

The OTN Data Centre: enabling reliable acoustic telemetry data through a global cooperative data exchange

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Abstract

Acoustic telemetry is a powerful tool for aquatic animal movement studies, and to enhance its potential to inform management and conservation, sound data management and quality control structures are crucial. The Ocean Tracking Network (OTN) has been a leader in the coordination of acoustic telemetry researchers globally, connecting tracking programs through standardized data formats and processes. The OTN Data Centre (OTNDC) provides reliable, transparent, and internationally certified data management structures, which support researchers as they embark on their animal tracking programs. This article details OTNDC's data pipelines and processes, governance, and “network of networks” data model (implemented via *database nodes*) and how this system influences the acoustic telemetry research landscape. The OTNDC is continually adapting to meet the needs of the research community, and its partner networks, to remain relevant and reliable. Researchers supported by OTNDC's structures are addressing key questions about the movements of ecologically, culturally, and economically important species across the globe.

Key words: data management, acoustic telemetry, aquatic animal movement, conservation, data standardization

1. Introduction

Acoustic telemetry networks (a formal or informal, multi-organizational, collaborative research group, committed to fostering shared expertise, and research outcomes) have proven to be critical for data sharing between acoustic telemetry research projects, enabling the coordinated monitoring of animals across large areas (O'Dor and Stokesbury 2009; Cooke et al. 2011; Hussey et al. 2015; Block et al. 2016; Hoenner et al. 2018; Young et al. 2020). The Ocean Tracking Network (OTN) supports acoustic telemetry networks globally through its Data Centre with a mission to inform the sustainable management and stewardship of aquatic animals by providing knowledge on their movements, habitats, and survival in the face of changing global environments (O'Dor and Stokesbury 2009; Cooke et al. 2011; Iverson et al. 2019; “Ocean Tracking Network” 2025). OTN's core infrastructure is built around acoustic telemetry, a technology which uses stationary or mobile receivers in conjunction with encoded acoustic transmitters to detect the presence and location of aquatic animals (Matley et al. 2022). Collaboration and data sharing are especially important in movement ecology and biologging (Bangley et al. 2020) since animals regularly leave their study area and cross borders into neighboring research regions (Griffin et al. 2018; Hays et al. 2019; Lédée et al. 2021; Lennox et al. 2024). Matley et al. (2022) state that “the implementation of collaborative acoustic telemetry networks is the most promising pathway to effectively address these ex-

isting spatiotemporal constraints because they pool regional resources and possess the infrastructure to maintain equipment and databases. The establishment of acoustic telemetry networks also creates opportunities for a wider variety of species to be studied (e.g., threatened and non-exploited species) with relatively minimal financial investment.” Beyond detection-sharing and capacity-sharing across project borders, acoustic telemetry networks facilitate the quality control (QC) of acoustic telemetry data, share it among network members, and can provide archiving of project data (Hoenner et al. 2018; Krueger et al. 2018; Bangley et al. 2020; Young et al. 2020). The formation of many acoustic telemetry networks happens at the regional scale, sometimes according to conservation and management priorities or to the proximity of researchers (Reubens et al. 2019; Matley et al. 2022). While regional communities and common goals have been instrumental in building these networks, and have proven beneficial to participants (as outlined in Hussey et al. 2015; Block et al. 2016; Hoenner et al. 2018; Iverson et al. 2019; Bangley et al. 2020; Young et al. 2020; Friess et al. 2021; Lédée et al. 2021; Matley et al. 2022; Lennox et al. 2024; Livernois et al. 2025), changing climates and increasing globalization require researchers to work on even larger scales to understand aquatic animal movements, hence making a global network like OTN relevant.

Despite the success of the research generated within collaborative acoustic telemetry networks, data-sharing

between networks can be difficult when no single data standard is followed, or when individual researchers disagree on data ownership (Hoenner et al. 2018; Bangle et al. 2020). Networks have grown to support the demand for expanded interconnectivity, becoming national (Block et al. 2016) and then continental (Hoenner et al. 2018; Krueger et al. 2018; <https://europeantrackingnetwork.org/en>), but these scales still result in fragmentation when viewing oceans and animal movement in a global context. Each of these regional-to-continental scale networks have different data policies, which guide when and by whom their information can be accessed. Each network may also collect and share information of different granularity and organize their data products with different schemas and naming conventions, which requires pre-processing to make information generated by different networks compatible. Additionally, the data management capabilities of networks vary, but can be limited by resources or funding, and can span from offering long-term archival data storage to operating only a shared email list. These factors, along with the variable attitudes toward data sharing both beyond and even within networks, result in a fragmented ability to detect animals that travel globally (Matley et al. 2022; Davidson et al. 2025). A method to address the aforementioned limitations, build compatibility, and improve data access across disparate networks is the aggregation of individual networks into a “network of networks” (this model is also highlighted in Vanderbilt et al. 2015, 2017; Waide and Kingsland 2021), wherein each member network operates an intercompatible data system (referred to herein as a database “node”) and continues to serve their community while also contributing, in a standardized way, to other networks and the global science community (Krueger et al. 2018; Bangle et al. 2020).

To support the database node model OTN, through its Data Centre (OTNDC), has established data pipelines and data products that follow international standards, are reproducible, and can be shared widely (<https://github.com/ocean-tracking-network>; Ocean Tracking Network 2024). Using these pipelines and outputs, individual networks can contribute into a global network (OTN) in a manner that allows each network to maintain their independence and organize themselves in the ways that best serve their community (Iverson et al. 2019). This “network of networks” approach thereby facilitates data sharing at the global scale based on the geographical coverage of member networks (Waide and Kingsland 2021). The OTNDC is working to maintain global compatibility of animal movement data while building a community of researchers working in diverse locations. OTN’s mandate could not be accomplished by one network alone; it is only through relationships with network partners that OTN can work to support the needs of the research community and build a common framework of animal movement data. The “network of networks” model contributes to enhanced insights into animal movements across scales (Hays et al. 2019; Lennox et al. 2024) and, to maximize the scientific outcomes within this framework, OTN has also created pipelines to publish eligible data to higher endpoints which are findable by those outside of any individual network (e.g., the Ocean Biodiversity Information System (OBIS),

the Global Biodiversity Information Facility (GBIF), Environmental Research Division Data Access Program (ERDDAP)). This high-level data publishing allows networks to move from coordinated regional monitoring to coordinated monitoring across political boundaries and on global scales, with positive outcomes for the researchers associated with the networks.

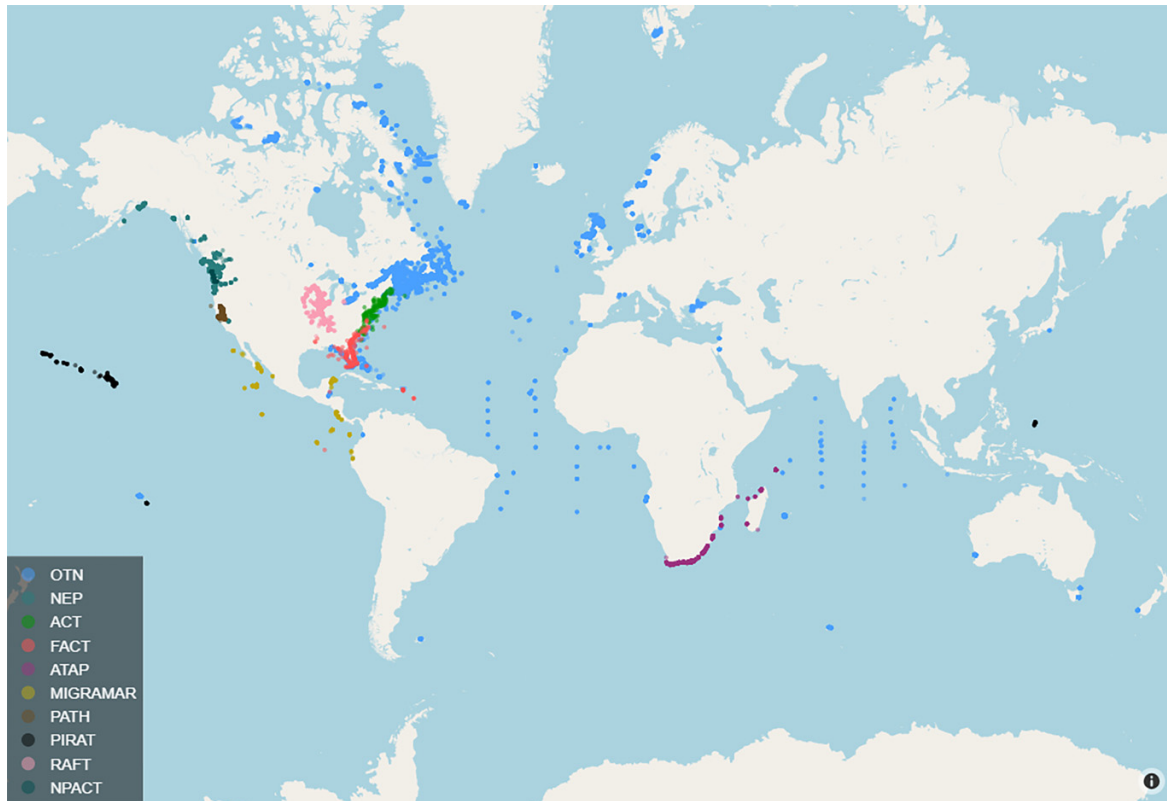
The objectives of this article are to (1) introduce OTNDC’s “network of networks” database node model for global telemetry data exchange, (2) describe OTNDC’s data processing pipelines to provide data system users with a transparent overview of implemented protocols, and (3) to highlight the international data certifications and governance oversight that makes OTNDC’s data flows trustworthy and reliable (reliability in data can be described as accuracy, completeness, and traceability as per Riskin et al. (2025)). This article can provide data system users with enhanced trust, confidence, and deeper understanding of how OTNDC and its partner networks manage data.

2. Database node model

As a global organization, OTN strives to facilitate research collaboration on a global scale, but building collaborations with regional research communities as outsiders is a challenging task. Ecological systems and their research needs are more similar when they are nearer to each other (such as Tobler’s Law; Tobler 1970; Miller 2004), which is also the same for research communities who may form collaborations based on spatial proximity. In response to the reality of Tobler’s Law in acoustic telemetry research networks, OTN has partnered with several regional acoustic telemetry networks across the globe to enable data sharing between these networks, effectively increasing the geographic detectability of tagged animals. Telemetry researchers who have formed natural collaboration networks across the movement range of their animals are able to share resources, expertise, and improve scientific outcomes. Supporting these local collaborations, instead of replacing them, is an important way OTN has grown globally. There are many ways in which OTN supports local networks, the culmination of which is the installation of OTN database nodes.

An OTN database node is a copy of OTN’s database structure provided to partner networks to operate independently and allows for direct cross-referencing between every participating group due to its identical structure. Providing infrastructure to regional networks supports them by standardizing and organizing datasets and data sharing (Bangle et al. 2020). By finding and connecting existing research collaborations and networks, OTN has supported global acoustic telemetry growth and scientific outcomes (Bangle et al. 2020; Young et al. 2020; Matley et al. 2022; Lennox et al. 2024). Instead of requiring all researchers to communicate and share data directly with OTN, each can participate in their regional networks and maintain their local relationships. Network-to-network level arrangements are created which benefit local and international collaborators alike, while enabling local communities to be in control of their own data.

Fig. 1. Current geographic coverage of Ocean Tracking Network's (OTN's) "network of networks" model of database nodes. Each colour is a different participating network (iTAG, Integrated Tracking of Aquatic Animals in the Gulf, is excluded due to data sharing limitations but is centered in the Gulf of Mexico, USA), and the points are locations where acoustic receivers have been deployed, denoting the rough geographic region of each node. There are additional networks that exist between these points that do not currently host database nodes and are therefore not included in this global map. Basemap: © OpenStreetMap contributors, web Mercator projection (EPSG:3857), WGS84 datum. NEP, OTN's North East Pacific Node; ACT, Atlantic Cooperative Telemetry Network; ATAP, Acoustic Tracking Array Platform; PATH, Pacific Aquatic Telemetry Hub; PIRAT, Pacific Islands Region Acoustic Telemetry Network; RAFT, Riverine Acoustic Fish Telemetry Network; N-PAcT, Northeast Pacific Acoustic Telemetry Network.



The OTN node concept empowers each network to hold the best-possible copy of their regional data, leveraging OTNDC's existing tools, training, and infrastructure to develop highly qualified data management personnel at local scales (Young et al. 2020). Standardization and sharing of data ingestion, quality control and assurance (QA/QC), and analytical tools are possible because the metadata formats, database structure, and outputs are identical across all nodes. OTNDC hosts training and capacity building events for networks to enhance regional collaboration, ensuring that networks will continue to grow and expand independently of OTN support. Data standardization across nodes supports the FAIR data principles of findability, accessibility, interoperability, and repeatability, which guide data management groups including OTNDC during all phases of data flow development and implementation (Wilkinson et al. 2016; OTN 2024). The deployment of the OTN node system has been successful in connecting research communities across multiple continents (Fig. 1). At time of writing, member networks implementing OTN nodes include the FACT Network (<https://secoora.org/fact/>),

the Atlantic Cooperative Telemetry Network (<https://theactnetwork.com/>), MigraMar (<https://www.migramar.org/>), the Acoustic Tracking Array Platform (<https://saiaab.ac.za/platforms/acoustic-tracking-array-platform/>), the Pacific Aquatic Telemetry Hub (<https://path.wfcb.ucdavis.edu/>), the Northeast Pacific Acoustic Telemetry Network (<https://npact.aos.org/>), Riverine Acoustic Fish Telemetry Network (<https://umesc-gisdb03.er.usgs.gov/raft/>), Pacific Islands Region Acoustic Telemetry Network (<https://piratnetwork.org/>), and integrated Tracking of Aquatic Animals in the Gulf (<https://itag.science.com/>) with additional nodes under development in 2026.

Membership in a regional network builds trust and support in a smaller community while the OTN node system provides infrastructure and capacity which may be needed by networks. By connecting regional networks through database nodes, the acoustic telemetry community can align data standards, support data sharing, and enhance scientific outcomes. Global acoustic telemetry connectivity has been strengthened through OTN's regional "network of networks" model, where shared standards and FAIR data

principles (Wilkinson et al. 2016) have been disseminated across scales.

3. Data pipeline/pathways

To reinforce transparency and trust between OTNDC and data-users or node members, below is an outline of OTNDC's database node structure, suite of QA/QC tools, and protocols for supporting open software and code.

3.1. The path of acoustic telemetry data in the OTN database

As part of the OTNDC's reproducible pipeline, acoustic telemetry data are received, ingested, cleaned, and promoted into the database. First, researchers can upload a variety of data (i.e., acoustic telemetry detections) and meta-data (i.e., project, tag, and deployment metadata) to a private folder on OTN's Data Portal website. These files are then visually inspected by OTNDC staff and run through the OTN *nodebooks*—a suite of interactive python scripts that are communally maintained through OTN's GitLab code repository (<https://gitlab.oceantrack.org/otn-partner-nodes/ipython-utilities/>). These *nodebooks* programmatically check for a suite of possible discrepancies to ensure the data are of the highest quality (specifications about the QA/QC checks in the *nodebooks* can be found in Section 3.2). If any errors or warnings are reported, they are reviewed and assessed by the *nodebook* user, and the data-provider is consulted to resolve problems. After the submitted dataset passes the initial QA/QC checks, it is promoted to intermediate-level tables in the database, again through the *nodebooks* (Fig. 2).

These data are then verified against existing project data by the *nodebook* scripts, and any new errors or warnings are assessed, and relevant researchers are consulted. Finally, data are promoted to the upper-level tables in the database (Fig. 2), where they are verified once again. Data at this level are considered to be the “best possible dataset” for a given project and are then aggregated with all other submitted data in the database in the highest-level tables (inherited tables) through an automatic process within the database called inheritance (Fig. 3).

Every 4 months OTNDC coordinates an event called the “Data Push”. During a Data Push, the highest-level tables undergo a final round of verification, and a process called *cross-matching* is performed. During *cross-matching*, tags and detections are compared across all node databases, looking for relevant detection-tag matches. All steps up to *cross-matching* have occurred locally within each node database, and it is only during a Data Push event that QC steps occur between databases. The highest-level tables within each database, which now include additional detection-tag matches, are then summarized into discovery tables. These discovery tables are used to populate the OTN website and can be used as a source for data access and publishing platforms, such as GeoServer and ERDDAP (Fig. 4). Information is summarized in the discovery tables according to the data policies that govern each network and may or may not be shared between net-

works and OTN according to data policies and sharing agreements.

In addition to publishing data to open data portals such as GeoServer and ERDDAP, projects can update their public data archive in global biodiversity repositories such as OBIS and GBIF after each Data Push. This is done by tracking each project's publication dates and permissions based on their data policy, then calculating a “publish date” for each individual animal record. A *nodebook* is then used to summarize any animal data that has reached its publish date into a Darwin Core Archive and contributes that data summary to OBIS (a high-level view of all OTN data currently published to OBIS can be seen on OTN's OBIS webpage <https://obis.org/node/68f83ea7-69a7-44fd-be77-3c3afd6f3cf8>).

3.2. Data assurance/quality control (QA/QC) processes

Ensuring excellent data and metadata quality is essential for producing reliable, consistent, and interoperable datasets for researchers around the world (Molloy 2011; Wilkinson et al. 2016; Hoenner et al. 2018; Katz et al. 2019). Quality-controlled data reduce the risk of errors in analysis and improve the long-term usability of complex datasets (Wang and Strong 1996). However, both human- and machine-generated data can contain subtle errors, such as formatting inconsistencies, time zone issues, or mislabeled instruments, that may go unnoticed without a structured QA/QC process. To address this, OTNDC has designed a combination of visual inspection, automatic *nodebooks*, and database-level checks to catch and resolve issues as early as possible. These pipelines have been created to appropriately check both metadata submitted by users and machine generated data files, which require a different approach.

Metadata submitted by users first undergoes a visual inspection, as mentioned in Section 3.1. This allows for quick identification of common errors typically associated with metadata entry, allowing for a fast turn-around and prompt resolution of any corrections requested from researchers. If any errors remain undetected following the visual inspection, the subsequent automated steps in the QA/QC and loading process will flag any outstanding issues. These steps include checking data types, vendor specifications, geospatial results, and date formatting. Some data quality checks compare data submission values to the database, checking for differences in key columns between the tables. Common errors include “overlapping” deployments of tags or receivers caused by one serial number appearing in two rows. *Nodebooks* also query the World Register of Marine Species to align user-submitted taxonomic data with global taxonomic standards. Through the *nodebooks*, these QA/QC checks remain consistent across partner nodes and are updated and expanded regularly based on user feedback.

The process for manually verifying issues in machine-generated data files that are submitted to the OTN Data Portal requires different pipelines due to the different nature of the data. OTN's suite of *nodebooks* can also efficiently detect common issues associated with machine-generated data. Key checks include verifying changes in output format, identify-

Fig. 2. The path of data through the Ocean Tracking Network's (OTN's) Python notebooks. Data start as a metadata template, submitted to the OTN Data Centre by the researcher. Using the notebooks, data are added to the database first as a raw table and, through various stages of quality control/quality assurance checks and database tables, ends up in inherited tables in the database, which hold the highest quality aggregated data.

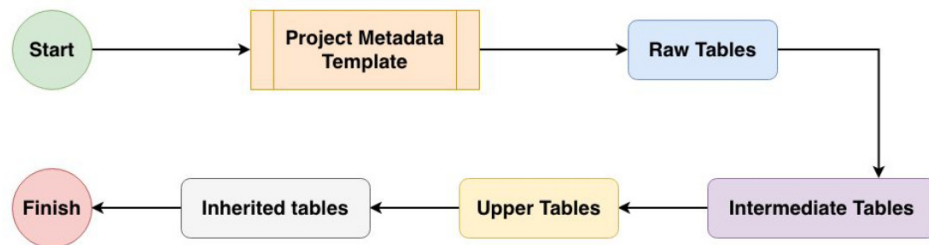
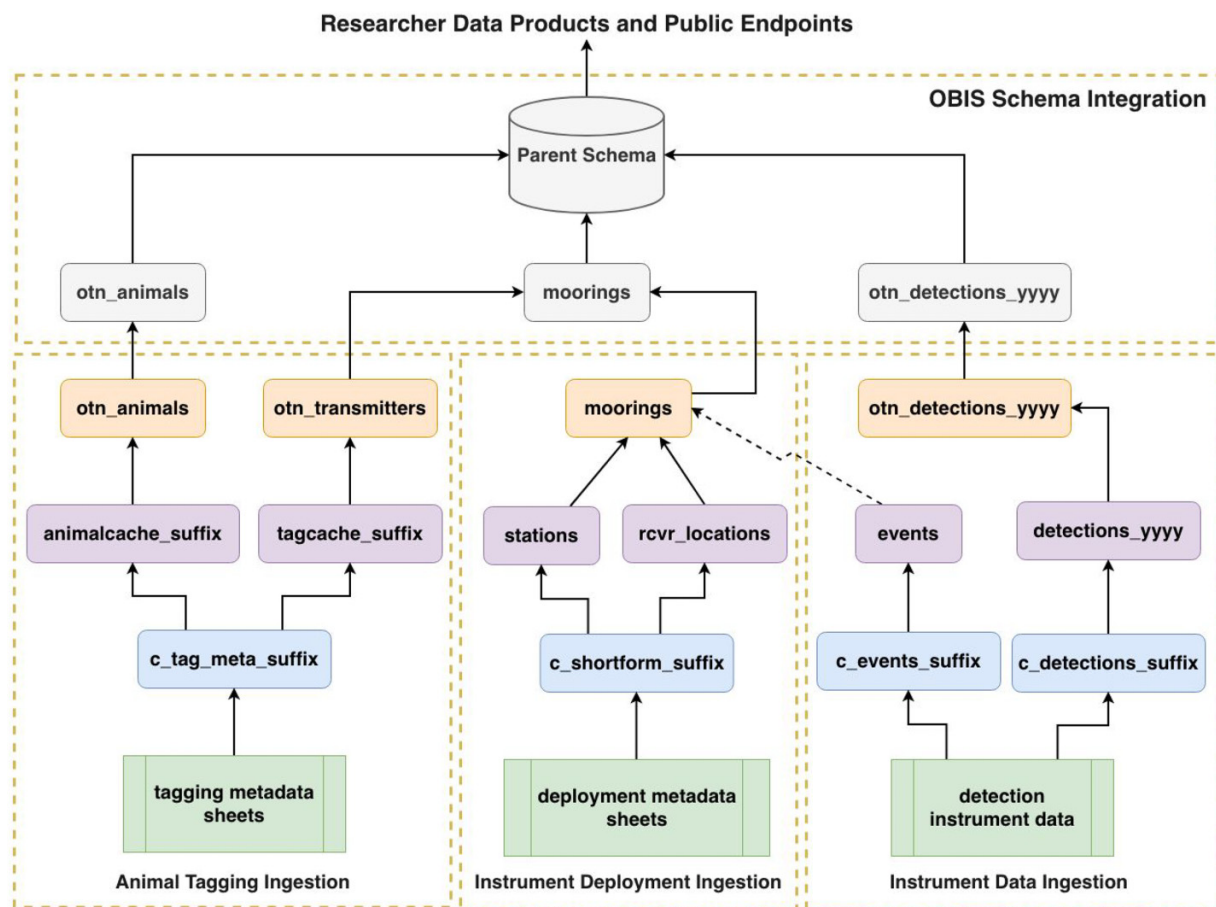


Fig. 3. The path of data through the database, showing the specific tables relevant to each type of common telemetry data. Beginning at the bottom with the original metadata submitted by the researcher, then the blue boxes denote raw tables in the database, purple boxes denote intermediate-level tables, yellow boxes denote the upper-level tables, and dark grey boxes denote the inherited tables which contain the highest quality aggregated data.

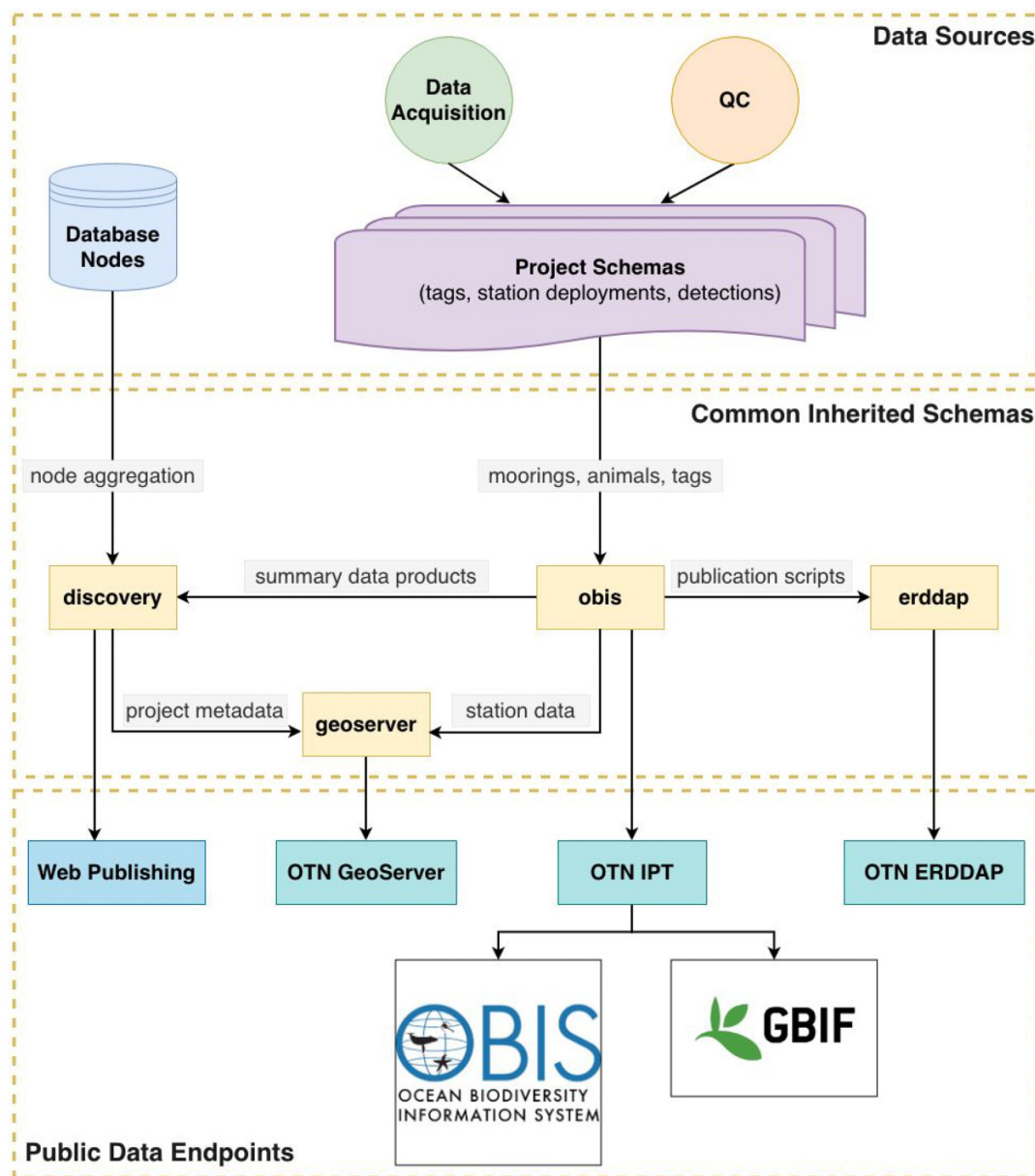


ing internal clock errors that result in implausible date outputs, and removing duplicate data from uncleared receivers.

The QA/QC processes described above are designed to ensure that the OTN and node databases maintain the best copy of the data at all stages. The structure of the *nodebooks* ensures that errors can be caught earlier in the process so researchers

can be consulted before data are aggregated to higher levels of the database or shared with researchers, thus maintaining the integrity of the higher-level tables. In advance of each Data Push, another suite of *nodebooks*, the Full Database Checks, are used to find and address any errors that may exist in the higher-level tables. If an error is found in the upper lev-

Fig. 4. The process through which data move from individual researchers to public endpoints, while aligning with the relevant data policy. Light green boxes denote data acquisition activities, orange denotes quality control (QC) processes, purple denotes project-specific schemas, yellow denotes common schemas shared across projects, light blue denotes database nodes, dark blue denotes partner web pages, teal denotes Ocean Tracking Network (OTN)-hosted data services, and light grey denotes external global archives. GBIF, Global Biodiversity Information Facility; ERDDAP, Environmental Research Division Data Access Program; OBIS IPT, Ocean Biodiversity Information System Integrated Publishing Toolkit.



els of the node databases, or a researcher corrects a mistake they have identified since submitting, there is also a suite of Database Fix *nodebooks* intended to ensure that higher-level errors can be properly corrected in a standardized way across all the necessary locations in the database. For thoroughness, many tables across the OTN database contain an update log in the form of a “datelastmodified” column that tracks when metadata rows have been changed by either corrections from the researcher or node data managers.

3.3. Community-supported development

To understand and respond to the needs of the community, an array of formal and informal communication channels are employed to support active engagement between OTNDC and researchers. Platforms such as Slack, GitHub, virtual Study Hall sessions, workshops, and social media are all used to facilitate rapid feedback from researchers and encourage the reporting of issues related to OTNDC’s software products. This approach informs a continuous improvement plan and

allows OTNDC to be responsive to the needs of the community.

This type of open-science community-supported development promotes transparency, reproducibility, and collaboration in scientific research by integrating user feedback and community standards into software and data workflows. As highlighted by Katz et al. (2019), sustainability in research software relies on three pillars: strong leadership, community collaboration, and open-source development. Data pipelines developed and maintained by OTNDC encourage consistent and accessible data sharing. Through these pipelines, data are transformed into widely adopted open science data formats and systems such as Darwin Core, OBIS, GBIF, enhancing interoperability, and global accessibility.

OTNDC also maintains and improves community-built data analysis software products, serving the research community by updating products in an iterative approach. OTNDC's software products are developed with open-source frameworks and made publicly available on the Ocean Tracking Network GitHub repository (<https://github.com/ocean-tracking-network>). These tools, such as the collection of community-built R packages that make up the *trackyverse* (<https://trackyverse.org/>) empower researchers to explore and validate their standardized data in novel ways. When using OTNDC-authored software products, users can submit tickets for feature requests and bug fixes via GitHub or GitLab. These fixes and requests are actioned during periodic OTNDC software development cycles and ultimately result in code improvements for the benefit of the research community.

OTNDC also offers more targeted support by triaging issues related to specific vendors and data formats, conducting troubleshooting and pair programming sessions, and hosting data rescue sessions in which members of the OTNDC team work closely with a research group to get a substantial amount of data converted to OTN format and loaded into the node databases. These efforts are designed to support researcher engagement with ongoing and future open science directions (Thibault et al. 2023). Examples of the academic impact that OTN has had on aquatic research can be seen through the tracking of publications (Colavizza et al. 2024). The number of publications supported by OTN has exceeded 669 since 2008 by 988 authors who are direct OTN collaborators (Fig. 5). The community-supported model that OTN is built on ensures continuous improvement and responsiveness to the evolving needs of users while advancing the principles of open science.

4. Data governance

This section highlights how OTNDC's data pipelines are trustworthy and internationally recognized as reputable. Collaborative telemetry networks use OTN's shared data system to aggregate independently collected data from hundreds of distinct research efforts, effectively extending the observing capabilities of all participating researchers and institutions (Bangley et al. 2020; Young et al. 2020).

4.1. Data oversight

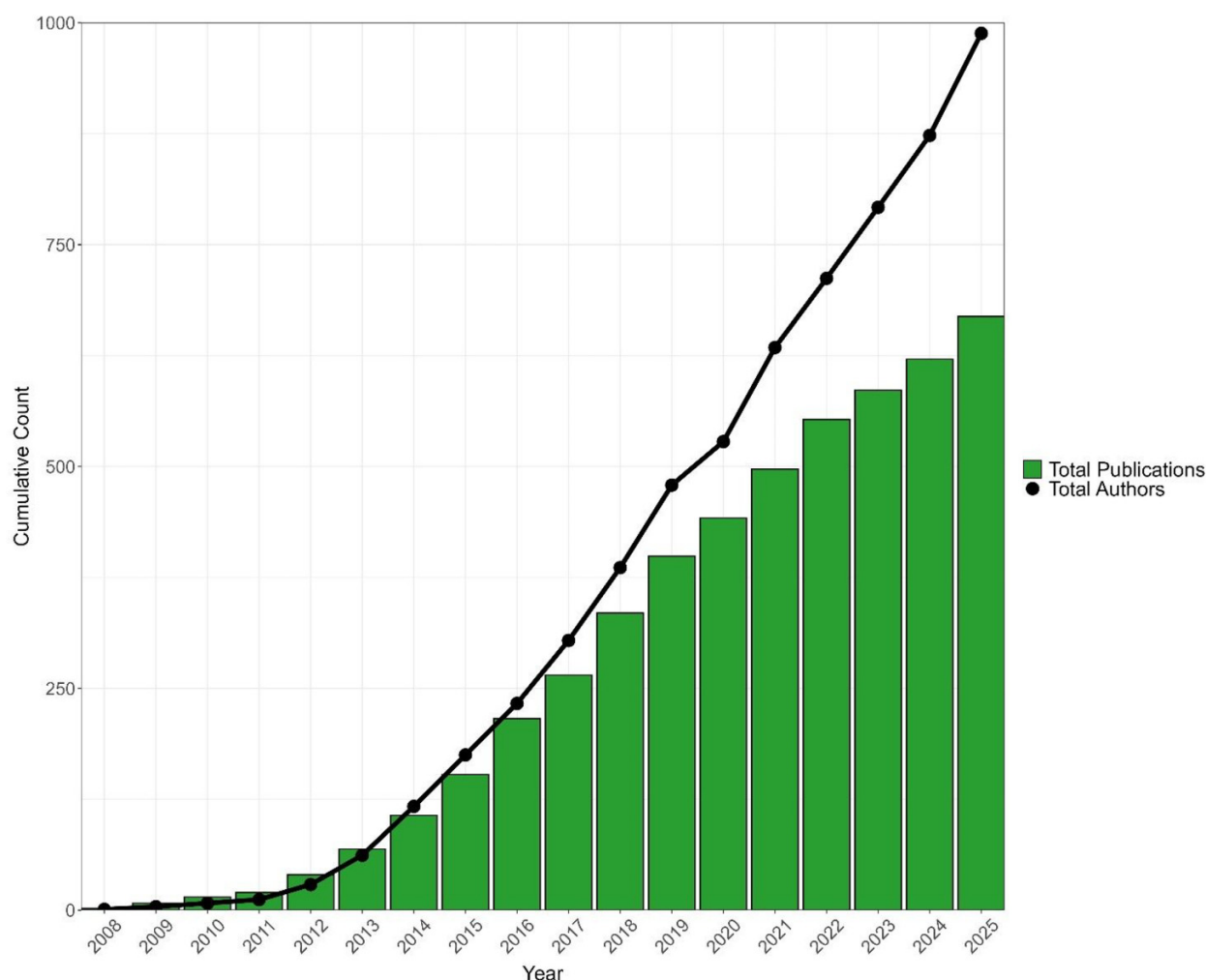
To adhere to the expectations of the tracking community and international data quality standards, the OTNDC is transparent and open about its data validation and QC processes (Section 3 above). Through certifications by globally respected data management standards bodies like CoreTrust-Seal and the World Data System, as well as standards promoted by the International Oceanographic Data Exchange (IODE), OTN has obtained multiple certifications for its data infrastructure, pipelines, and quality management framework (OTN 2024). These certifications catalogue all aspects of the data pipelines implemented by OTNDC and its partners, ensuring data validation and QC processes are understandable, auditable, and meet the needs of the research community and the public. Additionally, OTN's status as an accredited Associate Data Unit of IODE communicates to the ocean data community the global excellence of our animal telemetry data platforms. These activities are important to maintain international data stewardship certifications, signaling to data users that OTN-mediated data products meet FAIR data principles and are of the highest quality.

The work of OTN and of its Data Centre is guided by diverse advisors through its governing bodies: the OTN Council, the OTN International Science Advisory Committee (ISAC), and the OTN International Data Management Committee (IDMC) (see details here <https://oceantrackingnetwork.org/governance/>). OTN's Council guides and positions the operations of OTN in the global landscape of aquatic biodiversity conservation and sustainable development of the blue economy. The ISAC ensures that OTN is meeting the changing needs of the researchers who depend on its infrastructure, exploring innovative technologies and developments in data analysis, advocating for greater instrument compatibility, as well as identifying knowledge gaps in translating animal tracking data to policy. Of these groups, the IDMC is most directly involved in guiding the operations of the Data Centre by representing the opinions of the research community on topics such as data publication, attribution for collaborative data contributions, and public data formats and endpoints. IDMC membership strives to represent diverse perspectives from the global animal tracking, research data management, and data sovereignty communities. Our certifications and governance structures are in place to ensure that OTNDC remains trustworthy and transparent in data management practices and is positioned to adapt to the changing needs of the global telemetry research community.

4.2. Data policies

While sharing and cross-referencing compatible telemetry data can offer advantages to scientists (Hussey et al. 2015), concerns remain regarding the ownership of animal tracking data (Hawkes et al. 2024). The OTN Data Policy (<https://members.oceantrack.org/data/policies>) balances the benefits of data sharing within the acoustic telemetry community and the broader public while addressing concerns over sensitive ecological information. It serves as an agreement between OTN, its partner networks, and its contribut-

Fig. 5. Cumulative number of publications (sponsored by the Ocean Tracking Network in forms of Authorship, Funding, Field Support, Infrastructure, and Data; green bars) and authors (black line) who are direct collaborators with the Ocean Tracking Network.



ing researchers, emphasizing that animal presence information often requires greater protection than moored instrument data.

OTN's Data Policy applies to OTN data, and other policies and data sharing agreements are developed by each network. Responsibility for upholding the relevant data policy or data sharing agreement is shared between OTNDC, the relevant partner network, and the users submitting data. Those submitting data are responsible for timely and accurate reporting of all project-related data and metadata, maintaining data integrity (for example by notifying their network data manager if an error was found in previously submitted data), providing equipment specifications to allow for better QA/QC, and updating contact information when necessary. Data users are responsible for properly attributing data sources in publications, notifying OTN of related publications or applications, understanding the data limitations, and acknowledging that data are provided as-is without liability for inaccuracies. OTNDC and other networks are responsible for generating aggregated data products for their users, securely managing restricted data, upholding data embargoes, facili-

tating data access for authorized users, and promoting best practices in data management.

In special circumstances, OTN can develop alternate data-use agreements with data providers. These cases are especially relevant when a collaboration includes Indigenous-led data. Alternate agreements can be established at any stage to ensure alignment with First Nations Principles of Ownership, Control, Access, and Possession for Canadian collaborators or the international principle of Collective Benefit, Authority to Control, Responsibility, and Ethics (Carroll et al. 2020). OTNDC supports Indigenous data sovereignty and policies have flexibility to allow custom agreements in all cases where the data-owners require it.

In accordance with established data sharing agreements and policies, remotely matched tags and detections (i.e., tags matched to detections in other nodes) have their original source-network designated as their "primary database" during *cross-matching*. This designation is used to inform the data citation, tag embargo, and publication status for these data. Regional data sharing values are preserved and maintained in each network by promoting each to have a distinct Data

Policy which supports its users. To ensure the database nodes work together effectively, the one key uniting concept shared by all networks is the idea that the detection of a tagged animal should always be shared to the tagger and never withheld by the array operator. In addition to this universal agreement by all networks, each network can set their own protections for that tag data, and these policies will follow the tag as it is detected across the databases of other networks. In cases where partner databases have conflicting Data Policies, *cross-matching* cannot occur until project collaborators agree to all Data Policies. OTNDC supports networks to maintain autonomy over data sharing at their local scale through individual Data Policies, which builds trust within communities and reduces hesitation to sharing data between researchers.

While data security and quality are assured through the processes outlined above, data availability and transparency are fostered by the OTNDC publication pipelines described in [Section 3.1](#). Publication to OBIS is based on the Data Policy relevant to the tagged animal data and dictates what information can be published to OBIS and when. The current OTN Data Policy considers tagged animal data as “default public” but embargoes are available upon request. Each network can have a unique Data Policy, and the publication pipeline ensures the correct Data Policy is being followed. Data are published to OBIS on a tag-by-tag basis, not at a project-level. Researchers can opt to make data public at any time, even if their network data policy has a 2-year embargo, and those projects can then be added to the publication pipeline.

5. Discussion

OTNDC’s certifications in data management show that OTNDC’s data pipelines and pathways do not just align with global data stewardship standards, but are also transparent and FAIR. OTN’s oversight committees, governance structures, and regular certification renewals affirm the continued ability to serve the needs of the community in a trustworthy manner. In this way, the methods outlined above remain aligned with the latest updates to global data standards and enable OTNDC to effectively serve as the global telemetry data aggregator.

Harmonizing QC tools across regional networks allows researchers to use data collected by partners in other networks reliably. Without unified standards, QC and QA protocols differ between research labs, regions, and networks who have built their own custom tools, code, and pipelines. This means that data provided by another researcher may not match the same standards for analysis or publication as a target dataset. To prevent data integrity issues, or excessive time spent re-cleaning partner data, OTNDC’s node concept for networks makes sharing easier and trustworthy. The “*network of networks*” model supports scientists by matching trustworthy detections across larger spatial scales, providing researchers with new insights into long-range movements ([Lennox et al. 2024](#)) and resulting in fruitful international collaborations with enhanced outcomes for research ([Iverson et al. 2019](#); [Bangley et al. 2020](#); [Young et al. 2020](#)).

While the node model has been successful, the expertise required to operate the database system, maintain its pipelines, and train regional groups requires numerous personnel and significant financial investment. Due to OTN’s funding model and mission to support external research groups, OTNDC is uniquely positioned to provide these services to the global animal tracking community. As the node network has grown, so too has the number of OTNDC staff, the server hardware budget, and the complexity of the data products created by the team. While always looking for ways to enhance the data system’s capability, a limiting factor for OTNDC is the need for examples of new, emerging data types upon which to build new features. To adapt and grow OTNDC services to accept new types of data or unique datasets, a researcher needs to first share that data with OTNDC, before the database system can be modified to handle it. As technologies advance and new technologies emerge in animal tracking, the OTNDC team also must expand their knowledge and skillsets, through both team development and additions to the staff. Building robust, reliable, and secure data pipelines takes time and researcher input. Qualified data personnel are essential to the process, and budgets need to account for this.

The standardized data formats utilized by OTNDC have supported research excellence across the global telemetry community. For instance, spatially disconnected researchers have come together to write synthesis papers ([Brodie et al. 2018](#); [Bangley et al. 2020](#); [Udyawer et al. 2023](#)), and new conclusions have been revealed through the data shared by networks ([Friess et al. 2021](#); [Lennox et al. 2024](#)). These researchers are also able to easily meet the requirements of their funding agencies and journals for data publishing through OTNDC’s public data pipelines. Publication of project data through OTNDC aligns with the requirements of many academic journals and funders by meeting international data standards, aligning with FAIR principles ([Wilkinson et al. 2016](#)), and providing open access to anyone ([Molloy 2011](#)).

OTN database nodes support researchers who are working to advance aquatic species management and conservation by tracking species of ecological, cultural, and economic importance across spatial scales ([Matley et al. 2022](#)). Understanding the habitat use and movement patterns of important species can directly assist in their conservation planning by informing spawning sites, movement corridors, or interactions with anthropogenic threats ([Lea et al. 2016](#); [Hays et al. 2019](#); [Jacoby and Piper 2023](#)). With the clean, transparent data provided by the OTN data system, researchers are better able to answer key questions about critical species. In this way, OTNDC’s pipelines are supporting good scientific outcomes for users of the data system.

While this manuscript highlights the current data pipelines, processes, and policies at OTNDC, the tools will continue to grow and adapt to serve community needs effectively. Current initiatives include developing OTNDC data pipelines to include non-acoustic telemetry technologies: including cleaning and archiving of satellite-collected animal detections, ingesting and matching tags and detections from Passive Integrated Transponder tagging arrays, and more robust archiving of anchor tag records (i.e., Floy, dart, or T-bar tags) to ensure mark-recapture efforts are

adequately documented. Future developments may include the use of automation and modelling to enhance workflows and reproducibility.

Interoperability, through the adoption of database nodes or other means, is an important goal for OTNDC as the global network expands to support other regional telemetry networks. Acoustic telemetry technology is continually changing (Lennox et al. 2023, 2025; Aspillaga et al. 2024) and as a global leader in the field, OTN is committed to remaining compatible and adaptable, changing as technologies change. To support interoperability in analysis methods, OTNDC will continue to prioritize the creation and dissemination of animal movement analysis code by hosting weekly peer-support Study Halls, regular workshops, and initiatives such as the *trackyverse*. OTN's mission to generate knowledge on aquatic animal movements is upheld by its Data Centre, and by documenting OTNDC's database node model, data pipelines, and governance we supply this article to demonstrate our support for the global acoustic telemetry research community.

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References

- Aspillaga, E., Bruneel, S., Alós, J., Verhelst, P., Abecasis, D., Aarestrup, K., et al. 2024. Open Protocols, the new standard for acoustic tracking: results from interoperability and performance tests in European waters. *Anim. Biotelemetry*, **12**(1): 40. doi:[10.1186/s40317-024-00396-9](https://doi.org/10.1186/s40317-024-00396-9).
- Bangley, C.W., Whoriskey, F.G., Young, J.M., and Ogburn, M.B. 2020. Networked animal telemetry in the northwest Atlantic and Caribbean waters. *Mar. Coastal Fishes*. **12**(5): 339–347. doi:[10.1002/mcf2.10128](https://doi.org/10.1002/mcf2.10128).
- Block, B.A., Holbrook, C.M., Simmons, S.E., Holland, K.N., Ault, J.S., Costa, D.P., et al. 2016. Toward a national animal telemetry network for aquatic observations in the United States. *Anima. Biotelemetry*, **4**(1): 6. doi:[10.1186/s40317-015-0092-1](https://doi.org/10.1186/s40317-015-0092-1).
- Brodie, S., Lédée, E.J.L., Heupel, M.R., Babcock, R.C., Campbell, H.A., Gledhill, D.C., et al. 2018. Continental-scale animal tracking reveals functional movement classes across marine taxa. *Sci. Rep.* **8**(1): 3717. doi:[10.1038/s41598-018-21988-5](https://doi.org/10.1038/s41598-018-21988-5). PMID: 29487384.
- Carroll, S.R., Garba, I., Figueroa-Rodríguez, O.L., Holbrook, J., Lovett, R., Materechera, S., et al. 2020. The CARE principles for Indigenous Data governance. *Data Sci. J.* **19**(1). doi:[10.5334/dsj-2020-043](https://doi.org/10.5334/dsj-2020-043).
- Colavizza, G., Cadwallader, L., LaFlamme, M., Dozot, G., Lecorney, S., Rappo, D., and Hrynaskiewicz, I. 2024. An analysis of the effects of sharing research data, code, and preprints on citations. *PLoS*

- One, 19(10): e0311493. doi:10.1371/journal.pone.0311493. PMID: 39475849.
- Cooke, S.J., Iverson, S.J., Stokesbury, M.J.W., Hinch, S.G., Fisk, A.T., VanderZwaag, D.L., et al. 2011. Ocean Tracking Network Canada: a network approach to addressing critical issues in fisheries and resource management with implications for Ocean governance. *Fisheries*, 36(12): 583–592. doi:10.1080/03632415.2011.633464.
- Davidson, S.C., Cagnacci, F., Newman, P., Dettki, H., Urbano, F., Desmet, P., et al. 2025. Establishing bio-logging data collections as dynamic archives of animal life on Earth. *Nat. Ecol. Evol.* 9(2): 204–213. doi:10.1038/s41559-024-02585-4. PMID: 39753915.
- Friess, C., Lowerre-Barbieri, S.K., Poulakis, G.R., Hammerschlag, N., Gardiner, J.M., Kroetz, A.M., et al. 2021. Regional-scale variability in the movement ecology of marine fishes revealed by an integrative acoustic tracking network. *Mar. Ecol. Prog. Ser.* 663: 157–177. doi:10.3354/meps13637.
- Griffin, L.P., Brownscombe, J.W., Adams, A.J., Boucek, R.E., Finn, J.T., Heithaus, M.R., et al. 2018. Keeping up with the Silver King: using cooperative acoustic telemetry networks to quantify the movements of Atlantic tarpon (*Megalops atlanticus*) in the coastal waters of the southeastern United States. *Fish. Res.* 205: 65–76. doi:10.1016/j.fishres.2018.04.008.
- Hawkes, L.A., Davies, P., Hall, A.E., Horton, T.W., Stamp, T., Witt, M.J., and Sheehan, E.V. 2024. People behind the “pings”: limiting authorship threatens collaboration in telemetry. *J. Fish Biol.* 104(6): 1662–1666. doi:10.1111/jfb.15700. PMID: 38519854.
- Hays, G.C., Bailey, H., Bograd, S.J., Bowen, W.D., Campagna, C., Carmichael, R.H., et al. 2019. Translating marine animal tracking data into conservation policy and management. *Trends Ecol. Evol.* 34(5): 459–473. doi:10.1016/j.tree.2019.01.009. PMID: 30879872.
- Hoerner, X., Huvneers, C., Steckenreuter, A., Sumpfendorfer, C., Tattersall, K., Jaine, F., et al. 2018. Australia’s continental-scale acoustic tracking database and its automated quality control process. *Sci. Data*, 5(1): 170206. doi:10.1038/sdata.2017.206. PMID: 29381146.
- Hussey, N.E., Kessel, S.T., Aarestrup, K., Cooke, S.J., Cowley, P.D., Fisk, A.T., et al. 2015. Aquatic animal telemetry: a panoramic window into the underwater world. *Science*, 348(6240): 1255642. doi:10.1126/science.1255642. PMID: 26068859.
- Iverson, S.J., Fisk, A.T., Hinch, S.G., Mills Flemming, J., Cooke, S.J., and Whoriskey, F.G. 2019. The Ocean Tracking Network: advancing frontiers in aquatic science and management. *Can. J. Fish. Aquat. Sci.* 76(7): 1041–1051. doi:10.1139/cjfas-2018-0481.
- Jacoby, D.M.P., and Piper, A.T. 2023. What acoustic telemetry can and cannot tell us about fish biology. *J. Fish Biol.* 1–25. doi:10.1111/jfb.15588.
- Katz, D.S., McInnes, L.C., Bernholdt, D.E., Mayes, A.C., Hong, N.P.C., Duckles, J., et al. 2019. Community Organizations: changing the culture in which research software is developed and sustained. *Comput. Sci. Eng.* 21(2): 8–24. doi:10.1109/MCSE.2018.2883051.
- Krueger, C.C., Holbrook, C.M., Binder, T.R., Vandergoot, C.S., Hayden, T.A., Hondorp, D.W., et al. 2018. Acoustic telemetry observation systems: challenges encountered and overcome in the Laurentian Great Lakes. *Can. J. Fish. Aquat. Sci.* 75(10): 1755–1763. doi:10.1139/cjfas-2017-0406.
- Lea, J.S.E., Humphries, N.E., von Brandis, R.G., Clarke, C.R., and Sims, D.W. 2016. Acoustic telemetry and network analysis reveal the space use of multiple reef predators and enhance marine protected area design. *Proc. R. Soc. B. Biol. Sci.* 283(1834): 20160717. doi:10.1098/rspb.2016.0717.
- Lédée, E.J.L., Heupel, M.R., Taylor, M.D., Harcourt, R.G., Jaine, F.R.A., Huvneers, C., et al. 2021. Continental-scale acoustic telemetry and network analysis reveal new insights into stock structure. *Fish. Fish.* 22(5): 987–1005. doi:10.1111/faf.12565.
- Lennox, R.J., Eldøy, S.H., Dahlmo, L.S., Matley, J.K., and Vollset, K.W. 2023. Acoustic accelerometer transmitters and their growing relevance to aquatic science. *Mov. Ecol.* 11(1): 45. doi:10.1186/s40462-023-00403-3.
- Lennox, R.J., Whoriskey, F.G., Verhelst, P., Vandergoot, C.S., Soria, M., Reubens, J., et al. 2024. Globally coordinated acoustic aquatic animal tracking reveals unexpected, ecologically important movements across oceans, lakes and rivers. *Ecography*, 2024(1): e06801. doi:10.1111/ecog.06801.
- Lennox, R.J., Mastrodimitropoulos, P.M.B., Flávio, H., Cyr, K., Deng, Z.D., Cooke, S.J., and Piczak, M.L. 2025. How small can they go? Microelectronic tags for movement ecology of small aquatic organisms. *Fisheries*, vuaf002. doi:10.1093/fshmag/vuaf002.
- Livernois, M.C., Ogburn, M.B., Legett, H.D., Richie, K.D., Aguilar, R., Heggie, K., and Furey, N.B. 2025. Tracking animal movements via collaborative acoustic telemetry networks: multiscale habitat use, phenology, and management insights. *J. Fish Biol.* 106(5): 1619–1638. doi:10.1111/jfb.15952. PMID: 39350433.
- Matley, J.K., Klinard, N.V., Barbosa Martins, A.P., Aarestrup, K., Aspillaga, E., Cooke, S.J., et al. 2022. Global trends in aquatic animal tracking with acoustic telemetry. *Trends Ecol. Evol.* 37(1): 79–94. doi:10.1016/j.tree.2021.09.001. PMID: 34563403.
- Miller, H.J. 2004. Tobler’s first law and spatial analysis. *Ann. Assoc. Am. Geogr.* 94(2): 284–289. doi:10.1111/j.1467-8306.2004.09402005.x.
- Molloy, J.C. 2011. The Open Knowledge Foundation: open data means better science. *PLoS Biol.* 9(12): e1001195. doi:10.1371/journal.pbio.1001195. PMID: 22162946.
- Ocean Tracking Network. 2024. 2026-11-08—Ocean Tracking Network—CoreTrustSeal requirements 2020–2022. DataverseNL. doi:10.34894/XANOTV.
- Ocean Tracking Network. 2025. Halifax, NS. Available from <https://oceantrackingnetwork.org/> [accessed 17 March 2026].
- O’Dor, R.K., and Stokesbury, M.J.W. 2009. The Ocean Tracking Network—adding marine animal movements to the Global Ocean observing system. In *Tagging and tracking of marine animals with electronic devices*. Edited by J.L. Nielsen, H. Arrizabalaga, N. Fragoso, A. Hobday, M. Lutcavage and J. Sibert. Springer Netherlands, Dordrecht. pp. 91–100. doi:10.1007/978-1-4020-9640-2_6.
- Reubens, J., Verhelst, P., van der Knaap, I., Wydooghe, B., Milotic, T., Deneudt, K., et al. 2019. The need for aquatic tracking networks: the Permanent Belgian Acoustic Receiver Network. *Anim. Biotelemetry*, 7(1): 2. doi:10.1186/s40317-019-0164-8.
- Riskin, D.J., Monda, K.L., Gagne, J.J., Reynolds, R., Garan, A.R., Dreyer, N., et al. 2025. Implementing accuracy, completeness, and traceability for data reliability. *JAMA Netw. Open*, 8(3): e250128. doi:10.1001/jamanetworkopen.2025.0128. PMID: 40063029.
- Thibault, R.T., Amaral, O.B., Argolo, F., Bandrowski, A.E., Davidson, A.R., and Drude, N.I. 2023. Open science 2.0: towards a truly collaborative research ecosystem. *PLoS Biol.* 21(10): e3002362. doi:10.1371/journal.pbio.3002362.
- Tobler, W.R. 1970. A computer movie simulating urban growth in the Detroit region. *Econ. Geogr.* 46: 234–240. doi:10.2307/143141.
- Udyawer, V., Huvneers, C., Jaine, F., Babcock, R.C., Brodie, S., Buscot, M.-J., et al. 2023. Scaling of activity space in marine organisms across latitudinal gradients. *Am. Nat.* 201(4): 586–602. doi:10.1086/723405. PMID: 36958006.
- Vanderbilt, K., Porter, J.H., Lu, S.-S., Bertrand, N., Blankman, D., Guo, X., et al. 2017. A prototype system for multilingual data discovery of International Long-Term Ecological Research (ILTER) Network data. *Ecol. Inf.* 40: 93–101. doi:10.1016/j.ecoinf.2016.11.011.
- Vanderbilt, K.L., Lin, C.-C., Lu, S.-S., Kassim, A.R., He, H., Guo, X., et al. 2015. Fostering ecological data sharing: collaborations in the International Long Term Ecological Research Network. *Ecosphere*, 6(10): 1. doi:10.1890/ES14-00281.1.
- Waide, R.B., and Kingsland, S.E. (Editors). 2021. The challenges of long term ecological research: a historical analysis. Springer Nature. doi:10.1007/978-3-030-66933-1.
- Wang, R.Y., and Strong, D.M. 1996. Beyond accuracy: what data quality means to data consumers. *J. Manage. Inf. Syst.* 12(4): 5–33. doi:10.1080/07421222.1996.11518099.
- Wilkinson, M.D., Dumontier, M., Aalbersberg, I.J., Appleton, G., Axton, M., Baak, A., et al. 2016. The FAIR Guiding Principles for scientific data management and stewardship. *Sci. Data*, 3(1): 160018. doi:10.1038/sdata.2016.18. PMID: 26978244.
- Young, J.M., Bowers, M.E., Reyier, E.A., Morley, D., Ault, E.R., Pye, J.D., et al. 2020. The FACT Network: philosophy, evolution, and management of a Collaborative Coastal Tracking Network. *Mar. Coastal Fish.* 12(5): 258–271. doi:10.1002/mcf2.10100.