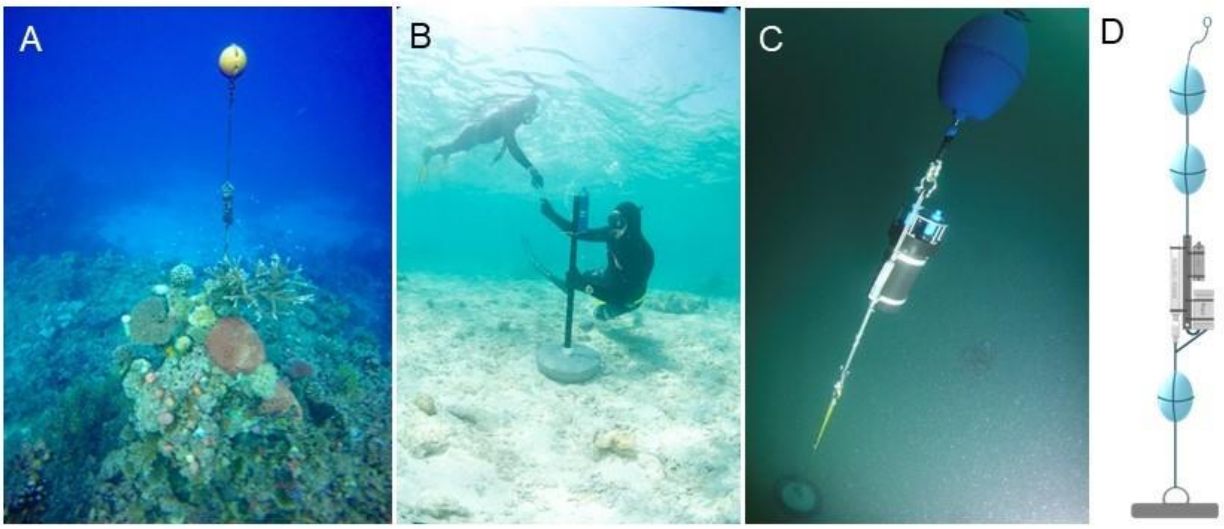

Fig. 3: Examples of mooring designs; (A) Shallow water mooring on tropical reef structure, (B) Shallow water mooring on sand/gravel substrate, (C) Deep water mooring without acoustic release, (D) Deep water mooring with multiple floats and integrated acoustic release.

Maintaining acoustic telemetry studies

To avoid data gaps, acoustic receiver moorings need to be serviced at regular intervals, i.e. within conservative estimates of the minimum battery life time of a specific mooring component, such as the acoustic receiver itself or, mandatorily, of an acoustic release if your station recovery depends on one. During typical service for most receiver models, the acoustic receiver will be recovered, the logged data downloaded and ultimately uploaded to the ETN data management platform. Exceptions to this rule are cabled receivers that can transfer real-time data. Prior to a potential re-deployment, it is mandatory to inspect each mooring's integrity and exchange faulty or worn components as necessary. A serviced receiver that is part of long-duration arrays needs to be re-deployed at exactly the same location it previously occupied. Moorings that have been partially dissembled or where only the acoustic receiver has been retrieved by divers need to be reassembled accordingly.

For all re-deployments of acoustic receiver moorings, new metadata also needs to be recorded and transmitted to the ETN data management platform.

Data handling and management

For the upload of recorded acoustic telemetry data, it is first necessary to register on the ETN data management platform (http://www.lifewatch.be/etn/account?p=register). In the following, we provide a summary of the structure of this platform and its use. A more detailed overview is outlined in the Manual for the European Tracking Network data management platform (http://www.lifewatch.be/etn/assets/docs/ETN-DataManual.pdf?1.0).

Metadata management and data upload

After the initiation of a new project, the platform offers four options for metadata management: entering a new record, editing, duplicating, and deleting an existing record. All data entry should be as detailed as possible, but users must at least complete the designated mandatory data fields. For receivers, mandatory metadata are the manufacturer, serial number and model number. Tags require information on manufacturer, owner organisation, tag type and model, ID code/code space, and serial number. When deploying receivers, information on station name, location (latitude and longitude), depth, and deployment date and time need to be provided. For tagged animals, information identifying the unique ID code of the tag, the species, and catch and release date and time need to be provided.

Metadata from receivers, tags, deployments and tagged animals can be uploaded in bulk using a single csv file. All recorded data can be uploaded to the repository according to the mandatory metadata standards (http://www.lifewatch.be/etn/dataimport).

Visualisation of acoustic arrays

Active and historic acoustic receiver arrays are visualised on a map on the landing page of the ETN data management platform. Project information such as contact person, contributors and a short project summary are available when a specific array is selected. More detailed project information about the people involved, affiliated institutions, datasets, publications, etc. can be accessed via a link to the Flanders Marine Institute website (http://www.vliz.be/en/imis). Furthermore, a detailed overview of all receiver locations of a specific project can be accessed via a link.

Visualise and export metadata

The ETN data management platform provides several functionalities to explore the metadata. The user can filter and sort specific metadata fields to select a subset of data or investigate queried views of detections. The latter can be accessed via the detection page where all detections can be listed that are associated to all receivers of a specific network and/or animal project. The metadata (subset) can then be exported and downloaded. These exported files will only contain data that the user has access to. The R-shiny application provides access to visualise datasets (http://rshiny.lifewatch.be/ETN%20data/).

Data Policy

By registering to the ETN data management platform, participants automatically agree to abide by the ETN Data Policy (http://www.lifewatch.be/etn/assets/docs/ETN-DataPolicy.pdf?1.0). ETN makes a distinction between *restricted* and *unrestricted* data. Unrestricted data is publicly available and can be freely accessed through the R-shiny data explorer (http://rshiny.lifewatch.be/ETN%20data/). Restricted data can only be accessed by the registered data collaborators that submitted the data, or to others who have been granted permission by the data collaborators to access those data sets, for a certain agreed period (moratorium). A moratorium can be put on data related to tagged animals and on detection data. For the former, the moratorium period is by default set at four years, starting from the moment a tag is attached to the animal. The moratorium period can be extended by the principal investigator on request in one-year increments, with the future ETN Data Committee reviewing requests. Detection data are by default placed under moratorium following a three-tier process; (1) A tag owner has access to all detections of his/her tags (also from receivers that do not belong to the tag owner), (2) A receiver owner has access to all detections on the device including species information (also from tags than do not belong to the receiver owner), and (3) All others have no access to detection information from data under moratorium.

Quality control

Large-scale acoustic telemetry networks such as ETN produce large volumes of information-rich geospatial data that need to be subject of continuous quality control measures (Hoenner et al. 2018). The current quality controls for the ETN data management platform are outlined in the Manual for the European Tracking Network data management platform (http://www.lifewatch.be/etn/assets/docs/ETN-DataManual.pdf?1.0). However, additional quality control measures are planned to be added in future versions.

The aim of the ETN data management platform is to increase the scientific use of acoustic telemetry data by providing a tool for enhanced data sharing, standardised data protocols and analytical tools, and public access to data sets for new approaches to analysis including examination of trends over long time periods. Therefore, the data system will also provide an historic archive which can be used in the future to evaluate shifts in animal movements and distribution in the face of a changing world (Steckenreuter et al. in review).

Currently, ETN is developing data standardisation protocols in cooperation with several working groups such as the Ocean Tracking Network, the US Integrated Ocean Observing System Animal Telemetry Network, the Integrated Marine Observing System, the Ocean Biogeographic Information System, and the International Bio-logging Society.

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