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Acoustic telemetry array evolution: From species- and project-specific designs to large-scale, multispecies, cooperative networks

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ABSTRACT

Acoustic telemetry is a powerful tool for investigating the movement ecology of aquatic animals. As the number of studies using passive acoustic telemetry technology has grown in recent years, so has membership in regional collaborative networks in which methodologies and detection data are shared among researchers. These networks can significantly augment research projects by increasing the geographic coverage of detection data beyond the initial monitored area, and encourage the development of research collaborations with the goal of improving aquatic research management. As tags expire and projects end, researchers must decide whether to maintain their receiver stations, adjust the configuration to accommodate a new scope of research, or remove the stations. We assessed telemetry data from two projects designed to monitor fishes in nearshore and offshore habitats of the eastern Gulf of Mexico to determine the configuration of receiver stations most informative for network scale monitoring. Modeled on the Index of Relative Importance commonly used to analyze fish diets, the Receiver Efficiency Index (REI) allowed us to reduce the size of the two arrays from 59 to 24 and 33 to 21 stations, reductions of 59% and 27%, while retaining more than 75% of all detections. The application of this method has general relevance to understanding the spatial dynamics of these arrays while providing researchers with a quantitative tool to guide decision making that can maximize spatial coverage at the lowest maintenance cost.

1. Introduction

Through technological improvements, the capacity to track aquatic animals using passive acoustic telemetry has improved tremendously over the past 20 years. Passive acoustic telemetry—the use of acoustic monitors capable of recording the presence of animals tagged with acoustic transmitters (Heupel et al., 2006)—allows researchers to track aquatic animals at unprecedented spatial and temporal resolutions. By providing nearly continuous data for tagged animals within the detection range of receivers, passive tracking is useful for determining site fidelity and spatial and temporal behaviors that are difficult to assess with commonly used external tagging methods (Pecl et al., 2006; Lowerre-Barbieri et al., 2013; Ajemian et al., 2018). As acoustic monitoring technology has advanced, so has the affordability of equipment, allowing it to become commonplace in many research disciplines, including fisheries science, ecology, and conservation (Hussey et al., 2015).

With the growing use of this technology, the spatial coverage of passive acoustic telemetry has expanded from a few distinct and geographically isolated areas to regional networks of arrays (Hussey et al., 2015). The monitoring capabilities afforded by widespread use of common technology presents opportunities for new research facilitated through collaborations among researchers that share data beyond the scope of individual initiatives. Researchers can now maximize data collection by expanding passive acoustic arrays and combining efforts to better understand the spatiotemporal patterns of animal movements (Ellis et al., 2014; Guttridge et al., 2017; Pratt et al., 2018; Crossin et al., 2017). As aquatic telemetry networks evolve there is a need to

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address broader issues in terms of spatial coverage including the maintenance of deployed receivers for consistent monitoring, identifying gaps in coverage, and deploying new receivers in key habitats to build monitoring capacity at the regional or Large Marine Ecosystem scale (Lowerre-Barbieri et al., 2017). Furthermore, the shift to collaborative, connected units of passive acoustic arrays and an increased emphasis on leveraging resources will impact future decisions regarding array design and tag deployment. Rather than designing arrays to maximize detections of one or more species of interest, researchers working in conjunction with partners from network organizations may be motivated to consider modified array designs that will also facilitate data collection for their colleagues. Maintaining acoustic telemetry arrays is expensive and time-consuming, and methods that enable researchers to evaluate the cost and benefits of reducing or modifying arrays are needed.

An ongoing challenge for acoustic telemetry networks is to maintain a balance between continuity in spatial coverage while allowing arrays to evolve with changing research objectives. The Integrated Tracking of Aquatic Animals in the Gulf of Mexico (iTAG) network was developed in 2014 so that researchers could share detections across telemetry arrays deployed from Texas to Florida (http://myfwc.com/research/saltwater/telemetry/itag). As of May 2017, iTAG had 85 members from three countries with > 1000 tags and > 2000 receivers deployed across more than 35 arrays deployed throughout the Gulf (Lowerre-Barbieri et al., 2017). The iTAG Data Exchange, an automated, web-based platform designed for the exchange of data between detection collectors and tag owners, provides the ability for data to be shared among researchers within the iTAG network (e.g., Pratt et al., 2018), as well as members of array networks on the east coast of the US, demonstrating the geographic scope and value of this tool.

The growth of passive acoustic telemetry technology and of networks of associated researchers demands novel methodologies to inform decision-making regarding receiver station retention through time and beyond the scope of individual project objectives. In this study, we used data collected by two independent arrays in the iTAG network. Located on the central Gulf coast of Florida and developed by researchers at the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute (FWC/FWRI), these arrays were deployed to monitor red drum (*Sciaenops ocellatus*) in nearshore coastal waters and Atlantic goliath grouper (*Epinephelus itajara*) and gag (*Mycteroperca microlepis*) on natural and artificial reef habitats of the west Florida shelf. We conducted a cross-site comparative study as a proof of concept of a method that provides a quantitative approach to optimizing array configuration based on the detection value of each receiver. The metric we propose is modified from an index commonly used in fish-diet studies, the Index of Relative Importance (IRI; Pinkas et al., 1971; Hart et al., 2002), which we used to provide a weighted and relativized value of the importance of each station in an acoustic array. We applied this method to data collected from two discrete acoustic arrays to demonstrate how this analysis can be applied and interpreted to guide future decisions on array maintenance that will maximize network utility while minimizing effort.

2. Materials and methods

2.1. Acoustic telemetry networks

The two arrays analyzed for this study were located in the eastern Gulf of Mexico and are part of the iTAG network (Fig. 1). The iTAG network seeks to increase and facilitate the capability of researchers in the Gulf to assess movement and spatial ecology of aquatic animals through improved networking, increased infrastructure, and sharing of acoustic transmitter detection data. Data are shared by iTAG members through a web-based platform, the iTAG data exchange, in which members can upload detections from their arrays of non-study species and be notified via email when those tags are claimed by other network members (http://myfwc.com/research/saltwater/telemetry/itag/orphan-tag-database/). Members can also upload a list of their deployed tag numbers and be automatically notified when other members upload detections of those tags. The FACT Network provides a similar service for acoustic telemetry researchers on the Florida Atlantic coast. FACT network members deploy and maintain receivers along a continuum of coastal habitats from freshwater estuaries to marine waters of the adjacent continental shelf from Georgia to the Florida Keys, as well as the Bahamas, Puerto Rico, and the U.S. Virgin Islands. Members of FACT have access to a shared database of array stations and tag metadata and are expected to directly share detection data with other FACT Network members. Many researchers, including the authors, belong to both iTAG and FACT, and the networks work closely to share tag IDs and other information.

2.2. Passive acoustic telemetry arrays

We analyzed data collected from two project-specific arrays located in the Gulf of Mexico off west central Florida: a nearshore array (the coastal array), deployed to monitor red drum, and an offshore array (the reef array), deployed to monitor goliath grouper and gag (Fig. 1). These two arrays are typical, based on size and duration of deployment, of other arrays within the iTAG and FACT networks, but differed in terms of the design configuration, study goals, and life history characteristics of focal species.

2.2.1. Coastal array

The coastal array was initially deployed in 2012 at nearshore sites off Tampa Bay and Charlotte Harbor (plus two sites within the estuary) to track movements of red drum (Lowerre-Barbieri et al., 2016a, 2016b). The Tampa Bay section of the array comprised 33 stations, 20 at sites at which red drum aggregations had been identified and 13 to fill in spatial gaps, primarily in the southern portion of this sampling area (Fig. 1). For the Charlotte Harbor section of the array 15 receivers were initially deployed in an evenly spaced grid directly offshore of the estuary, with four additional stations added in 2012 and 2013, two at red drum aggregation sites and two located within the estuary to monitor subadults which had been captured and released there. In August 2014, seven more stations were added to the Charlotte Harbor section and in the area between Tampa Bay and Charlotte Harbor, again in locations where red drum aggregations had been observed. Receivers (VR2W; Vemco, Bedford, Nova Scotia, Canada) were moored using sand augers (122 cm long) screwed into the sediment to an approximate depth of 0.5 m. The receiver was attached to the sand auger with heavy-duty cable ties and positioned on the auger so that the hydrophone was approximately 0.8 m above the substrate and elevated above the metal auger. A range test was performed prior to deployment, from September 2010 to January 2011, in the Tampa Bay section of the array, with a detection rate of more than 50% observed at a range of 400 m. Routine array maintenance included replacing receivers at stations approximately once per quarter. During the study period (2014–2015), six sites in the coastal array experienced receiver failure or were lost (operational for 518–716 days).

2.2.2. Reef array

The reef array was deployed initially in 2011 to monitor the effects of catch and release angling on goliath grouper. Sites were originally identified based upon goliath grouper preference for artificial reefs (Collins et al., 2015) and the array was enlarged in 2014 to incorporate natural reef and hard-bottom habitats after gag were added to research initiatives. Sites were chosen to represent a range of reef sizes and spanned the general range of depths at which most recreational angling for these species occurs on the West Florida Shelf (10–40 m, Fig. 1). Sites were also chosen based on relative proximity to one another to maximize the odds of detecting fish moving between sites. Range detection tests were performed at six sites chosen as representative of the