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The FACT Network: Philosophy, Evolution, and Management of a Collaborative Coastal Tracking Network

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Acoustic telemetry is a tool that is well suited to document the plasticity of species movement patterns through aquatic habitats and that enables researchers and managers to infer and predict population-level patterns from individual behaviors. First introduced as an instrument for fisheries research in 1956 to study the movement of adult salmon in the Columbia River (Trefethen 1956), acoustic telemetry has been widely adopted as a cost-effective means to track aquatic animals over large temporal and spatial scales (Hussey et al. 2015). It has been employed to evaluate migratory behavior, site fidelity, population dynamics, and habitat use for a variety of marine animals, including bony and cartilaginous fishes, turtles, crustaceans, gastropods, and marine mammals (Lydersen 1991; Bertelsen and Hornbeck 2009; Scales et al. 2011; Reyier et al. 2014; Young et al. 2016; Stiegeltz and Dujon 2017; Cote et al. 2018). When integrated with environmental or physiological sensor tags, acoustic telemetry can provide novel insights into the biology and ecology of tagged animals (e.g., Landry et al. 2018; Adams et al. 2019; Block et al. 2019).

Acoustic telemetry involves the use of specialized listening devices to detect uniquely coded transmitters (tags) that are attached to or implanted in animals. This technology allows for multi-year tags that can increase the length of a study and that do not require the resighting or recapture of animals to confirm their movements, thus offering researchers an alternative to traditional mark–recapture or satellite telemetry. Although the cost per sample may be much lower in traditional mark–recapture studies, such studies often result in a small sample size due to the dependence of recapture and they only produce a straight-line estimate of the pathways that animals traveled between the capture and recapture points, thus often failing to reveal critical behaviors and habitat associations (Kohler et al. 1998; Kohler and Turner 2001; Wiggers 2010). Satellite telemetry often provides a more detailed movement pathway compared to acoustic telemetry, but these studies typically have low sample sizes due to the high cost of the individual tags (Saunders et al. 2011). Additionally, the size of satellite telemetry equipment currently restricts its use to relatively large animals that can accommodate the larger tags without injury or physiological disruption (Thorstad et al. 2009).

Acoustic telemetry is a rapidly expanding method for researchers to understand animal movements. In a review of the use of telemetry in aquatic environments, Hussey et al. (2015) reported that by 2014 the number of acoustic telemetry projects exceeded the number of satellite telemetry studies and that this divide was continuing to increase. The existence of established infrastructure and the cooperation of scientists willing to share data are both vital to the effectiveness of tracking an animal over great distances with acoustic telemetry (e.g., Harcourt et al. 2019). The deployment of compatible acoustic telemetry hardware and the resulting needs to coordinate regional efforts and facilitate data sharing have inspired the establishment of large-scale networks around the world (see Table 1; Harcourt et al. 2019). There is currently a large number of regional networks in North America, including the FACT Network in the southeastern USA; the Atlantic Cooperative Telemetry (ACT) Network and Mid-Atlantic Telemetry Observation System (MATOS) in the U.S. mid-Atlantic; the Ocean Tracking Network (OTN) Canada in the northeastern Atlantic and Arctic Ocean; the integrated Tracking of Aquatic Animals in the Gulf of Mexico (iTAG; Currier et al. 2015); the Great Lakes Acoustic
The FACT Network began as an ad hoc effort among researchers on the Atlantic coast of Florida to broaden the scope of animal tracking while simultaneously creating a supportive community of telemetry users. Until the early 2000s, acoustic telemetry along the Atlantic coast of Florida consisted of small-scale, widely spaced, and independent studies that were conducted on primarily resident fish. Many of these early studies focused on reef-associated species in the Florida Keys (Tulevech and Recksiek 1994; Glazer et al. 2003; Humston et al. 2005; Lindholm et al. 2005; Delgado and Glazer 2007; Bertelsen and Hornbeck 2009) but also included studies on Red Drum *Sciaenops ocellatus* off Cape Canaveral, Florida (Reyier et al. 2011); American alligators *Alligator mississippiensis* in the Everglades (Rosenblatt and Heithaus 2011); and Common Snook *Centropomus undecimalis* (Lowerre-Barbieri et al. 2003; Young et al. 2014) and Lemon Sharks *Negaprion brevirostris* (Kessel et al. 2014) off Jupiter, Florida. The success of these studies led to an

### Table 1: Examples of how partnership in acoustic telemetry networks is improving the quality of animal tracking studies in the southeastern USA.

For each study, comparisons are made between data produced solely by the lead tagging organization's (org.) acoustic array versus that produced by the full FACT Network and Atlantic Cooperative Telemetry Network. Results are from ongoing or recently completed studies.

| Species                  | Lead organization                  | Animals detected | Mean detections per animal | Mean stations visited per animal | Mean coastline used per animal (km) |
|--------------------------|------------------------------------|------------------|----------------------------|----------------------------------|-------------------------------------|
| Finetooth Shark          | Bureau of Ocean Energy Management  | 55               | 3,814                      | 38.6                             | 78.0                                |
| *Carcharhinus isodon*    |                                     | 55               | 4,678                      | 62.4                             | 511.4                               |
| Blacktip Shark           | Florida Atlantic University        | 28               | 857                        | 1.7                              | 15.4                                |
| *C. limbatus*            |                                     | 41               | 1,538                      | 45.8                             | 897.9                               |
| Cobia                    | Florida Fish and Wildlife Conservation Commission | 29           | 5,813                      | 7.4                              | 17.8                                |
| *Rachycentron canadum*   |                                     | 34               | 5,153                      | 9.0                              | 151.2                               |
| Atlantic Tripletail      | Georgia Department of Natural Resources | 49           | 5,318                      | 6.0                              | 4.8                                 |
| *Lobotes surinamensis*   |                                     | 49               | 10,669                     | 17.7                             | 352.1                               |
| Atlantic Goliath Grouper | Florida State University           | 46               | 33,633                     | 3.2                              | 41.7                                |
| *Epinephelus itajara*    |                                     | 50               | 74,728                     | 12.8                             | 143.3                               |
expansion of tagging efforts on more mobile species and a
desire to close the receiver coverage gap between Cape
Canaveral and Jupiter. These common interests in turn
provided motivation to organize a work group that would
eventually become the FACT Network.

In spring 2007, scientists representing six organiza-
tions (see Acknowledgments) formed the Florida Atlantic
Coast Telemetry (FACT) working group. Collectively, this
original group maintained 94 acoustic receivers placed in estu-
aries, coastal rivers, and nearshore waters along Florida’s
Atlantic coast and deployed 226 tags to monitor the move-
ments of teleost and cartilaginous fishes and sea turtles.
Discussions during the original meeting resulted in the
development of an informal governing framework that
described agreements on data rights, minimum contribu-
tion levels, and membership responsibilities. In the original
document, detection data were deemed the property of the tag
owner, not the agency maintaining the receiver infras-
structure on which the tagged animal was detected. It was
expected that all researchers would provide and maintain
receiver stations—or, alternatively, provide staff or equip-
ment to assist other groups with array maintenance. Contri-
bution levels were meant to ensure that the monitoring
workload was being distributed in an equitable manner
while also accommodating members with access to fewer
resources. Lastly, members agreed to share tag and receiver
data and committed to attending a biannual meeting. In
addition to troubleshooting, data management, and analy-
sis support, these biannual meetings promoted in-person
communication between researchers and fostered profes-
sional trust, which maintained the integrity of data sharing
within the network. Although FACT had no dedicated
funding early on, support from the Florida Fish and Wild-
life Conservation Commission’s (FWC) Fish and Wildlife
Research Institute (FWRI) helped to foster growth by host-
ing meetings and allowing personnel to devote time to
FACT.

The FACT group rapidly expanded in membership to
include organizations outside of Florida (Figure 1). Within
the first 5 years, the number of organizations nearly tripled,
while the number of individual members increased fivefold.
In the subsequent 5 years, the number of organizational
members quadrupled, while the number of individual mem-
bers again increased fivefold. By fall 2014, FACT member-
ship had grown to 30 organizations with 2,217 deployed
tags in 46 species of aquatic animals and 488 receiver sta-
tions ranging from South Carolina to the Florida Keys, the
Bahamas, and the U.S. Caribbean. To facilitate the rapid
growth of the network while maintaining the core principles
upon which the group was founded, committees were
formed to address several key issues, including methods to
elevate the network’s profile using information technology
platforms, ways to share data more efficiently, whether to
update the network’s name to reflect the geography of its
expanded membership, and the design of a network logo.
The resulting changes formalized a data sharing policy
(see https://secoora.org/fact/resources/fact-user-agreement/
for the most recent data policy) and officially declared that
the FACT group required a process that could manage large
data sets. The acronym “FACT” became non-acronymous
to preserve its recognition while shedding the boundary of
the Florida Atlantic coast, and the name “FACT Network”
was adopted. A new logo design was agreed upon and
became the network’s symbol across information technology
platforms, while volunteer members and organizations allo-
cated time and resources to establish a FACT presence on
the World Wide Web and through various social media out-
lets, which served to greatly increase its profile among both
the scientific community and the general public.

At the time of this publication, the FACT Network has
283 members representing 93 partner groups, including
academic institutions (n = 45), state and federal govern-
ment agencies (n = 18), industry (n = 7), nonprofit organi-
izations (n = 14), private consulting firms (n = 4), zoological
institutions (n = 4), and a private citizen (n = 1). The
FACT Network includes over 46 individual arrays encom-
passing over 1,500 acoustic receiver stations, and there are
1,964 active tag deployments (i.e., tags within battery life
limits) in 45 species of aquatic animals (Figure 2). Including
expired tags, 5,681 tags have been deployed in 94 spe-
cies of aquatic animals. Receivers are deployed in a
variety of habitats, including coastal rivers, open estuarine
waters, tidal inlets, beachfronts, offshore reefs, wrecks,
and sand shoals in the continental USA (Florida, Georgia,
South Carolina, North Carolina, Virginia, and New Jer-
sy), the U.S. Caribbean, and the Bahamas (Figure 3). To
date, the data collected by FACT Network members have
contributed to at least 37 technical reports and have gen-
erated 33 peer-reviewed publications.
Despite its growth, the FACT Network maintains its philosophy of inclusion, which was codified during the first in-person meetings. The twice-yearly, in-person FACT meetings are formatted to encourage participation, and equal time is provided to every FACT member to present on their project status or relevant topics. Attendees from a diverse background (e.g., academia, state, and federal governments) provide feedback in an informal setting that encourages junior members to interact with more senior members. In a recent survey, 36% ($n = 24$) of members identified joining the FACT Network less than 2 years prior, while 26% ($n = 18$) had been a member of FACT for 5 years or more, providing a balanced mix of junior and senior members. Every FACT meeting is concluded with a group discussion that allows members to ask questions, voice concerns, or weigh in on network-wide issues (e.g., data sharing practices) regardless of their experience with acoustic telemetry or professional status (e.g., student, professor, field technician, or senior fisheries biologist). Junior members are especially encouraged to participate by taking on roles within the network (e.g., email moderator or social media director), providing input on the focus of future data management and/or analysis workshops, drafting clarifications and updates to the FACT data sharing agreement, or choosing locations for the next meeting. An “After the FACT Social” follows each meeting and is a place for conversations, collaborations, and ideas to continue between junior and senior members. By facilitating networking between members, fostering collaborations across experience levels, and enforcing a framework of fair contribution, the FACT Network serves as a technical, emotional, and professional support group for those who are learning the advantages and the limitations of data sharing and acoustic telemetry.

To better understand the motivating factors in joining FACT and maintaining FACT membership, in March 2019 FACT members were asked to fill out an online survey. All members were asked to give information about their personal experiences with acoustic telemetry and collaborative networks. To reduce double reporting by multiple members of the same partner group, only project managers were asked to give details about the scope of tag and array deployments and data sharing. In total, 67 individual members (28.2% of the total network membership) filled out the first part of the survey, while members representing 44 different partners (47.3% of all partner groups) filled out the second part of the survey.

**FACTORS PROMOTING FACT NETWORK EXPANSION**

Hastened by biogeographical factors, management requirements, and support by stakeholder partnerships, the FACT Network grew organically to meet the needs of researchers. Membership in a regional network became intertwined with conducting movement studies as passive acoustic telemetry monitoring became more prevalent throughout the southeastern USA and the Caribbean. A clear majority of respondents to the FACT membership survey (57 of 67; 85.1%) reported that they first heard of FACT through another network member. By far, the most popular reason reported for being a member of the FACT Network was data sharing (mean rank = 1.56), followed by access to automated data management via the FACT node (mean rank = 2.44) and being part of a community of researchers with common interests (mean rank = 2.77; Figure 4). Despite an economic incentive to joining the network via potential discounts on telemetry equipment...

![Figure 2](image2.png)  
**FIGURE 2.** Growth in the number of animals and species tagged by FACT Network partners from 2008 to 2018 (2019 is not presented due to incomplete reporting).

![Figure 3](image3.png)  
**FIGURE 3.** Map of receiver stations (yellow dots) registered in the FACT Network.
for network members, this was the least important reason reported by members as motivating their network membership (mean rank = 4.30); the reasoning behind such a low rank of importance could not be discerned from the survey responses. Membership in multiple regional networks was common, particularly for researchers studying migratory species or maintaining arrays in transitional areas. Fifty-eight percent of respondents to the FACT survey (39 of 67) reported that they were also members of another collaborative telemetry network, including iTAG (61.5%), ACT Network (41.0%), and OTN (23.1%). Other networks included the European Tracking Network (ETN), GLATOS, MATOS, and USCAN.

The FACT Network overlaps with the geographic range of every marine and anadromous fish currently protected under the U.S. Endangered Species Act (ESA) in the eastern USA and surrounding waters except for the Atlantic Salmon *Salmo salar*. Five of the seven fishes and four of the five sea turtles listed under the ESA in the eastern USA have been studied within the FACT Network. The ESA-listed fish species tracked by FACT members include the Smalltooth Sawfish *Pristis pectinata*, Giant Manta *Manta birostris*, Nassau Grouper *Epinephelus striatus*, Atlantic Sturgeon *Acipenser oxyrinchus oxyrinchus*, and Shortnose Sturgeon *Acipenser brevirostrum*. The southeastern USA and the Caribbean Islands are inhabited by five species of ESA-listed sea turtles, more than any other region in North America. To date, four turtle species have been tracked by FACT researchers: the loggerhead sea turtle *Caretta caretta*, green sea turtle *Chelonia mydas*, Kemp’s ridley sea turtle *Lepidochelys kempii*, and hawksbill sea turtle *Eretmochelys imbricata* (e.g., Hart et al. 2012).

Limited overlap of research interests increases the collaboration and cooperation of scientists (Mayrose and Freilich 2015) and arguably minimizes competition for funding. Moderate to high species richness is found within the geographic scope of the FACT Network (Stuart-Smith et al. 2013), which decreases the potential for overlap of species-based studies. Of the 94 tagged species released in the FACT Network since its inception in 2007, the most intensively studied are the Bull Shark, Lemon Shark, and Blacktip Shark, which have been the subject of seven studies each by FACT-affiliated organizations. However, 81% of species (76 of 94) are under study within only one or two research projects.

The geography and climate in the southeastern USA and the Caribbean are favorable to passive acoustic telemetry studies. Warm to hot summers followed by mild winters allow for extended field seasons and access to submerged telemetry equipment year-round. Most arrays within FACT are roughly aligned on a north–south axis across a recognized climatic transition zone in eastern Florida (Briggs 1974; Gilmore 1995). Many coastal sharks and sport fish migrate seasonally from the U.S. Middle Atlantic Bight to eastern Florida (e.g., Stormer and Juanes 2018). The present configuration of telemetry assets in FACT is well positioned for studies that document these migrations in detail. The importance and geography of the Indian River Lagoon, a 250-km-long estuary on the

![FIGURE 4. Reported reasons for being a member of the FACT Network (n = 67 survey respondents). Members were asked to rank each of the seven reasons on a scale from 1 (most important) to 7 (least important) but were able to rank multiple responses with the same value; therefore, percentages totaled across rows do not necessarily sum to 100%.](image-url)
east coast of Florida, contributed to the formation of FACT, and this area continues to support many studies. The Indian River Lagoon is one of the most diverse estuaries in the continental USA (Gilmore et al. 1983), crosses two climate zones, contains many natural and manmade constrictions (e.g., creek mouths, earthen causeways, and narrow canals), and connects to the Atlantic Ocean by only five narrow inlets. These conditions force mobile species to regularly pass through migratory bottlenecks and have allowed movements of tagged animals to be effectively monitored over great distances and through multiple habitat types with only modest investments in receiver infrastructure.

Strong partnerships with the Southeast Coastal Ocean Observing Regional Association (SECOORA), OTN, and ATN have been critical to the growth of the FACT Network since 2014. As 1 of 11 regional associations established nationwide through the National Oceanic and Atmospheric Administration (NOAA)-led Integrated Ocean Observing System, SECOORA collects real-time and archival oceanographic data and manages the data contributed by SECOORA members. The OTN emerged from two Census of Marine Life projects (TOPP and POST), endeavoring to (1) create a global network of equipment and information about the movement of electronically tagged aquatic species and (2) report and aggregate these data to inform decision makers at all levels of government (O’Dor and Stokesbury 2009). By supporting national and regional efforts to aggregate and standardize animal tracking data collection and reporting, the OTN empowers researchers and provides critical pathways to the publication and dissemination of marine animal data. To date, the OTN has loaned 101 receivers to members of the FACT Network to improve receiver coverage in existing studies or to support new studies. The ATN is a national coordinating group, the goals of which are to build alliances and collaborations amongst researchers and stakeholders, provide telemetry data management through an ATN Data Assembly Center, and support baseline telemetry efforts in the USA.

As a grassroots organization without dedicated funding, FACT has relied largely on the support of partner groups for meeting sponsorship, Web presence, and data processing services. For example, the implementation and maintenance of the cloud-based data sharing system (see Data Sharing and Management Strategy section below) were made possible by the collective efforts of SECOORA, OTN, and ATN. The FACT online data sharing system was created by the OTN and is hosted by SECOORA, which also ensures ongoing compatibility. The OTN created and maintains the database structure and accompanying verification software, accepts feature requests from node managers, and integrates new technologies into the database structure. The ATN provides support for a dedicated FACT data manager to collect, verify, and aggregate researcher data to the database. Additionally, SECOORA hosts the FACT Web site and sponsors FACT meetings along with the OTN.

DATA SHARING AND MANAGEMENT STRATEGY

Acoustic telemetry researchers are increasingly aware of the benefits of sharing telemetry data and that a community that standardizes rules for its membership can encourage participation (Campbell et al. 2016; Nguyen et al. 2017; Hoenner et al. 2018). As researchers organize into larger communities to collaborate, coordinate their field work, design complementary receiver coverage, and cross-reference the resulting data, logistical pressure is applied as a result of the community’s growing data footprint. Sharing between two individuals within a small community is simple, whereas sharing becomes challenging as the number of researchers grows. Technological solutions for handling the high volume of data that are shared between researchers must also adhere to the standards set forth by the community (Nguyen et al. 2017). Likewise, the standardization of metadata and quality control of shared data become critical to a functioning data system. These requirements, although necessary, represent a burden placed on participating members, especially those accepting administrative roles.

Prior to 2017, FACT members practiced person-to-person data sharing, whereby researchers contributed important tag and receiver station metadata to a collective list and shared detection files directly between members. After a receiver download cycle, an array owner consulted the communal tag list to identify the tag owners associated with detections within the array owner’s detection files. At a moderate network size, this system of sharing data to tag owners was effective and common: most FACT members reported that they have received at least some detection data from other network members (35 of 44; 79.5%), and nine members (20.5%) reported that most of their detection data have come from other FACT members (Figure 5). However, this simple, person-to-person data sharing system had two main drawbacks that made it unscaleable with the growth of the FACT Network. First, person-to-person data sharing is labor intensive, forcing large-array owners to send hundreds of files each year. Second, there was no simple way to retroactively search for tags that were not included in the communal list at the time that the array owner initially processed their data (e.g., a situation in which a new member joined FACT who had already deployed tags and requested that partnering researchers retroactively look for data from those tags). In addition, keeping track of detection data formats is challenging when they are contributed from multiple sources. Although most FACT members shared intact
receiver files, an array owner could also choose to provide extracts that only contained the detections associated with specific tags. These extracts were formatted per the array owner; thus, a tag owner could receive files in multiple formats, making it difficult to combine detection files. Array owners also suffered from the challenge of detection data that were stored in multiple locations and formats as their databases grew too large for certain software or as personnel who were tasked with organization of the data changed. Lastly, this system offered no ability to archive or push detection data to public endpoints to satisfy grant requirements and could not ensure the integrity and safelykeeping of telemetry data over time, as is now required under certain government grants and programs.

To address these concerns, in 2018 FACT transitioned to a cloud-based sharing system, termed the “FACT/SECOORA node,” and adopted a data sharing policy to reflect the changes (see https://secoora.org/fact/resources/fact-user-agreement/ for the most recent data policy). The transition to the node allowed FACT to function as a data sharing platform, making data sharing cost effective and convenient without associated scaling issues. The OTN began open dissemination of this system in spring 2015 and continues to maintain a public database framework that can be used to create autonomous versions of the online system that are suitable for data aggregation and management of regional data sharing networks. In an OTN node, user-contributed data are loaded into self-contained project schemas, and quality-controlled final representations of all data and metadata components are inherited into an aggregated schema after verification. The aggregated schema can then be used to generate authoritative summaries for Web and data products. For tag owners, detection extract files are generated and disseminated privately, giving researchers a complete summary of every location where their tags have been detected across all node-held stations without requiring publication of their tag data. This principle of project schema inheritance along with the identical data structures also allows for tag matching across all OTN-structured nodes. Subsets of data that are deemed publishable can be expressed in exchange-ready formats expected by other partner networks via a pair of popular Web-based, geospatially aware data portals (the Open Geospatial Consortium’s GeoServer and NOAA’s ERDDAP server) if the tag project principal investigators choose to do so.

Document management is a crucial component of the FACT/SECOORA node as a place where researchers upload data and metadata and access the resulting data products in project folders via a secure Web site (www.researchworkspace.com). Projects are divided by type (array or tag), and each has granular data access permissions that allow for multiple collaborations while maintaining appropriate privacy within each project group. All project leaders are required to submit project metadata forms, which provide general discovery information about the project and contact information for the initial set of collaborators. Specific to project type, array owners contribute detection files (e.g., .vrl files) and deployment metadata, which describe the spatial and temporal components of the detection file. Tag owners contribute tag metadata similar to what was collected in the former communal list but with additional information (e.g., release coordinates). Project metadata forms are only submitted once and updated only when necessary, whereas all other forms (e.g., receiver and tagging metadata forms) are continually submitted as project managers download receivers and/or deploy tags. Forms may be filled out via a template or through export functions of the Vemco Biotelemetry User Database (termed “the VEMBU”), a Microsoft Access database that was designed to standardize, quality control, and organize receiver and tag metadata and that is named after a dear friend of many FACT members, Vembu Subramanian of SECOORA (see Acknowledgments).

Cumulative detection files, separated by year, are maintained in the project folders along with submitted metadata. The array owner detection file contains all detections from that array, appended with the project code and species matched to each detection. The tag owner detection file contains all detections matched to the owner’s tags, noted with the contributor of the detection. When a tag-detection match occurs, a new detection file is created and the array and tag owner(s) are notified via email.

FIGURE 5. (A) Percentage of detection data that FACT Network members have received from other members of the network; and (B) total number of detection files that organizations have shared with other researchers since becoming members of the FACT Network.
April 2019, the FACT/SECOORA node represents one of the largest aggregates of acoustic telemetry data within the USA. The node currently houses 129.5 million detections, including 52.1 million verified tag detections matched to tagged animals, 13.6 million unmatched detections (e.g., yet-to-be-resolved and false detections), and 63.7 million nonanimal (e.g., sentinel or test tag) detections from 7,996 individual deployments at 1,842 stations. Metadata from 5,979 tags have been registered in the database. The size and scope of the FACT/SECOORA node are expected to grow as historic data are uploaded and more FACT members adopt this online, semi-automated system.

APPLICATION OF TELEMETRY DATA FROM THE FACT NETWORK

Ongoing and recently completed tracking studies now provide empirical examples as to the benefit of partnership in FACT and other regional telemetry networks. In numerous instances, data sharing across researchers in the southeastern USA has resulted in dramatic increases in data richness (e.g., greater numbers of detections and locations per animal) and the geographic extent of animal tracks (Table 1). These partnerships also generally extend the duration of animal tracks and can even result in a higher percentage of tagged animals being detected. Although the effect is observed across species with diverse life history strategies, the benefit is greatest for studies of mobile coastal species that are known to undertake seasonal migrations. This data sharing has also been critical in describing the migratory nature of species such as the Atlantic Tripletail Lobotes surinamensis and Atlantic Goliath Grouper Epinephelus itajara, for which long-distance coastal movements were not previously recognized (Ellis et al. 2014; C. Kalinowsky, Georgia Department of Natural Resources, personal communication).

Despite the potential application of acoustic telemetry to aid in fisheries management through detailed information about species movements, relatively few examples can be found in the published literature (Crossin et al. 2017). Here, we highlight a few notable examples, based on personal communications with FACT members, where acoustic telemetry data directly informed management decisions on a variety of species, including endangered, threatened, and recreationally and commercially important fishes.

- Telemetry data were used to designate new “habitat area of particular concern” (HAPC) protection for Sand Tigers Carcharias taurus in Massachusetts and Lemon Sharks in southeastern Florida (Rauch 2017). These represent two of only three species of sharks with HAPC protection in the U.S. Atlantic.
- Telemetry data from Cobia Rachycentron canadum were used to describe exchange between the Atlantic and Gulf of Mexico stocks as part of a stock assessment. Specifically, movement data collected within FACT were used to support retaining the existing stock line at the Florida–Georgia border (NOAA Fisheries 2018).
- Survival estimates based on movement data for Common Snook were used to reopen the harvest season on Florida’s eastern coast earlier than the western coast after a historic and statewide cold kill in 2010 (Stevens et al. 2016).
- Arrival time to spawning sites by Permit Trachinotus falcatus, as inferred from acoustic telemetry, was used to refine the harvest season for the species (Brown-scombe et al. 2019).
- Twenty-year extension of a no-take reserve in the Dry Tortugas National Park by FWC commission was granted in part due to movement data on Mutton Snapper Lutjanus analis and Nurse Sharks Ginglymostoma cirratum (Feeley et al. 2018; Pratt et al. 2018).
- Acoustic telemetry data from the FACT Network helped to define critical habitat for ESA-listed Atlantic Sturgeon (Fox et al. 2018). Additionally, movements of threatened Gulf Sturgeon Acipenser oxyrinchus desotoi were used to set minimum flow levels for the Suwannee River (Mike Randall, U.S. Geological Survey, Wetland and Aquatic Research Center, personal communication).

CHALLENGES OF ACOUSTIC TELEMETRY

There are important limitations to consider when employing acoustic telemetry to study animal movements, including intermittent spatial receiver coverage, temporal discontinuity of receiver deployments, and a lack of tool development for analysis of acoustic telemetry data. Tagged animals must pass within a certain distance of a receiver, typically less than 1 km, meaning that animal observations are limited to the placement of static receivers (e.g., Kessel et al. 2014). Ninety-four percent (n = 1,303) of the receiver stations within the FACT Network are less than 30 m deep, thereby limiting observations to semi-nearshore environments. Although receivers mounted on mobile platforms (e.g., Wave Gliders; Liquid Robotics, Sunnyvale, California) and deployments of specialized deepwater static receivers have increased our capacity to monitor deep water (Lembke et al. 2018), they represent a very small proportion of telemetry assets in the FACT Network.

Maintaining the temporal continuity of arrays within the network is hindered by a lack of centralized, dedicated funding. Deployment of an array is dependent upon the finances of the organization that maintains it, and array
maintenance can be costly. Vessel costs, SCUBA dive equipment and tank refills, mooring hardware, receiver repair costs, and personnel time needed to download receivers on an annual or semi-annual basis can range from US$200 to $1,000 per receiver station per download (FWC–FWRI, unpublished data, based on the FWC–FWRI’s Tequesta Laboratory nearshore array). This results in a dynamic network structure as arrays are established and decommissioned due to shifting research priorities, funding constraints, and/or the completion of projects (e.g., Cowley et al. 2017; Steckenreuter et al. 2017). Within the FACT Network, 402 receiver locations have been retired between 2007 and 2019, representing 27% of the current network. Dedicated funding for critical receiver locations would increase the effectiveness of tracking by providing a core infrastructure to consistently record tag presence over time. Recognizing this need, the ATN implemented five new projects in fiscal year 2018 aimed at strengthening the existing U.S. marine animal telemetry observation and data management infrastructure. These projects included funding the offshore portion of the FACT-affiliated St. Simons Sound Coastal Receiver Array (Georgia Department of Natural Resources) plus support for a dedicated data manager for each of the FACT and ACT networks. To help prioritize areas of critical receiver coverage, methods to evaluate the importance of a receiver location have emerged to assist researchers in determining critical areas within their array (e.g., Cowley et al. 2017; Steckenreuter et al. 2017; Ellis et al. 2019). However, the importance of receiver stations may differ among tag owners and consensus on qualitative metrics is needed.

The advancement of biotelemetry tags has given rise to a suite of analytical techniques for studying animal movement. However, more widely available and user-friendly tools to analyze and visualize acoustic telemetry data are needed. Available programs (e.g., VTrack: Campbell et al. 2012; GLATOS: Holbrook et al. 2017) require knowledge of advanced software, such as ArcGIS, PostGIS, R, SAS, MatLab, and Java, which may be challenging for researchers who are new to telemetry or those who are not versed in the required software. The FACT Network has been working closely with the OTN, Axiom Data Science, and ATN to develop more capable and intuitive analysis and visualization tools (e.g., DiveBomb and resonate) and to aggregate useful resources in a single warehouse.

**FUTURE OF THE FACT NETWORK**

The continued success of the FACT Network will depend on how effectively it can adapt to changing needs and conditions in the scientific landscape. Of the 67 FACT members that responded to the survey, 62 (92.5%) foresee using acoustic telemetry technology for the next 5 years, suggesting that membership will, at a minimum, remain stable. Several areas for potential change within the network were identified by FACT members in the survey, including reorganization of the network structure, reaching group consensus on field operating procedures, and expanding the role of the network to include public outreach and communication.

Through survey responses, FACT members expressed interest in the development of the technology and commented on the future of FACT. Among the 67 survey respondents, 41 (61.2%) identified the need for continuously improving technology and offered suggestions on how tags and receivers could be improved. Specific suggestions included quicker tag transmission rates to reduce signal collisions that result in data loss or spurious detections (when a receiver hears two distinct tag transmissions simultaneously and cannot interpret either tag code), longer battery life and/or rechargeable batteries, an increased variety of sensor options for both tags and receivers with high measurement accuracy, and improved detection efficiency in noisy environments. The necessity for both tags and receivers to become more cost effective was petitioned by 17% of FACT member respondents, and a few members requested more integration between different technologies among manufacturers. Improving communication between the networks and industry will decrease the uncertainty of revenue projections for manufacturers and direct research and development of products that are desirable to network members. Additionally, in answer to a free-response question about the telemetry industry, 20.5% of respondents expressed a desire for increased competition between telemetry manufacturers to bring down prices and improve the technology.

Methods for deployment of acoustic telemetry equipment and array structure depend on the scientific purpose of the study (e.g., capture, migration, or fidelity), species of interest (e.g., bottom- or top-dwelling animal), surrounding habitat (e.g., depth, bottom type, and flow), and use of the area (e.g., area commonly trawled). Diverse environments require equally diverse methods; however, standardization of field operating procedures would increase productivity within individual projects by reducing the time and energy required to design and fabricate attachment devices. The FACT Network is an excellent forum in which to create a best practices document for field deployment techniques and metadata collection, potentially resulting from an extended workshop during a future FACT meeting.

Until recently, FACT has functioned to support the scientific community, with minimal effort toward public outreach due to modest funding availability. Because acoustic telemetry results have the potential to impact society (e.g., in the establishment of no-take zones and modification of harvest regulations), it is imperative to bridge the gap
between scientists and the communities they serve. As evidence of this growing need, some funding agencies require a public outreach component in research proposals, including a guarantee of the public dissemination of data (e.g., NOAA–EDMC 2016). The newly implemented cloud-based data sharing system employed by FACT allows data to flow to public endpoints with the permission of the principal investigator(s). Reluctance to share data publicly is attributable to confidentiality concerns, a sense of individual ownership, concerns over inadequate sharing standards and protocols, a lack of incentive or perceived benefits, and unfamiliarity with how to register data with public sites (Ferguson et al. 2014; Nguyen et al. 2017; Campbell et al. 2019). Potential misuse of telemetry data creates competing ethical obligations: one to make data available to the public and the other to protect the animals and environment within a study. Recently, scientists have warned of how published location data may be used to poach animals or increase the effectiveness of capture (e.g., Cooke et al. 2017). Debate on the appropriateness of timing, resolution, and completeness of published location data (Lindenmayer and Scheele 2017; Lindenmayer et al. 2017) continues with limited consensus. Tulloch et al. (2018) presented a decision-making tree based on the risks and benefits of publishing species identifiers and location. Fishing spawning aggregations—the subject of many studies within the FACT Network—warranted the most restrictive protocol for masking species and location information based on the decision-making tree. As a community of researchers, the FACT Network supports normative pressure for the public dissemination of data while encouraging conversation and evolving data sharing agreements that answer the concerns of scientists. Communication between researchers, stakeholders, and lawmakers to identify the specific goals and legal obligations of making telemetry data public and discussion as to how that goal may be achieved without causing undue harm to study animals or the environment are critical to moving forward in publishing location data in public forums.

Public outreach and communication typically include summarization and interpretation of results to a lay audience as opposed to dissemination of entire data sets to a publicly accessible Web site (Heagerty 2015), a skill that many scientists feel ill-equipped to successfully accomplish (Ecklund et al. 2012). As a potential remedy, FACT biannual meetings could serve as a platform for science communication training while enlisting the help of stakeholders with expertise in the communication of scientific results to engage the public through the FACT Web site and social media. The FACT Web site (www.secoora.org/FACT) was designed with the goal of serving a public audience. Future funding to improve FACT Web presence under the guidance of science communicators is key for the public outreach goal to be fully realized.

Creating an organizational structure within FACT that preserves the group consensus will facilitate future planning and growth. A standing steering committee may be needed as the network faces major decisions and actions, such as registering as a nonprofit organization, grant solicitation, member-to-member conflicts, and coordinating large-scale synthesis manuscripts. To maintain a philosophy of inclusion, representatives on the steering committee would include students, fisheries managers, government researchers, and the private sector. Recommendations by the steering committee would be presented to the entire network for discussion. Given the current speed at which FACT is growing in membership and geographical scale, increased organizational structure will be critical to addressing the changing community and data standards and to maximizing the effectiveness of research within the network.

**DISCUSSION**

Across the globe, telemetry networks function to facilitate the use of telemetry data to inform species and habitat management across large spatial scales, often crossing jurisdictional lines. Independent networks have been established in Australia (Integrated Marine Observing System), Europe (ETN), the USA (ATN), and South Africa (Acoustic Tracking Array Platform), several of which are connected by the OTN, a global network operating in several countries. These networks serve multiple purposes, including aggregating and standardizing data (e.g., Hoenner et al. 2018), providing detection matching between tag owners and array owners (e.g., Cooke et al. 2011), organizing regional efforts (e.g., Cowley et al. 2017; Abecasis et al. 2018), and providing archival services to hold data in legacy for future researchers (e.g., Block et al. 2016). Regional networks provide some to all of the same services on scales that reflect the heterogeneous geography and scientific and management needs in the USA.

Regional collaborative networks are vital to the organization and support of researchers using acoustic telemetry. The FACT work group formed in an effort to benefit neighboring projects in Florida and grew into the FACT Network, which serves the U.S. South Atlantic, Bahamas, and Caribbean. A growing number of research questions based on animal movement is emerging as a result of advances in collaboration, data sharing, and technology. The FACT Network is poised to facilitate future large-scale collaborations that tackle these questions as well as encourage cross-disciplinary collaboration on small and large spatial scales through community-level activism and pioneering participation in cloud-based data sharing and archiving. The FACT Network is dedicated to working with other regional, national, and international networks to accomplish a singular goal of broadening our understanding of animal movements: Because fish move. Fact.
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REFERENCES

Abecasis, D., A. Stecknreuter, J. Reubens, K. Aarestrup, J. Alós, F. Badalamenti, L. Bajona, P. Boylan, K. Deneudt, L. Greenberg, and N. Brevé. 2018. A review of acoustic telemetry in Europe and the need for a regional aquatic telemetry network. Animal Biotelemetry [online serial] 6:12.

Adams, A. J., J. M. Shenker, Z. R. Jud, J. P. Lewis, E. Carey, and A. J. Danylchuk. 2019. Identifying pre-spawning aggregation sites for Bonefish (Albula vulpes) in the Bahamas to inform habitat protection and species conservation. Environmental Biology of Fishes 102:159–173.

Bertelsen, R. D., and J. Hornbeck. 2009. Using acoustic tagging to determine adult spiny lobster (Panulirus argus) movement patterns in the western Sambo Ecological Reserve (Florida, United States). New Zealand Journal of Marine and Freshwater Research 43:35-46.

Block, B. A., C. M. Holbrook, S. E. Simmons, K. N. Holland, J. S. Ault, D. P. Costa, B. R. Mate, A. C. Seitz, M. D. Arendt, J. C. Payne, B. Mahmoudi, P. Moore, J. M. Price, J. J. Levenson, D. Wilson, and R. E. Kochevar. 2016. Toward a national animal telemetry network for aquatic observations in the United States. Animal Biotelemetry [online serial] 4:6.

Block, B. A., R. Whitlock, R. J. Schallert, S. Wilson, M. J. W. Stokesbury, M. Castleton, and A. Boustany. 2019. Estimating natural mortality of Atlantic Bluefin Tuna using acoustic telemetry. Scientific Reports [online serial] 9:4918.

Briggs, J. C. 1974. Marine zoogeography. McGraw-Hill, New York.

Browncombe, J. W., A. J. Adams, N. Young, L. P. Griffin, P. E. Holder, J. Hunt, A. Acosta, D. Morley, R. Boucek, and S. J. Cooke. 2019. Bridging the knowledge-action gap: a case of research rapidly impacting recreational fisheries policy. Marine Policy 104:210–215.

Campbell, H. A., M. A. Micheli-Campbell, and V. Udyawar. 2019. Early career researchers embrace data sharing. Trends in Ecology and Evolution 34:95–98.

Campbell, H. A., F. Urbano, S. Davidson, H. Dettki, and F. Cagnacci. 2016. A plea for standards in reporting data collected by animal-borne electronic devices. Animal Biotelemetry [online serial] 4:1.

Campbell, H. A., M. E. Watts, R. G. Dwyer, and C. E. Franklin. 2012. V-Track: software for analyzing and visualizing animal movement from acoustic telemetry detections. Marine and Freshwater Research 63:815–820.

Cooke, S. J., S. J. Iverson, M. J. Stokesbury, S. G. Hinch, A. T. Fisk, D. L. VanderZwaag, R. Apostle, and F. Whoriskey. 2011. Ocean Tracking Network Canada: a network approach to addressing critical issues in fisheries and resource management with implications for ocean governance. Fisheries 36:583–592.

Cooke, S. J., V. M. Nguyen, S. T. Kessel, N. E. Hussey, N. Young, and A. T. Ford. 2017. Troubling issues at the frontier of animal tracking for conservation and management. Conservation Biology 31:1205–1207.

Cote, D., J.-M. Nicolas, F. Whoriskey, A. M. Cook, J. Broome, P. M. Regular, and D. Baker. 2018. Characterizing snow crab (Chionoecetes opilio) movements in the Sydney Bight (Nova Scotia, Canada): a collaborative approach using multiscale acoustic telemetry. Canadian Journal of Fisheries and Aquatic Sciences 76:334–346.

Cowley, P. D., R. H. Bennett, A. R. Childs, and T. S. Murray. 2017. Reflection on the first five years of South Africa’s Acoustic Tracking Array Platform (ATAP): status, challenges and opportunities. African Journal of Marine Science 39:363–372.

Crossin, G. T., M. R. Heupel, C. M. Holbrook, N. E. Hussey, S. K. Lowerre-Barbieri, V. M. Nguyen, G. D. Raby, and S. J. Cooke. 2017. Acoustic telemetry and fisheries management. Ecological Applications 27:1031–1049.

Currier, R., B. Kirkpatrick, C. Simonelli, S. Lowerre-Barbieri, and J. Bickford. 2015. ITAG: developing a cloud based, collaborative animal tracking network in the Gulf of Mexico. Pages 1–3 in OCEANS15 MTS/IEEE. Institute of Electrical and Electronics Engineers, Piscataway, New Jersey.

Delgado, G. A., and R. A. Glazer. 2007. Interactions between translocated and native queen conch Strombus gigas: evaluating a restoration strategy. Endangered Species Research 3:259–266.

Ecklund, E. H., S. A. James, and A. E. Lincoln. 2012. How academic biologists and physicists view science outreach. PLoS (Public Library of Science) One [online serial] 7:e36240.

Ellis, R. D., K. E. Flaherty-Walia, A. B. Collins, J. W. Bickford, R. Boucek, S. L. W. Burns, and S. K. Lowerre-Barbieri. 2019. Acoustic telemetry array evolution: from species- and project-specific designs to large-scale, multispecies, cooperative networks. Fisheries Research 209:186–195.

Ellis, R. D., C. Koenig, and F. Coleman. 2014. Spawning-related movement patterns of Goliath Grouper (Epinephelus itajara) off the Atlantic coast of Florida. Proceedings of the Gulf and Caribbean Fisheries Institute 66:395–400.

Feeley, M. W., D. Morley, A. Acosta, P. Barbera, J. Hunt, T. Switzer, and M. Burton. 2018. Spawning migration movements of Mutton Snapper in Tortugas, Florida: spatial dynamics within a marine reserve network. Fisheries Research 204:209–223.

Ferguson, A. R., J. L. Nielson, M. H. Cragin, A. E. Bandrowski, and M. E. Martone. 2014. Big data from small data: data-sharing in the neuroscience. Nature Neuroscience 17:1442.

Fox, A. G., I. I. Wirgin, and D. L. Peterson. 2018. Occurrence of Atlantic Sturgeon in the St. Marys River, Georgia. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem. Science [online serial] 10:606–618.

Gilmore, R. G. 1995. Environmental and biogeographic factors influencing ichthyofaunal diversity: Indian River Lagoon. Bulletin of Marine Science 57:153–170.

Gilmore, R., J. Dodrill, and P. Linley. 1983. Reproduction and embryonic development of the Sand Tiger Shark, Odontaspis taurus (Rafinesque). U.S. National Marine Fisheries Service Fishery Bulletin 81:201–225.
Glazer, R. A., G. A. Delgado, and J. A. Kidney. 2003. Estimating queen conch (Strombus gigas) home ranges using acoustic telemetry: implications for the design of marine fishery reserves. Gulf and Caribbean Research 14:79–89.

Harcourt, R., A. M. Martins Sequeira, X. Zhang, F. Rouquet, K. Komatsu, M. Heupel, C. R. McMahon, F. G. Whoriskey, M. Meekan, G. Carroll, S. Brodie, C. Simpfendorfer, M. Hindell, I. Jonsen, D. P. Costa, B. Block, M. Muelbert, B. Woodward, M. Weise, K. Aarestrup, M. Biuw, L. Boehme, S. J. Bogard, D. Cazau, J. Charrassin, S. J. Cooke, P. Cowley, P. J. de Bruyn, T. J. du Dot, C. Duarte, V. M. Egiluz, L. C. Ferreira, J. Fernández-Gracia, K. Goetz, Y. Goto, C. Guinet, M. Hammill, G. C. Hays, E. L. Hazen, L. A. Huchstätt, C. Huveneers, S. Iverson, S. A. Jaaman, K. Kittiwatthanawong, K. M. Kovacs, C. Lyonsen, T. Moltmann, M. Naruka, L. Philips, B. Picard, N. Queiroz, G. Reverdin, K. Sato, D. W. Sims, E. B. Thorstad, M. Thums, A. M. Treasure, A. W. Trites, G. D. Williams, Y. Yonehara, and M. A. Fedak. 2019. Animal-borne telemetry: an integral component of the ocean observing toolkit. Frontiers in Marine Science 6:326.

Hart, K. M., A. R. Sartain, I. Fujisaki, H. L. Pratt Jr., D. Morley, and M. W. Feeley. 2012. Home range, habitat use, and migrations of hawksbill turtles tracked from Dry Tortugas National Park, Florida, USA. Marine Ecology Progress Series 457:193–207.

Heagerty, B. 2015. Dissemination does not equal public engagement. Journal of Neuroscience 35:4483–4486.

Hoeman, X., C. Huveneers, A. Steckenuer, C. Simpfendorfer, K. Tattersall, F. Jaine, N. Atkins, R. Babcock, S. Brodie, J. Burgess, H. Campbell, M. Heupel, B. Pasquer, R. Proctor, M. D. Taylor, V. Udyawer, and R. Harcourt. 2018. Australia’s continental-scale acoustic tracking database and its automated quality control process. Scientific Data 5:170206.

Holbrook, C., T. Hayden, and T. Binder. 2017. glatos: a package for the Great Lakes acoustic telemetry observation system. Available: https://gitlab.oceantrack.org/GreatLakes/glatos.git. (December 2019).

Humston, R., J. S. Ault, M. F. Larkin, and J. Luo. 2005. Movements and site fidelity of the Bonefish Albula vulpes in the northern Florida Keys determined by acoustic telemetry. Marine Ecology Progress Series 291:237–248.

Hussey, N. E., S. T. Kessel, K. Aarestrup, S. J. Cooke, P. D. Cowley, A. T. Fisk, R. G. Harcourt, K. N. Holland, S. J. Iverson, and J. F. Kocik. 2015. Aquatic animal telemetry: a panoramic window into the underwater world. Science 348:1255642.

Kessel, S. T., S. J. Cooke, M. R. Heupel, N. E. Hussey, C. A. Simpfendorfer, S. Vague, and A. T. Fisk. 2014. A review of detection range testing in aquatic passive acoustic telemetry studies. Reviews in Fish Biology and Fisheries 24:199–218.

Kohler, N. E., J. G. Casey, and P. A. Turner. 1998. NMFS cooperative shark tagging program, 1962–1993: an atlas of shark tag and recapture data. Marine Fisheries Review 60:1–87.

Kohler, N. E., and P. A. Turner. 2001. Shark tagging: a review of conventional methods and studies. Environmental Biology of Fishes 60:191–223.

Kruenger, C. C., C. M. Holbrook, T. R. Binder, C. S. Vangervoot, T. A. Hayden, D. W. Hondorp, N. Nate, K. Paige, S. C. Riley, A. T. Fisk, and S. T. Cooke. 2018. Acoustic telemetry observation systems: challenges encountered and overcome in the Laurentian Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences 75:1755–1763.

Landry, J. J., S. T. Kessel, M. F. McLean, S. V. Ivanova, N. E. Hussey, C. O’Neill, S. Vague, T. A. Dick, and A. T. Fisk. 2018. Movement types of an Arctic benthic fish, Shorthorn Sculpin (Myoxocephalus scorpius), during open-water periods in response to biotic and abiotic factors. Canadian Journal of Fisheries and Aquatic Sciences 76:626–635.

Lembke, C., S. Lowerre-Barbieri, D. Mann, and J. C. Taylor. 2018. Using three acoustic technologies on underwater gliders to survey fish. Marine Technology Society Journal 52:39–52.

Lindemayer, D., G. Elmhke, and B. Scheele. 2017. Publish openly but responsibly—response. Science 357:142–143.

Lindemayer, D., and B. Scheele. 2017. Do not publish. Science 356:800–801.

Lindholm, J., L. Kaufman, S. Miller, A. Wagschal, and M. Newville. 2005. Movement of Yellowtail Snapper (Ocyurus chrysurus Block 1790) and Black Grouper (Mycteroperca bonaci Poey 1860) in the northern Florida Keys National Marine Sanctuary as determined by acoustic telemetry. National Oceanic and Atmospheric Administration, National Ocean Service, Marine Sanctuaries Division, Silver Spring, Maryland.

Lowerre-Barbieri, S. K., F. E. Vose, and J. A. Whittington. 2003. Catch-and-release fishing on a spawning aggregation of Common Snook: does it affect reproductive output? Transactions of the American Fisheries Society 132:940–952.

Lydersen, C. 1991. Monitoring ringed seal (Phoca hispida) activity by means of acoustic telemetry. Canadian Journal of Zoology 69:1178–1182.

Mayrose, I., and S. Freilich. 2015. The interplay between scientific overlap and cooperation and the resulting gain in co-authorship interactions. PLoS ONE [online serial] 10:e0157856.

Nguyen, V. M., J. L. Brooks, N. Young, R. J. Lennox, N. Haddaway, F. G. Whoriskey, R. Harcourt, and S. J. Cooke. 2017. To share or not to share in the emerging era of big data: perspectives from fish telemetry researchers on data sharing. Canadian Journal of Fisheries and Aquatic Sciences 74:1260–1274.

NOAA-EDMC (National Oceanic and Atmospheric Administration–Environmental Data Management Committee). 2016. Data sharing directive for NOAA grants, cooperative agreements, and contracts, version 3.0. Available: https://www.nos.noaa.gov/EDMC/PD.DSP.php (February 2016).

NOAA (National Oceanic and Atmospheric Administration) Fisheries. 2018. SEDAR 58 Atlantic Cobia benchmark assessment: Cobia stock ID workshop overall recommendations. NOAA Fisheries, Southeast Fisheries Science Center, Miami.

O’Dor, R. K., and M. J. W. Stokesbury. 2009. The Ocean Tracking Network—adding marine animal movements to the global ocean observing system. Pages 91–100 in J. L. Nielsen, H. Arrizabalaga, N. Fragozo, A. Hobday, M. Lutcavage, and J. Sibert, editors. Tagging and tracking of marine animals with electronic devices. Springer, Dordrecht, The Netherlands.

Pittman, S. J., M. E. Monaco, A. M. Friedlander, B. Legare, R. S. Nemeth, M. S. Kendall, M. Poti, R. D. Clark, L. M. Wedding, and C. Caldow. 2014. Fish with chips: tracking reef fish movements to evaluate size and connectivity of Caribbean marine protected areas. PLoS ONE [online serial] 9:e96028.

Pratt, H. L., T. C. Pratt, D. Morley, S. Lowerre-Barbieri, A. Collins, J. C. Carrier, K. M. Hart, and N. M. Whitney. 2018. Partial migration of the Nurse Shark, Ginglymostoma cirratum (Bonaparte), from the Dry Tortugas Islands. Environmental Biology of Fishes 101:515–530.

Rauch, S. D. III. 2017. Amendment 10 Atlantic highly migratory species; essential fish habitat. National Marine Fisheries Service, Washington, D.C.

Reyier, E. A., B. R. Franks, D. D. Chapman, D. M. Scheidt, E. D. Stolen, and S. H. Gruber. 2014. Regional-scale migrations and habitat use of juvenile Lemon Sharks (Negaprion brevirostris) in the U.S. South Atlantic. PLoS ONE [online serial] 9:e88470.

Reyier, E. A., R. H. Lowers, D. M. Scheidt, and D. H. Adams. 2011. Movement patterns of adult Red Drum, Sciaenops ocellatus, in shallow Florida lagoons as inferred through autonomous acoustic telemetry. Environmental Biology of Fishes 90:343–360.

Rosenblatt, A. E., and M. R. Heithaus. 2011. Does variation in movement tactics and trophic interactions among American alligators create habitat linkages? Journal of Animal Ecology 80:786–798.
Saunders, R. A., F. Royer, and M. W. Clarke. 2011. Winter migration and diving behaviour of Porbeagle Shark, Lamna nasus, in the north-east Atlantic. ICES Journal of Marine Science 68:166–174.

Scales, K. L., J. A. Lewis, J. P. Lewis, D. Castellanos, B. J. Godley, and R. T. Graham. 2011. Insights into habitat utilisation of the hawksbill turtle, Eretmochelys imbricata (Linnaeus, 1766), using acoustic telemetry. Journal of Experimental Marine Biology and Ecology 407:122–129.

Steckenreuter, A., X. Hoenner, C. Huveneers, C. Simpfendorfer, M. J. Buscot, K. Tattersall, R. Babcock, M. Heupel, M. Meekan, J. Van Den Broek, and P. McDowall. 2017. Optimising the design of large-scale acoustic telemetry curtains. Marine and Freshwater Research 68:1403–1413.

Stevens, P. W., D. A. Blewett, R. E. Boucek, J. S. Rehage, B. L. Winner, J. M. Young, J. A. Whittington, and R. Paperno. 2016. Resilience of a tropical sport fish population to a severe cold event varies across five estuaries in southern Florida. Ecosphere [online serial] 7:e01400.

Stieglitz, T. C., and A. M. Dujon. 2017. A groundwater-fed coastal inlet as habitat for the Caribbean queen conch Lobatus gigas—an acoustic telemetry and space use analysis. Marine Ecology Progress Series 571:139–152.

Stormer, D. G., and F. Juanes. 2018. Overwinter habitat use, feeding habits and energetics of juvenile Bluefish in the northern Florida coastal ocean. Estuaries and Coasts 41:1422–1435.

Stuart-Smith, R. D., A. E. Bates, J. S. Lefcheck, J. E. Duffy, S. C. Baker, R. J. Thomson, J. F. Stuart-Smith, N. A. Hill, S. J. Kininmonth, and L. Airola. 2013. Integrating abundance and functional traits reveals new global hotspots of fish diversity. Nature 501:539–542.

Thorstad, E. B., S. E. Kerwath, C. G. Atwood, F. Okland, C. G. Wilke, P. D. Cowley, and T. F. Nesje. 2009. Long-term effects of two sizes of surgically implanted acoustic transmitters on a predatory marine fish (Pomatomus saltatrix). Marine and Freshwater Research 60:183–186.

Trefethen, P. S. 1956. Sonic equipment for tracking individual fish. U.S. Fish and Wildlife Service Special Scientific Report Fisheries 179.

Tulevech, S. M., and C. W. Recksie. 1994. Acoustic tracking of adult White Grunt, Haemulon plumieri. Puerto Rico and Florida. Fisheries Research 19:301–319.

Tulloch, A. I. T., N. Auerbach, S. Avery-Gomm, S. Bayratarov, N. Butt, C. R. Dickman, G. Ehmke, D. O. Fisher, H. Grantham, M. H. Holden, T. H. Lavery, N. P. Leesberg, M. Nicholls, J. O’Connor, L. Roberson, A. K. Smyth, Z. Stone, V. Tulloch, E. Turak, G. M. Wardle, and J. E. Watson. 2018. A decision tree for assessing the risks and benefits of publishing biodiversity data. Nature Ecology and Evolution 2:1209–1217.

Whitcraft, S. R., B. Richards, J. Lamkin, T. Gerard, T. Carlson, G. McMichael, J. Vucelick, G. Williams, and L. Pytka. 2007. Developing shallow-water acoustic telemetry methods for juvenile snapper habitat studies in the Florida Keys National Marine Sanctuary. Bulletin of Marine Science Miami 80:935.

Wiggers, R. K. 2010. South Carolina marine game fish tagging program 1978–2009. South Carolina Department of Natural Resources, Charleston.

Young, J. M., B. G. Yeiser, E. R. Ault, J. A. Whittington, and J. Dutka-Gianelli. 2016. Spawning site fidelity, catchment, and dispersal of Common Snook along the east coast of Florida. Transactions of the American Fisheries Society 145:400–415.

Young, J. M., B. G. Yeiser, and J. A. Whittington. 2014. Spatiotemporal dynamics of spawning aggregations of Common Snook on the east coast of Florida. Marine Ecology Progress Series 505:227–240.