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Demonstrating the value of cross-ecosystem syntheses and comparisons in animal movement and acoustic telemetry research

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ABSTRACT

Ecological and fisheries research continues to shift emphasis from single isolated studies, to studies focused on understanding more regional and global processes. At the same time, the growing and wide-spread use of acoustic telemetry has inspired the formation of telemetry networks. A potential way to increase the impact of acoustic telemetry networks, and answer broad scale ecological questions is the promotion of cross-site ecosystem studies, or the comparison and synthesis of animal behavior among spatially distinct units. In this introduction paper we 1) Overview papers featured in the special issue, '*Using telemetry for cross-ecosystem comparisons of animal behaviors*' 2) provide a summary of one network that has integrated cross-site research into their mission, the National Science Foundation's Long Term Ecological Research network (LTER, U.S.) And, 3) offer suggestions on ways telemetry researchers and networks can facilitate cross-ecosystem study using the LTER network as a model. Understanding processes related to global change, better defining stock structure, and other larger spatial scale questions are at the forefront of conservation and science. Pairing telemetry networks with cross-site initiatives provides a great venue to facilitate these broad scale science questions.

Introduction

In an era of increasing collaborative and team science, the growing and wide-spread use of acoustic telemetry has inspired the formation of telemetry networks (i.e. networks of acoustic telemetry researchers that share data Hussey et al., 2015; Abecasis et al., 2018). The purpose of these networks is generally for improving our understanding of the spatial ecology of coastal or nearshore highly- migratory species, such as sharks and rays (Hussey et al., 2015). In just the United States alone, telemetry networks such as the Florida Atlantic Coast Telemetry (FACT), Atlantic Coast Telemetry (ACT), integrated Tracking of Aquatic Animals in the Gulf of Mexico (iTAG), Southern California Acoustic Telemetry Network, (SCATTN), and Great Lakes Acoustic Telemetry Observation System (GLATOS) demonstrate the utility of these efforts (Hussey et al., 2015; Pratt et al., 2018).

A potential way to increase the impact of acoustic telemetry networks is the promotion of cross-site ecosystem studies, or the comparison and synthesis of animal behavior among spatially distinct units. For example, concurrent telemetry studies could be used to understand how animal movement behaviors vary between a system treated with a management intervention, or a scientific manipulation relative to a control habitat or ecosystem (Reynolds et al., 2010; Hellström et al., 2016; Hall et al., 2019). Likewise, paralleling telemetry studies could be designed to control for, and isolate, a few environmental variables that influence processes relevant for assessment, such as the interaction of temperature and depth on the effects of barotrauma (Jackson et al., 2018). Cross-ecosystem telemetry studies also allow for the capacity to test hypotheses regarding the context dependence of animal behaviors across environmental gradients directly applicable to management, such as age at functional maturity and patterns of skip spawning, and identification of critical habitats for endangered species (Scharer et al., 2017; Boucek et al. 2019). These studies can even improve our understanding of how global processes, such as climate change, may be influencing our fisheries (Stevens et al., 2018). Though this concept of cross-site comparisons is not novel, surprisingly few research networks have infrastructure or conceptual models to facilitate these types of study.

The special issue features eight case studies illustrating how telemetry networks can facilitate cross-ecosystem comparative research and synthesis that improve management and conservation. This introductory article is meant to provide some resources that may help telemetry network members and network leadership pursue cross-site collaborative research. In this introduction paper we 1) Overview papers featured in this special issue, 2) provide a summary of one network that has integrated cross-site research into their mission, the National Science Foundation's Long Term Ecological Research network (LTER, U.S.) And, 3) offer suggestions on ways telemetry researchers and networks can facilitate cross-ecosystem study using the LTER network as a model. As ecological and fisheries research continues to shift emphasis from single isolated studies, to studies focused on understanding more regional and global processes, cross-site studies and network-level science will become increasingly important. Therefore, research networks such as telemetry networks should begin building in the infrastructure to facilitate these types of study.

Examples of cross-site synthesis from the iTAG network

The mission of the iTAG network is to improve our understanding of animal migration and residency to assess stock resilience to spatially-explicit disturbances and provide important information needed for

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management. At the iTAG 2017 meeting, a working group was held to better integrate researchers into the network that are maintaining arrays, sharing data, but may not be studying highly migratory species (Lowerre-Barbieri et al., 2017). These researchers are detecting highly migratory species, however are often not receiving reciprocal benefits important for motivating data sharing (Porter and Callahan, 1994; Nguyen et al., 2017). The outcome of this working group was a proposal to improve and facilitate cross-site synthesis research in iTAG, which would provide a benefit for those telemetry researchers not studying more mobile species. At the same time, provide research products that answer broad scale questions on animal movement.

Here, we feature studies that provide quantitative comparisons of animal behaviors (Boucek et al., 2019; Eggenberger et al., 2019; Jackson et al., 2018), as well as those where comparisons are more qualitative (Stevens et al., 2018; Hall et al., 2019). Interagency and inter-institution collaborations (Boucek et al. 2019; Ellis et al., 2019), as well as cross-site comparisons that were entirely conducted via a single research program (Eggenberger et al., 2019) are represented. We highlight these eight studies, and partition them into three themes of research: 1) context dependence of animal behaviors, 2) habitat restoration, 3) species migration and gear performance.

Half of the papers in this issue fell into the category of context-dependence of animal behaviors and other processes that inform fisheries management. Boucek et al. (2019) and Stevens et al. (2018) contrasted Common Snook (*Centropomus undecimalis;* Snook hereafter) migrations and habitat use across multiple estuaries. Boucek et al. (2019) compared out-river migrations of Snook in two estuaries separated by over 200 km. One of the rivers has been modified to an essentially straight canal used for freshwater conveyance (U.S., Caloosahatchee River), while the other river occurs in the center of a world heritage site, with much if the ecological processes remaining intact (U.S., Shark River). Meanwhile, Stevens et al. (2018) tested whether freshwater flows or temperature were a more important driver of Snook river use across four different estuaries along a latitudinal gradient spanning approximately 500 KMs. The estuary occurring at the highest latitude approximates to the northern extreme of the species range. In both studies, environmental context does seem to affect Snook, Boucek et al. (2019) showed that year to year variability in the proportion of Snook that emigrated from rivers to spawn was greater, and that Snook spent fewer days outside of rivers during the spawning season in the less degraded river system. Likewise, Stevens et al. (2018) demonstrated that freshwater flows predicted Snook river use in the two most southern rivers, and variation in temperature best explained river use within their northernmost rivers at the extreme edge of their range. Stevens et al. (2018) suggests that behavioral plasticity in Snook could explain drivers behind ongoing rapid range expansions for Snook and other tropical species in subtropical latitudes.

Differing from Stevens et al. (2018) that used abiotic variables to predict Snook behaviors across systems, Wilber et al. (2018) examined how variation in biotic drivers, helped explain endangered Gulf Sturgeon (*Acipenser oxyrhynchus desotoi*) activity across 5 coastal systems in the Northern Gulf. Their results showed that areas with high sturgeon activity corresponded to where prey density is highest, and that prey landscape varies across systems. And lastly, Jackson et al. (2018), used telemetry at two wreck sites occurring at different depths to study Greater Amberjack (*Seriola dumerili*) post-release survival. In the Gulf of Mexico, 75% of Amberjack caught are released, setting the stage for discard mortality to be an important driver of the stock. Across the two study sites, Jackson et al. (2018) found that discard mortality was high (approximately 20%), abet similar to current values used in stock assessment. And, that Greater Amberjack are relatively resilient to capture at depth.

Two studies in this issue were focused on understanding or predicting effects of habitat restoration on fish movements. First, Eggenberger et al. (2019) used a combination of stable isotopes and acoustic telemetry to compare resource use and movements of Snook in two sub-estuaries. These sub-estuarine systems, due to differences in freshwater inputs, have different trophic states; one that receives less freshwater being hyper-eutrophic (Chlα 15 μg/l to > 100 μg/l in some years), while the other that receives freshwater deliveries more representative on the natural system is meso-trophic. Eggenberger et al. (2019) found that in the more enriched systems, snook moved less, and only acquired resources from local sources. In contrast, in the less enriched system snook moved more and acquired energy from multiple foodwebs. As such, measuring changes in consumer movement and their resource use could serve as an indicator of restoration performance. Hall et al. (2019) studied the movements of Red Drum (*Sciaenops ocellatus*), and how their habitat use and migrations change once a tidal inlet is opened. They showed that following the restoration project Red Drum traversed the inlet in ways that would resemble spawning migrations. The larger effort for this restoration research was set up in a Before After Control Impact design to evaluate overall impacts of the restoration effort on nekton communities, relative to a control system (Hall et al., 2016).

In the final theme of research for this special issue, two case studies featured species migrations. Ellis et al. (2019) developed metrics to determine what receivers in existing arrays are most important in detecting unknown tag IDs from coastal migratory species in two environments, coastal inlets, or nearshore artificial reefs. Their metrics allowed them to reduce the size of arrays by 59% and 27% while still retaining over 70% of recorded detections. And Griffin et al. (2018) highlighted early findings from tracking the movements of a highly migratory coastal gamefish fish, Atlantic Tarpon (*Megalops atlanticus*), and discusses potential for cross-site research with migratory species across the Atlantic and Gulf of Mexico coasts of Florida.

Studies in this issue span across the entire U.S. Gulf of Mexico shorelines, with studies occurring as far south as the Florida Keys (Eggenberger et al., 2019; Griffin et al., 2018), to the Northern Gulf of Mexico (Wilber et al., 2018), and along the Texas Coast (Hall et al., 2019; Fig. 1). The papers in this issue exemplify the utility of building in cross-site comparisons in telemetry networks, and the potential for these types of study to be fostered by telemetry leadership.

Improving cross-site initiatives in telemetry networks: an overview of the LTER network

As we discuss ways to integrate cross-site research into research telemetry networks, we first summarize the LTER network which has integrated cross-site synthesis into their research mission. The LTER network was established in 1980 with the overarching mission to develop research and monitoring programs that continue over long term (i.e. decades) across 28 distinct ecosystems. In terms of research, the LTER mission has two prongs relevant to cross-site synthesis: *Understanding* and *Synthesis* (U.S. LTER, 2007; Redman et al., 2004).

The mission of the *Understanding* prong is site specific, and focuses on improving fundamental and mechanistic knowledge at each of the 28 focal ecosystems (Redman et al., 2004; Childers, 2006; Bestelmeyer et al., 2015). Ecological process at each site are influenced by differing environmental drivers and show unique ecosystem responses to drivers, and thus sites ask different research questions. For example, research for the Florida Coastal Everglades LTER centers on how sea-level rise interacts with anthropogenic demands for freshwater to influence ecosystem function of two Everglades National Park estuaries. In contrast, Central Arizona Phoenix LTER has an overarching research question to understand how the services provided by dynamic urban ecosystems and their infrastructure affect human outcomes and behavior.

The second prong is *Synthesis,* which facilitates research across LTER

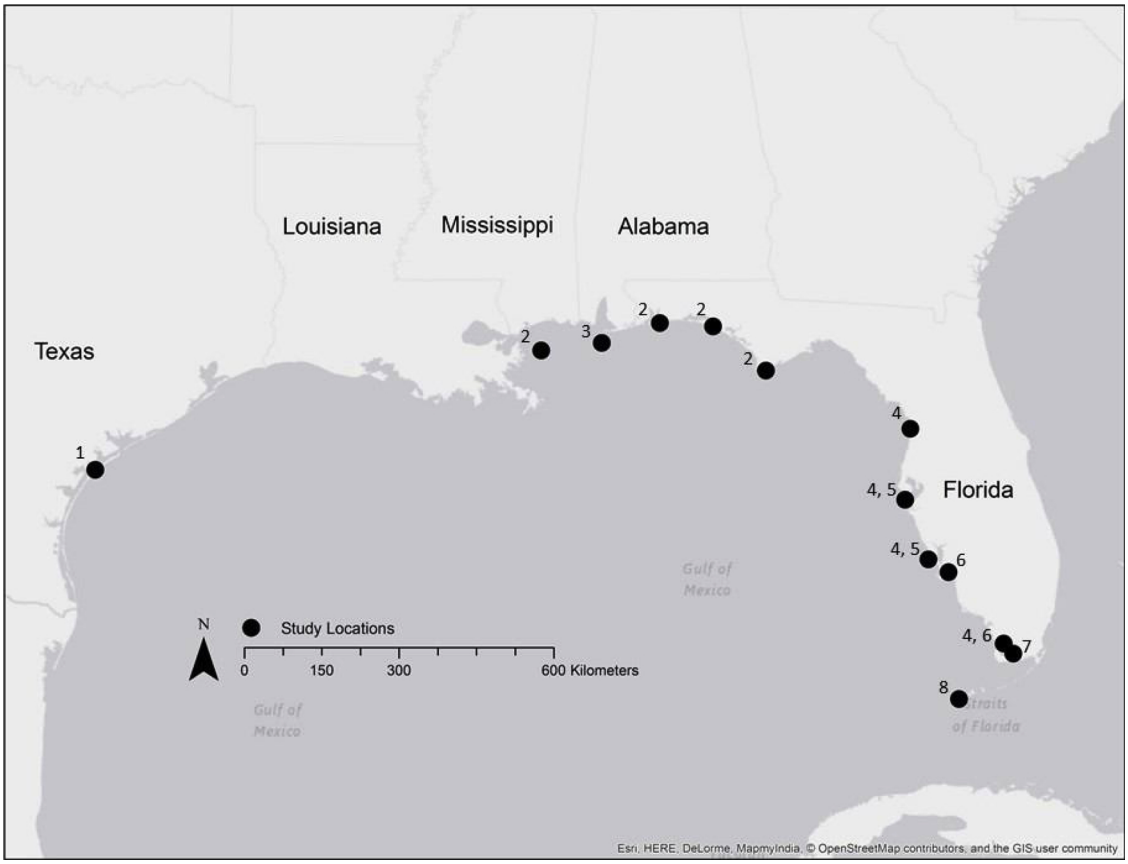

Fig. 1. Study locations of the papers submitted for this special issue. 1) Hall et al. 2) Wilber et al. 3) Jackson et al. 4) Stevens et al. 5) Ellis et al. 6)Boucek et al. 7) Eggenberger et al. 8) Griffin et al.

sites (Lindenmayer et al., 2010; Collins et al., 2011; Peters et al., 2015; Sylvain et al., 2014). Using data sets from pelagic ocean, coastal benthic, polar marine, and semi-arid grassland ecosystems, Bestelmeyer et al. (2011) developed a conceptual model of the relationships between the elements of abrupt ecological transitions and the analytical approaches used to investigate them. Likewise, cross-site synthesis initiatives within the LTER have tested how larger global drivers such as sea-level rise and climate warming result in varied or similar ecological responses (Rogora et al., 2018).

The structure of the LTER network parallels many telemetry-specific networks. For instance, telemetry networks are generally made up of many smaller, not necessarily connected, acoustic arrays, where research questions are not identical. Although the technology is similar, the configuration of the arrays, species tracked, and inherent biases vary across arrays, making direct quantitative comparisons across ecosystems more challenging. The similarities in the structure of the LTER and acoustic telemetry networks provides an excellent model for acoustic telemetry.

Building in infrastructure for cross-site synthesis

The LTER creates opportunities for cross-site synthesis at their All Scientists Meetings (ASM), where leadership hosts concurrent half day workshops throughout the meeting. These workshops are meant to lay the foundation for cross-site synthesis projects and include topics such as: producing larger research proposals, synthesis papers, special issues in peer reviewed journals (Boucek et al., 2016), K-12 education plans, improving diversity within professional networks, and other forms of cross-site synthesis projects. These working groups have proven to be very successful in facilitating cross-site research in the LTER and could easily be incorporated to telemetry network meetings.

These working groups provide the foundation for building synthesis research proposals, which are available to everyone. The National Center for Ecology, Analysis, and Synthesis (NCEAS) periodically invites researchers to submit proposals for synthesis-based research. NCEAS awards provide travel for up to 12–18 researchers to visit NCEAS headquarters in Santa Barbara CA, (U.S.) to execute their projects (Rodrigo et al., 2013; Baron et al., 2017). Awards are also available for post-doctoral fellowships to conduct synthesis-based projects. At the time of writing this manuscript, NCEAS announced calls for proposals on synthesis research on ocean sustainability, clearly a topic within the realm of multi-ecosystem based telemetry research.

Building the culture of sharing data

Well-designed data repositories and data sharing agreements can help accelerate datasharing and cross-site collaborations. Repositories facilitate more standardized exchange of data, and policies protect the researchers engaged in the exercise. The LTER network started developing repositories and data sharing policies almost 30 years ago (Porter, 2010). In its inception, the data repository proposal was rejected by the membership (Porter, 2010). However, by 2001, LTER introduced a new goal to their mission, “Information: To inform the LTER and broader scientific community by creating well-designed and well-documented databases.” Currently, over 40,000 ecological, abiotic, biogeochemical, climate and even a few acoustic telemetry datasets and meta data are available to use for synthesis-based science.

Porter (2010) identified 3 lessons to be learned from the LTERs path to accepted datasharing. These include; 1) engaging researchers and institutions that will be providing data in the formulation of data

policies. 2) that for data sharing to be successful, all involved have responsibilities to adhere to. Data collectors must provide thoughtful meta-data to maximize their usefulness. Likewise, data managers must build infrastructure to archive and store these data in a way that ensures these are only accessible to users that have agreed to datasharing policies. Last, the data user must, at the very minimum, properly cite or acknowledge the data supplier. 3) The final lesson from Porter (2010) is that building the culture of datasharing is stepwise. Treating the process as step-wise provides members opportunities to provide input in datasharing agreements and become comfortable with the concept of sharing data.

The three lessons from the LTER network can help guide in building a culture of datasharing in telemetry networks. First, network leaders should engage the network membership in designing datasharing agreements. Second, datasharing agreements should consider holding both data-suppliers (provide usable datasets with clear meta-data) and data users (no misuse) accountable for responsible datasharing. Similarly, network leadership is responsible for designing a user friendly and secure datasharing platform. The FACT network is working in partnership with the Ocean Tracking Network to develop such a platform. Last, and probably most important, network leadership should consider datasharing and policies a step-wise process, necessitating some multi-year strategic plan.

Wrap up

Throughout this manuscript, we highlight key reasons why telemetry networks and telemetry researchers should consider adapting cross-site initiatives. First, from the researcher perspective, understanding processes related to global change, better defining stock structure, and other larger spatial scale questions are at the forefront of conservation and science (Crossin et al., 2017). Being comfortable with data sharing and engaging in cross-site science will be an eventual necessity for most researchers to answer these broad scale questions. From the network perspective, facilitating cross-site research will only improve the science produced by the network, which will help continue network growth, provide other avenues for funding, and thus help maintain their sustainability.

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