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|---|---|
| **Project** | AtlantOS – 633211 |
| **Deliverable number** | D3.2 |
| **Deliverable title** | EAATN Valued species Report |
| **Description** | Provide operations and maintenance support to scientific teams initiating studies of valued species, such as Bluefin tuna, European eel, sea bass, sea trout. To achieve this deliverable a workshop will be hold focussing on launching and networking activities. |
| **Work Package number** | WP3 |
| **Work Package title** | |
| **Lead beneficiary** | IMAR |
| **Lead authors** | Pedro Afonso, Frederick Whoriskey |
| **Contributors** | |
| **Submission data** | 25 October 2016 |
| **Due date** | month 24 – April 2017 |
| **Comments** | Missing details for this deliverable (ex. proposals for funding) will be included in D3.10 *Technical standards* (Development of technical standards for specific European lines and tagging projects in the form of a report) which is due in Month 36 and in D3.21 *the EATN Data base* due in month 45. |

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# European Tracking Network

## kick-off workshop

### Ostend, Belgium, 19-20 April 2017

**AtlantOS D3.2 – Valued Species and Sites Report**

This report should be cited as:

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# INDEX

## Summary

There is a large and growing number of researchers based in Europe using biotelemetry as a tool to study aquatic animals. However, the European telemetry research community lacks a formal or informal network organizational structure, such as those existing in other regions, with substantial loss of scientific, funding, and data sharing opportunities. One of the many actions within AtlantOS is to promote and launch a European Tracking Network (ETN) that can bring together researchers based in Europe using marine biotelemetry as a tool. key objectives of ETN are i) to promote the establishment of key acoustic telemetry lines of receivers in strategic sites across Europe, ii) to leverage resources for tagging ecologically and economically valuable species, iii) to promote the maintenance of existing arrays and the development of new arrays in Europe, and iv) to expand monitoring operations to the Atlantic open ocean by taking advantage of platforms of opportunity (e.g. the PIRATA Buoy and Glider Networks). To address these questions and to formally initialize ETN, a two-day workshop was organized from 19-20 April 2017 in Ostend, Belgium, hosted by the Flanders Marine Institute (VLIZ). Given the nascent state of this network and the current absence of a steering committee, this workshop also served to prepare the way towards creating a more formal network structure. The group addressed the challenges and opportunities of ETN, including a SWOT analysis, identified key resources including a centralized database, the long-term goals that ETN should aim, the governance, actions and contact points, and a list of valued (flagship) sites and species that ETN should focus on by promoting the establishment of acoustic receivers and tagging studies in Europe. This list is also developed and refined in this report.

## INTRODUCTION

There is a large and growing number of researchers based in Europe using biotelemetry as a tool to study aquatic animals. Amongst these, the great majority are researchers using acoustic telemetry to study marine and diadromous species, although a considerable number of studies also use PIT and radio telemetry technology traditionally used in freshwater studies for several decades. A search on the Web of Knowledge shows a five time increase during the last 25 years in the number of published papers using acoustic telemetry on marine and anadromous species (Figure 1a). These studies were conducted primarily in Atlantic Ocean, Mediterranean and North Sea bordering nations (Figure 1b). The vast majority of these studies were conducted on fishes, with only four studies on crustaceans, three on cephalopods and one on marine mammals (Figure 2a). Not surprisingly, over 90% of these studies took place in coastal areas, estuaries or rivers, with only a handful of recent studies in deep sea environments such as seamounts and none in the open ocean alone.

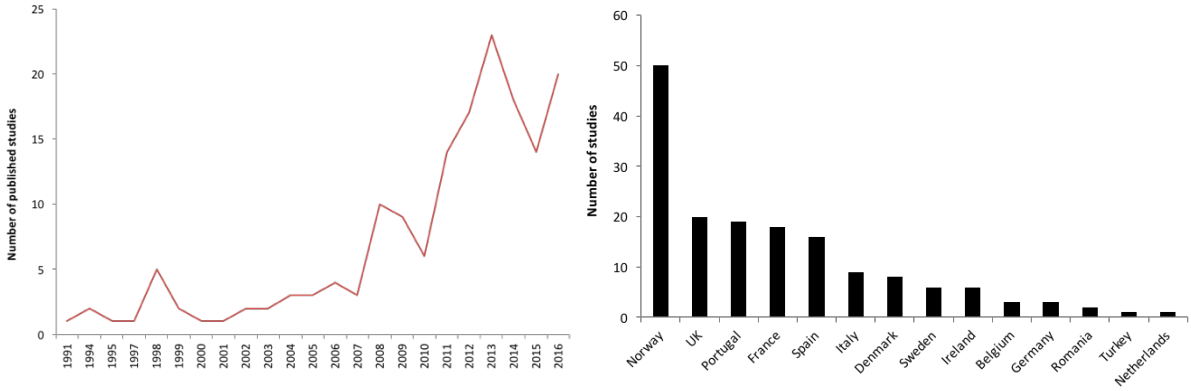


***Figure 1: a)*** *Temporal evolution of the total number of published studies using acoustic telemetry on marine and diadromous species in Europe and* ***b)*** *Number of published studies by country (source: WoK search using 'acoustic telemetry', 148/937 studies; P. Afonso and D. Abecasis, unpublished data).*

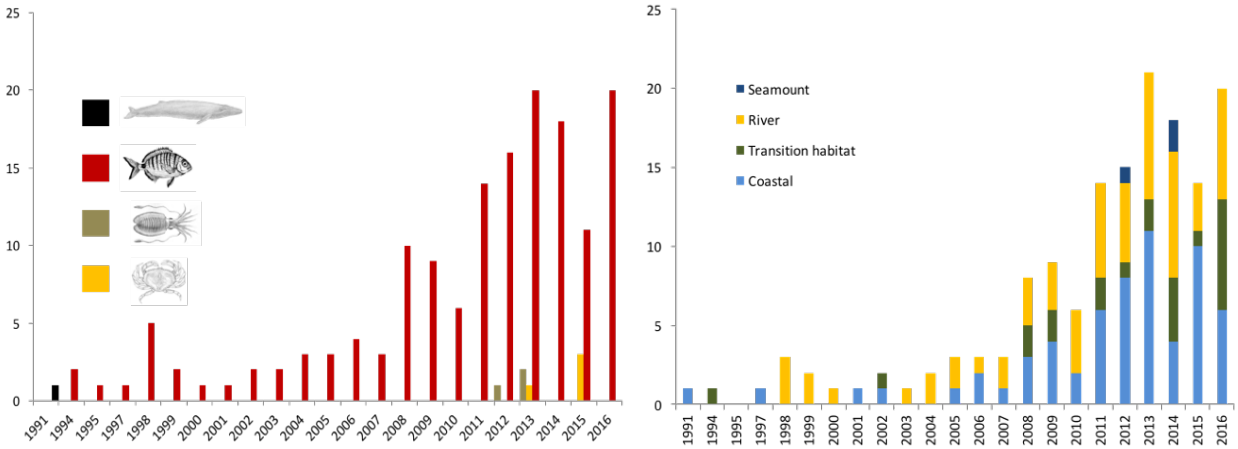


***Figure 2:*** *Temporal evolution of the number of studies published using acoustic telemetry on marine and diadromous species in Europe per large taxa* ***(a)*** *and habitat type* ***(b)*** *(source: WoK search using 'acoustic telemetry', 148/937 studies; P. Afonso and D. Abecasis, unpublished data).*

Yet, the European telemetry research community lacks a formal or informal network organizational structure such as those existing in other regions (e.g. IMOS in Australia, POST-OTN in the US and Canada's west coasts, ACT-FACT on the US east coast, iTAG in the Gulf of Mexico, and ATAP in South Africa). This situation represents a substantial loss of opportunities for i) data sharing among researchers using telemetry technology and other oceanographic researchers, e.g. by using 'animals as oceanographers' to gather ocean observation data, ii) funding leverage through upscaling by a network approach and by the EU blue growth agenda, and iii) scientists by benefiting through utilizing compatible telemetry equipment. In a broader sense, it obscures the bigger picture that an organized pan-European telemetry community could develop.

Despite the increasing number of species studied and studies published, there is a prominent lack of in-field acoustic telemetry collaborations in Europe. The very few examples of acoustic detections of animals at transboundary scales (continental shelf and oceanic) illustrate the benefits of data sharing in a network. For example, European eels (*Anguilla anguilla*) tagged in Belgium, Germany and the Netherlands were detected at the acoustic telemetry network in the Scheldt Estuary and Belgian part of the North Sea (Huiman et al. 2016; Figure 3), and tuna (*Thunnus thynnus*) tagged in the western Atlantic Ocean have been detected by receivers on the summits of Azorean seamounts over the mid-Atlantic ridge (P. Afonso, unpublished data).

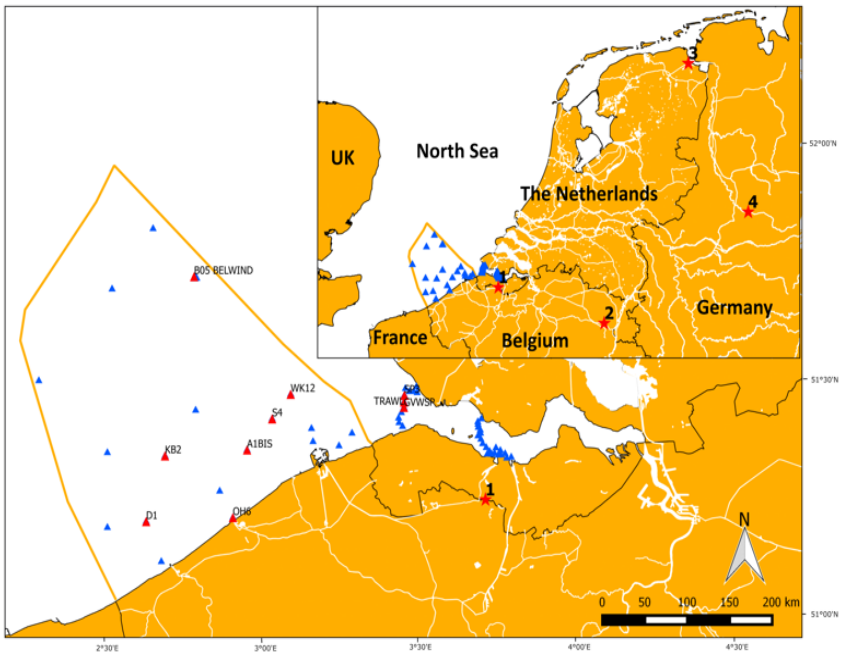


***Figure 3:*** *European eels tagged in Belgium, Germany and the Netherlands (red asterisks) detected at the cross border acoustic telemetry network in the Scheldt Estuary and Belgian North Sea (red triangles) (Huiman et al. 2016).*

The EU funded project AtlantOS (https://www.atlantos-h2020.eu/) is a large-scale effort that aims to foster increased and sustainable transatlantic ocean observations. One of the many actions within AtlantOS is to promote and launch a European Tracking Network (ETN) that can bring together researchers based in Europe using marine biotelemetry as a tool. The ETN task is co-coordinated by

IMAR/University of the Azores and by Dalhousie University through the Canadian led global Ocean Tracking Network (OTN) initiative.

ETN proposes to leverage the already existing aquatic animal telemetry infrastructure and the community of researchers working in Europe with electronic telemetry equipment. With regards to acoustic telemetry, the most widely used tool, key objectives of ETN within the AtlantOS framework and lifetime are i) to promote the establishment of key acoustic telemetry lines of receivers in strategic sites across Europe, ii) to leverage resources for tagging ecologically and economically valuable species, iii) to promote the maintenance of existing arrays and the development of new arrays in Europe, and iv) to expand monitoring operations to the Atlantic open ocean by taking advantage of platforms of opportunity (e.g. the PIRATA Buoy and Glider Networks).

There are a number of important questions that need to be addressed before such a network can effectively become active, namely:

1) Which scientific, management, logistical, technological and data challenges/opportunities does the European marine tracking community face and how could a network approach help?

2) How can transatlantic scientific issues be addressed by the technology and the network approach and how does the Atlantic links with the Mediterranean, North, Baltic and Black seas?

3) Which resources (technical support, data center and tools) and synergies (science groups, institutions and industry) can be built for the community through ETN?

4) What should be the short- and long-term goals of ETN?

5) What are the important short- and mid-term actions that ETN should take?

6) What should the ETN governance structure be at this stage of development?

To address these questions and to formally initialize ETN, a two-day workshop was organized from 19-20 April 2017 in Ostend, Belgium, hosted by the Flanders Marine Institute (VLIZ). Given the nascent state of this network and the current absence of a steering committee, this workshop also served to prepare the way towards creating a more formal network structure.

Preliminary actions and enquiries carried out within the project indicated that the European aquatic telemetry community is firstly largely composed of researchers working on coastal or anadromous species in coastal and riverine environments and secondly uses acoustic telemetry as their main tool. This is also the case of the other telemetry networks worldwide. Therefore, a representative group of acoustic telemetry researchers from countries across Europe, including nations bordering the Atlantic Ocean, Mediterranean, North and Baltic Seas, was selected to attend this workshop (Figure 4; Appendix A). This practical approach, however, does not preclude the recognition that the emerging ETN should maintain a broad and integrative perspective for future integration of (sub-) telemetry communities, including those working in the open Atlantic Ocean and using satellite telemetry as their main tool. Specific actions targeting these communities should be considered within ETN in the future.

The list of workshop attendees was composed of Alan Walker (CEFAS, UK), Andre Steckenreuter (IMOS, Germany), Barbara Koeck (University of Gothenburg, France/Sweden), Carl Meyer (University

of Hawaii, Channel Islands/US), David Abecasis (CCMAR-University of Algarve, Portugal), Eva Thorstadt (NINA, Norway), Fabio Badalamenti (NRC, Italy), Francisco Hernández (VLIZ, Belgium) Frederick Whoriskey (OTN-University of Dalhousie, Canada), Jan Reubens (VLIZ, Belgium), Josep Alós (LIFEIF, Spain), Kim Aarestrup (DTU, Denmark), Klaas Deneudt (VLIZ, Belgium), Larry Greenberg (University of Karlstad, Sweden), Lenore Bajona (OTN, Canada), Nick Humphries (MBL, UK), Niels Breve (SportvisserijNederland, Holland), Patrick Boylan (Loughs Agency, UK/Ireland), Pedro Afonso (IMAR-University of Azores, Portugal).

The workshop was organized to answer the six questions outlined above. During the morning of the first day, after an introductory welcoming round by the organizers and a round table where participants expressed their expectations with regards to ETN, several presentations outlined the experience of other acoustic telemetry networks and platforms, including OTN (Fred Whoriskey), IMOS (Andre Steckenreuter) and PAICOOS (Carl Meyer). The group then set out to address the first two questions on the challenges and opportunities and on the regional scope of ETN, including a SWOT analysis. The afternoon of day one was dedicated to identify the key resources that ETN should develop and offer, including the issue of a centralized database as a key asset for ETN which was addressed by a presentation on the database under development at VLIZ (Jan Reubens). The morning of day two was dedicated to identify the long-term goals that ETN should aim for and a list of valued (flagship) sites and species that ETN should focus on by promoting the establishment of acoustic receivers and tagging studies in Europe, respectively. This list was later developed and refined by the workshop participants resulting in the summaries on sites and species. The workshop ended with the identification of the governance, actions and contact points that ETN will adopt in the short and medium terms. This report resumes the conclusions reached during this workshop.


***Figure 4:*** *Participants of the European Tracking Network kick-off Workshop; from left to right: F. Hernández, A. Walker, E. Thorstadt, K. Aarestrup, P. Afonso, L. Bajona, J. Alós, F. Whoriskey, D. Abecasis, N. Humphries, J. Reubens, B. Koeck, P. Boylan, C. Meyer, A. Steckenreuter, F. Badalamenti, K. Deneudt.*

## CHALLENGES AND OPPORTUNITIES FOR ETN

*Experiences from other telemetry networks*

Various marine tracking networks developed globally following the growth of the tracking community, especially in North America, Australia and South Africa. OTN is one of the oldest and the largest network, having emerged from the global Census of Marine Life initiative. It is a collaborative, globally linked infrastructure platform and research network focusing on the measurement of marine animal movements and survival. OTN grew from a passive acoustic network to the present state, where it integrates information from *bio-probing* (using large marine animals equipped to track other tagged animals) and *robo-probing* (ocean-going remote monitoring gliders). It is a good example of the opportunities offered by networking a large scientific community with common goals and challenges and by seizing the technological developments to expand the operational capabilities of such a network (Figure 5). Since its foundation, OTN became an umbrella network that works with other regional networks in a collaborative fashion, with operational, logistic and scientific advantages. This approach is also desirable for the emerging ETN and will be achieved through close collaboration with OTN under the AtlantOS project.

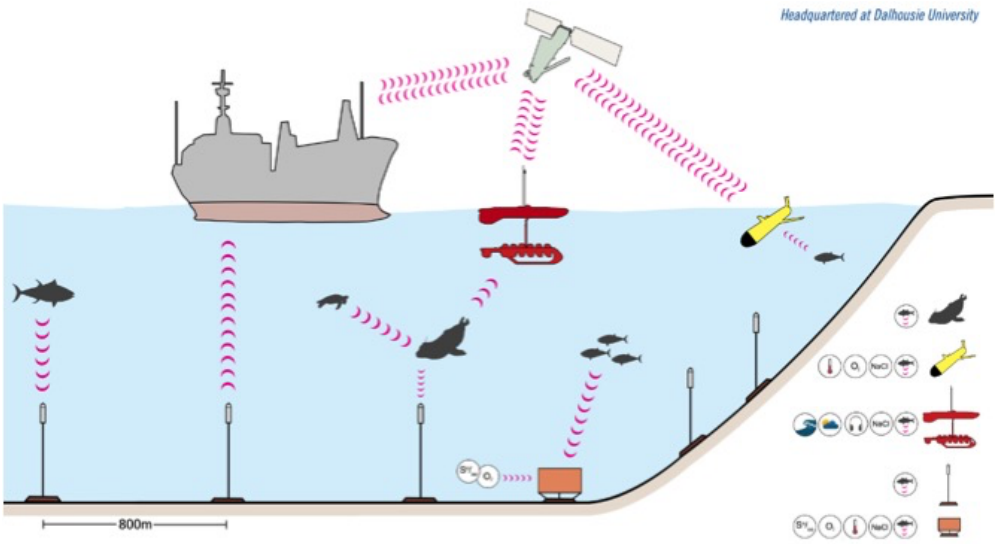


***Figure 5:*** *The Ocean Tracking Network's multi-modal, multi-platform acoustic tracking concept.*

The Australian animal tracking network is another key project and probably the best national-level example of an acoustic tracking network. Currently, it represents a national, collaborative research infrastructure program that brings together Australian universities and publicly funded research agencies working in marine and climate science under the institutional umbrella of the Integrated Marine Observing System (IMOS). 10 facilities create and develop data streams that build the research infrastructure, including the Animal Tracking Facility, to provide freely available data.

These and other large-scale networks provide technical expertise on research design, hardware, data handling, mooring setups, etc. and provide key research infrastructure to interconnect regional projects and network support, for example, by developing centralized databases and web-interfaces (at different scales) and through in-kind loans to researchers. The advantages of such large-scale networks include i) meta-analyses of large datasets to improve research designs, technical advancement and inter-project spatiotemporal species movements, with an impact through Big Science with functional, large scale, and multi-decadal acoustic telemetry, ii) quality controlled and standardized data, iii) improved output through joint publications, and iv) advanced leverage of funding opportunities.

However, large-large networks can be jeopardized by common pitfalls such as i) network miscommunication that may reduce willingness to cooperate with, participate in, and support the network by regional projects, ii) restrictions on data availability that hamper the advancement of knowledge and may distort meta-analyses on important issues due to incomplete datasets, and iii) substandard or missing/incorrect data which may restrict usability of datasets for meta-analyses. Actions taken to reduce these pitfalls include special attention to network communication and policy, implementation of dataset DOIs and security measures due to potential data sensitivity, and implementation of standardization and quality control measures (Figure 6).

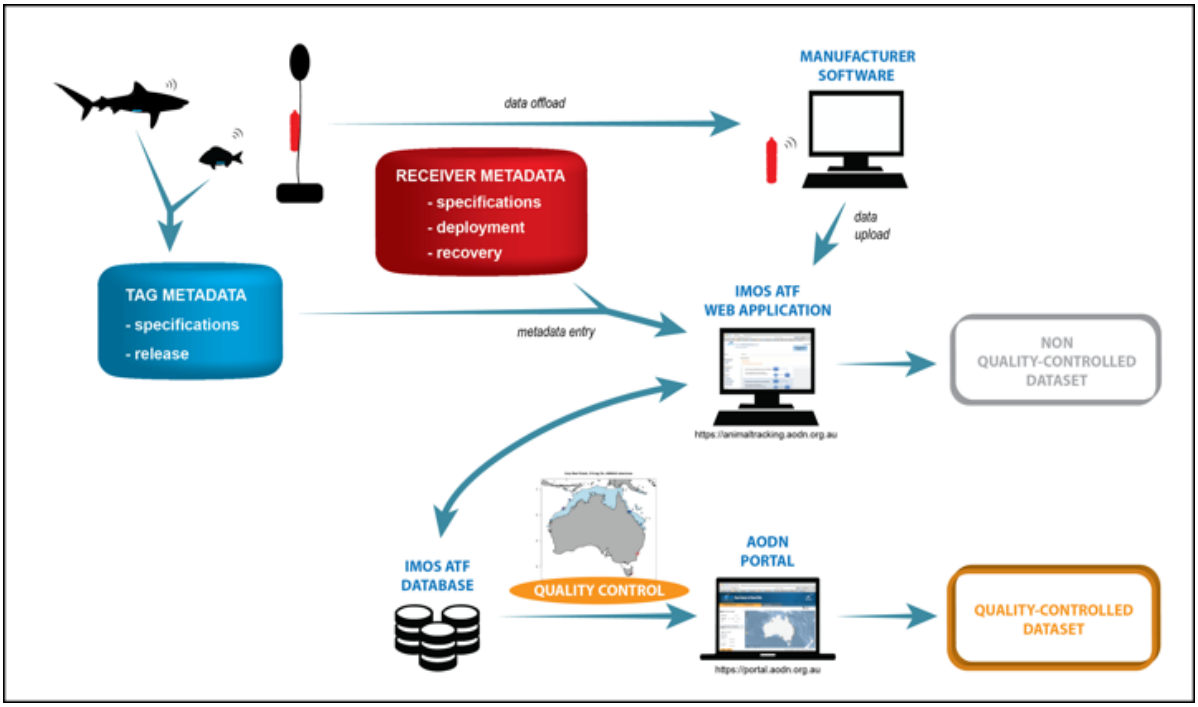


***Figure 6:*** *Data quality control system implemented by the Integrated Marine Observing System (Hoenner et al., in prep.).*

*SWOT analysis*

A SWOT analysis was conducted to identify the strengths, weaknesses, opportunities and threats that face the aquatic acoustic telemetry community in Europe (Table 1). The analysis focused on the

science, data, management, logistic and technology aspects. Some outstanding issues were identified, including the threats posed by the current near-monopoly of one (non-European) acoustic telemetry equipment manufacturer and the related issue of code duplication between these tags and tags of other manufacturers, and by a certain lack of tradition in data-sharing of the marine biology community in general. These issues will deserve special attention by ETN through a proactive problem solving approach in these areas in the near future.

## RESOURCES AND SYNERGIES FOR ETN

*Flagship arrays and species*

The concept of ETN promoting the development of a set of flagship acoustic arrays placed in strategic locations (gates between ocean basins and migratory bottlenecks) and flagship species to be studied was identified as a key resource for ETN to focus on. The group identified the Strait of Gibraltar, the English Channel, the Danish Straits, the Malin Head (Ireland/Scotland), the Strait of Messina and the Bosphorus Strait as the key flagship arrays. These should be able to then foster the establishment of other lines in key areas on estuaries, narrow continental shelves, seamounts and the open ocean. European eel, salmon, bluefin tuna, European sea bass, elasmobranchs (skates and sharks), marine mammals and marine turtles were identified as flagship species. The scientific and economical interest and applicability of acoustic telemetry studies at the proposed sites and regarding mentioned species are developed in sections 3 and 4.

*Centralized database*

A common, centralized database will provide the essential data sharing platform for networking telemetrists in Europe. A database and data repository is currently being built at VLIZ. The database is a detection repository from acoustic arrays from various researchers across Europe. The goal is to increase the scientific use of raw data, benefiting from data sharing, standardized data protocols, and analysis tools. The database was built in coordination with OTN and follows the general data quality and standards of OTN. This is initially a LifeWatch project initiative but it was discussed and agreed upon that it is a necessity for ETN to upscale it to be the backbone of a common data repository and data handling tool. The database should include both the raw data and metadata levels (tags, receivers, animals, deployments, (upcoming) projects, people, technology). Currently, the database was populated by a few research datasets from Belgium, the Netherlands, and the Azores. Its expansion to other countries and datasets was identified as a key action during this workshop so that it can become a fully-fledged database like the ones hosted by OTN or IMOS. Key issues for this development are to get researchers to populate the database (which will require extra manpower) and how funding can be secured. The LifeWatch and AtlantOS projects will initially provide support for this action but other funding sources will be need in the future (e.g. ESFRI). Possibilities of merging with other initiatives should also be considered (e.g. the Movebank, Max Planck Institute).

**Table 1:** SWOT analysis of a developing acoustic tracking network (i.e. people and infrastructure) in Europe.

| | Strengths | Weaknesses | Opportunities | Threats |
|---|---|---|---|---|
| **Science** | - promote data exchange<br>- existing network of people<br>- support growing demand for scier decision making<br>- existing excellence of science<br>- demand for cost-effective science | - lack of long term datasets<br>- mismatch with funding | - applied/fundamental science complement<br>- ensure long-term datasets<br>- long-term stability of a funded network infrastructure/maintenance<br>- cross-border knowledge<br>- blue growth agenda<br>- upscaling of data in space, time and species | - if no network funding  only short term info<br>- loss of expertise<br>- loss of investment |
| **Management** | - Europe can learn from other networks (e.g. IMOS and OTN) in relation to management | - current lack of management body/structure<br>- lack of sustained funding | - be inclusive: marine, estuarine and freshwater<br>- get ETN in an ESFRI and use all available funding opportunities to keep things running | - hard to find long-term European funding,<br>- broad range of expectations of ETN in community<br>- lack of communication leads to less support |
| **Data** | - framework available from OTN and IMOS<br>- data architecture available at VLIZ<br>- expertise in analysis tools/routines | - lack of long term datasets<br>- lack of sharing tradition (both for data and analysis tools) | - use historical data<br>- improve data quality<br>- improve and share analysis tools/routines<br>- knowledge transfer and access to expertise<br>- promote teaching courses/workshops<br>- coordination of open access requirements | - reluctance for cooperation/data sharing<br>- reduced data quality due to complexity, different standards, etc.<br>- high investment needed for data sharing |
| **Logistics** | - established local knowledge and informal networks | - ship time restricted availability<br>- different groups use different brands/technologies to track the same species in same area<br>- brand non- compatibility<br>- difficulties with legal infrastructure establishment | - better organize available ship time → coordination<br>- organize coordinated tagging cruises<br>- coordinated tagging plans among groups/institutes<br>- facilitate legal authorization (e.g. moorings) | - duplication of tag codes<br>- lack of funding for infrastructure servicing |
| **Technology** | - already established and tested technologies | - brand non- compatibility<br>- obsolescence, because of fast-evolving technology | - invest in common issues improves the technology, price competitiveness, and promotes compatibility<br>- applicability: marine, estuarine, freshwater<br>- open access, centralized tag ID management | - lack of compatibility of tags/monopoly of companies<br>- loss of investment<br>- duplicate codes |

*Capacity building*

Capacity building was also identified as a main resource that ETN should foster, for example, by supporting the training of students and technicians that can ensure local capacity to design, deploy, service and data handle receivers and related tagging operations. This support may be provided in the form of training courses or onsite technical support for field staff. Ship time is also a main limiting factor in terms of the deployment of local studies and there is an opportunity for ETN to facilitate this. ETN may be able to provide information on ships of opportunity (e.g. berths/replacements on oceanographic cruises) or identifying/promoting opportunities for regional case-studies via stakeholder involvement. A map of positions with easy-attachment opportunities (e.g. wave and, navigation buoys as mapped in Open-sea Mark (the European glider group)) may be another potential information asset to be offered by ETN.

Acoustic receivers may be another key asset that ETN should consider making available or fostering its access to for members. One possibility may be to have a pool of receivers available in the medium to long term. However, this will require appropriate funding, not only for receivers, but also for related moorings, potential acoustic releases, etc. OTN's policy for flexible equipment loans and IMOS' receiver pool program may serve as good examples to be adopted by ETN.

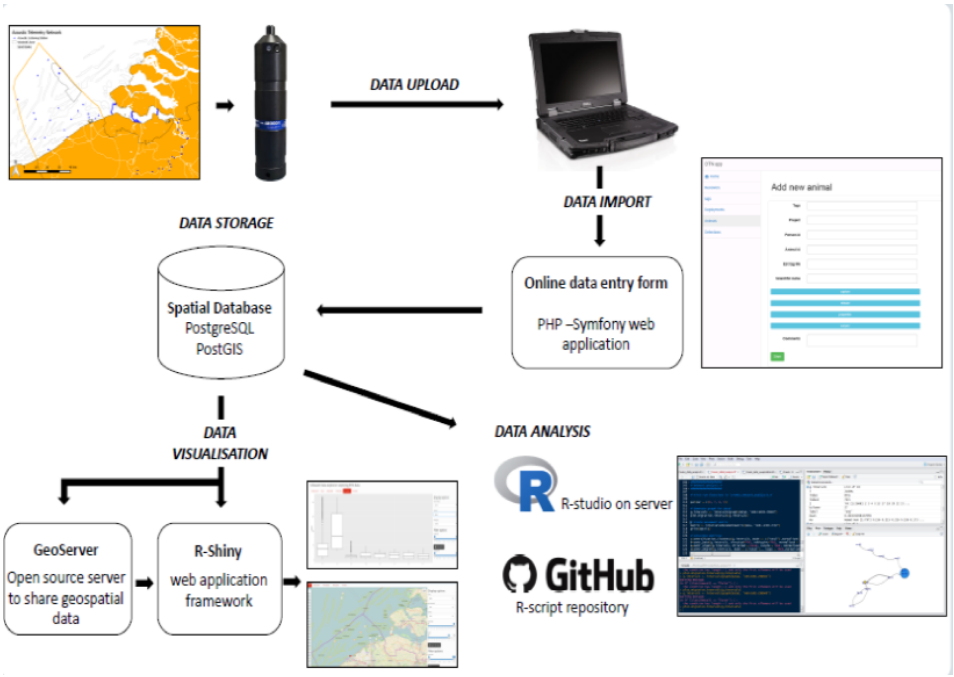


***Figure 7:*** *The Flanders Institute of Marine Science and European Tracking Network's acoustic detection database architecture.*

## GOALS AND ACTIONS OF ETN

The following goals and actions were identified:

1. Define conditions to participate in ETN – what it is and what roles ETN can take – and update a short list of obvious players across Europe (scientists with track record, equipment owners, etc.) for the next ETN expansion phase; target deadline is December 2017; to be coordinated by provisory Steering Committee (contact person: Pedro Afonso).
2. Develop a COST-action before the end of the AtlantOS project to ensure the funding of ETN in the medium term (meetings, training actions - data analysis, deployments, etc.); target deadline is January 2018; to be coordinated by VLIZ (contact person: Francisco Hernández).
3. Develop a series of proposals for flagship species tagging and infrastructure implementation for funding applications; strategically, this can result in different approaches between flagship sites and species, i.e., sites meaning acoustic telemetry actions and species depending on the different technologies); funding can be sought assuming proposals for flagship species or focusing on regional species and use acoustic lines as leverage; multi-species projects should also be prioritized; to be coordinated by the provisory Steering Committee (contact person: Pedro Afonso and contact persons mentioned in flagship sites and species summaries).
4. Survey possible funding opportunities (H2020, Interreg, blue growth, national funding, private funding); target deadline is January 2018; to be coordinated by the provisory Steering Committee (contact persons: Patrick Boylan and Andre Steckenreuter)
5. Develop the VLIZ database until the end of AtlantOS; this development should include i) a 'mystery tag' application, ii) a visualization function of the active receiver network, iii) a database of (upcoming) projects, iv) a list of people involved in telemetry in Europe, v) a manual on the database, vi) compatibility with other technologies and brands when applicable, and vii) an analytical tool package (contact persons: Josep Alos and Nick Humphries); priority is to feed the database with some acoustic datasets from different countries and regions to achieve European wide representativity; target deadlines are the end of the AtlantOS project; to be coordinated by VLIZ (contact person: Jan Reubens).
6. Develop a website and social media platforms to publicize ETN's activities; target deadlines are a private webpage by March 2018 and a public webpage by the end of AtlantOS; to be coordinated by VLIZ (contact person: Francisco Hernández).

## GOVERNANCE OF ETN

The governance structure of ETN is not yet defined. It was decided that a provisory Steering Committee (pSC) is to be composed of one member from IMAR, UDal/OTN and VLIZ each plus the contact persons mentioned in the flagship sites and species summaries. This pSC should further organize and propose a governance structure, possibly in the framework of the COST-action to be developed. The next meeting of ETN is tentatively scheduled for June 2018, possibly with previous meetings of smaller groups for proposal writing.

## FLAGSHIP SITES FOR ACOUSTIC TELEMETRY

### Strait of Gibraltar

*Array description* - The Strait of Gibraltar is situated between the southern tip of the Iberian Peninsula and the Moroccan north shore. At its narrowest point, the strait separates Europe and Africa by a mere 4.3 km at depths of 300 to 900 m. The geographic location and the different characteristics of the Atlantic and Mediterranean water masses renders the Strait of Gibraltar's unique oceanography and marine biodiversity hot-spot characteristics. This makes the Strait of Gibraltar a highly strategic location to deploy a curtain of acoustic receivers for tracking marine species and particularly so to monitor the movements in and out of the Mediterranean of many large migratory species. This could help answering many classical ecological questions (such as the spawning migrations of eel and bluefin tuna) to mitigate marine conservation, pollution and fisheries concerns (such as the survival of endangered species) and monitor species' distribution shifts induced by climate change.

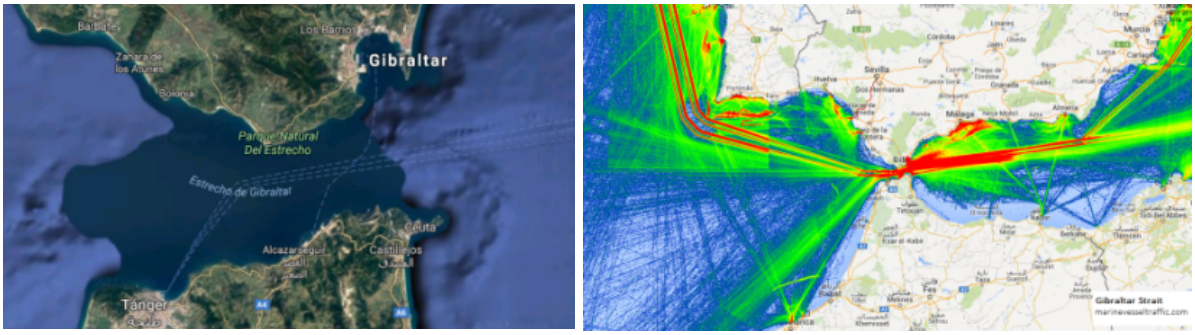


**Figure 8:** Proposed receiver locations in the Strait of Gibraltar (left) and **b)** its shipping traffic

*Key species of interest* - Key species of interest are different species of sharks (including great white, hammerheads, basking, blue and mako sharks), large and smaller-bodied highly migratory fishes (e.g. bluefin and albacore tuna, small tunids, billfishes, dolphinfish, sunfish, European eel, sea bass, meagre), marine mammals (dolphins and whales) and sea turtles (loggerhead and leatherback turtles). All of these species are large-scale, transboundary migrators and have high ecological and economical importance; most are considered threatened by IUCN and other international agencies and conventions.

*Benefits* - The flagship array serves as a pan-European and trans-continental cooperation with potential knowledge transfer and capacity building. It is a biodiversity hotspot with potential to monitor many charismatic, threatened and highly important species (both ecologically and economically), climate change regime shifts and biological invasions. ETN will benefit from a preliminary range and equipment testing done in 2012 by OTN (Canada), IEO and UB (Spain).

*Challenges* - Challenges identified for this particular array are institutional support, oceanographic characteristics and depth range of the strait (300-900 m) and marine traffic.

*Potential primary partners* - CSIC, IEO and University of Cadiz (Spain), University of Azores and University of Algarve (Portugal), Marine Biological Association of the UK (United Kingdom) and Université Internationale de Casablanca (Morocco).

## English Channel

*Array description* - This flagship array consists of an acoustic receiver gate across the narrow (33 km) Dover Strait (Figure 9) to monitor fish transiting between the Atlantic Ocean and North Sea via the English Channel. A double gate, i.e. two parallel curtains of receivers, would enable monitoring directional movement of species. In order to create overlapping detection ranges, approximately 45 receivers would be required for each curtain. Seabed depth across the strait ranges from 20 m to 68 m (mean depth 30 m), making acoustic release moorings (VR2AR equivalents) the most practical deployment option.

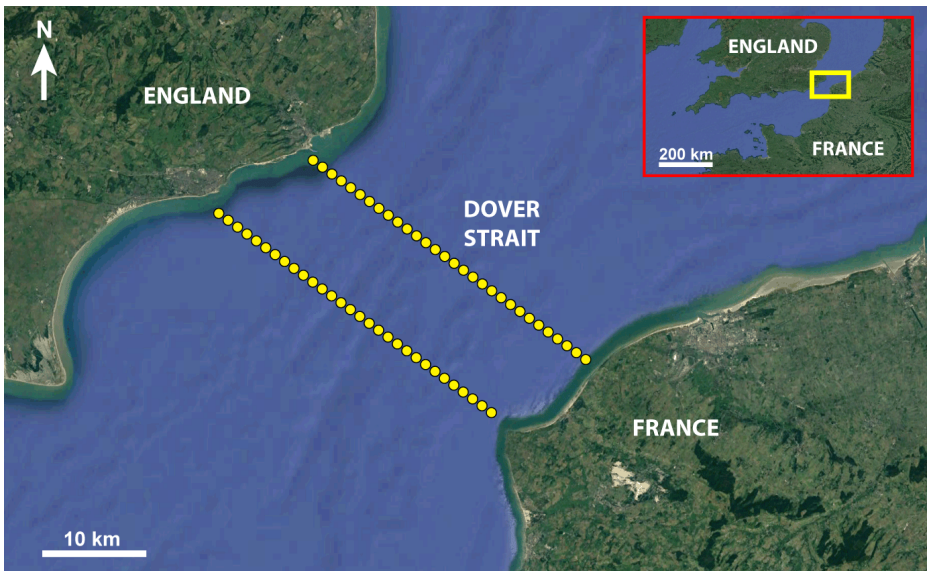


**Figure 9:** Proposed receiver locations (yellow points) across the Dover Strait; inset shows location of Dover Strait (yellow box) within the English Channel.

*Key species of interest* - A wide variety of commercially important, mobile species transit through the Dover Strait, several of which are threatened or endangered. These species include eel, sea bass, cod, rays, skates, sharks (tope, porbeagle), bluefin tuna, twaite shad, salmon, spiny dogfish, sturgeon and marine mammals.

*Benefits* - The English Channel, and especially the Dover Strait, represents a geographic bottleneck through which mobile species must pass when transiting between the Atlantic Ocean and North Sea. Establishing a listening array across the Dover Strait would enable key questions about connectivity (e.g. frequency, timing) between the Atlantic Ocean and the North Sea to be addressed for a wide variety of important fishes and other marine animals. Due to the multitude of important species that cross the Dover Strait, its shallow depth, relatively narrow width and possibility for transnational cooperation make it an ideal location for an ETN flagship receiver array.

## Danish Straits

*Array description* - The Danish Straits are situated between Denmark and Sweden. They are separating the largest inland sea in the world, i.e. the Baltic Sea and the Atlantic Ocean. The two basins have different characteristics, leading to interesting differences in terms of species' movement and populations as well as being a biodiversity hotspot. Species' migratory activities between the basins are virtually unknown, although the scale of migration is known to be large as a number of commercially important and protected species are moving between those ocean basins. The narrow confinement and the fact that trawling is prohibited makes the place ideal for an acoustic array deployment. The three straits have a total length across of approximately 13 km (Lillebelt 1 km, Storebelt 8 km and Øresund 4 km) with a maximum depth of 50 m (Figure 10). The main objective will be to increase the knowledge on the marine ecology of important species either of particular interest to conservation, highly valued and/or representing a significant economic foundation.

*Key species of interest* - Species such as European eel, bluefin tuna, sturgeon, Atlantic salmon, sea trout, herring, cod, turbot, mackerel and marine mammals exhibit long-range transboundary migration patterns along geographical and ecological axes. These life-history features make them particularly vulnerable to over-exploitation because the transitions of populations between different geographic locations increase their exposure to fishing activity, degraded or polluted habitats and environmental hazards (e.g. hydroelectric dams). With the proposed arrays, it is possible to collect information on habitat utilisation, distribution and migrations, thereby providing new knowledge and information as support for developing conservation measures and restoration options.

*Benefits* - The Danish Straits are characterized by narrow straits, low depths and multiple important species. The region reflects high economic growth with large public interest. Thus, this flagship array may foster knowledge transfer and capacity building amongst European countries through the development of ETN with far reaching future opportunities.

*Potential primary partners* - DTU (Denmark), SLU (Sweden), Geomar (Germany), Von-Thünen Institute (Germany), NMFRI (Poland), NRC (Lithuania), BIOR (Latvia).

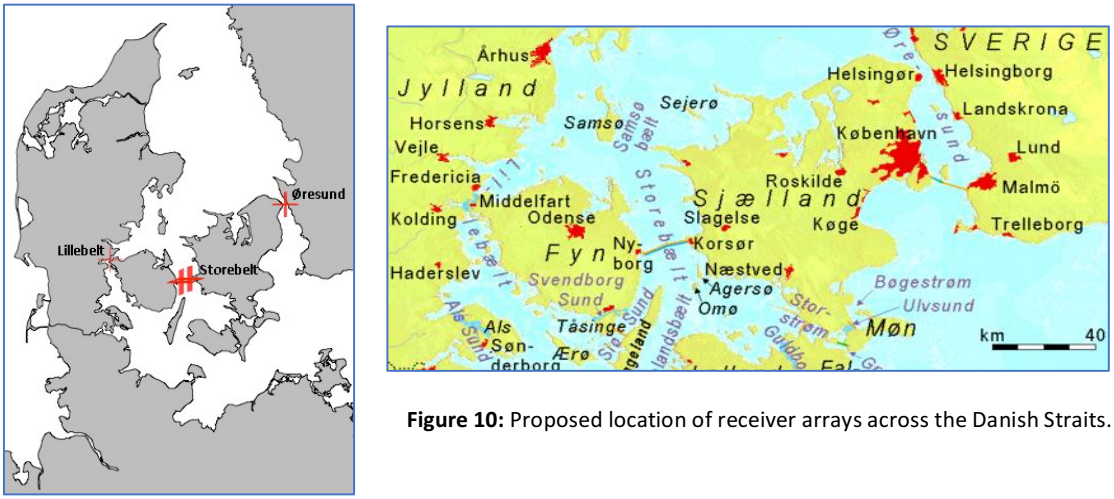


**Figure 10:** Proposed location of receiver arrays across the Danish Straits.

## Malin Head (Scotland/Ireland)

*Array description* - There are five elements to this array within the Seamonitor project concept (see Figure 11). 1) The main array – the focus of ETN - links the north coast of Ireland at Malin Head to Islay in Scotland, approximately 70 km, it is estimated that 90 units will be required to cover this distance. This array would have the potential to capture movement in and out of the Irish Sea by species using the North Channel and using the Islay front. 2) A secondary array between the Isle of Lewis and Scottish mainland would close off a significant northwards migration corridor, this would require 50 units. 3) Inshore arrays where partners will mainly use existing receiver units. However, it is estimated that an additional 30 units will be required to help fill gaps. 4) To monitor movement along the continental shelf the use of an Autonomous Underwater Vehicle (AUV) is proposed.

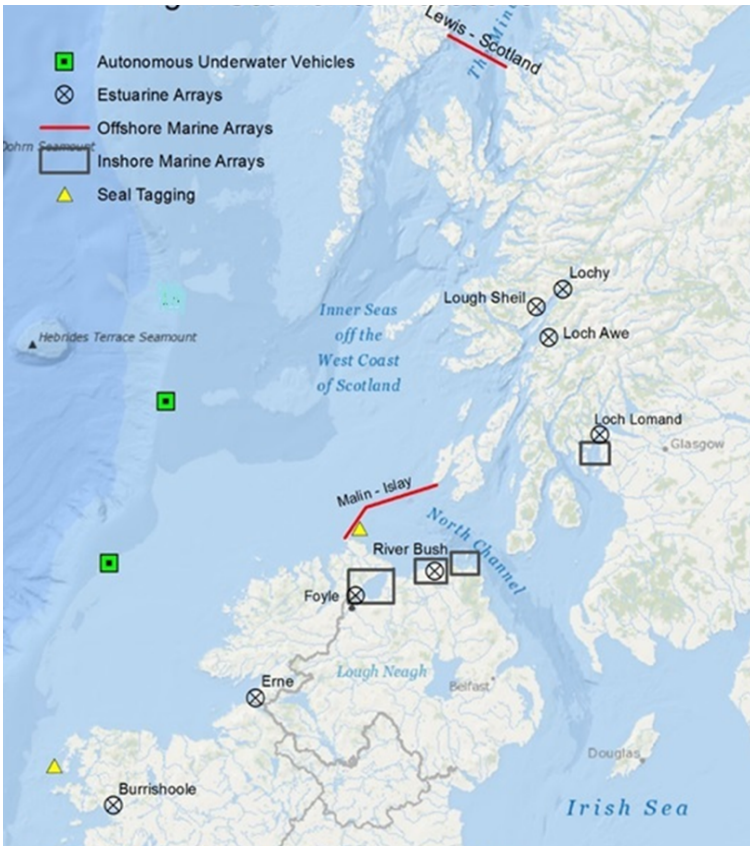


**Figure 11:** Proposed location of receiver arrays in the Irish Sea.

*Key species of interest* - Atlantic salmon, sea trout, basking shark, bluefin tuna, sea bass, porbeagle shark, blue shark, tope shark, sunfish, seals, dolphins and whales.

*Benefits* - The ETN Malin Head line and related SeaMonitor infrastructure will support the "blue economy" by specifically addressing important gaps in our knowledge of marine systems, for example on the sustainability of commercial marine developments highlighted by Scottish Government's "National Marine Plan", N Irelands Marine Act (2013) and the Irish Government's

"Harnessing Our Ocean Wealth strategy". It would also develop research projects to test, evaluate and capitalise upon the monitoring network. Information generated will be combined with other available datasets and will be used to build spatially and temporally explicit models to enable predictions supporting the management of highly mobile, high conservation value species. One of the lasting legacies would be the marine monitoring array which will fill a need for information on marine habitat quality and mobile marine species for many years following completion. There will also be a legacy from predictive modelling, the research studies and the monitoring network and species/habitats plans outputs. All of these outputs would, in the medium to long term, result in improved management of important marine species and their habitats.

*Potential primary partners* - Loughs Agency, the Marine Institute, University of Glasgow, Queens University Belfast, Marine Scotland Science, Agriculture, Food and Biosciences Institute for Northern Ireland, University College Cork, Galway Mayo Institute of Technology.

## Bosphorus Strait

*Array description* - We propose two acoustic receiver arrays to record tagged fish moving among the Black Sea, Marmara Sea and Aegean/Mediterranean Sea; one across the Bosphorus Strait at Istanbul and one across the Dardanelles Strait (Figure 12). Both straits are narrow, natural straits in the passage between the Black Sea and the Mediterranean Sea. The Bosphorus is 0.7-3.4 km wide with an average depth of 36 m (max. 110 m). The Dardanelles is 1.2-6.0 km wide with an average depth of 55 m (max. 103 m). Each array may consist of eight VR2AR receiver equivalents deployed in two parallel lines with four receivers in each line. This design ensures recording the presence and directional movement of marine species at these arrays.


**Figure 12:** Proposed location of receiver arrays across the Bosphorus and Dardanelles Straits.

*Key species of interest* - marine mammals; bluefish, sturgeons, bluefin tuna, Atlantic bonito, mackerels, swordfish, leerfish, and other pelagic migratory fishes important for fisheries.

*Benefits* - The Bosphorus Strait is characterized by narrow straits, making it possible to monitor all tagged fish and marine mammals passing, when they move between separate seas. Seasonally migrating fishes between the Mediterranean Sea, Marmara Sea and Black Sea are of great importance for commercial fisheries. The area resembles large aquatic biodiversity.

## Strait of Messina

*Array description* - The Strait of Messina separates Sicily from Italy by a narrow, funnel shaped, passage that stretches between the eastern tip of Sicily and the western tip of Calabria (Fig. 1, left). At its narrowest point the Strait is about 3.1 km wide. The Strait minimum depth is about 80 m and the maximum 250 m. The Strait connects the Tyrrhenian Sea (northern part) to the Ionian Sea (southern part) and given its peculiar position, it contributes in forming a very complex and peculiar current system. The different times of high and low tide of the two Seas drives an alternate flow of waters from the Ionian to the Tyrrhenian Sea and vice versa that changes every 6 h. Such a peculiar hydrological makes the area very productive due to upwelling phenomena, rich in biodiversity and a key point for migratory species. Indeed, the above-mentioned structure of the Straits and its position make the area an obliged passage point for several pelagic species that here swim at very shallow water and, for this reason have historically been caught and exploited by a distinctive fishing technique that uses the so called felucca (Fig. 1, right), a unique fishing boat specifically developed to fish the large pelagic fish species that cross the Strait swimming almost close to the sea surface.

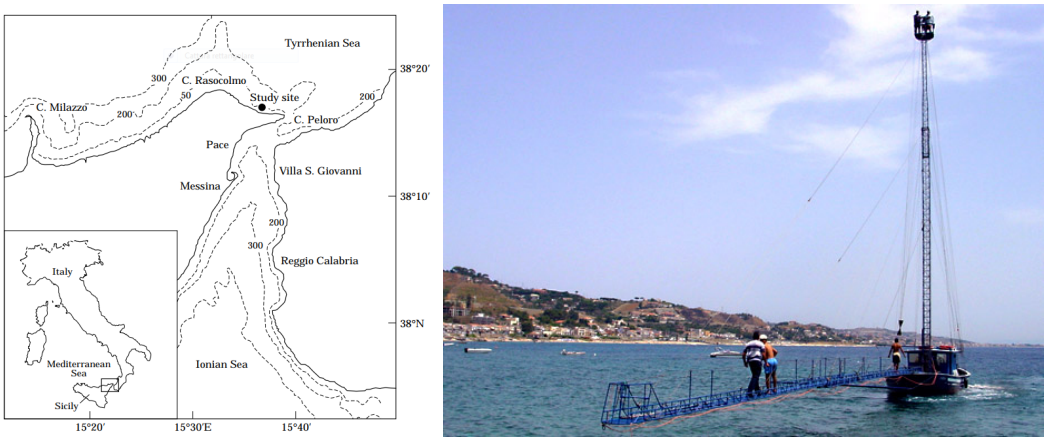


**Figure 13**. Left, map showing the Strait of Messina, with depth profile in meters. Right a typical "felucca" fishing boat.

*Key species of interest* - large pelagic fishes such as bluefin tuna, albacore (*T. alalunga)*, Atlantic bonito (*S. sarda)*, Mediterranean spearfish (*T. belone)*, Moon fish (*M. mola)* and swordfish (*X. gladius)*; Sharks, notably white (*C. carcharias*) and bluntnose sixgill (*H. griseus*) sharks; Cetaceans with several species of dolphins and Fin (*B physalus*) and Sperm *(P. microcephalus*) whales; loggerhead sea turtle (*C. caretta)*. Most of these species migrate, are ecologically or/and economically highly relevant important and are catalogued as Threatened Species by the IUCN.
*Benefits* - Pan-European and Trans-Continental cooperative network with lot of knowledge transfer and capacity building potential, hot-spot for biodiversity, many Threatened and highly important species (both ecologically and economically) with high public interest, potential to monitor climatic change regime shifts and biological invasions. Deepen knowledge for an ecologically very important area of the Mediterranean Sea that unfortunately has been poorly investigated so far.
*Challenges* - Institutional support, strong currents, maritime traffic, fishery, military constrains.
*Potential partners* – Univ. Messina (Italy); Tethys Institute Milan (Italy).

## Summary of flagship arrays and associated costs

The five flagship arrays proposed as research infrastructure under ETN are considered an essential part to foster connectivity between regional acoustic telemetry studies within Europe. The detections collated at these arrays will be made publicly available in the ETN database to serve as a major incentive for the telemetry research community to join the network to access potential detections of their own tagged species.

ETN proposes to deploy a total of 255 acoustic receivers (a combination of VR4UM and VR2AR equivalents) across these arrays for five years. The total estimated cost for receivers, their deployment and maintenance, moorings and shiptime will be 6.6 million Euros (Table 2).

**Table 2:** Summary of flagship arrays including the number of acoustic receivers and associated deployment and maintenance costs for a five year plan; for contact details see Appendix A.

| **Array** | **Acoustic Receivers [N]** | **Estimated Costs [€]** | **Contact** |
|---|---|---|---|
| Strait of Gibraltar | 40 | 2.000.000 | J. Alós, P. Afonso |
| English Channel | 45/90 | 2.000.000 | C. Meyer, J. Reubens |
| Danish Straits | 19 | 500.000 | K. Aarestrup |
| Malin Head | 90 | 2.000.000 | P. Boylan |
| Bosphorus Strait | 16 | 100.000 | A. Steckenreuter |
| Messina Strait | 14 | 800.000 | F. Badalamenti |
| **Total** | **269** | **7.400.000** | |

# FLAGSHIP SPECIES FOR ACOUSTIC TELEMETRY

## European eel

*Species description and status* - European eel (*Anguilla anguilla* L.) is a high-value, mobile species widely distributed, with its southern limit in Mauritania (30°N) and northern limit in the Barents Sea (72°N) and spanning all of the Mediterranean basin (ICES 2014; Figure 13). The spawning area is in the Sargasso Sea (McCleave et al. 1987). Eels are found in all types of water bodies in fresh, transitional and marine waters. The European eel is a single genetic stock across its range (Palm et al. 2009). Fisheries exploit recruits (glass eel), the growth stage (yellow eel), and the emigrating pre-spawning stage (silver eels). Additionally, eels are traded both locally and internationally.

Eel recruitment declined dramatically in the early 1980s, reaching extreme low recruitment numbers in 2011, i.e. <1% in the North Sea and 5% elsewhere, in relation to mean levels during the 1960s and 1970s (ICES 2014). To date, the reasons are uncertain but likely due to migratory barriers, habitat loss, over-exploitation, pollution, non-native parasites, diseases, increased mortality in artificial barriers such as turbines or pumps, and changes in oceanic factors linked to climate change.

The International Council for Exploration of the Sea (ICES) advises that "the European eel is outside safe biological limits and that all anthropogenic impacts decreasing production and escapement of silver eels should be reduced to (or kept close to) zero as possible" (ICES 2016a). The International Union for the Conservation of Nature (IUCN) has assessed the European eel as critically endangered on its Red List (Jacoby and Gollock 2014). Most recently, European eel was listed on Appendix II of the Convention on Migratory Species (CMS) whereby parties call for cooperative conservation.

The EC Regulation (European Council 2017) for the recovery of the eel required EU member states to establish eel management plans covering all eel-producing waters in freshwater and marine environments. Member states should monitor the eel stock, evaluate current silver eel escapement and evaluate management actions aimed at reducing eel mortality and increasing escapement. The European eel was listed in Appendix II of the Convention on International Trade in Endangered Species (CITES) in 2007. All trade into and out of the EU is currently banned.

*Knowledge gaps* - Migration routes, distribution and production in marine and transitional waters are poorly understood, as are the effects of natural and human-induced environmental change. Tagging studies show high predation rates by fish and marine mammals in coastal waters (Righton et al. 2016) but data are not sufficient to inform on variations at spatial or temporal scales to quantify human impacts from marine development or chronic impacts from the freshwater environment, or to adjust stock assessments. Knowledge on the relative importance of different human impacts is vital for prioritizing management measures. More information on the coastal migration and large-scale ocean distribution and migration routes of European eel is required.

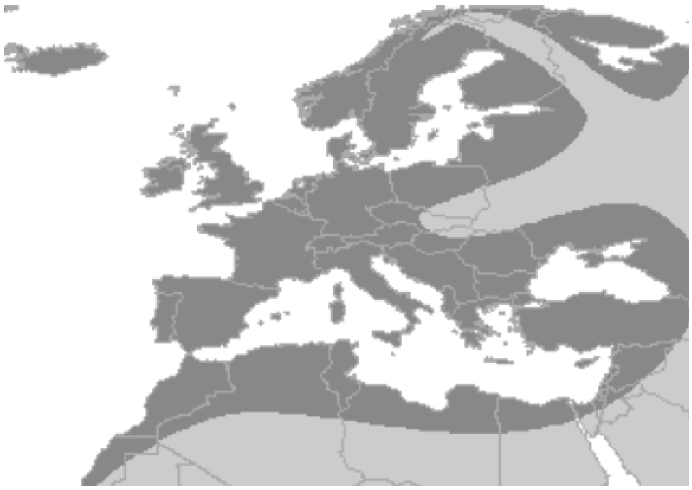

**Figure 13:** European eel distribution during continental growth phases (Moriarty and Dekker 1997); note that this map does not show the oceanic migration routes to and from the spawning area in the Sargasso Sea.

*Regions of interest* - Given the widely dispersed nature of this panmictic species, the region of interest spans the extend of the ETN and much of the North Atlantic including freshwater systems, coastal regions as well as the open ocean.

*Telemetry tools* - Size constraints make acoustic telemetry, data loggers and pop-up satellite archival tags (PSAT) the best available tools for characterizing movement patterns of eel in the marine environment. Telemetry methods are also used to research eel migrations and habitat use in freshwater, transitional and coastal waters.

*Benefits* - Using the ETN to further characterize eel movements and behaviour throughout Europe and beyond would greatly enhance our ability to better manage this culturally and economically important species. The extensive migrations of this species making it an absolute necessity to join research efforts, share research infrastructure and foster international collaborations. In addition, ETN may provide necessary insights in environmental preferences and possible barriers encountered during their journey.

*Contact* - A. Walker, J. Reubens, K. Aarestrup

## Atlantic salmon

*Species description and status* - Atlantic salmon (*Salmo salar* L.) is native to the temperate and subarctic regions of the North Atlantic Ocean. In many areas, it is one of the most economically and culturally valuable fish species - being exploited in commercial, subsistence and recreational fisheries. Atlantic salmon have a diverse array of life-histories but most forms are anadromous with a juvenile phase in fresh water, followed by a long migration to the ocean for feeding and growth, and a return migration to freshwater environments to spawn. Salmon reproduce in rivers on both sides of the North Atlantic Ocean and their oceanic feeding areas cover large areas (Figure 14). Long-distance migrations between freshwater and ocean habitats expose Atlantic salmon to multiple threats. Additionally, a number of human factors have contributed to the species general decline during the

last decades. Atlantic salmon have been lost from many rivers and during the past decades, substantial reductions in population sizes have been observed for numerous populations.

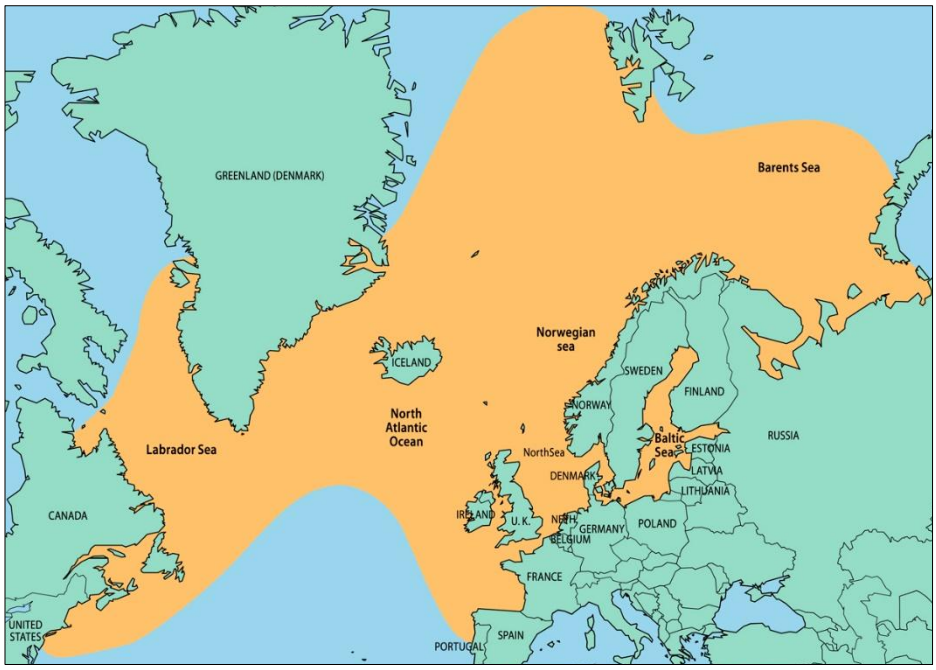


**Figure 14:** Assumed geographical marine distribution of the Atlantic salmon in the North Atlantic Ocean and the associated countries that hold natural spawning populations of Atlantic salmon (Thorstad et al. 2011).

*Knowledge gaps* - Human impacts in rivers and coastal areas affect many Atlantic salmon populations. In large parts of the distribution range, aquaculture activities in coastal areas affect Atlantic salmon populations negatively, and to some extent so do other coastal, human activities. Many local and regional impact factors are well studied, whereas some are less well known. On a broad scale, changes in marine ecosystems are considered prominent contributors to the recent declines. For European populations, it is perceived that declines are associated with shifts in marine food web structure that reduce salmon growth at sea. However, this is not well understood and it is difficult to investigate due to great uncertainty over how Atlantic salmon use the ocean and how they distribute themselves at sea as a function of inter-year differences in environmental conditions, the animals age and experience, and the time of the year. Knowledge on the relative importance of the different human impacts is vital for prioritizing management measures. It is necessary to disentangle impacts occurring in rivers, coastal areas and the ocean - and ecosystem driven population declines - from these impacts. Much more information on the coastal migration and large-scale ocean distribution and migration routes of Atlantic salmon is required. This has been recognized as a priority by the North Atlantic Salmon Conservation Organization (NASCO http://www.nasco.int/sas/pdf/archive/other_reports/SALSEA_TrackBrochure.pdf).

*Regions of interest* - Due to the migratory nature of this species, regions of interest are the entire North Atlantic Ocean including the Baltic Sea.

*Telemetry Tools* - Potential telemetry tools for the monitoring of this species include acoustic transmitters and receivers in coastal areas and offshore sites where marine receiver lines can be deployed, PIT-tags for recording at sea survival, pop-up satellite archival tags (PSAT) and data storage tags (DST).

*Benefits* - Using the ETN to further characterize Atlantic salmon movements and behaviour throughout coastal and ocean areas in the North Atlantic would greatly enhance our ability to manage this culturally and economically important species. To study a widely migrating species that crosses many national jurisdictions like the Atlantic salmon with many hundreds of genetic stocks, joint research efforts, sharing of infrastructure and international collaboration are needed.

*Contact* - K. Aarestrup, P. Boylan, E. Thorstad

## Atlantic Bluefin Tuna

*Species description and status* - Atlantic Bluefin Tuna (*Thunnus thynnus* L.; ABFT) is an iconic, highly migratory species that distributes widely across the Atlantic Ocean and the Mediterranean, North and Black Seas (Figure 15). In the North Atlantic, the International Commission for the Conservation of Atlantic Tunas (ICCAT) considers two separate stocks: an eastern Atlantic, with the Mediterranean as the recognized main spawning area, and a smaller western Atlantic stock with fish spawning mostly in the Gulf of Mexico (e.g. Fromentin & Powers 2005). Both stocks are thought to utilize common winter feeding habitats in northern latitudes (e.g. Druon et al 2016). It is highly valued for the Japanese sashimi markets, with dramatic declines and severe overfishing over the past three generation lengths (40 years) in both the Eastern and Western Atlantic (ICCAT 2009; Collete et al. 2011). Ocean-wide migrations of adult ABFT tagged on common grounds and different biological characteristics of populations suggest evidence of a meta-population requiring more spatially explicit management than the current simple two-stock structure (e.g. Walli et al. 2008; Galuardi et al. 2010). ABFT is classified as endangered by IUCN (Collete et al. 2011).

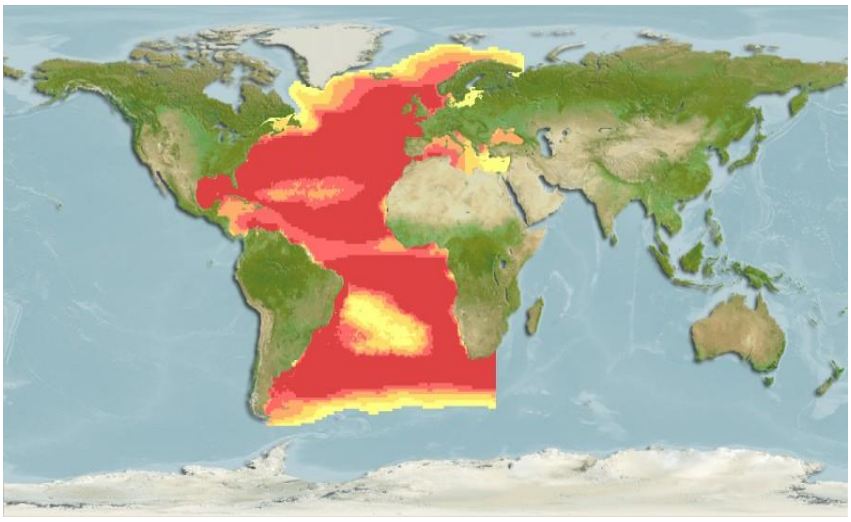

**Figure 15:** Distribution of Atlantic bluefin tuna as indicated by habitat suitability (probability of occurrence – FishBase).

*Knowledge gaps* - ABFT is by far the best studied tuna with multiple studies and programs (e.g. ICCAT) on its biology and movements deployed in the last 15 years. However, essential uncertainties still subsist mostly regarding the individual behavioral plasticity and its effect on population resilience including fidelity to feeding and spawning grounds. Another area of stringent need for data is the long-term study of climate change impacts on the migrations, habitat use and resilience of ABFT. A solid science-based management of the eastern Atlantic stock is essential to the future of this species as it represents the majority of this species global population.

*Regions of interest* - Movement of ABFT between the Atlantic Ocean and the Mediterranean Sea are still not well understood at the population level and would benefit from further tracking studies.

*Telemetry tools* - ABFT are large and robust animals and therefore suitable for acoustic tags, DST and satellite transmitters. Given the large size of the individuals, long-life (5-10 years) tags could be deployed which could potentially provide important new information on long-term movements.

*Benefits* - The acoustic array deployments proposed as part of the ETN umbrella will be strategically placed to monitor the movements of ABFT and answer outstanding questions regarding migrations and the structure and connectivity of wild ABFT populations. In particular, it will allow the long-term monitoring of movements between the Atlantic Ocean and adjacent seas as well as habitat use in specific oceanic and coastal areas where other arrays exist or may become available.

*Contact* - P. Afonso, K. Aarestrup

## European Sea bass

*Species description and status* - European sea bass (*Dicentrarchus labrax*, L.) is a high-value, mobile species with a pan-European distribution in coastal waters (Figure 16). Sea bass are heavily targeted by commercial fisheries and highly sought after by recreational fishermen. Since 2015, the European Commission has taken several measures to address the declining state of the Atlantic stock and protect livelihoods in the sector: 1) Periodic area closures for commercial fishing activities, 2) Reduced catch quotas, 3) Increase of minimum landing size from 36 to 42 cm, and 4) A 1-fish bag limit for recreational fishermen. Nonetheless, sea bass stocks have declined severely in recent years, following increased fishing pressure and low recruitment and the International Council for Exploration of the Sea (ICES) recommends a moratorium on all bass catches in 2017 (ICES 2016b).

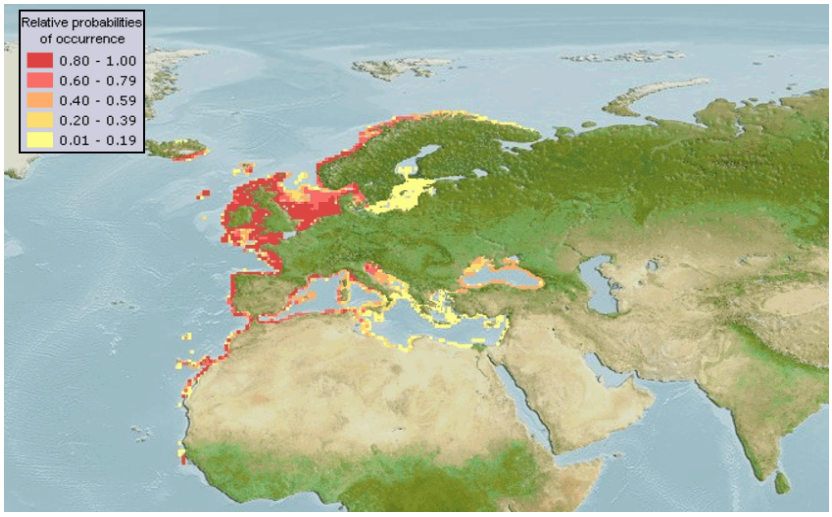


**Figure 16:** European sea bass distribution; colours indicate degree of habitat suitability (FishBase).

*Knowledge gaps* - European sea bass movement patterns are not fully understood and may be changing in response to rising sea temperatures. Atlantic and Mediterranean sea bass populations are generally segregated but genetic evidence and suggest that large scale movements occur across geographic basins (Souche et al. 2015). Tagging studies from Northern Europe show that sea bass migrate seasonally (Pawson et al. 2007, Quayle et al. 2009, De Pontual et al. 2013), but equivalent data are lacking for Southern Europe and the Mediterranean Sea.

*Regions of interest* - Two broad geographic regions of interest exist for sea bass: 1) Northeast Atlantic (Celtic Sea, Irish Sea, Southern North Sea, English Channel and Bay of Biscay) and 2) the Mediterranean Sea. Northeast Atlantic stocks are in stark decline despite existing management measures and additional data on sea bass movements are needed to improve conservation strategies. In the Mediterranean Sea, a general lack of data on sea bass stock structure and migration patterns is hampering fact-based management and conservation. Migration and connectivity of sea bass between regions via the Strait of Gibraltar also needs to be better characterized.

*Telemetry tools* - Size constraints make acoustic telemetry and data loggers the best available tools for characterizing sea bass movement patterns. Fish tracking should be carried out in conjunction with sampling of natural markers to evaluate diet, fitness and population structure to provide supplementary information on ecology, life history and population dynamics of sea bass.

*Benefits* - Using the ETN to further characterize sea bass movements and behaviour throughout Europe would greatly enhance our ability to better manage this culturally and economically important species and assess whether the current management is sufficient to restore healthy population levels. In addition, ETN would give necessary insights in environmental preferences and possible barriers encountered during their journey.

*Contact* - C. Meyer, J. Reubens, B. Koeck

## Elasmobranchs

### I: Skates

*Species description and status* - Skates (Rajidae) are coastal demersal elasmobranchs that occupy a wide range of substrates from sand and mud to gravel and are distributed around the coasts of the North Atlantic, North Sea and Mediterranean Sea (Ellis et al. 2005a). Skates are important benthic predators of significant commercial value but are vulnerable to over-exploitation through their *k*-selected life histories. Skates are taken in both targeted and mixed fisheries and commonly as bycatch but have only recently been reported to species level in landings data. Most species are considered near threatened by the IUCN and some (e.g. *Dipturis batis* complex) are extirpated in many areas. Few fisheries controls exist for either minimum landings sizes or TAC, and when existent they are regional and inconsistent (GOV UK 2015, DGRM 2017, MAP 2017).

*Knowledge gaps* - Although large scale movements and migrations of *Raja clavata* have been studied in the Southern North Sea (Hunter et al. 2005a, Hunter et al. 2005b, Hunter et al. 2006), little is known about the behavior of other Rajidae species. This gap, together with the historic poor detail in landings data, seriously hampers attempts at stock assessments and the design of effective fisheries controls (Ellis et al. 2005b). Knowledge on coastal movements, large migrations (e.g. English Channel or Celtic Sea) and in general the connectivity among wild populations is almost entirely lacking. Consequently, there is insufficient information about stock structure or fishing impacts.

*Regions of interest* -Movement between the Atlantic Ocean and adjacent seas (e.g. the Mediterranean, North and Baltic seas) and across continental platform areas including transborder movement (e.g. English Channel, North Sea, Celtic Sea) is poorly understood and would benefit from tracking studies. Therefore, the principal regions of interest for such studies would be the English Channel, the Strait of Gibraltar and the Danish Straits. However, there are multiple coastal locations of interest in European continental shelves that would further benefit from such flagship receiver curtains (e.g. around the UK and Ireland, along the Iberian Peninsula and along the northern Mediterranean Sea).

*Telemetry tools* - Skates are comparatively large and robust animals and therefore suitable for both acoustic and DST/satellite tags. With mature individuals, long-life (5-10 year) tags could be deployed which could potentially provide important new information on their unknown long-term movements.

*Benefits* - The acoustic deployments proposed as part of the ETN project will be well placed to monitor the movements of skates and answer outstanding questions regarding movement, migrations and the structure and connectivity of wild populations.

### II: Sharks

*Species description and status*

Sharks (Selachimorpha) are widely distributed throughout the world's oceans (coastal to oceanic areas and pelagic to deep-sea). Over 500 species, many of which inhabit European waters, present a wide range of sizes (from the 17 cm long dwarf shark to the 12 m long whale shark) and trophic

position (from plankton feeder basking and whale sharks to top predators such as great white sharks). Most shark species are *k*-selected reproducers, characterized by a late sexual maturity, low fecundity and long life cycle (Dulvy and Forrest 2010). These particular life-history traits result in low resilience to exploitation and high vulnerability to human pressure (Dulvy and Forrest 2010, Dulvy et al. 2014). In fact, severe reductions on shark populations have been described all over the world (e.g. Baum et al. 2003, Ferreti et al. 2008, Ferreti et al. 2010, Dulvy et al. 2014) with consequences to the whole ecosystem.

*Knowledge gaps* - Despite recent increases in knowledge of the spatial ecology of some shark species (e.g. Sims et al. 2006, Pade et al. 2009, Vandeperre et al. 2014) there is still a generalized lack of information regarding migrations, long-term habitat use and the location of essential fish habitats.

*Regions of interest* - Sharks occupy and can move between different oceanic environments, from coastal to oceanic areas, from pelagic to demersal waters, from The Atlantic Ocean to the Mediterranean and North Sea. Thus, areas of particular interest include the Strait of Gibraltar, the English Channel, Malin Head, the Strait of Messina and the Danish Straits, as well as continental shelves and slopes and key seamounts.

*Telemetry tools* - Sharks are relatively large and robust animals and therefore most species are suitable for acoustic, DST and satellite tags. With large species, long-life (5-10 year) acoustic tags could be deployed which could potentially provide important new information on long-term movements of which almost nothing is currently known.

*Benefits* - The acoustic array proposed as part of the ETN project will provide monitoring capabilities that will allow us to answer outstanding questions regarding movement, migration routes, essential habitat and the structure and connectivity of wild, endangered shark populations.

*Contact* - N. Humphries, P. Afonso

## REFERENCES

Baum, J.K., Myers, R.A., Kehler, D., Worm, B., Harley, S.J., Doherty, P.A., 2003. Collapse and conservation of shark populations in the Northwest Atlantic. *Science* 299: 389-392.

CCMAR, 2017. https://web.ccmar.pt/en/project/mako-wide-estudo-de-larga-escala-inter-hemisferico-e-interdisciplinar-para-conservacao-do; accessed 25/07/2017.

CIBIO, 2017a. https://cibio.up.pt/people/details/ncqueiro/projects/3; accessed 25/07/2017.

CIBIO, 2017b. https://cibio.up.pt/people/details/ncqueiro/projects/7; accessed 25/07/2017.

Collette, B. et al., 2011. *Thunnus thynnus*. The IUCN Red List of Threatened Species 2011: e.T21860A9331546; http://dx.doi.org/10.2305/IUCN.UK.2011-2.RLTS.T21860A9331546.en.

DEFRA, 2017. http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=2&ProjectID=18963; accessed 25/07/2017.

De Pontual, H., Ngo Tran, T., Lalire, M., Lazure, P., Garren, F., Drogou, M., Woillez, M., Fablet, R., 2013. Understanding the spatial dynamics of European sea bass: new insights on seasonal migration patterns from electronic tagging off the coast of west Brittany. ICES CM 2013/O:05.

DGRM, 2017. https://www.dgrm.mm.gov.pt/xportal/xmain?xpid=dgrm&xpgid=genericPageV2&conteudoDetalhe_v2=6467463; accessed 25/07/2017.

Druon, J., et al., 2016. Habitat suitability of the Atlantic bluefin tuna by size class: An ecological niche approach. *Progress in Oceanography* 142: 30-46.

Dulvy, N.K., Forrest, R.E., 2010. Life histories, population dynamics and extinction risks in chondrichthyans. In: Sharks and Their Relatives II: Biodiversity, Adaptive Physiology, and Conservation (Carrier, J.C., Musick, J.A., Heithaus, M.R.); pp. 639-679.

Dulvy, N.K., Fowler, S.L., Musick, J.A., Cavanagh, R.D., Kyne, P.M., Harrison, L.R., Carlson, J,K,, Davidson, L.N.K., Fordham, S.V., Francis, M.P., Pollock, C.M., Simpfendorfer, C.A., Burgess, G.H., Carpenter, K.E., Compagno, L.J.V., Ebert, D.A., Gibson, C., Heupel, M.R., Livingstone, S.R., Sanciangco, J.C., Stevens, J.D., Valenti, S., White, W.T., 2014. Extinction risk and conservation of the world's sharks and rays. eLife 3:e00590

Ellis, J., Dulvy, N.K., Jennings, S., Parker-Humphreys, M., Rogers, S.I., 2005a. Assessing the status of demersal elasmobranchs in UK waters: a review. *Journal of the Marine Biological Association of the United Kingdom* 85: 1025-1047.

Ellis, J., Cruz-Martinez, A., Rackham, B.D., Rogers, S.I., 2005b. The distribution of chondrichthyan fishes around the British Isles and implications for conservation. *Journal of Northwest Atlantic fishery science* 35: 195-213.

European Council, 2007. Council Regulation (EC) No 1100/2007 of 18 September 2007 establishing measures for the recovery of the stock of European eel. Official Journal of the European Union L248/17: 1-7.

Ferretit, F., Myers, R.A., Serena, F., Lotze, H.K., 2008. Loss of large predatory sharks from the Mediterranean Sea. *Conservation Biology* 22: 952-9.

Ferretti, F., Worm, B., Britten, G.L., Heithaus, M.R., Lotze, H.K., 2010. Patterns and ecosystem consequences of shark declines in the ocean. *Ecology Letters* 13: 1055-1071.

Fromentin, J.M., Powers, J.E., 2005. Atlantic bluefin tuna: population dynamics, ecology, fisheries and management. *Fish and Fisheries*, 6(4): 281-306.

Galuardi, B., Royer, F., Golet, W., Logan, J.M., Neilson, J.D., Lutcavage, L.E., 2010. Complex migration routes of Atlantic bluefin tuna (*Thunnus thynnus*) question current population structure paradigm. *Canadian Journal of Fisheries and Aquatic Sciences* 67(6): 966-976.

GOV UK, 2015. https://www.gov.uk/government/news/restrictions-on-fishing-for-certain-sharks-skates-and-rays; accessed 25/07/2017.

Hunter, E., 2014. https://marinescience.blog.gov.uk/2014/06/16/conservation-seabass/; accessed 25/07/2017.

Hunter, E., Berry, F., Buckley, A.A., Stewart, C., Metcalfe, J.D., 2006. Seasonal migration of thornback rays and implications for closure management. *Journal of Applied Ecology* 43: 710-720.

Hunter, E., Blickley, A.A., Stewart, C., Metcalfe, J.D., 2005a. Repeated seasonal migration by a thornback ray in the southern North Sea. *Journal of the Marine Biological Association of the United Kingdom* 85: 1199-1200.

Hunter, E., Buckley, A.A., Stewart, C., Metcalfe, J.D. 2005b. Migratory behaviour of the thornback ray *Raja clavata* in the southern North Sea. *Journal of the Marine Biological Association of the United Kingdom* 85: 1095-1105.

ICES, 2014. Report of the Joint EIFAAC/ICES/GFCM Working Group on Eel. ICES CM 2014/ACOM:18. 203 pp.

ICES, 2016a. European eel (*Anguilla anguilla*) throughout its natural range. In: ICES Advice 2016, Book 9, Section 9.3.8.

ICES, 2016b. Sea bass (*Dicentrarchus labrax*) in divisions 4.b–c, 7.a, and 7.d–h (central and southern North Sea, Irish Sea, English Channel, Bristol Channel, and Celtic Sea). In: ICES Advice 2016, Book 5, Section 5.3.57.

IFREMER, 2017. http://wwz.ifremer.fr/bar_eng/The-Bargip-project; accessed 25/07/2017.

Inland Fisheries Ireland, 2017. http://www.fisheriesireland.ie/Projects/national-bass-programme.html; accessed 25/07/2017.

Jacoby, D., Gollock, M., 2014. *Anguilla anguilla*. The IUCN Red List of Threatened Species 2014: e.T60344A45833138.

McCleave, J.D., Kleckner, R.C., Castonguay, M., 1987. Reproductive sympatry of American and European eels and implications for migration and taxonomy. American Fisheries Society Symposium, 1, pp. 286-297.

Ministerio de Agricultura y Pesca, 2017. http://www.mapama.gob.es/es/pesca/temas/control-e-inspeccion-pesquera/cierre-rayas-srx-89c-10-junio_tcm7-459731.pdf; accessed 25/07/2017.

Morel, G.M., Shrives, J., Bossy, S.F., Meyer, C.G., 2013. Residency and behavioural rhythmicity of ballan wrasse (*Labrus bergylta*) and rays (*Raja spp.*) captured in Portelet Bay, Jersey: implications for Marine Protected Area design. *Journal of the Marine Biological Association of the United Kingdom* 93: 1407-1414.

Moriarty, C., Dekker, W. (eds.), 1997. Management of the European Eel. Fisheries Bulletin (Dublin) 15: 110 pp.

Pade, N.G., Queiroz, N., Humphries, N.E., Witt, M.J., Jones, C.S., Noble, L.R., Sims, D.W., 2009. First results from satellite-linked archival tagging of porbeagle shark, *Lamna nasus*: area fidelity, wider-scale movements and plasticity in diel depth changes. J*ournal of Experimental Marine Biology and Ecology*, 370(1-2): 64-74.

Palm, S., Dannewitz, J., Prestegaard, T., Wickstrom, H., 2009. Panmixia in European eel revisited: no genetic difference between maturing adults from southern and northern Europe. *Heredity* 103: 82-89.

Pawson, M.G., Pickett, G.D., Leballeur, J., Brown, M., Fritsch, M., 2007. Migrations, fishery interactions, and management units of sea bass (*Dicentrarchus labrax*) in Northwest Europe. *ICES Journal of Marine Science* 64: 332-345.

Quayle, V.A., Righton, D., Hetherington, S., Pickett, G., 2009. Observations of the behaviour of European sea bass (*Dicentrarchus labrax*) in the North Sea. In: Tagging and tracking of marine animals with electronic devices, pp. 103-119. Ed. by J. L. Nielsen, H. Arrizabalaga, N. Fragoso, A. Hobday, M. Lutcavage, J. Sibert.

Queiroz, N., Humphries, N.E., Mucientes, G., Hammerschlag, N., Lima, F.P., Scales, K.L., Miller, P.I., Sousa, L.L., Seabra, R., Sims, D.W., 2016. Ocean-wide tracking of pelagic sharks reveals extent of overlap with longline fishing hotspots. *Proceedings of the National Academy of Sciences of the United States of America* 113(6): 1582-1587.

Righton, D., Westerberg, H., Feunteun, E., Økland, F., Gargan, P., Amilhat, E., Metcalfe, J., Lobon-Cervia, J., Sjöberg, N., Simon, J., Acou, A., Vedor, M., Walker, A.M., Trancart, T., Brämick, U., Aarestrup, K., 2016. Empirical observations of the spawning migration of European eels: The long and dangerous road to the Sargasso Sea. *Science Advances* e1501694.

Sims, D.W., Wearmouth, V.J., Southall, E.J., Hill, J.M., Moore, P., Rawlinson, K., Hutchinson, N., Budd, G.C., Righton, D., Metcalfe, J.D., Nash, J.P., Morritt, D., 2006. Hunt warm, rest cool: bioenergetic strategy underlying diel vertical migration of a benthic shark. *Journal of Animal Ecology* 75: 176-190.

Souche, E.L., Hellemans, B., Babbucci, M., MacAoidh, E., Guinand, B., Bargelloni, L., Chistiakov, D.A., Patarnello, T., Bonhomme, F., Martinsohn, J.T., Volckaert, F.A.M., 2015. Range-wide population structure of European sea bass *Dicentrarchus labrax*. *Biological Journal of the Linnean Society* 116: 86-105.

Thorstad, E.B., Whoriskey, F.G., Rikardsen, A.H., Aarestrup, K., 2011. Aquatic nomads: the life and migrations of the Atlantic salmon. In: Aas, Ø., Einum, S., Klemetsen, A. & Skurdal, J. (eds.) Atlantic Salmon Ecology, Chapter 1, pp. 1-32. Wiley-Blackwell.

Vandeperre, F., Aires-da-Silva, A., Fontes, J., Santos, M., Serrão Santos, R., Afonso, P., 2014. Movements of Blue Sharks (*Prionace glauca*) across their life history. *PLoS ONE* 9(8): e103538. https://doi.org/10.1371/journal.pone.0103538.

Walker, P., Howlett, G., Millner, R., 1997. Distribution, movement and stock structure of three ray species in the North Sea and eastern English Channel. *ICES Journal of Marine Science* 54: 797-808.

Walli, A., Teo, S.L.H., Boustany, A., Farwell, C.J., Williams, T., Dewar, H., Prince, E., Block, B.A., 2009. Seasonal movements, aggregations and diving behavior of Atlantic bluefin tuna (*Thunnus thynnus*) revealed with archival tags. *PLoS One* 4.7: e6151.

Wildsea Europe, 2017. https://www.wildsea.eu/conservation/irish-basking-shark-project.html; accessed 25/07/2017.

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