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Bridging the knowledge-action gap: A case of research rapidly impacting recreational fisheries policy

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ABSTRACT

Telemetry is being used to generate an unprecedented level of knowledge on the underwater environment, much of which is relevant to marine policy and management. Yet, examples of telemetry directly informing management practices are still rare or undocumented. Here we describe a case in which fish telemetry data were rapidly incorporated into recreational fisheries policy for Permit (*Trachinotus falcatus*) in Florida. The reproductive strategy of Permit involves forming large aggregations, during which time they are often targeted by recreational anglers. To protect Permit from overfishing, the Florida Fish and Wildlife Conservation Commission established regulations in 2011 to prohibit Permit harvest during May through July, based on knowledge of seasonal Permit reproductive status. However, an acoustic telemetry study initiated in 2016 revealed that spawning aggregations were forming prior to this period, during the month of April. This information had a rapid and definitive impact on fisheries management policy. Given the well-documented difficulties of incorporating new science and information into environmental decision-making, this case provides valuable insights into how the knowledge-action gap may be bridged. Many factors contributed to the rapid uptake of this telemetry-derived knowledge into management, including applied research funding and objectives, integrating managers and stakeholders into the research, rapid dissemination of preliminary data, plus well-established relationships amongst scientists, managers, and stakeholders mediated by a non-government organization, Bonefish & Tarpon Trust. These factors may serve as a basis for researchers and managers seeking to translate new research into management practice, improving research impact and achievement of conservation goals.

1. Introduction

Increasing anthropogenic impacts on marine ecosystems are posing unprecedented challenges for environmental managers and policy-makers [1]. Responding to such challenges requires the marshalling of cutting edge science and large amounts of biological and environmental data, including local and traditional ecological knowledge [2]. The human dimensions of environmental problems are also complex, meaning that evidence-based decision-making requires knowledge generated by both biophysical and social sciences. However, there are significant challenges to bridging the gap between knowledge and management or policy action [3–5]. To overcome these challenges, Cook et al. [3] recognized the importance for science (and other forms of knowledge) to be seen as salient, credible, and legitimate from the perspectives of both knowledge generators (often but not always scientists) and research users (a broad community of stakeholders that includes citizens, other researchers, and public and private organizations). It goes without saying that the perspectives of these groups are often inconsistent with each other. Bureaucratic or professional inertia can add to the problem, as conservation decisions have a history of

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being made based on common knowledge rather than new evidence [5]. This can be due to mistrust of new information or research methods, as well as uncertainty over the applicability of new information to policy or management decisions [6,7]. In brief, the literature indicates that knowledge-action gaps are common, and the result of disjuncture between the norms, practices, and expectations of knowledge generators and potential users [6,8,9]. Bridging such gaps requires substantial effort on behalf of all parties, as well as conducive institutional and socio-political environments [10]. Given the contextual nature of these factors, much can be learned from case studies of efforts to bridge the knowledge-action gap. In this article, we present a case in which fish telemetry data were rapidly incorporated into recreational fisheries management policy for Permit (*Trachinotus falcatus*) in South Florida, providing insights for researchers and policy makers to ensure natural resources are managed with the most relevant and up-to-date knowledge for evidence-based decision-making.

In the realm of environmental policy, one critical source of knowledge is the tracking of wild animals as they move through their habitats [11]. Acoustic telemetry has become a technology of choice for characterizing the spatial, behavioural, and physiological ecology of diverse marine organisms over extended periods in the wild [12]. This involves tagging aquatic animals with transmitters that emit unique ultrasonic signals, which are detected by specialized receivers. Using this technology, tagged animals can be tracked manually by a research team with a mobile hydrophone or using a system of stationary hydrophones, also known as receivers, placed throughout the aquatic environment to constantly 'listen' for tagged animals [13]. This widespread approach is now providing valuable insights into diverse fields including population, community, and ecosystem dynamics, spatial connectivity, biotic and abiotic interactions, and animal exploitation rates [12–15]. Much of this information is relevant to marine policy and management; for example, designing marine protected areas and fishing regulations [14,16]. The level of detail provided by telemetry data is unprecedented. It has been termed a disruptive science, in that it has the potential to radically alter understanding of aquatic environments and to fundamentally challenge key fisheries management assumptions [14,17]. However, direct applications of telemetry study findings to management are surprisingly rare (but see Brooks et al. [18] for examples) or are occurring without formal academic documentation [14,19,20].

There is a clear gap between the knowledge generated by telemetry studies and management action, and with a paucity of documented success stories it is challenging to identify why. Empirical research has cited concerns among fisheries managers about the reliability of the technology and methods, particularly the effects of tagging on animals and the ability to extrapolate findings about tagged individuals to whole populations [7,9]. Occasionally, managers also express unfamiliarity or discomfort with telemetry findings, or skepticism that telemetry findings have relevance to management needs [7,9,17]. Nguyen et al. [7] developed a sociological knowledge-action framework to address this gap, and identified the primary impediments of knowledge mobilization as perceived uncertainties or unclear relevance of study findings, underlying motivations and constrained rationalities of actors, institutional constraints or lack of support, and mismatches in scale, culture, and worldviews. The translation of science findings into management action can be quite nuanced and complex, involving both the qualities of the science as well as the sociological characteristics of the researchers and managers involved. Examining diverse potential factors leading to telemetry knowledge uptake, Nguyen et al. [21] found researchers who tend to experience greater uptake of their findings by managers or conservation practitioners are those who collaborate intensively, have greater familiarity with management needs, engage in public outreach, and have longer experience with telemetry research. Overall, to overcome the barriers of translating telemetry research into policy or management action, it appears crucial to develop telemetry studies with consideration of management needs and disseminate the findings directly and effectively to end users.

Considering the challenges associated with bridging the knowledge-action gap with telemetry research, we describe a case where this was accomplished by using acoustic telemetry research to rapidly influence fisheries regulations. We describe the study details, findings, and how they were integrated with management, along with discussion on how the study characteristics, sociopolitical conditions, and environmental context resulted in rapid knowledge mobilization. This paper is a form of action research from the researchers involved, reflecting on how this project resulted in successful knowledge mobilization. Consideration of this case may provide insights into how cutting-edge science such as telemetry research can be better integrated into fisheries and ecosystem management.

2. Study details

Permit (*Trachinotus falcatus*) is a species of marine fish in the Carangidae (jack) family, distributed throughout the tropical and subtropical regions of the Western Atlantic Ocean, Caribbean Sea, and the Gulf of Mexico [22]. This species supports highly popular and valuable recreational fisheries in many regions, including South Florida [23]. However, there is a dearth of information on Permit ecology, with limited data on population dynamics, diet, habitat use, or regional connectivity. Much of the information on this species is anecdotal, based on local ecological knowledge from fishing guides, anglers, and divers. Juvenile Permit are commonly found along shallow beaches [24], but adults and sub-adults live in nearshore regions at water depths between 2 and 40 m in proximity to structures such as reef promontories, patch reefs, and shipwrecks. However, Permit also move into shallow intertidal zones to feed on the benthos. Limited diet data on Permit from Belize indicate they feed on crabs, urchins, and various mollusks (R Clarke, *unpublished data*).

Permit reproductive ecology involves aggregating in large groups in deep water in proximity to specific reef structures [25]. Based on egg development in Permit harvested in the recreational fishery in the Florida Keys and Tampa Bay in the 1990s, reproductive activity occurs primarily from May to July in Florida [23]. While Permit are in spawning aggregations recreational anglers commonly target them; Permit are especially vulnerable to capture at this time because large groups are easy for anglers to locate. In addition to concerns related to anglers harvesting fish prior to successful spawning, predator densities can also be high around Permit spawning aggregations, leading to depredation issues when Permit are hooked on the fishing line (JW Brownscombe, *unpublished data*).

With a lack of any formal population monitoring, reports from fishing guides in South Florida suggested a recent and ongoing Permit abundance decline. To address these concerns, in 2011 the Florida Fish and Wildlife Conservation Commission (FWC) established additional regulations in South Florida in the form of the Special Permit Zone (SPZ), which spanned from Biscayne Bay, southwest past the Dry Tortugas, including the entire Florida Keys (http://myfwc.com/fishing/saltwater/recreational/Permit/). Within the SPZ, Permit harvest was limited to 1 fish > 22 inches fork length per angler per day, with the exception of May 1st to July 31st, when harvest was prohibited to protect spawning fish. Outside of the SPZ, two Permit between 11 and 22 inches may be harvested per angler per day all year. These regulations represented a positive step toward Permit conservation but were based on histological data from Permit harvested in specific locations over two decades ago. Information on when Permit were in spawning aggregations, and hence more vulnerable to harvest, was still lacking.

3. Research approach

To address the above-mentioned knowledge gap, an acoustic telemetry study was initiated in 2016 (Table 1) funded by a non-profit, non-government organization, Bonefish & Tarpon Trust (BTT), and

Table 1
Timeline of relevant events in translating telemetry-derived knowledge into recreational fishing regulations for Permit in South Florida.

Date	Event
2011	Establishment of the Special Permit Zone (SPZ) by FWC, providing Permit extended protection from harvest in South Florida
March 2016	Beginning of the Permit acoustic telemetry project
August 2016	Letter sent from BTT to FWC Commissioner Spottswood and Director of the Division of Marine Fisheries Management Jessica McCawley requesting they consider extending Permit harvest closure in the SPZ
July 2017	FWC requested information from BTT including a summary of the conservation concern, sources of information, and sources of concern in the fishing community
August 2017	First major acoustic receiver download, providing information on Permit movement patterns
October 2017	Report delivered by the research team to FWC on Permit movement patterns and use of spawning sites, explicitly urging the extension of the closed harvest season to include April based on findings
November 2017	BTT sent a letter to all FWC Commissioners officially requesting and justifying the expansion of the spawning season closure.
December 2017	Draft rule incorporating the month of April into the closed season approved at FWC Commission Meeting for advertising and directing staff to bring it back to a Final Public Hearing
February 2018	FWC Commissioners unanimously passed the Final Rule (68B-35.006 Closed Season Florida Administrative Code, effective April 1, 2018) extending the Permit harvest closure to encompass April through July in the Special Permit Zone

carried out by researchers from Carleton University, University of Massachusetts Amherst, and Florida International University, in partnership with FWC researchers in Marathon, Florida. The project focused on the Lower Florida Keys, where Permit were captured by recreational angling and tagged via surgical implantation in the coelomic cavity with acoustic transmitters (V13; Vemco Inc, Halifax, NS). As of October 2017, 42 fish were tagged with acoustic transmitters, 27 fish in inshore shallow water habitats (< 3 m water depth; referred to hereon as flats), 10 on nearshore reefs and shipwrecks, and 5 at a spawning aggregation on the Florida Reef Tract. Tagged Permit were tracked with an array of 75 acoustic receivers (VR2W; Vemco Inc) located throughout the Lower Florida Keys, in addition to the 1000 + acoustic receivers maintained by various researchers in the Florida Acoustic Telemetry (FACT) network, and the integrated Tracking of Animals in the Gulf (iTAG) network, which supplemented receiver coverage on the Florida Reef Tract where local ecological knowledge from recreational anglers and fishing guides suggested Permit spawn.

4. Study findings

As of October 2017, the system of acoustic receivers in the Florida Keys along with those of research collaborators in FACT and iTAG had collected a total of 40,650 detections from 27 individual Permit at 78 locations in proximity to the flats in the Lower Florida Keys, as well as various locations along the Florida Reef Tract (Fig. 1). Specific locations are not shown here, as these are sensitive data informed by local fishing guides and may also imperil Permit conservation [26].

Only 18 months into a four-year telemetry project it was evident that there was a high level of connectivity between the flats habitats of the Lower Florida Keys and the Florida Reef Tract. Of the 27 Permit detected by acoustic receivers, 10 (37%) were detected on both the flats and the Florida Reef Tract. Further, a high proportion of detections on the Reef Tract occurred in April (Fig. 2), during which time 10 (37%) individuals were detected at a specific reef site where a large spawning aggregation of Permit was observed by the research team and was

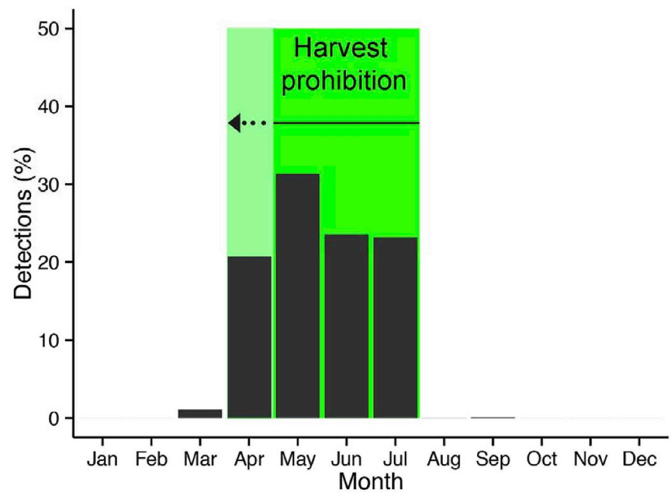

Fig. 2. The percentage of detections of Permit tagged with acoustic transmitters on the Florida Reef Tract by month (black bars) overlaid on the previous Permit harvest prohibition period (green area), and the extended period as of February 2018 (light green with dashed arrow). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

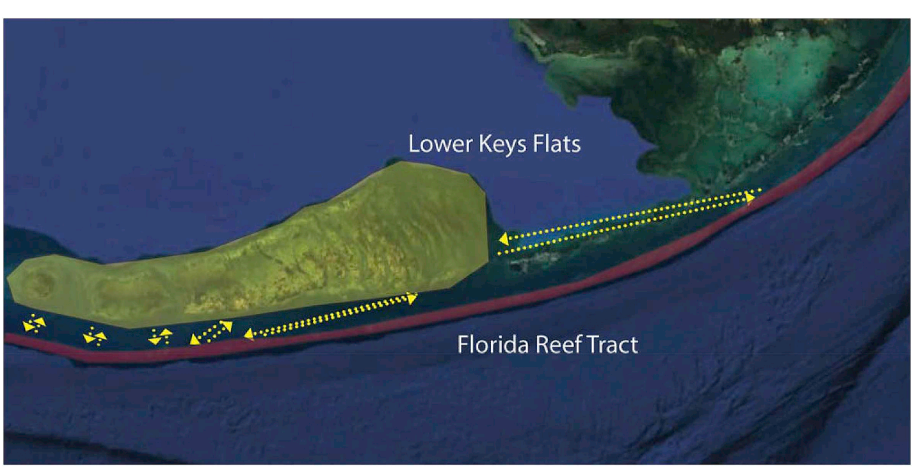

Fig. 1. Map of The Florida Keys delineating the flats in the Lower Florida Keys (yellow) and the Florida Reef Tract (red). Yellow lines indicate general regional connectivity by Permit between the two habitat types. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

known to many regional fishing guides and anglers. Permit spawning aggregations consist of large, tightly aggregated schools of Permit in proximity to deep-water structures [25]. Although these findings were preliminary for the overall project, there was clear evidence that a high proportion of individual Permit were moving between habitat types, and large aggregations of Permit were occurring on the Florida Reef Tract in April, prior to the harvest prohibition period in May through July.

5. Integration into fisheries management

Based on reports by fishing guides in the Florida Keys that large aggregations of Permit were occurring on the Florida Reef Tract in April, in August 2016 a letter was written by BTT to an FWC Commissioner and the Director of the FWC's Division of Marine Fisheries Management requesting they consider altering the Permit spawning prohibition period to include April (Table 1). This occurred prior to any telemetry findings. In July 2017, the FWC requested further information on the issue, including the sources of information and any concerns from the fishing community. BTT consulted local angling associations including the Lower Keys Guides Association (LKGA) and the Florida Keys Fishing Guides Association (FKFGA), responding to FWC with this information as an informal report. In October 2017, a management briefing was delivered to the Director of Marine Fisheries Management for the FWC, outlining the preliminary findings of the Permit acoustic telemetry study in a similar manner to how they were reported above in **Study findings**. The report was transparent about the scope of the project (i.e., findings were preliminary), and reported clear, simple statistics from the telemetry data on Permit space use, including the proportion of individuals and the proportion of total overall fish detections of fish utilizing spawning habitats throughout the tracking project, highlighting spawning habitat use in April. A draft rule was presented at the FWC Commission Meeting on December 7, 2017 to expand the harvest closure period to include April, in addition to May through July in the SPZ (See Supplementary Material, p. 22 for meeting details). A statement of support was delivered by BTT and the American Sportfishing Association. The Coastal Conservation Association of Florida stated they were not opposed to the regulation change. The Commissioners approved advertising the draft rule and directed staff to bring it back to a Final Public Hearing. In February 2018, the final rule language was approved unanimously by the FWC Commissioners as part of the Consent Agenda that extended the harvest closure period for Permit in the SPZ to include April. The rule became effective on April 1, 2018 [27].

6. Lessons learned: bridging the knowledge-action gap

The case described above represents an exceptional, documented example of a telemetry study rapidly influencing fisheries management policy– even prior to formal publication of findings. Such examples are very rare, due to the challenges related to bridging the knowledge-action gap described in the **Introduction**, as well as a lack of formal process for documenting successful cases in retrospect of government policy actions. Nonetheless, it is worthwhile reflecting on the success of the Permit telemetry study to identify key factors that enabled scientific findings to translate rapidly into policy action. Empirical research in the realm of knowledge mobilization in the field of natural sciences has identified a number of factors that influence knowledge uptake, as discussed in the **Introduction** [8,11–13]. Many important qualities related to the research, management, stakeholders, and sociological conditions are recognized here (Table 2), which will be discussed in detail.

Intuitively, a key starting point for generating actionable conservation knowledge is to design research projects aimed at fulfilling management needs. Young et al. [9] point out that mismatches between research and management are often exacerbated by the traditional conceptual separation in science and innovation policy between basic and applied research, with its attendant assumption that producers and users of knowledge operate in separate social and institutional environments. In the Permit telemetry example, the project was funded by BTT, which formed as a group of recreational anglers, guides, and scientists with the common goal of the applied conservation of fish species that support shallow water fisheries in the South Florida region, primarily Bonefish (*Albula* spp), Atlantic Tarpon (*Megalops atlanticus*), and Permit. According to the literature, BTT fits the description of a "boundary organization" that transects the social boundaries of multiple cultural and epistemic groups [28]. Boundary organizations often play key roles in bridging knowledge-action gaps by bringing different people with variable backgrounds into routine contact. This facilitates the identification of gaps in existing knowledge (or incongruities between scientific and local/traditional knowledge), identifying researchable questions, and disseminating new knowledge to potential users [28–30]. The level of engagement with both managers and stakeholders involved to rapidly influence fisheries regulations in the Permit example (Table 1) is testament to the value of these types of organizations in bridging the gaps between research and management.

Funding for applied conservation research with focused goals is a key starting point for producing actionable conservation knowledge, but this quality is insufficient on its own to bridge the knowledge-action gap. One of the most effective ways to ensure an applied study bridges this gap is to integrate the end knowledge users (e.g., management agencies, resource stakeholders) into the research process itself [7,9,17,21]. In the case of the Permit telemetry project, both FWC and stakeholders (LKGA) were involved with the project from the beginning. Further, long-term relationships (built and maintained over a decade) had been established between BTT and the fishing guide community in South Florida. Such well-established relationships in this case fostered levels of trust and continual communication that are rarely achieved in shorter-term research projects. Brooks et al. [18] identified engaging managers and stakeholders early in research projects as a key component to successful knowledge mobilization. This can help overcome numerous knowledge-action barriers related to trust and communication, reduce stakeholder resistance to change, and aid in effective study design for addressing management needs. Having established relationships with the broader stakeholder and conservation community can also be highly beneficial, as was observed by the show of support from multiple organizations (the American Sportfishing Association and the Coastal Conservation Association of Florida) for the Permit regulation change at the FWC Commissioners Meeting (Appendix 1).

Integrated, collaborative science projects often require significant effort from all members involved to operate effectively. For researchers, a recent analysis of the factors leading to telemetry knowledge uptake identified numerous researcher attributes as being important factors influencing knowledge mobilization, including experience with telemetry, the level of collaborative activity, and familiarity and experience with management practices [21]. These qualities reflect the ability of researchers to effectively identify research questions relevant to management, acquire that knowledge, and disseminate it through well-developed relationships with managers and stakeholders. In the case of the Permit telemetry project, many of the senior members of the research team had invested significant effort in these activities. They also mobilized well-established relationships with members of FWC from previously working on addressing other conservation issues with management actions. Having frequent communication throughout the project between research partners is essential; admittedly gaps in this communication were the source of some contention among researchers, managers, and stakeholders during this project. Having a well-structured system for communication through project updates and established expectations can help avoid such issues.

Knowledge mobilization also relies on the openness of decision-makers to integrate new knowledge into policies and management

Table 2
Factors influencing the translation of research knowledge into management and conservation actions.

Factors	Value
Specific, applied study objectives	• Ensures research is addressing a relevant knowledge gap
Integration of end users in research	• Builds trusted relationships, improves communication between researchers and managers • Increases familiarity of managers with research approaches • Ensures research approaches address key knowledge gaps for management
Integration of stakeholders in research	• Avoids or alleviates opposition to management changes • Ensures research approaches address relevant conservation issues and stakeholder concerns
Effective dissemination of study findings	• Clear communication of approaches and findings increases the ability of managers to interpret and act upon the information
Researcher experience	• Relates to the ability of researchers to effectively implement the study assets outlined above
Policy-maker openness to new knowledge	• Determines whether generated knowledge results in policy changes
Stakeholder perspectives toward conservation issue	• Influences their level of support or resistance to a policy change

practices. In some cases, conservation practitioners have been resistant to new knowledge, and instead rely on experiential and tacit knowledge, and/or their social networks as the primary means of decision making [5,9]. The mistrust of research techniques by managers is often cited as a knowledge-action barrier, particularly with telemetry studies [7,14,21]. This mistrust may be related to a lack of knowledge or experience with the technology and approach, or an unclear communication of the methods, analysis, and data interpretation by the researchers. However, in the case of the Permit telemetry project, FWC was highly familiar with the acoustic telemetry techniques as they utilize this technology extensively in their research and monitoring programs [31] and have even been integral to the development of a collaborative acoustic telemetry networks, iTAG [32] and FACT. Additionally, the FWC has incorporated many of the factors cited by Nguyen et al. [20] regarding uptake of telemetry findings in their multi-year process that culminated in the decision to retain regulations specifying no fishing in the Dry Tortugas National Park Research Natural Area for an additional 20 years [33]. Hence, using Permit telemetry to make a rapid management decision was met with confidence by the FWC managers.

The perspective of the user groups toward a conservation issue is also a major factor mediating changes in marine policy. Stakeholders can pose major resistance to environmental management actions, particularly with changes to fisheries regulations [34,35]. In the Permit telemetry case, the local fishing guides association (LKGA), a major user group of the resource, had been advocating for this regulation change (i.e., extending Permit harvest prohibition to include April) based on the observations of the fishery by their members prior to the research project. Having this user group integrated in the project helped to shape research approaches at the outset of the research to address this specific conservation concern. Further, at the FWC Commissioners Meeting, the draft rule to extend Permit harvest prohibition was supported by multiple other resource user groups (see Appendix 1). Ultimately, this scenario was well-suited for science to impact management; an integrated research project involving researchers, managers, and stakeholders ensured an important knowledge gap was addressed, all parties were familiar with the issue and research approach, and there were open lines of communication throughout the process.

A final consideration from bridging the knowledge-action gap is to ensure the generated knowledge is disseminated in effective ways so that it is interpretable by end users (Table 2). The Permit telemetry data were disseminated relatively rapidly (for a long-term study approach like telemetry), in a clear and simple management briefing that acknowledged its limitations, including that the data were preliminary and not yet published through peer-review. Based on the initial briefing from researchers to the FWC, additional details were provided by researchers when requested by FWC to address concerns related to the study approach, details, and findings, including more extensive visuals of Permit movement patterns and residency at spawning sites. Brooks et al. [18] noted that data visualizations are a particularly powerful tool for knowledge mobilization. This is an example of where open lines of communication were essential for translating knowledge into action. It is important to emphasize again how little information was known about Permit spatial ecology such that this information, albeit rather simple, was truly novel.

Telemetry is often cited as a valuable tool for understanding diverse aspects of fish and aquatic ecosystem ecology, with numerous potential applications to fisheries management [14]; indeed, examples of its effective application are emerging (e.g., Brooks et al. [18]). The Permit telemetry example highlights the value of telemetry, combined with other approaches (e.g., visual observations, histological sampling) for informing questions relevant to management. Histological sampling had provided an indication of the phenology of Permit spawning, yet telemetry and visual observations were able to inform the behavioural aspects (i.e., the timing of spawning aggregations) relevant to fisheries regulations. Further, the continuous, long-term monitoring of fish movement patterns revealed a high level of connectivity amongst nearshore marine habitats, as well as multiple fisheries. With this information, stakeholders comprising the shallow water fishery became aware that Permit conservation issues in other nearshore habitats (i.e., reefs and shipwrecks) are relevant to their fishery, which may change the sociopolitical landscape moving forward with Permit management.

Overall, this case study serves as an example where fish telemetry data were effectively translated into conservation action, conforming to many of the characteristics identified in the knowledge-action literature including: applied research funding and objectives, integrating fisheries managers and stakeholders into the research program, rapid dissemination of preliminary data via management briefs, and well-established relationships and extensive knowledge exchange amongst scientists, managers, and stakeholders. Undoubtedly, the manager and stakeholder perspectives toward a particular conservation issue or management decision play a key role in mediating management actions as well. In order to overcome the unprecedented challenges we currently face with environmental conservation through policy and management, effective translation of the knowledge generated by research is essential. We conclude based on the Permit telemetry project example that research involving specific qualities related to the cooperation and collaboration between scientists, managers, and stakeholders can help to steer research that better addresses management needs and achieves conservation goals.

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Appendix A. Supplementary data

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